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Development of the BUILDER Engineered Management System for Building Maintenance: Initial Decision and Concept Report

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The U.S. Army owns and operates over 1 billion sq ft of building area in approximately 194,000 facilities. The number of facilities at a given installation is potentially large, which makes it difficult to effectively manage their maintenance and repair (M&R). Nevertheless, effective maintenance management of facilities is required so M&R budgets can be accurately determined and funds allocated where they are needed most.

Effective maintenance management requires knowledge of the inventory and physical condition of the buildings, the performance over time of building components, and the impact of component performance on overall building performance. A condition index rating system is necessary to provide a standard basis for rating current building and component condition. Unfortunately, the Army has neither a structured objective index rating system for buildings nor a procedure for capably monitoring the effectiveness of applied M&R.

A BUILDER system will provide maintenance managers with a means of performing effective, meaningful maintenance management. By combining engineering, architectural, and management methods with data base management technology, BUILDER will facilitate decision support so an optimal level of building M&R can be planned and accomplished at the lowest cost. BUILDER will include methods for gathering, storing, manipulating, retrieving, and reporting information on building inspection and assessment.

This report defines the management problems related to M&R of Army buildings, investigates and assesses available technology, and presents concepts for developing and implementing a structured objective condition index rating system for building maintenance management.

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The number of facilities at a given U.S. Army installation is potentially large, making it difficult to effectively manage their maintenance and repair (M&R). Nevertheless, effective maintenance management of facilities is required so M&R budgets can be accurately determined and funds allocated where they are needed most.

Effective maintenance management requires knowledge of the inventory and physical condition of the buildings, the performance over time of building components, and the impact of component performance on overall building performance. A condition index rating system is necessary to provide a standard basis for rating current building and component condition.

A BUILDER system will provide a means of performing effective, meaningful maintenance management. By combining engineering, architectural, and management methods with data base management technology, BUILDER will facilitate decision support so an optimal level of building M&R can be planned and accomplished at the lowest cost. BUILDER will include methods for gathering, storing, manipulating, retrieving, and reporting information on building inspection and assessment.

This report defines the management problems related to M&R of Army buildings, investigates and assesses available technology, and presents concepts for developing and implementing a structured objective condition index rating system for building maintenance management.

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FOREWORD

This research was conducted for the U.S. Army Engineering and Housing Support Center (USAEHSC) under Project 4A162731AT41, "Military Facilities Engineering Technology"; Task C, "Operation, Management, and Repair"; Work Unit 067, "BUILDER Engineered Management System." A portion of the work was conducted under the sponsorship of the Northern Division, Naval Facilities Engineering Command (NORTHNAVFACENGCOM), under Project RD9P69M598, "Building Condition Index Concept." The work was conducted by the Engineering and Materials Division (EM) of the U.S. Army Construction Engineering Research Laboratory (USACERL). The initial USAEHSC Technical Monitor was Michael Smith; later it was Chester Kirk, CEHSC-FB. The NORTHNAVFACENGCOM Technical Monitor was Richard Caldwell. Their support is very much appreciated.

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Dr. Paul A. Howdyshell is Acting Chief of USACERL-EM. COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

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DEVELOPMENT OF THE BUILDER ENGINEERED MANAGEMENT SYSTEM FOR BUILDING MAINTENANCE: INITIAL DECISION AND CONCEPT REPORT

1 INTRODUCTION

Background

The Army owns and operates a very large inventory of buildings, including over 1 billion sq ft of floor area in approximately 194,000 facilities.[1] This inventory encompasses everything from one-room sheds to highly sophisticated complexes comprising thousands of square feet. These buildings range in age from several decades to newly constructed, and individual buildings may be unique or members of a group of similar buildings. An installation may consist of only a few buildings or it may have hundreds of buildings in its inventory.

Effectively managing maintenance and repair (M&R) of such a widely diversified building inventory is a challenging task. Moreover, nearly 55 percent of the facility M&R budget goes to buildings, and in fiscal year 1986 (FY86) this totaled over $1.2B.[2] Clearly, effective maintenance management methods are warranted to ensure the maximum return on this sizable investment.

Effective maintenance management requires knowledge of the building inventory (sizes, types, and interrelationships of component parts), physical condition (measure of deterioration of individual components and building as a whole), component performance (condition over time), and the impact of component performance on overall building performance. Also, understanding how building performance affects an installation's mission is essential to effective maintenance management.

