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Committing to the Cost of Ownership

Maintenance and Repair of Public Buildings

Committee on Advanced Maintenance Concepts for Buildings
Building Research Board
Commission on Engineering and Technical Systems
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1990

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PREFACE

Dig a well before you are thirsty.

Chinese proverb

Maintenance of buildings and other constructed facilities--an important part of our national assets--demonstrates confidence in the future and recognition of the investment made by preceding generations for the sake of their children. The closing decade of the 20th century finds us beset by many indications that public policy is failing, either by conscious decision or insufficient foresight, to protect the value of these assets.

Some observers write of “America in ruins” and describe the “fragile foundations” upon which our economic prosperity rests. Alarming characterizations of the condition of our schools, other public buildings, and transportation systems abound, seemingly with good reason. Credible analyses indicate that we are systematically neglecting the maintenance of public facilities at all levels of government. We are spending our assets and wasting our inheritance.

The earliest signs of neglect are often subtle and escape the notice of those unprepared by training or experience to recognize them. Herein lies a major element of the problem: It is difficult, in times of tight budgets and competing demands for public resources, to convince those responsible for public policy that neglect can lead to losses. We seem to need a disaster to focus our attention and motivate action.

Yet we and the committee whose deliberations are the basis for this report subscribe to the wisdom of the Chinese proverb. We argue not that disaster is upon us but that our experience demonstrates that greater commitment is needed if disaster is to be avoided. We hope that our work will enhance this commitment.

Robert F. Jortberg, Chairman,
Committee on Advanced
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Andrew C. Lemer, Director,
Building Research Board

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SUMMARY OF FINDINGS AND RECOMMENDATIONS

The nation's public buildings--government administration buildings, health care facilities, schools, correctional facilities, and a variety of other elements of public infrastructure--are assets acquired through the investment of tax dollars over the years and are critical to the nation's high quality of life and productive environment. Public officials, the stewards of these assets, must bear responsibility for their effective maintenance. Widespread underfunding of maintenance of public facilities, caused by many factors, can affect public health and safety, reduce productivity of public employees, and cause long-term financial losses when buildings must be prematurely renewed or replaced.

This document is the report of a committee asked by the Building Research Board to undertake a broad review of maintenance and repair activities of government agencies and to recommend how these activities might be improved. Based on its own review of available information, consideration of reports by agency personnel and other professionals, and the experience of its members, the committee is troubled. The procedures and allocations of resources for managing the public's built assets--influenced by a variety of financial and political pressures as well as technical requirements--are failing to protect these assets, and the potential costs of correcting past neglect are measured in billions of dollars. (See Chapter 2.) These procedures and allocations must be changed to recognize the full **costs of ownership** of these assets and to support appropriate maintenance activities. The committee hopes that its findings and recommendations will help to bring about these changes:

1. **Underfunding is a widespread and persistent problem** that undermines maintenance and repair (M&R) of public buildings. To overcome this problem, **M&R budgets should** be structured to **identify explicitly** the expenditures associated with **routine M&R**

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requirements and activities to reduce the backlog of deferred deficiencies. **An appropriate budget allocation for routine M&R** for a substantial inventory of facilities **will typically be in the range of 2 to 4 percent of the aggregate current replacement value** of those facilities (excluding land and major associated infrastructure). In the absence of specific information upon which to base the M&R budget, this funding level should be used as an absolute minimum value. Where neglect of maintenance has caused a backlog of needed repairs to accumulate, spending must exceed this minimum level until the backlog has been eliminated. (See Chapter 3.)

2. Periodic condition assessment is an essential step in effective facilities management. **Formal condition assessment programs should be implemented by agencies responsible for M&R budgets.** These programs will initially serve as the basis for establishing appropriate levels of funding required to reduce and eventually eliminate backlog. Once backlog is eliminated and a steady-state performance is achieved, the condition assessment becomes a management tool for monitoring the effectiveness of M&R activities. Condition assessment programs require trained technicians and managers and should be standardized to control their cost and to ensure consistency of the results. Federal agencies and other owners and users of large inventories of buildings should undertake to establish guidelines for such programs. (See Chapter 4.)
3. While adequate M&R funding based on recognition of the full costs of ownership is a prerequisite for protection of the public's assets, effective maintenance management is also required to realize the full benefit of the funds made available. **Agencies should make specific assignments of responsibility for M&R** to qualified and trained staff and managers. Activities such as **minor alterations and improvements** that may be disguised as M&R **should be clearly identified** and not permitted to divert resources from legitimate M&R functions. Education, training, and recognition of staff members responsible for M&R are needed, along with firm commitment to effective management of our built assets. (See Chapter 5.)

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1

INTRODUCTION

The nation's public buildings--government administration buildings, health care facilities, schools, correctional facilities, and a variety of other elements of public infrastructure--are critical to the nation's high quality of life and productive environment. These facilities are public assets that have been acquired through the investment of public tax dollars over the years. Public officials are the stewards of these assets, and their decisions about how these facilities are used, operated, maintained, retired, or replaced can have far-reaching consequences for the public.

These public assets are substantial. Department of Defense buildings alone are estimated to be worth more than $500 billion. Replacement cost of the nation's 88,021 public school buildings might exceed $422 billion. It would cost more than $300 billion to replace the physical structure of America's institutions of higher learning (public and private). State and local government building replacement value is estimated to be $400 billion.[1]

[1] There is no compiled estimate of current replacement value for all publicly owned buildings. The committee drew these examples primarily from recently published reports and notes the variety of methods used to determine replacement costs: insured values, appraised values, unit costs to reconstruct per square foot of facility space. Department of Defense estimates are reported in Renewing the Built Environment: Real Property Maintenance Activities, Department of Defense Report to Congress, 1989. Replacement value of public school buildings is estimated in Wolves at the Schoolhouse Door, Education Writers Association, 1989, page 4. College and university estimates are stated in The Decaying American Campus: A Ticking Time Bomb, Association of Physical Plant Administrators of Universities and Colleges, 1989, page 21. State and local government building replacement values were calculated by Building Research Board staff based on an estimated inventory of 4 billion square feet at an average replacement cost of $100 per square foot. All estimates exclude costs of land and major infrastructure.

In addition, water supply, waste disposal, transportation, and other physical infrastructure systems, an investment worth many billions of dollars, are beyond the scope of this report but play a similarly critical national role.

It is unfortunate but inevitable that the construction of new facilities attracts far greater attention than the maintenance and repair of existing ones. While facilities are designed to provide service over long periods of time, the substantial costs of construction are addressed all at once in public debate and management decision. In contrast, the yearly costs of maintenance seem small, although over the course of a facility's service life they generally total much more than the initial costs of construction. The commissioning and occupancy of a new facility are a newsworthy event that attracts public attention, but the ongoing work of maintenance and repair receives little notice except when failures occur that affect the ability of a facility's users to perform their work.

At local levels particularly, few government entities recognize their buildings as more than a “trapping incidental to the provision of public services, to be maintained at the lowest possible cost” (ICMA, 1989). This view pervades all levels of government.

Public agency managers and elected officials, faced with the constant challenge of balancing competing public priorities and limited fiscal resources, often find it easy to neglect the maintenance and repair of public buildings, and not only because new construction or other activities have greater public interest. The cumulative effects of wear on a facility are slow to become apparent and only infrequently disrupt a facility's users. Managers of facilities seldom have adequate information to predict when problems will occur if maintenance efforts are deferred. These managers are often poorly equipped to argue persuasively the need for steady continuing commitment to maintenance. Underfunding of maintenance and repair is such a prevalent practice in the public sector that it has become in many agencies a de facto policy that each year compounds the problem as the backlog of deficiencies grows.

Neglect of maintenance can nevertheless affect public health and safety, reduce productivity of public employees, and cause long-term financial losses as buildings wear out prematurely and must be replaced. Decisions to neglect maintenance, whether made intentionally or through ignorance, violate the public trust and constitute a mismanagement of public funds. In those cases

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where political expediency motivates the decision, it is not too harsh to term neglect of maintenance a form of embezzlement of public funds, a wasting of the nation's assets.

The purpose of this report is to provide public decision makers and facility managers guidance that may help to overcome this persistent problem of underfunding of maintenance and repair. The central principle of this guidance is full recognition and firm commitment to the cost of ownership of public facilities, the stream of costs incurred by the decision to acquire a new facility. In the absence of an adequate statistical basis for recommendations, the authors of this report have applied their extensive experience and judgment to propose a benchmark for budgeting for the maintenance and repair component of this cost of ownership. Adequate funding is not the only element of effective maintenance and repair, but it is so critical that no maintenance and repair program can be successful for long without it.

SOURCE OF THIS STUDY

Concern about maintenance and repair of public buildings led the agencies of the Federal Construction Council (FCC)[2] to ask the Building Research Board (BRB) of the National Research Council to undertake a broad review of the operation, maintenance, and repair activities of federal facilities. The FCC asked specifically for advice on how federal agencies might (1) predict the impact of decisions regarding construction materials and building systems on future operation, maintenance, and repair costs; (2) improve their methods of determining professional staffing requirements for field-level facilities management; (3) improve their procedures for programming and budgeting for operation, maintenance, and repair work; and (4) make effective use of diagnostic techniques for determining the need for maintenance and repair.

The concern about maintenance and repair is not limited to federal agencies. State and local governments are similarly confronted with problems of inadequate maintenance and repair of their facilities. A number of these agencies formally

[2] Fourteen federal government agencies with major interests in building and facilities research, construction, operation, and maintenance comprise the FCC. These agencies have a combined annual construction budget that typically exceeds $12 billion.

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articulated their concerns through the BRB's Public Facilities Council (PFC), a group of state and local government agencies organized to identify and share technical needs for buildings at state and local levels. A statement endorsed by the BRB's PFC sponsors in 1987 urged the undertaking of a research project that would “lead to a determination of the percentage of building replacement cost that should be reinvested annually in building maintenance in order to protect the original investment, assure structural integrity, assure continuous usage within designed capacity, and reduce the potential for system breakdown or incapacitation.”[3] The PFC thus became cosponsors of the study that led to this report.

THE STUDY COMMITTEE AND ITS WORK

The BRB selected a committee of professionals with broad expertise and extensive experience to respond to the FCC and PFC request.[4] This committee reviewed available information; heard testimony by professional staff of federal, state, and local government agencies; and debated at length the key issues and institutional challenges inherent in its charge.

The committee decided early in its deliberations that the problem of persistent underfunding of maintenance and repair in public buildings is of such overriding importance that the four tasks given in the committee's statement of work should be recast. The committee concluded that prediction of the impacts of decisions about building materials and systems and advice on operation and maintenance staffing requirements--legitimate concerns of substantial importance--can be considered only within a context of an integrated maintenance and repair management program and that such a program is impossible without adequate and reliable funding.

The committee therefore focused on the latter two tasks as a means to combat the institutional incentives to underfund--that is, improving maintenance and repair budgeting procedures and using diagnostic techniques to determine the need for maintenance and repair. The committee undertook to propose means to demonstrate the need for an effective maintenance and repair

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3 From “Proposal for Public Facilities Council,” submitted to the Public Facilities Council on June 5, 1986, by Mr. Harry Stevens, then director of Design and Construction for the State of New York.

4 Appendix A presents biographical descriptions of committee members.

management effort and to describe the impact of underfunding; to define elements of an effective maintenance and repair management effort, including condition assessment and resource management; and to propose tools for facilities managers to use in justifying resource requirements for maintenance and repair of public buildings.

WORK YET TO BE DONE

It was recognized at the start that time and available resources would not permit the committee to deal adequately with all aspects of the problems of maintenance and repair. Under a cooperative agreement between the National Research Council and the American Public Works Association (APWA), an arrangement was made to have active APWA liaison participation on the committee in order to bring to the committee the views and experiences of APWA's 850 member jurisdictions that comprise the association's Institute for Buildings and Grounds. The APWA's Research Foundation subsequently approved a research project to be sponsored and supported by APWA members to use the results of the BRB committee's work to develop tools, techniques, and procedures for use by facility managers at state and local levels to forecast maintenance and repair needs. The Research Foundation plans to develop training materials to make these management aids accessible to a broad audience through an APWA-sponsored workshop series. (See Appendix B.)

Other work will be needed as well, to develop applications, guidelines, education programs, and reliable measures of the influence of maintenance on the government and private users of facilities. This committee's work is at best an important step toward overcoming a serious problem.

KEY DEFINITIONS

The committee found in its early deliberations that such commonly used terms as operation and maintenance (O&M) or maintenance and repair (M&R) are often defined and measured quite differently by different agencies. The committee appointed a subcommittee to review public and private sector definitions of such key terms and to develop working definitions for the

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committee's use.[5] The following definitions are meant to be simple while conveying important principles that the committee wishes to emphasize in this report:

Cost of ownership of a building is the total of all expenditures an owner will make over the course of the building's service lifetime. How these expenditures are measured and reported may vary from owner to owner, depending on such factors as whether the owner is a private individual, business enterprise, or a public agency as well as relevant accounting procedures and current tax laws. Regardless of the specific accounting methods, the cost of ownership will generally include not only planning, design, and construction but also maintenance, repairs, replacements, alterations, and normal operations such as heating, cooling, and lighting as well as ultimate disposal. A building owner should recognize at the outset that the cost of ownership is not fully paid when construction is complete or when a building is purchased but instead continues for many years. Failure to recognize this can lead to short-sighted decisions that increase the overall cost of ownership.

A building's service lifetime is the period of years over which the building provides shelter and an environment supportive of the activities it houses. Buildings can have lifetimes that last centuries, although parts of the building may change greatly during that period. Building owners, designers, and managers generally make decisions about maintenance, repairs, operations, and alterations with an assumed design service life in mind, typically between 10 and 30 years.

Maintenance is the upkeep of property and equipment, work necessary to realize the originally anticipated useful life of a fixed asset. Maintenance includes periodic or occasional inspection; adjustment, lubrication, and cleaning (nonjanitorial) of equipment; replacement of parts; painting; resurfacing; and other actions to assure continuing service and to prevent breakdown. Maintenance does not prolong the design service life of the property or equipment, nor does it add to the asset's value.

[5] The subcommittee consulted the following sources to develop its definitions, which the full committee accepted: (1) Webster's Seventh Collegiate Dictionary, (2) DuPont's Cost Accounting Procedures Manual, (3) OMB Circular A-87, (4) ASTM Standard Terminology of Building Constructions, (5) Public Health Service Facilities Manual, and (6) Indian Health Service Facilities Manual.

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However, lack of maintenance can reduce an asset's value by leading to equipment breakdown, premature failure of a building's subsystems, and shortening of the asset's useful service lifetime.

Repair is work to restore damaged or worn-out property to a normal operating condition. Repairs are curative, while maintenance is preventative.

Replacement of an item that is part of the permanent investment of plant and equipment is an exchange or substitution of one fixed asset for another having the capacity to perform the same function. Replacement may arise from obsolescence, cumulative effect of wear and tear throughout the anticipated service lifetime, premature service failure, or destruction through exposure to fire or other hazard. In contrast to repair, replacement generally involves a complete identifiable item of investment (i.e., a major building component or subsystem). When major building subsystems fail, a building owner may sometimes have a choice of repair or replacement of that subsystem. Replacement is typically funded in maintenance and repair budgets.

Deficiencies occur when maintenance and repair tasks are not performed in a timely manner. Deficiencies may or may not have immediately observable physical consequences, but when allowed to accumulate uncorrected, they inevitably lead to deterioration of performance, loss of asset value, or both. An accumulation of such uncorrected or deferred deficiencies is a backlog that represents a liability (in both physical and financial terms) for a building. When a backlog is permitted to exist from year to year, some deficiencies in it may threaten public health or safety or result in major long-term economic losses. Such deficiencies are critical and require urgent attention. Until deficiencies reach this state of urgency, building owners and the public at large may fail to recognize or may choose to ignore the problem, but it remains a problem nevertheless, a problem of growing proportions.

Operations encompass those activities related to a building's normal performance of the functions for which it is used. The costs of utilities, janitorial services, window cleaning, rodent and pest control, and waste management are generally included within the scope of operations and are not maintenance.