The U.S. Army Construction Engineering Research Laboratory (USACERL) has created or is in the process of creating Engineered Management Systems (EMSs) to aid the Directorate of Engineering and Housing (DEH) and Facility Engineers (FEs) in performing effective maintenance management. These include PAVER,[3] RAILER,[4] PIPER,[5] ROOFER, PAINTER, SCALER, and BRIDGER. Most of these systems apply to single-component facilities (PAVER and PIPER) or a major component within a facility (ROOFER, SCALER, and PAINTER) RAILER and BRIDGER apply to several components. The goal of an EMS is to use engineering technology systematically to determine when, where, and how best to maintain facilities. No EMS now exists for Army buildings, although ROOFER, PAINTER, and SCALER focus on specific building components.

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[1] *Facilities Engineering and Housing (FEH) Annual Summary of Operations Report* (Directorate of Military Programs, Office of the Assistant Chief of Engineers, 1986).

[2] *FEH Annual Summary of Operations Report.*

[3] M.Y. Shahin and S.D. Kohn, *Overview of the PAVER Pavement Management System and Economic Analysis of Field Implementing the PAVER Pavement Management System,* Technical Manuscript M-310/ADA116311 (U.S. Army Construction Engineering Research Laboratory [USACERL], March 1982); M.Y. Shahin and S.D. Kohn, *Pavement Maintenance Management for Roads and Parking Lots,* Technical Report M-294/ADA110296 (USACERL, October 1981).

[4] D.R. Uzarski, D.E. Plotkin, and D.G. Brown, *The RAILER System for Maintenance Management of U.S. Army Railroad Networks: RAILER I Description and Use,* Technical Report M-88/18/ADA199859 (USACERL, September 1988).

[5] A. Kumar, W. Riggs, and M. Blyth, *Demonstration of the Pipe Corrosion Management System (PIPER),* Technical Report M-86/08/ADA166807 (USACERL, April 1986).

Objectives

The objectives of this study are the following:

1. Define management problems related to M&R of buildings on Army installations.

2. Obtain agreement and commitment from users, early in the research and development (R&D) cycle, about which problems should be solved and which R&D products are required.

3. Assess available technology that can be implemented without further R&D.

4. Recommend R&D and outline a concept for developing and implementing a structured objective condition index rating system for building maintenance management.

Approach

A literature search was conducted to determine what has been published regarding building maintenance management, component inspections, condition rating procedures, and software development. Also, the American Public Works Association (APWA) and the Building Research Board (BRB) were contacted to identify agencies, companies, and organizations doing research, development, or implementations in these areas. As a result, many organizations were contacted directly for additional information.

In addition, USACERL engineers and architects spent time defining building maintenance management needs within the Army's organizational and managerial structure. Understanding management needs and DEH constraints was accomplished by the creation of an informal user's group consisting of DEH, Major Command (MACOM), and U.S. Navy representatives. To ensure that the proposed concepts were compatible with existing regulations, programs, software systems, and proposed new developments, the authors formed a research group consisting of USACERL researchers technically proficient in the various building component areas. The USACERL EMS committee served as a steering committee for this work.

Scope

This report addresses the problems DEH faces in performing effective maintenance management and provides a summary of available systems designed to improve maintenance management. The BUILDER EMS concept presented is compatible both with existing and proposed overall Army management systems and procedures and with EMS technology already developed for the DEH.

Mode of Technology Transfer

This report provides a basis for the development of a BUILDER EMS. Should BUILDER be developed, as recommended, the technology could be transferred through an implementation procedure either by contract or by in-house personnel within the Department of Defense. The U.S. Army Engineering and Housing Support Center (USAEHSC) should serve as a system champion for technology transfer and in a facilitating role for obtaining those contracts, at least for the Army. The other military departments are welcome to join in the R&D effort and use the results in a technology transfer mode appropriate to and consistent with their policies.

It is recommended that BUILDER be transferred to the civilian sector through an agreement with agencies such as the APWA, where it could be transferred to the public and private sectors.

Proper implementation and use of the BUILDER EMS would require an appropriate level of training. This could be accomplished through a training program conducted by USACERL and USAEHSC in conjunction with a major university and/or by the APWA as part of their ongoing education program.

2 PROBLEM DEFINITION

Approximately 55 percent of Army installation real property maintenance funds are devoted to M&R of buildings.[6] The Army does not have a structured objective condition index rating system for buildings and most building components, although generalized "c" ratings exist that broadly classify conditions.[7] Without such indexes, and a means for analyzing and reporting key building information, it is impossible to simultaneously assess current conditions, accurately project future conditions, and track building performance. Key components cannot be properly evaluated, nor can deficiencies be identified. When determining maintenance needs, interaction between components is difficult to evaluate, and work may not be effectively planned, budgeted, and accomplished. Also, if an installation has a large number of buildings, it is difficult to budget funds effectively and allocate them where they are needed most. In addition, it is difficult to properly institute preventive maintenance programs, evaluate their effectiveness, and prioritize work. Thus, optimal M&R programs cannot be attained.

These problems were highlighted during two recent USACERL research projects: the first addressed the Army's building renewal problem,[8] and the second addressed current maintenance management practices within the Army, including facility inspection methods and technologies.[9] The reports indicate that over 40 percent of the M&R effort Army-wide is accomplished through service orders, even though DEH personnel consider this percentage too high. Also, many DEH administrators stated that although they lack the resources to properly inspect and evaluate facilities, they would like to do more inspection and evaluation because they need more information on facility conditions. This lack of information input has resulted in reliance on building managers to identify and report work needs to DEH. Management has thus become reactive instead of active--work is primarily dictated by component failures and the demands of "customers." Thus, objective planning is sacrificed. Although many DEHs prepare annual work plans, few are followed or used because resources are lacking and commanders do not have the information to support them.

When maintenance management is accomplished reactively, ad hoc, maintenance becomes expensive. For example, as pavement condition deteriorates, the funds needed for M&R increase several times (Figure 1).[10] A similar relationship would be expected to hold for building components. But since condition index rating systems do not exist for most building components, this relationship cannot be demonstrated. Nevertheless, when work tends to be accomplished reactively, the facility or component condition is generally found at the lower end of the condition index scale. Major restoration of components is very costly; thus, other needed work must be deferred due to budget constraints. Although immediate M&R needs may be met by this approach, the process is self-defeating because goals are not attained in a resource-constrained environment.

Current M&R budget trends suggest reductions from the FY 85-87 levels over the next few years. Unfortunately, the Army's building inventory M&R needs will outpace those anticipated budgets. Clearly,

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[6] *FEH Annual Summary of Operations Report.*

[7] *Real Property Maintenance Activity (RPMA) Component Inspection Handbook* (U.S. Army Facilities Engineering Support Agency [FESA], May 1979).

[8] O. Coskunoglu and A.W. Moore, *An Analysis of the Building Renewal Problem,* Technical Report P-87/11/ADB112755L (USACERL, June 1987).

[9] D.R. Uzarski, T.D. Tonyan, and K.R. Maser, *Facility and Component Inspection Technology Concepts: Potential Use in U.S. Army Maintenance Management,* Technical Report M-90/01/ADA217260 (USACERL, December 1989).

[10] C. Johnson, "Pavement (Maintenance) Management Systems," *APWA Reporter* (American Public Works Association, 1983).

to meet this challenge effectively—to attain maximum return on M&R expenditures—DEHs Army-wide must improve current maintenance management practices. However, this goal cannot be met unless managers have tools to help them make better, smarter decisions. One very helpful tool would be a structured BUILDER engineered management system (EMS) for buildings. To be meaningful, the BUILDER system must incorporate a minimum level of inspection, contain building information from available data bases and condition indexes, and use microcomputer software technology. It must also be flexible enough to account for the organizational and operating differences associated with the Army's decentralized management philosophy.