Alterations are work performed to change the interior arrangements or other physical characteristics of an existing facility or installed equipment so that it can be used more effectively for its currently designated purpose or adapted to a new use. Alterations may include work referred to as improvement, conversion, remodeling, and modernization but are not maintenance.

In principle, any building owner must establish an annual maintenance and repair (M&R) budget .[6] An annual maintenance and repair budget will in general be the sum of two components: (1) routine expenditures for maintenance, repairs, and planned replacement and (2) expenditures for correction of deferred deficiencies (i.e., backlog reduction). An M&R budget should not include operations or alterations expenditures.

The scale and scope of routine expenditures, the first component, are related to the physical nature of the inventory of buildings and building uses, including design, age, intensity of use, and climate of the region where a building is located. These factors influence the rate at which a building deteriorates through normal aging and use.

The second component, backlog reduction, is related to the level of funding available for routine maintenance and repair and the effectiveness of the owner's maintenance efforts. If maintenance and repair needs that should be addressed on an ongoing basis are neglected, the backlog of deferred deficiencies grows. When physical consequences of deferred deficiencies lead to more serious repair or replacement needs than might otherwise have been anticipated, the rate of backlog growth may accelerate.

Taken together, M&R expenses are an important element of the costs of ownership. Many factors--financial, political, and social as well as technical--influence a building owner's assessment of what should be done to control the costs of ownership while assuring that the facilities provide the shelter and services for which they were designed.

REFERENCE

International City Management Association (ICMA), MIS Report, Washington, D.C., April 1989.

[6] In practice, small-scale property owners or managers may not have a formal budget or may fail even to anticipate the need for M&R expenditures. Public agencies and experienced private property owners will establish formal budgets for such expenditures.

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2

CAUSES, CONSEQUENCES, AND SCALE OF NEGLECT

Neglect of maintenance and repair (M&R) and consequent growth of backlog are caused generally by shortages of funds or by failure to recognize fully the need for M&R. These two causes are often closely related.

PHYSICAL AND MANAGEMENT CAUSES OF NEGLECT

Physical causes of neglect grow out of difficulties owners and managers have in determining the condition of building subsystems and the likelihood of failures. The effects of wear or deterioration are cumulative and manifest themselves slowly. Serious conditions can develop without being visible. Thus, it is possible to simply underestimate the need for M&R.

In addition, decisions made in a building's design to use short-lived materials and equipment (to save on construction costs) generally increase M&R requirements. Poor design or improper construction or installation can cause inadequate performance from the outset and increase M&R needs. Abuse, misuse, neglect, and overuse of building components all increase needs for M&R. Furthermore, incorrect maintenance procedures can shorten the life of systems and components and cause premature failures.

Management causes of neglect spring primarily from failure to allocate adequate funds to M&R. Secondarily, management of the M&R function is frequently ineffectively planned. Maintenance personnel are often not properly trained and maintenance methods are ineffective. Records are often poorly kept and not reviewed to extract lessons for future maintenance planning.

An M&R backlog is often the result of a combination of these physical and management causes. Facilities managers, lacking

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firm performance criteria and statistical bases to describe M&R needs and the consequences of its neglect, can find it difficult to defend their budget requests. Public officials (and private owners as well) faced with neither convincing technical arguments for the need nor immediately visible consequences of neglect are typically persuaded to give higher priority to other demands for limited public resources.[7] M&R budgets are then set at too low a level and the backlog grows.

CONSEQUENCES OF NEGLECT

It is often difficult to discern the direct consequences of neglect of M&R because the physical evidence may not be immediately visible. Several years may pass before the consequences are noticed by the building user. However, eventually a decline in appearance, increased operations costs, and premature failures occur and are evident to both the building user and the management of the facility.[8] The typical consequences of neglect are summarized in Table 2.1.

Threats to health and safety have received increasing attention in the nation's aging building stock. Legionnaires disease at one extreme as well as more prevalent sinus problems and allergic reactions have resulted from inadequate maintenance of air ducts, humidifiers, and filters. Poorly maintained lighting,

[7] For example, a study of expenditures for school building maintenance in Kansas found that the local government's level of outstanding debt was the best predictor of maintenance expenditures--larger debt led to lower maintenance effort. As may be expected, expenditure limitations were cited as a causal factor for the scale of estimated backlog (Stewart and Honeyman, 1988).

[8] The link between maintenance and productivity has not received extensive analysis but is measurable. Chaudhry and Ali (1989), for example, estimated that increasing maintenance expenditures on irrigation canals in Pakistan by 10 percent increases agricultural output by more than 3 percent and, in general, that the ratio of marginal benefits to investments in operation and maintenance has been in the range of 11 to 26. Studies of bridge maintenance in New York City have found that the city government may “save” $20 million over the years by reducing maintenance but that taxpayers at all levels directly bear a premature $300 million cost of replacement (Robison, 1989).

stair coverings, and floors lead to accidents. Water infiltration of poorly maintained roof decks can lead to structural corrosion and failure.[9]

TABLE 2.1 Potential Consequences of Underfunding

Threats to Health and Safety
Health failure
Safety failure
Structural failure
Service Failures
Power service loss
Heating, ventilation, and air-conditioning system failure
Leakage for other shelter failure other losses of use
Excessive Costs
Energy costs
"Domino effect," minor failures leading to major failure
Replacement versus repair costs
Absenteeism and turnover
Losses of production
Loss of assets (building contents)
Social Costs
Inability to attract and retain personnel
Poor morale
Poor image
Loss of readiness

Service failures of building systems or components often result from a lack of maintenance resources. Trade-offs are made within a limited maintenance budget, taking a gamble that

[9] A report on the corrosion of the weathering steel decks in the garage atop the New Haven Coliseum, which could result in demolition of the entire 17-year-old facility, stated that "a jury found that because the owner had not adequately maintained the building throughout its life, the owner--and not the design engineer--was totally responsible" (ENR, 1988).

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nothing will go wrong. For example, in a case known to the committee, an owner decided not to contract for services to maintain an emergency generator and also neglected to train and equip in-house personnel, ostensibly due to lack of resources. Consequent failure to inspect and test the generator each year resulted in loss of coolant and failure of the automatic high-temperature shutdown circuit[10] when the generator is needed.

Inadequate maintenance can result in excessive operating costs. For example, during the Vietnam war era, the U.S. Navy's funding for M&R dropped significantly. (The funds gained from the M&R reduction were used to fight the war.) Consequently, there was a gradual degradation of Naval facilities. At one installation the refueling piers deteriorated so badly that ships could not dock, and they had to be serviced by fuel barges, a costly operation. Funding of the functional operations but not the facility's M&R resulted in costs that were higher than if adequate M&R had taken place. In addition, the disregard of maintenance for the pier resulted in its ultimate replacement at a considerable cost to the Navy.[11]

Social costs are harder to measure but can be documented. For example, interviews of teachers in public schools have found neglect of maintenance to have a definite impact on the educational process (Corcoran et al., 1988). Poorly maintained school buildings were cited as demoralizing to teachers and students alike. The committee learned of another example in which reductions in personnel staffing and training in a private corporation's electrical power distribution facilities were soon followed by a higher incidence of personnel injury and equipment damage.

In its discussions of the impacts of underfunding M&R functions, the committee observed that one of the worst consequences of long-term neglect of maintenance is the crisis management condition in which building managers and owners

[10] This example also resulted in excess cost--$30,000 for overhaul of the generator. Other modes of failure could have occurred, with different consequences.

[11] In another instance the Navy found that inspection and repair of steam traps was being deferred by many shore activities. It was determined that $23 million was lost each year due to failed steam traps. As a consequence, boiler plants were straining to meet heavier loads. Up to 20 percent of the steam generated was lost due to failed traps. A Navy survey showed that for every dollar invested in steam trap maintenance at least $3 in steam costs was avoided (Navy Civil Engineer, 1988-1989).

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are put. Hasty decisions are often made, with expensive and even inappropriate products and services purchased.

SCALE OF THE PROBLEM

The committee knows of no comprehensive study on maintenance deferral and backlog, but anecdotal evidence suggests that the scale of the problem is substantial. In unofficial discussion with the committee, representatives of the Department of the Navy, for example, estimated its backlog to exceed $1 billion in 1987. The Commonwealth of Massachusetts has estimated that it had a backlog of approximately $300 million in 1989, and the amount may be growing under the constraints of the state's fiscal austerity.