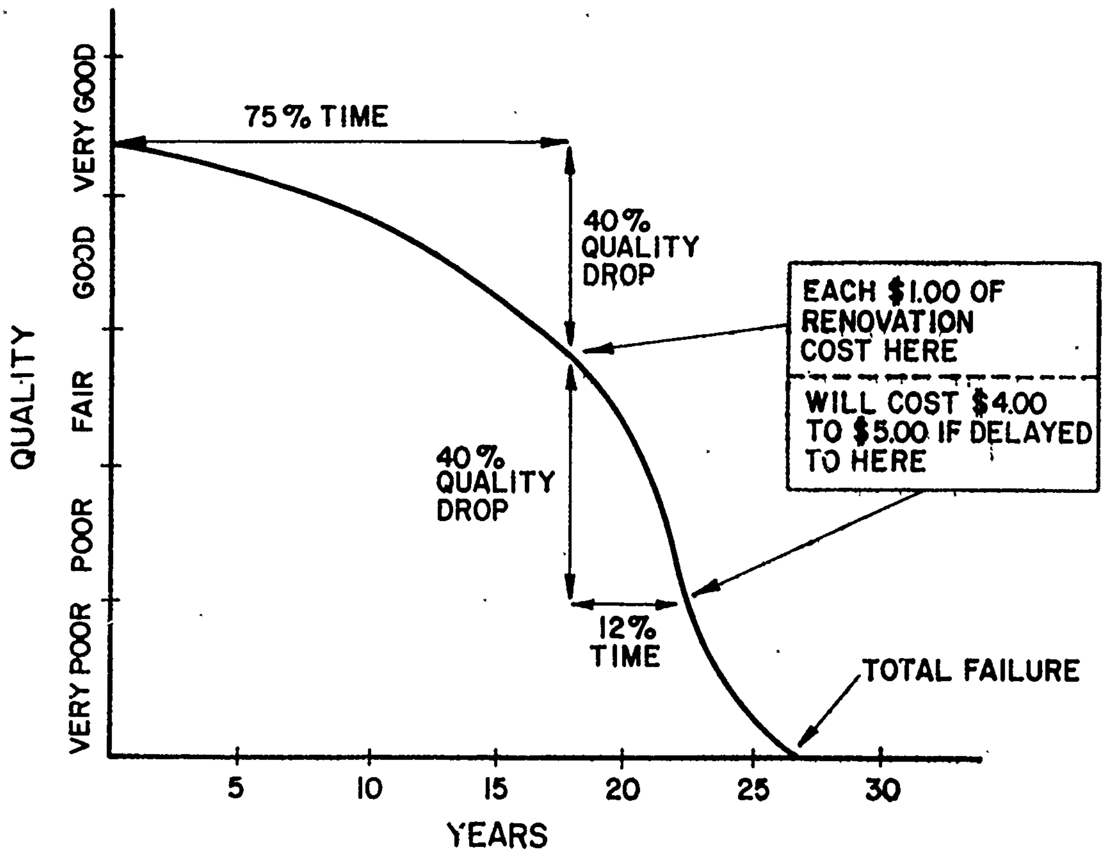

Figure 1. Pavement deterioration versus time.

3 STATE-OF-THE-ART MAINTENANCE MANAGEMENT PROGRAMS, SYSTEMS, AND TECHNOLOGY

A literature search was performed to determine what state-of-the-art building maintenance management programs, systems, and technology are currently available or under development, and private and public sector professionals were questioned. The following sections summarize the findings for building operation-related software programs, budget prediction method, condition assessment methods, research activities, and committee activities.

Building Operation-Related Software Programs

The researchers surveyed many consulting firms offering building-related software (Appendix A). The main categories of available software were equipment programs and facilities programs. The equipment programs focused on planning regular equipment preventive maintenance schedules, keeping track of parts inventory, producing work and purchase orders, and storing records on maintenance personnel. The facilities programs were used to manage energy efficiency, hold records on facilities inventory such as rooms and parking spaces, and provide analysis and planning of spaces for effective building operation. None of the programs surveyed addressed using inspection checklists and condition indexes or developing prioritized work plans based on inspection results.

Budget Prediction Methods

Budget prediction methods are a process for predicting maintenance budget resource requirements through either a life-cycle methodology or an historical records analysis. These methods are not used to determine the condition of a facility, establish maintenance requirements, or develop annual work plans which address specific needs to a specific building or component. But they can help organizations develop budgets for many facilities for a given period. Appendix B explains both approaches in greater detail.

Condition Assessment Approaches

Condition assessment is a procedure that uses an inspection process and analysis procedure for determining the condition of a building or group of buildings. The purposes of condition assessment include the following:[11]

- Developing property files
- Establishing maintenance priorities
- Assessing maintenance backlog

[11] R. Holmes, "A Systematic Approach to Property Condition Assessment," in *Proceedings of the Working Commission W70 on Maintenance and Modernization, CIB International Seminar, Edinburgh, Scotland* (International Council for Building Research, Studies, and Documentation, September 1988), pp 140-150.

- Preparing maintenance strategies
- Preparing maintenance budgets
- Upgrading property files.

A number of agencies, states, universities, and organizations in Europe and the United States (Appendix C) use or plan to use condition assessment as part of their overall building building management procedure. The procedures used were reviewed through published data, project reports, and telephone conversations. Generally, visual approaches using the human eye are used for data collection by which the condition assessment is made. There are differences between agencies as to what and how much data is collected, and the method or model used for the actual condition assessment. But two basic inspection approaches were found to be common to all. These are the use of sampling techniques for inspection and comprehensive inspection procedures. The following discussion and Table 1 provide a brief overview of each. Appendixes D through F provide further detailed discussion.

Sampling Techniques

Two sampling techniques were identified. The first involves inspecting and evaluating representative buildings within a building group to determine the group's condition. The level of inspection detail is the same for all buildings sampled within the group. The second technique involves a limited inspection of all buildings of a group, but a representative sample of the buildings receives a more comprehensive inspection. The limited inspection assesses building condition. The comprehensive inspection not only assesses condition, but it also identifies specific deficiencies. Appendix D describes approaches to each technique.

Comprehensive Inspections

Comprehensive inspections are the most widely accepted form of condition assessment. They assess every building within a facility or installation. However, the detail level of comprehensive inspections is determined by an organization's needs and requirements and the intended use of the inspection results. Typically, the inspections collect deficiency information for the major building components (structural, roofing, mechanical, electrical).

Table 1

Organization's Component Divisions

CONDITION ASSESSMENT METHODS:	ORGANIZATIONS:	BUILDING COMPONENTS												COMMENTS: (Other components)
		Foundations	Structure	Roofing	Ext Closure	Ext Painting	Int Const	Int Painting	Conveying	Mechanical	HVAC	Plumbing	Electrical	
Sampling Techniques	United States Air Force		XXX XXX	XXX XXX	XXX XXX						XXX XXX	XXX XXX	XXX XXX	(Other) flooring, int. finishes
	Dutch Housing Condition Survey: limited investigation			XXX XXX XXX XXX		XXX XXX XXX XXX		XXX XXX XXX XXX						(Other) ext. walls, doors, windows, frames, & balcony / gallery; int. walls, doors, floors, ceiling
Comprehensive Inspections	United States Navy		XXX XXX	XXX XXX						XXX XXX			XXX XXX	
	State of North Carolina	XXX XXX XXX XXX XXX		XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX		XXX XXX XXX XXX XXX		XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX			XXX XXX XXX XXX XXX	(Other) fixed equip, sub & super structure, life safety, energy mgmt, environmental hazards, special requirements
	State of Florida				XXX XXX XXX XXX	XXX XXX XXX XXX					XXX XXX XXX XXX	XXX XXX XXX XXX	XXX XXX XXX XXX	(Other) immediate site
	State of Missouri		XXX XXX XXX XXX	XXX XXX XXX XXX	XXX XXX XXX XXX		XXX XXX XXX XXX		XXX XXX XXX XXX		XXX XXX XXX XXX		XXX XXX XXX XXX	(Other) misc. equipment. Interior includes ceilings, interior facing, flooring. HVAC includes equipment and distribution. Electrical includes equipment and distribution.
	University of N C. at Chapel Hill	XXX XXX XXX XXX XXX XXX		XXX XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX XXX			XXX XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX XXX	(Other) ext. & int. doors & windows, ceiling, floor, site, alarm, conveying, emer. generator, water, distillation, animal quarters, and classrooms
	National Park Service			XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX		XXX XXX XXX XXX XXX				XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX	Ext Closure includes roofing. (Other) fire/life safety, site, public health, handicapped accessibility
	Veterans Administration		XXX XXX XXX XXX XXX XXX								XXX XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX XXX	(Other) site, equipment, fire protection, aesbestos, architectural, steam generation & distribution, automatic transportation, miscellaneous
	Bohm-NBBJ Architects & Planners						XXX XXX XXX XXX			XXX XXX XXX XXX			XXX XXX XXX XXX	(Other) basic bldg shell, fixed equipment, energy conservation, life safety, bldg function features
	Meli Simon & Associates			XXX XXX							XXX XXX		XXX XXX	
	Transport Canada	XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX	XXX XXX XXX XXX XXX		XXX XXX XXX XXX XXX			XXX XXX XXX XXX XXX	(Other) ceilings, stairs, floors, doors, windows, fire exits, life safety, energy conservation, and energy consumption
	English House Condition Survey		XXX XXX		XXX XXX		XXX XXX							Exterior includes roofing.
	Scottish Special Housing Association			XXX XXX XXX XXX							XXX XXX XXX XXX	XXX XXX XXX XXX	XXX XXX XXX XXX	(Other) walls, floors, doors, windows, balconies, access stairs, chimney stacks, landscaping
	United States Army - EMS Systems			XXX XXX		XXX XXX		XXX XXX				XXX		Steel and copper water piping only for plumbing. Low-sloped roofs only for roofing.