A study by the Association of Physical Plant Administrators of Colleges and Universities estimates the current capital asset value of colleges and universities to be $300 billion with capital renewal and replacement needs of $60 billion to $70 billion. M&R funding needs were estimated at $6 billion with a backlog of approximately $1.2 billion (Rush and Johnson, 1989). A study of the nation's largest urban school districts found that in one district the current M&R budgets were only adequate to paint classrooms once every 100 years and to replace floor coverings once every 50 years (Corcoran et al., 1988). Another study collected data on over one-half of the nation's schools in all 50 states and found that one of every four is in inadequate condition. Of these, 61 percent need maintenance and major repair (see Table 2.2). The study estimates $41 billion in M&R needs for public school buildings (EWA, 1989).

The committee recognizes that maintenance backlog needs may be often overstated for a variety of reasons. A major study of the Department of Defense's investment in real property maintenance activities was prompted in part by Congress's concern that "backlog estimates appear to have little validity and are not verified or developed consistently between services" (U.S. Senate, 1988). However, the committee observed that while the actual size of the backlog may be overstated, there is nevertheless a significant problem resulting from past policies and attitudes regarding the importance of maintenance funding.

APPROACHES TO SOLVING THE PROBLEM

The committee believes that the underfunding and subsequent neglect of M&R that prevails in many public agencies

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result in large measure from a failure of those who decide on funding levels to recognize fully the impact of their decisions on the public's capital assets, the investment in public buildings. These decision makers have limited information to help them evaluate the budgets submitted by their facilities managers and, thus, they must make relatively uninformed decisions. If these decision makers had better information to aid their evaluations, their management capabilities would be strengthened. The committee proposes that formulation and evaluation of M&R budgets should consider explicitly (1) the appropriate size of the routine M&R budget, which is a part of the cost of ownership (Chapter 3), and (Chapter 2) the M&R backlog, which may be estimated using the procedures of condition assessment (Chapter 4).

TABLE 2.2 “Inadequate” School Buildings Problem Areas

Problem Area	Percentage Reporting
Need maintenance	61
Obsolete	43
Environmental hazards	42
Overcrowded	25
Unsound structures	13

Source: EWA (1989).

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3

THE MAINTENANCE AND REPAIR COMPONENT OF THE COST OF OWNERSHIP

Building owners--and those elected and appointed officials who represent the owners of public buildings--should recognize explicitly the full cost of ownership to which they are committed by virtue of ownership. Important components of this cost are the routine expenditures for needed maintenance, repairs, and planned replacement. Characteristics of a building's design and construction, operating procedures, climate and location, and age influence the need for maintenance and repair (M&R). The owner's policies about M&R and service to tenants have influence as well. Random events such as heavy storms, human error, or air pollution may increase needs for M&R.

Most of the factors that influence the need for M&R apply to individual buildings. However, the manager of a substantial building inventory may enjoy what economists term economies of scale--opportunities for savings because larger quantities of materials are purchased or personnel are more effectively utilized or learn by experience to be more efficient. On the other hand, costs may be incurred in managing a large inventory--such as travel among buildings or costs of keeping parts and equipment in stock--that offset some of these economies. In general, the following factors can have a major influence on the appropriate level of M&R expenditures:

- Building size and complexity
- Types of finishes
- Current age and condition
- Mechanical and electrical system technologies
- Telecommunications and security technologies
- Historic or community value
- Type of occupants or users
- Climatic severity
- Churn (i.e., tenancy turnover rates)
- Criticality of role or function

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- Ownership time horizon
- Labor prices
- Energy prices
- Materials prices
- Distances between buildings in inventory

While the M&R component of the cost of ownership will vary from building to building, it is possible to develop a consistent relationship between this component and characteristics of an inventory of buildings. A variety of such relationships are in use to estimate average levels of the cost of M&R. Typical maintenance expenditure per square foot is frequently used as a yardstick for determining what an appropriate level of M&R budgeting should be, but such a measure is insufficiently sensitive to either external financial conditions or building characteristics. The relationship is better stated in terms of an annual percentage of the inventory's current replacement value.

Based on experience and judgment, the committee proposes that the appropriate level of M&R spending should be, on average, in the range of 2 to 4 percent of current replacement value of the inventory.[12] The specific percentage for any inventory will depend on such factors as the age of the buildings in the inventory, the type of construction (permanent vs. temporary), the level of use of the buildings, the structure of the maintenance organization, and the climate. However, the relationship between M&R requirements and the current replacement value of single buildings may vary widely and for any one building may be outside the proposed range.

This 2 to 4 percent range is most valid as a budget guide for a large inventory of buildings and over time periods of several years. A small town or school district may find that a severe winter, or an older building nearing the time that a substantial renovation is warranted, temporarily raises annual M&R costs above this normal range. Such a jurisdiction may also find that past decisions to reduce construction expenditures now have, as a consequence, higher M&R costs. However, even with small inventories the 2 to 4 percent rule of thumb may be applied over a longer period of time, such as 5 to 10 years.

A reliable estimate of the current replacement value of a building or an inventory is a necessary element of this budgeting rule. Current replacement value can be determined in several ways. The simplest approach estimates what it would cost in any given year to construct or purchase each building in the inventory. Another approach applies escalation factors to the original

[12] This rule is based on the committee's combined judgment.

acquisition cost of the buildings in the inventory. Some agencies have developed computer programs to perform such calculations and to provide a replacement value for the total inventory each year. There may be substantial uncertainties in these estimates, particularly among the older stock of public buildings (some more than 100 years old). Each agency must evaluate its own inventory and develop the best approach for determining its replacement value.

If an inventory of buildings receives an adequate level of M&R funding, a steady-state situation should exist wherein the inventory would remain in a service condition that would neither decline nor improve and a backlog of deferred deficiencies would not develop.[13]

However, if a backlog exists, it is unlikely to be reduced by expenditures limited to the 2 to 4 percent level. Further deterioration will occur if the backlog is not reduced, and the ultimate cost of correcting the deficiencies will increase. The committee proposes that a second element of the total M&R budget must be recognized--funds required to reduce the backlog. The total budget then includes the routine M#038;R components, which are a continuing part of the cost of ownership, and the backlog reduction component, which is determined by the physical condition of the inventory.

Assessing the size of the backlog that develops when M&R are neglected requires a condition assessment. A condition assessment is an evaluation of the degree of accumulated damage inferred from diagnostic observations and tests.[14]

Condition assessment, at its simplest, is a monitoring activity applied regularly as a part of a good M&R program. Systems and materials are inspected on a planned schedule to determine if they are sound and functional. Standards must be available as a basis for determining when systems or materials are deviating from their anticipated condition to spot potential problems before they become critical. Condition assessment is also used to

[13] This expectation depends on effective use of M&R funds, which requires adequate management and staff capability. Refer to Chapter 5.

[14] The general field of building diagnostics is still relatively young and evolving (BRB, 1985). Most diagnostic assessments are undertaken because of specific observable failures or performance problems, not for the broad assessment of backlog envisioned by the committee. This broader assessment is in some ways analogous to medical diagnostics that may alert a physician to a patient's potential problems or help assess the extent of those problems.

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develop information on facilities that have not received regular maintenance or inspections so as to develop comprehensive data bases on conditions and thereby establish the scope of maintenance backlogs.

If a substantial backlog has developed, several years of effort may be required to eliminate it. An appropriate M&R budget should be established to reduce the backlog as quickly as possible, which requires that repair spending must be adequate to outpace the backlog growth that occurs as a cumulative result of past neglect. No generally valid rules of thumb can be recommended for this determination.

If the backlog has been eliminated, maintenance spending may be reduced to levels truly required to maintain adequate facility performance. Escrow or set-aside accounts may be established to preserve funds budgeted but not actually expended in a given year due to favorable use conditions (e.g., warmer or drier than average weather or lower than typical utilization).[15] Condition assessment should be used to assure that performance is, in fact, being maintained at target levels.

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Building Research Board (BRB), Committee on Building Diagnostics, Building Diagnostics: A Conceptual Framework , Washington, D.C., National Academy Press, 1985.

[15] Establishing such accounts in the public sector requires changes in government financial practices.

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4

CONDITION ASSESSMENT AS A MAINTENANCE MANAGEMENT TOOL

The committee recommends that much greater use of formalized condition assessment should be adopted to protect public assets from wastage. Several federal and state agencies have undertaken condition assessment programs that can serve as models and teach useful lessons for improving the effectiveness of maintenance and repair (M&R) activity.[16] The committee's review of these programs is the basis for the following suggestions on scope, diagnostic interpretation, and effective use of condition assessment as a maintenance management tool.

SCOPE AND INITIAL SURVEY

The scope of condition assessment may be limited to the identification of one specific condition in a building or it may be a planned comprehensive evaluation of the building. The depth or level of detailed assessment can vary as well. Comprehensive assessment programs that address entire buildings and multiple buildings may be simple, visual, walk-through-type assessments, or they may be in-depth studies, using a variety of technical diagnostic techniques. In general, the scope of condition assessments must be designed to meet the information requirements of the property owner or manager. The cost of data collection and analysis and the time required to develop large amounts of data can be high. The only way to control costs and time of condition assessment is to clearly and definitively outline the scope of the effort.

The early detection of potential problems is important in preventing deterioration, possible damage to adjacent materials

[16] Refer to Appendix C, Appendix D, and Appendix E; see also State of North Carolina (1988) and APPA (1986).

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or systems, and failure of components and should thus be a primary objective in designing the condition assessment program. During condition assessment, systems and materials are inspected for outright signs of deterioration, failure, or more subtle symptoms that conditions are not normal. The standards and procedures that are the basis for assessments may often combine into checklists that prompt and assist inspectors in the identification process. The assessment process should be standardized and performed regularly by individuals trained to recognize and identify the symptoms of problems. Such symptoms are often subtle and meaningless to building users or even building managers who may not understand the significance of telltale staining, buckling of materials, or minor cracking.

Poor design decisions and faulty construction can create problems soon after a building is placed in service. This happens most frequently at the interfaces between components, especially different systems, or components by different manufacturers or suppliers. The implications of such interfaces may not be fully anticipated or understood during the design phase. Later, during construction, problems in compatibility or dimensioning may be exacerbated due to “field engineering” solutions. The condition assessment should direct particular attention to these interfaces.

DIAGNOSTIC INTERPRETATION

Following the survey to identify symptoms of problems or deficiencies, the next step in condition assessment is to perform a diagnostic analysis to determine if there is, in fact, a problem, the nature and extent of the problem, and options for corrective action. The successful analysis will require technical knowledge of the systems involved, most frequently the materials used in construction and maintenance. Interpretation may range from straightforward moisture problems caused by leaks to complex interpretation of risks associated with toxic materials, mechanical or electrical system performance, intelligent control systems, structural loading, or fire safety. Such knowledge may be gained initially through experience and training in the building trades or through university education.

Predictions or estimates of the remaining useful life of a component must often be made. Funding decisions must often be made based on which problems are most severe. Inspectors may be asked to indicate which components may fail first and which can be expected to continue to function--perhaps at a reduced level--for some period of time. Effective condition assessments depend on such predictions, which then become the basis for establishing the repair component of M&R budgets.

The diagnostic analysis should be based on logical, standardized, professionally developed procedures to ensure that identified deficiencies are efficiently and correctly evaluated. Faulty analysis or unsubstantiated speculation can be costly and dangerous.

EFFECTIVE USE OF CONDITION ASSESSMENT

Because condition assessment involves field surveys, accumulation and use of substantial amounts of data, and trained personnel, the exercise can be costly. Care must be taken to assure that the assessment program is cost effective in reducing backlog and in minimizing costs of ownership.

Control of costs is achieved through proper planning and control of the scope of the assessment. Decisions must be made on what aspects of the building are to be inspected and to what level of detail the evaluation will be undertaken. For example, will inspectors be required to examine every space or system? If inspecting electrical systems, will panel covers be removed? Will there be circuit testing? Answers to such questions depend on the specific needs of each property owner or agency.

One approach to reaching these answers is “filtering.” Filtering generally means applying selective criteria to larger numbers of buildings to determine if some should be inspected earlier than (or to the exclusion of) others. For example, the assessment may initially include only older buildings, buildings of a certain construction type, or a small number of buildings selected to be representative of the total inventory. Filtering may be applied to systems as well, such as when an owner is upgrading telecommunications or data processing in all buildings.

Standardization of the inspection and diagnostic analysis is one of the most important means of controlling costs of a condition assessment program. Fixed checklists or guidelines are the basis for such standardization and will assure that data collected are consistent from one building to another and can be summarized or “rolled up” to represent the larger numbers of buildings in a total inventory. Standardization improves data reliability and allows flaws, gaps, or inconsistencies in the data collection process to be detected more easily. More standardized assessment programs also may become more useful to the entire community of building owners or managers as a basis for statistical analysis and subsequent development of better management models for building systems maintenance.

The condition assessment team should be given target estimates of levels of anticipated problems, time required for inspection, number of buildings to be inspected, symptom of

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checklists, and standards to be applied in identifying symptoms. Assessments may be conducted by dedicated teams, including architects, engineers, inspectors, other consultants, students, or others trained for the job, depending on the requirements of the program.

GUIDELINES FOR ASSESSMENT

Standardization of condition assessment procedures and qualifications of the teams responsible for condition assessment will be achieved more rapidly if definite guidelines are developed. Federal agencies, as owners and users of large inventories of buildings, would benefit from the development of such guidelines, and the committee recommends that these agencies sponsor this development. The agencies should work together--and with state and local governments and private sector owners--to assure that the data bases ultimately resulting from their effort are of the broadest possible use.

Examples of programs already in operation may serve as useful models for this work. The State of Florida, for example, requires condition assessments of state buildings at least every 3 years, and the state's Department of General Services has established a computer-based inventory system to support the program.

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5

MAINTENANCE MANAGEMENT

Inadequate funding is the most significant maintenance and repair (M&R) problem for public buildings, but the committee recognizes as well the need for effective management of the M&R function to realize the full benefit of funds that are made available. While this report is not meant to be a comprehensive treatment of overall maintenance management, the committee wishes to emphasize the importance of certain specific issues: cost accounting, staff resources, and management commitment.

COST ACCOUNTING STRUCTURES

The cost accounting structure used by an agency should separately identify costs associated with M&R. Unfortunately, this separation is not now strictly defined in many agencies. Often budgets and expenditures are aggregated under a general heading of "Operations and Maintenance," and decision makers perceive only the whole of O&M and not its parts. Under pressures to reduce budgets, the O&M total may be cut without recognition that the operating portion is essentially irreducible. The reduction in funds then falls into the M&R portion of the O&M effort.

The cost accounting structure should also isolate minor alterations and improvements from routine M&R. Building users often desire minor alterations and improvements intended to improve the efficiency of their operation.[17] Often this work is given a higher priority than true M&R and, thus, represents a "leakage" of M&R funds.

[17] The committee observes that such "improvements in operations" are in fact often responses to requests by senior managers or commanding officers for changes in facilities.

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STAFF RESOURCES

Managing and operating an M&R program requires qualified engineers and technicians as well as trained managers. Agencies should assign to a senior executive the responsibility for oversight of M&R of field-level activities and budget formulation. In some agencies an executive-level manager for M&R would be required full time; in other agencies the task may be delegated as a part-time responsibility.

Finding qualified engineers and technicians to staff M&R programs is a recurrent problem. Many agencies successfully contract for some or all M&R functions,[18] but the committee believes that agency personnel should set requirements, establish procedures, and assure the quality of the work. Staffing with qualified people becomes more difficult as buildings become more complex, notably in their control systems.

Education and training of M&R management and technical personnel are an important element of an effective M&R program. The committee recommends that colleges and universities that educate facilities managers emphasize the importance of M&R management. Agencies should include ongoing training for their staffs. It must be recognized that facilities maintenance and management personnel are responsible for major assets that contribute to the productivity and welfare of the organizations and individuals who use these facilities.