Inspection teams vary from trained technicians to architectural/engineering consultants. They typically use inspection checklists to record deficiencies identified for each building component. The inspection team may assign a condition rating to the building components after the inspection; sometimes the team assigns a building condition rating based on the condition of its components. These condition ratings, however, typically reflect the inspection team's subjective assessment. Appendix G identifies approaches to comprehensive inspection.

USACERL has developed or is developing comprehensive inspection procedures for condition assessment for low sloped roofs, interior and exterior painting, and interior water piping and condensate return lines as part of the development of the ROOFER, PAINTER, and SCALER Engineered Management Systems (EMS), respectively.

ROOFER, PAINTER, and SCALER condition assessment procedures involve the establishment of condition index ratings for the components (roofs, interior/exterior painted surfaces, or pipes) and appropriate subcomponents. For example, Figure 2 illustrates the Roof Condition Index (RCI), in which the subcomponent ratings are combined into a single component rating. The inspection procedures generate not only condition index values but a quantifiable list of deficiencies. Further information is presented in Appendix F.

Research Activities

Various organizations and agencies in the United States, such as the U.S. Navy Civil Engineering Laboratory, USACERL, the Building Research Board (BRB) of the National Academy of Sciences, and the National Institute of Standards and Technology (formerly NBS), conduct research in building maintenance management. Organizations and agencies from Canada and Europe are also involved in developing building maintenance management concepts. These include the Division of Building Research—National Research Council (Ottawa, Ontario, Canada), the Building Research Establishment (Watford, United Kingdom), the Building Services Research and Information Association (Berkshire, England), and the Danish Building Research Institute (Hosholm, Denmark).

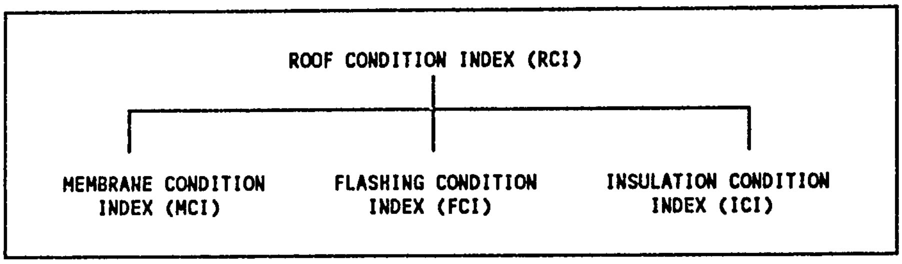

Figure 2. ROOFER: low sloped roofs.

The development activities of these organizations and agencies include the following: life cycle costing and design, sampling and inspection procedures, maintenance prediction analysis, voice-activated inspection procedures, engineered management systems (EMSs), expert systems, "intelligent" buildings, planning and budgeting for building maintenance, maintenance standards, condition assessment methodologies, real estate management, and professional education degrees in building management.

Research, in the form of national surveys, is being conducted to determine the state of the educational facilities within the United States. In general, these surveys are focusing on the amount of deferred maintenance that exists, current conditions, funding needs, budget methods, planning processes used, etc. The intent is to identify and quantify the problems and propose solutions. Appendix G describes these studies in greater detail.

Committee Activities

Two international and national committees are actively researching building maintenance management and condition assessment. The following is a brief description of each committee and its work.

International Council for Building Research, Studies, and Documentation (CIB): Working Commission W70

CIB Working Commission W70 was initiated over 10 years ago to discuss the maintenance and modernization of built assets. This commission's work has centered on collecting and exchanging information on research and experience in building maintenance and modernization and the functions associated with preserving building assets.

In September 1988, the W70 working commission held an international seminar in Edinburgh, Scotland, on "Whole-Life Property Asset Management." The following subjects were discussed:

- Government policies and economic options
- Repair/maintenance techniques and options
- Performance evaluation
- Building condition surveys
- Management of maintenance—techniques and processes
- Maintenance planning and information requirements
- Computer applications in building maintenance management
- Education and training of maintenance managers.