MANAGEMENT COMMITMENT

With this recognition must come an ongoing commitment by top-level agency management to the protection of the public's real property investment. This commitment should extend through the entire agency from the users of the building to the M&R program managers to the financial managers. The committee observes that such commitment is seldom in evidence in public agencies but is characteristic of many manufacturing concerns where M&R are viewed as tantamount to maintaining

[18] A survey conducted by a standing committee of the Federal Construction Council revealed that among the 11 responding agencies the percentage of O&M needs met through contracting out ranged from 5 percent or less for three agencies to 50 percent or more for four agencies (Federal Construction Council, The Experience of Federal Agencies with Operations and Maintenance Contracts for Facilities , Technical Report No. 90, Washington, D.C., National Academy Press, 1988).

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the ability to operate and produce goods. Elected officials and the public at large, as well as agency managers, must recognize that effective use of public resources and tax dollars depends on the performance of the government's facilities.

This commitment is especially important when new facilities are constructed, which some managers and officials may assume have less need of maintenance than older ones. This assumption is misguided and can undermine the benefits that new facilities and new technologies are intended to provide.

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APPENDIX A

BIOGRAPHICAL SKETCHES OF COMMITTEE MEMBERS

ROBERT F. JORTBERG, USN, Retired (Chairman), is associate director of the Construction Industry Institute. Rear Admiral Jortberg was previously a vice president with Lummus-Crest, an international engineering and construction company, and served 32 years in the Navy Civil Engineer Corps, including as director of the Shore Facilities Division, Office of the Chief of Naval Operations. A 1947 graduate of the U.S. Naval Academy, he earned a B.S. in civil engineering and an M.S. in industrial management at Rennsselaer Polytechnic Institute and is noted for having implemented a program for maintenance and repair of real property and capital programs for the Navy.

DONALD G. CARTER is president of Carter Engineering, Inc. He earned a B.S. in mechanical engineering from Washington University in 1949 and has lectured and published extensively. He is familiar with automated operations and maintenance systems. Mr. Carter has served as an officer and board member for several professional societies.

DAVID G. COTTS is chief of Building Maintenance and Repair for The World Bank. Mr. Cotts received his M.S. in civil engineering from Iowa State University. A veteran of 22 years with the U.S. Army Corps of Engineers, he has published and lectured on facility management and has served as a staff member at the United States Military Academy and the U.S. Army Engineer School. He has been active in professional societies and has served as president of the International Facility Management Association.

DAVID MICHAEL CROSKERY is currently consultant manager for the Maintenance Engineering Group of the Engineering Department of E. I. DuPont de Nemours & Co. He earned a B.S. in civil engineering from the University of Michigan in 1961. Mr. Croskery is active in several corporate committees looking at various aspects of the maintenance function in detail; one committee's activities have included a corporate benchmarking study of the maintenance functions of DuPont and 16 other companies.

VIVIAN LOFTNESS is an associate professor in the School of Architecture at Carnegie-Mellon University. Her research work has included world climate projects for the World Meteorological Organization, energy conservation and solar energy studies for the AIA Research Corporation, and work on the total building performance concept for a consortium of American Industries and Public Works Canada. She has been a faculty member at a number of universities, including MIT, where she obtained her graduate degree in architecture, and is the author of numerous publications and a recipient of many fellowships and awards.

JOHN H. MYERS is assistant dean for research at the College of Architecture, Georgia Institute of Technology. Professor Myers received his M. Arch. degree from the University of Florida in 1978. He is an expert in facilities diagnostics for capital renewal projects and has published and lectured extensively on many aspects of architecture.

DENNIS O'LEARY is commissioner of the Maintenance and Construction Department of the City of Scarborough, Ontario. He received a B.S. in mechanical engineering from the University of Saskatchewan in 1957. After service with the RCAF in Canada and overseas construction and maintenance of public works facilities, he assumed responsibility for maintenance of Scarborough's buildings and for construction of all new city facilities. He has been active in energy management and developed 5- and 30-year conservation maintenance plans for major building components. Mr. O'Leary has served as president of the Institute for Buildings and Grounds of the American Public Works Association and is a member of the Association of Professional Engineers and the Institute of Public Administration.

HARRY STEVENS, JR., is a former director of General Services, Design and Construction Group, for the State of New York. He holds a B.S. in civil engineering from Kansas State University and an M.B.A. from George Washington University. Prior to his service with the State of New York, Mr. Stevens retired with the rank of captain from the Civil Engineer Corps of the U.S. Navy after 30 years of service.

THOMAS E. WIGGINS is a project manager at Hanscomb Associates, Inc., in Atlanta. He holds an M. Arch. degree and an M.S. in industrial management from the Georgia Institute of Technology. He has specialized in the development of automated cost systems, where costs are segmented into identifiable and trackable elements of systems costs, and

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attendant data bases. He is responsible for projects requiring development of cost control systems, construction cost modeling, life-cycle cost analysis, and cost indexing.

STAFF

ANDREW C. LEMER, director, was formerly division vice president with PRC Engineering, Inc., and president of the MATRIX Group, Inc. An engineer-economist and planner, he received his S.B., S.M., and Ph.D. degrees in civil engineering from the Massachusetts Institute of Technology. He is a member of the American Institute of Certified Planners, the American Society of Civil Engineers, and the Urban Land Institute.

PETER H. SMEALLIE , senior program officer, and executive secretary of the Public Facilities Council has a B.A. in urban studies from St. Lawrence University. He has served as vice president of Thomas Vonier Associates, an architecture and consulting firm, and was a program director with the American Institute of Architects Research Corporation. He recently completed a book titled New Construction for Older Buildings: A Design Sourcebook for Architects for the publisher John Wiley & Sons.

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APPENDIX B

APWA PROPOSAL ON LIFE-CYCLE ANALYSIS OF BUILDING MAINTENANCE COSTS

This description was prepared by staff of the American Public Works Association prior to completion of the committee's study. Refer to Chapter 1.

Executive Summary

Public agencies invest millions in capital facilities, generally without sufficient attention to the long-term effects on the maintenance budget. A new building obliges public officials not only to maintain the asset but also to understand the impact of decisions made at the time the building is designed and constructed.

This research will provide public building managers with a planning tool enabling them to forecast maintenance requirements for both new and existing facilities. The product of this research will provide facility managers with a better method of forecasting short- and long-term maintenance expenses.

This project will develop a detailed process for analyzing annual as well as rehabilitation and replacement costs of individual building components. An accurate budget forecast, based on the facility's total maintenance needs, can then be prepared. Public managers will also be able to relate their maintenance requirements to a percentage of the replacement cost of their facilities.

Background

Forecasting maintenance needs for public buildings has created major problems for many public agencies. While it is possible to predict accurately many aspects of building performance, such as structural performance and energy use, we are not able to estimate with any degree of reliability what expenditures must be put back into the building on a regular basis to extend its useful life. Often, in order to secure funding for new facilities, the least expensive building construction design is selected with little concern for the long-term, life-cycle cost implications of the design. As public agencies budget for maintenance, major problems are encountered in making a case for adequate funding.

Maintenance requirements for buildings are largely governed by four factors: (1) quality of materials and equipment used; (2) quality of the workmanship in construction; (3) wear that the various components of the structure receive from occupancy or natural conditions; and (4) level of periodic preventive maintenance.

Materials and equipment for various components of new and/or rehabilitated buildings are frequently selected with seemingly little regard for long-term maintenance costs. In order to decrease life-cycle costs, building design must be more than a commitment to provide a given amount of space for a designated purpose. Effective public building design can serve to decrease both short- and long-term maintenance and operation requirements.

In the absence of any scientific data pertaining to building maintenance requirements, there is little, if any, correlation between building design and long-term maintenance investment requirements. As a result, the following adverse conditions may develop: (1) underfunded annual maintenance, leading to costly rehabilitation and repair; (2) budgetary fluctuations, resulting in sporadic maintenance of mechanical and other systems; and (3) overfunding, an unusual occurrence, in which the agency establishes a prohibitively costly and cumbersome maintenance program. These conditions stem from an ad hoc assessment of building maintenance requirements and their associated costs, rather than an analytical approach to determine long-term, or life-cycle, costs. Designers who wish to consider whether they are "building out" future maintenance problems do not have a reliable guide to judge selection of materials and equipment. Likewise, owners do not have reliable guides to judge the future consequences of their instructions as to types of materials and equipment to be used or regarding life-cycle costs that they consider acceptable for a type of structure.

This project will include the wide variety of buildings used by federal, state, provincial, and local governments, such as office facilities, garages and shops, libraries, police and fire stations, recreational facilities, institutional housing, and special structures, such as water and wastewater treatment plants. Structures will be assessed both as designed and as built.

Maintenance is often the first item to be eliminated or reduced as public agencies struggle to balance their budgets. Problems resulting from deferred maintenance have become increasingly apparent. In some cases, major rehabilitation may be necessary, requiring funds far exceeding the cost of timely maintenance. This project will develop the basis to support justification of annual aintenance investments in buildings.

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The research project will draw on the principles of life-cycle cost analysis that are used in the selection of materials and equipment for new and/or rehabilitated public structures and for budgeting funds for maintenance and replacement costs.

Proposed Research

The APWA Research Foundation proposes to develop a tool that will allow building managers to determine their ongoing maintenance and rehabilitation budgets. Specifically, the Foundation will: (1) analyze estimating techniques for determining annual building maintenance costs; (2) define methods to quantify the consequences of deferred maintenance; and (3) identify life-cycle costs of major building system components.

Development of this information will allow the agency to protect its original investment, assure continuous usage within design capacity, and reduce the possibility of expensive repairs.

The proposed research will be a joint effort by the APWA Research Foundation, the Public Facilities Council (PFC) of the National Research Council, and APWA's Institute for Buildings and Grounds.

The study will be conducted in three phases. During the first phase, the PFC will establish a committee to develop the most appropriate methodology required to develop annual maintenance cost analyses for public buildings. The committee will develop a methodology and approach to consider: (1) calculation of the effects of natural causes and occupants: (2) the cost relationship among building system components in various types of structures; (3) types and grades of commonly used building material system components; (4) annual and periodic maintenance costs associated with various systems based on use and climate considerations; and (5) effects of deferred maintenance.

In the second phase, the APWA Research Foundation will develop procedures to allow utilization of the Phase One findings by facility managers and by designers of new or rehabilitated structures. Data will be compiled in a format that can be readily used by facility managers.

In the third phase, the Research Foundation will develop training materials that will include a description of methods for life-cycle cost calculations and procedures to evaluate maintenance programs based on design and materials for separate building components. Training will also include details for managers in developing an inventory and data base for as-built facilities.

Key products available to each sponsor will be materials to assist building managers in assessing their annual and life-cycle cost for maintenance, including alternative assumptions on the effects of deferred maintenance.

Benefits of Project Sponsorship

Improved techniques for evaluating operations and maintenance programs will allow public agencies to establish optimum levels in annual budgets, with specific applications to:

- — Annual maintenance. You will be able to develop an optimum level of maintenance based on use and building condition to ensure that expenditures are not only justifiable but also quantifiable.
- — Deferred maintenance. You will be able to estimate the increased costs associated with postponing repairs and deferring maintenance.
- — Building components. You will be able to utilize comparative data when reviewing alternatives for new or replacement systems.

As a project sponsor you will assist in directing the project and have the opportunity to have your specific needs considered in developing the project's research activities. In addition, you will receive periodic reports that will allow you to begin implementation of the project findings immediately.

Cost to Participate

Cost is based on the population of the area served by the public agency. The range of sponsorship fees is from $750 to $3,000, based on estimated project costs to APWA for phase two and three of $96,000. The length of the project is expected to be 30 months. Projects conducted by the APWA Research Foundation are cooperatively funded by local, state, and federal agencies throughout Canada and the United States. This cooperative arrangement allows for a wide distribution of project costs, greatly reducing the financial burden of individual agencies to conduct essential research. A funding schedule and reply form accompany this proposal.

The Next Step

To join this research effort, return the cosponsorship form and designate a representative for followup contacts.

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APPENDIX C

CONDITION ASSESSMENT EXAMPLES

Four examples of condition assessment programs were submitted by committee members to show different levels of investigations and the costs associated with such programs.

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A.	Title:	Inventory and Condition Assessment Program (ICAP)
	Developer:	U.S. Department of the Interior, National Park Service (NPS), 1988-1989
	Scope:	Program visually inspects and describes up to 227 standard features in division of site, exterior and interior features, roofing, fire safety, accessibility, plumbing, electrical, and HVAC. Feature descriptions, deficiencies, recommendations for corrective action and costs are recorded, prioritized, and reported. Organizes general logistical and agency data for buildings.
	Frequency:	As required to support ongoing maintenance management and special focus programs such as safety and housing.
	Inspectors:	Varies from experienced internal maintenance staff to private architect and engineers under contract. All must use program documentation to perform standard condition assessment.
	Automation:	Microcomputers in over 250 sites; Clipper/dBase III; reporting for single buildings and groups of buildings.
	Interfaces:	Transfers data to and from three other computer programs in use by NPS. Rolls up feature and quantity data into maintenance management system.
	Application:	Building module applies to all buildings regardless of size and type of use. Applies to historic and nonhistoric buildings. Other modules on roads, grounds, etc., under development.
	Documentation:	Program manuals and forms and software documentation provided to assure standardized implementation.

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Testing Level:	Some use of nondestructive tests (circuit testing; cycling of systems in plumbing, HVAC, and fire safety; removal of system panels). No destructive testing. Follow-up testing may be recommended as part of corrective action.
Cost:	Costs range from $0.05 to $0.25 per square foot depending on the level of detail and size/type/ distribution of buildings (highly variable geographic and size distribution).

B.	Title:	State Facility Inventory
	Developer:	State of Florida, Department of General Services (DGS)
	Scope:	Comprehensive inventory and condition assessment of all major building components. Includes immediate site, exterior closure, interior construction, HVAC, plumbing, and electrical. Deficiencies are identified and described; corrective actions and costs are proposed.
	Frequency:	Scheduled on a 3-year cycle. First cycle has been completed; second cycle has been initiated.
	Inspectors:	Internal Department of General Services architects only. Regional system of four architects with one clerk and one supervisor. No engineers; no contractors.
	Automation:	Microcomputer system for IBM PCs and compatibles. Compiled Foxbase with data entry and storage at four remote PCs and transfer via modem to a central microcomputer in Tallahassee.
	Interfaces:	Data are used directly in the state budget process, but there are no current software/hardware linkages to other systems. Such linkages are planned.
	Application:	Applied to all building types 3,000 square feet and larger in all state agencies, except the university system. This includes offices, courts, correctional facilities, hospitals, warehouses, service buildings, etc.
	Documentation:	Standardized program forms and checklists plus software documentation are provided for system users.
	Testing Level:	No physical or destructive testing. Tests are recommended as part of corrective action or as needed to make final determinations.

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Cost:	Approximately $0.043 per square foot.

C.	Title:	Campus-wide Facility Condition Study
	Developer:	Vanderbilt University, Plant and Operations Division
	Scope:	Comprehensive inventory and condition assessment covering approximately 150 features in 9 categories, to identify deferred maintenance and capital renewal projects. Preventive maintenance standards were developed for selected equipment.
	Frequency:	One-time implementation in 1986 to develop capital planning data with 3-year follow-up to assess progress. Reinspection on a 3- to 5-year cycle.
	Inspectors:	Qualified architect and engineer teams under contract; experienced in use of program, accompanied by staff on site. No use of internal staff to perform assessments.
	Automation:	Microcomputers by plant management; special application of advanced revelation software, IBM PC and compatible 286 and 386; single building and summary reporting.
	Documentation:	Hard-copy building and summary reports. Multiple management summaries available. Operating manual for software.
	Testing Level:	Nondestructive only. Testing may be recommended as part of assessment.
	Cost:	From $0.035 to $0.05 per square foot (contiguous site; large volume)

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D.	Title:	Facility Condition Assessment Program (FCAP)
	Developer:	North Carolina Department of Administration, State Construction Office
	Scope:	Visual inspection of 17 building divisions, including site; foundations; roofing; exterior closure; interior construction; conveying, mechanical, and electrical systems. Building components are inventoried, and deficiencies are identified and described. Cost estimates and a priority are assigned for corrective actions.
	Frequency:	Implementation is in progress. Reinspections are planned on a 3-year cycle with selected buildings in poor condition to be reinspected annually.
	Inspectors:	Professional inspections by experienced internal staff work in teams of architects and engineers. Special 8-person division established to administer and perform.
	Automation:	Compiled dBase IV.
	Interfaces:	None current. Plan calls for interface with new project management systems.
	Application:	The program is applied to buildings of a minimum of 3,000 square feet. This will cover about 4,000 buildings from a total of 11,102 buildings in all state agencies. All building types are included.
	Documentation:	Forms, program manuals, and software manuals provided for implementation by state personnel. Multiple-choice checklists used for field work.

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Testing Level:	No destructive testing. Follow-up tests may be recommended to make final determinations or as part of corrective action.
Cost:	To be determined.

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APPENDIX D

NAVAL FACILITIES ENGINEERING COMMAND CONDITION ASSESSMENT PROGRAM

As an integral part of a comprehensive maintenance management program now known as the control maintenance management program, the U.S. Navy's Bureau of Yards and Docks (predecessor of the current Naval Facilities Engineering Command) established a continuous inspection program. This program had two basic parts:

1. A preventive maintenance program provided for periodic scheduled inspections and adjustments to selected elements of the physical plant, specifically including dynamic equipment such as pumps, air-conditioning units, boilers, and similar items. This program also identified the need for replacement or repair of these items on a continuing basis. The purpose of this preventive maintenance was to assure that necessary routine adjustments, lubricating, and fine tuning of operating equipment were performed on a scheduled basis and, ultimately, to assure a high degree of reliability of these items with a minimum cost.
2. Controlled inspection program scheduled comprehensive annual inspections of each facility and structure at a naval installation. The purpose of this program was to monitor the overall condition of the Navy's shore facilities and specifically to identify deficiencies at an early date so that corrective action could be planned and serious failures thereby avoided. The controlled inspection program was in fact a counterpart to what is now known as condition assessment. Detailed checklists were developed for the inspection of specific kinds of facilities such as waterfront structures, airfield pavements, roofs of buildings, painting, electrical distribution systems, etc. Industrial engineering studies were performed to determine the optimum frequency for inspections--at least annually.

Deficiencies observed were analyzed to determine whether immediate or short-term corrective action was required, engineering studies were necessary, or the deficiency was such that correction could be deferred until later. The results of this program generated a major input to the workload planning for each activity's public works department. Some deficiencies were scheduled for correction by the maintenance or utilities department, while others were designated for correction by contract. The controlled inspection program also provided the basis for an annual inspection report that was a summary statement of the condition of all of the Navy's real property. This report provided information to the command structure of the Navy concerning the readiness of Navy shore facilities to support missions and combat readiness of Navy sea units. The annual inspection summary was the source of information that supported estimation of the Navy's backlog of maintenance and repair, an important factor in the development of Navy maintenance and repair budgets. Starting from the mid-1970s the annual inspection summary also became a primary input to the development of justifications in the Navy's programming process for the commitment of resources in the “outyears” (i.e., for a 5-year planning period from which each annual budget was derived). The annual inspection summary was also analyzed by investment category (i.e., water-front facilities, aviation operational facilities, or ammunition storage facilities) to build an understanding of the factors influencing facility performance and maintenance needs.

While there have been evolutionary changes to the continuous inspection program, which was initiated in the 1950s, the program continues today with essentially the same structure and purpose.

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APPENDIX E

MISSOURI'S LAND AND BUILDINGS SYSTEM

The Land and Buildings System (LABS), administered by the Missouri Division of Design and Construction, is an automated real property inventory and condition assessment system. It is designed to provide a central and efficient source of data for reporting the existence and conditions of state properties (a statutory requirement) and for use in capital planning and budgeting.

LABS was developed shortly after staff from the Office of Administration testified before the State Fiscal Affairs Committee in July 1980. At that time the committee requested that the agency furnish information regarding the condition and use of state properties. In response the division conducted a one-time manual assessment of state facility conditions that was submitted in conjunction with the capital improvements budget requests in September 1980. In an attempt to reduce the workload and time required to furnish this information, LABS was created to automate the data collection.

The Office of Administration designed LABS based on the following objectives:

1. establish an automated base of information to monitor more effectively the condition and use of state-owned facilities;
2. provide the Missouri General Assembly and Executive Branch with comprehensive information about state-owned land and facilities;
3. establish uniform policies and procedures required for the assessment of the condition of state-owned facilities;
4. provide the General Assembly and Executive Branch with information to support budget requests; and
5. provide historical and statistical information on sites and facilities.

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INVENTORIES AND REPORTS

LABS maintains inventories and reports such information as original construction and acquisition costs of facilities, the major functions of facilities, the number of state-owned facilities, the average age of the buildings, and the cost to replace the buildings and to repair them to good condition.

In addition to current inventory and condition records, LABS contains maintenance history records on facilities. At the completion of each project, a brief scope of work, estimated life, cost, and funds source are recorded for all facilities involved.

HOW THE STATE USES LABS

Numerous reports on LABS data are used in communications with the Missouri General Assembly and the Executive Branch as well as internally and with other state agencies. LABS information is used in capital improvement planning, historical cost analysis, and managerial review. LABS data are also used by the Division of Design and Construction to support and project capital improvement budget requests and to provide justification for maintenance and repair funds. The Division of Accounting uses LABS for fixed asset reporting.

INTERFACING LABS WITH OTHER INFORMATION SYSTEMS

The Division of Design and Construction anticipates incorporating LABS data into new facilities management software to provide a comprehensive data base of information. This information will be used to plan and budget for capital improvements to branch into such areas as automated space inventory, planning and manipulation, fixed asset inventory, and other special planning and reporting.

In addition, the division is evaluating the feasibility of incorporating LABS data with the U.S. Army's Maintenance Resource Prediction Model to formulate a state predictive maintenance program. This study is being performed under the auspices of the American Public Works Association and the Construction Engineering Research Laboratory.

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TABLE 1 LABS Profile: Data Recording and Reporting Capabilities

Identify each site and facility by a unique code number.
Identify each site and facility by its generally accepted name.
Identify each site and facility to its owning or controlling state agency by hierarchical assignment (i.e., facility to site to complex to agency/institution to division to department)
Record agency-assigned numbers for each facility, as needed for cross-reference with LABS-required facility numbers.
Identify the geographic location of each site and the facilities there.
Identify the county in which each site is located.
Identify the city in which each site is located, if located within any city limits.
Identify the size in acres of each site.
Identify the Missouri House of Representatives and Missouri Senate districts in which each site is located.
Identify the physical location of property deeds.
Identify ownership conditions (e.g., state-owned facility on state-owned site, state-owned facility on leased site, leased facility on leased site, etc.).
Provide original construction and acquisition information, including original cost, funding source, and date of acquisition or occupation.
Identify the major functions of each facility.
Identify the size of each facility, including number of levels comprising each building facility, and the gross square footage and net assignable square footage of each level.
Identify the theoretical capacity and current use of each facility within appropriate parameters defined for its function.
Analyze the extent of use of each facility.
Calculate an estimate of the cost to replace each facility based on its function and size.
Identify all major components comprising each facility (e.g., frame, roof, interior facing, exterior facing, floor, utility systems, etc.).
Identify supporting, special, or unusual features of each facility (e.g., roads, land drainage, grounds, plant equipment, appurtenances, etc.).
Identify the type of construction of each component comprising a facility.

Indicate the physical and functional conditions of each component based on uniform rating standards and procedures.
Calculate the overall condition of each facility based on the condition of its components.
Record for each component rated as less than in “good” condition an estimate of the cost to restore the component to good condition.
Record historical cost data for each facility, including fiscal year expenditure, scope of work, fund sources, and project number.
Identify and evaluate the extent of access for handicapped persons at state facilities.
Identify and evaluate the extent of life safety features at state facilities.
Report current land and buildings inventory status in numerous sort/select options.
Report facility condition ratings and cost to repair estimates in numerous sort/select options.
Provide analysis and summary information on request, such as building use, cost to repair per component or building function, cost to repair per facility/agency/division/ department, etc.
Provide input/output control totals and system-generated edit reports.
Perform multiple transactions during the same processing cycle.
Provide system-generated documents that furnish inventory, condition, and maintenance history status in response to source document processing.

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APPENDIX F

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