The commission's publications include *Methods for Surveying and Describing the Building Stock: CIB Proceedings of the Tallberg Seminar, Sweden, 1981* and *Systems of Maintenance Planning: Edinburgh Seminar, United Kingdom, 1983.*

CIB working commission W70 sponsored another seminar in March 1990 in Singapore. This international symposium on property maintenance and modernization addressed a variety of building-related issues.

National Research Council: Building Research Board

Concerns about the maintenance and repair of public buildings led to the creation of the Committee on Advanced Maintenance Concepts for Buildings by the Building Research Board in response to a request received from the Public Facilities Council (PFC) and the Federal Construction Council (FCC). The committee decided that its report would focus on the obligations of building ownership, including requirements by management and the costs of ownership. The report also addresses the importance of building maintenance, the effects of underfunding building maintenance, the budgetary process, and the need for building condition assessment. The committee will recommend a building maintenance budgeting model which will establish a budgeting percentage based on maintenance requirements and current plant value (i.e., replacement value). The committee is due to complete a final report in 1990.

Summary and Conclusions

The literature search of the public and private sector showed that improved building maintenance management is receiving considerable attention. Several agencies, organizations, and consultants either have developed or are developing programs, systems, methods, or procedures for condition assessment and improved decision making. Several studies are in progress to quantify the building maintenance problem and recommend solutions.

Generally, the programs and systems in use or under development were created as hybrids, designed for the specific needs and applications of a specific agency; some are proprietary. Although several systems incorporate features the Army could use, no developed public domain system that would address the problem statement in Chapter 2 was found.

Chapter 4 outlines a recommended condition assessment procedure using condition indexes based on periodic facility inspections. However, the inspection procedures needed to attain the index values could be developed from the best features of the inspection approaches outlined in this chapter.

4 CONDITION ASSESSMENT CONCEPTS

To perform effective and meaningful maintenance management, an inspection-based condition assessment procedure is required which defines the current condition and predicts future conditions of building assets. Such a procedure must include methods to gather, store, manipulate, retrieve, and report inspection and assessment information, and it should include the following concepts:

- Division of the building into components
- Subdivision of components into management units
- Inspection procedure for the management units
- Use of component and building condition indexes
- Data base for storing and retrieving information.

Building Components/Subcomponents

Division of buildings into components and these components into subcomponents is essential for (1) identifying major features of a building, (2) identifying areas requiring unusual inspection skills, and (3) defining dissimilar building areas for M&R planning and work accomplishment.

Discussions with potential users of the BUILDER system indicated that from 8 to 12 building components would be the ideal number for planning and prioritizing building maintenance needs. A larger number of components would add unnecessary administrative burdens without providing technological or managerial benefits, and a smaller number would restrict the information-gathering ability needed for effective maintenance management. After reviewing the building component divisions for condition assessment systems outlined in Chapter 3 (Table 1), it is proposed that the BUILDER components be divided as follows:

1. Structure
2. Roofing
3. Exterior closure
4. Interior construction
5. Exterior painting
6. Interior painting
7. Heating, ventilating, and air-conditioning (HVAC)
8. Electrical

9. Plumbing

10. Other.

This division meets user needs, logically groups similar building items, and maintains emphasis on two M&R areas of major interest (roofing and painting).

The proposed component division is compatible with other Army systems and management approaches, including the Maintenance Resource Prediction Model (MRPM)[12] and the Computer Aided Cost Estimating System (CACES),[13] whose component divisions are based on the Army Uniformat component division; the procedures used by U.S. Army Forces Command (FORSCOM), which has identified component breakouts based on the first generation Integrated Facilities System (IFI-I);[14] the proposed component divisions in IFS-M (mini/micro),[15] and preventive maintenance guidelines.[16] These component divisions are shown in Table 2.

The proposed BUILDER component division differs from existing Army division methods as follows:

1. The Army has not recognized a single component division method which addresses all the major features of a building for inspection, work planning, and M&R accomplishment.

2. Component divisions listed in existing Army methods offer little managerial advantage to the DEH for inspection, work planning, and M&R accomplishment purposes. The proposed BUILDER component divisions address these components under broad categories such as Interior Construction, Structure, Electrical, and HVAC.

3. Many of the potential users have recommended that Interior and Exterior Painting should be identified as separate component divisions.

The rationale of defining paint, both interior and exterior, as separate components is derived from the importance painting receives in the DEH community. However, paint is not a true component in the physical sense that the other components are defined. Paint could also be logically considered as a finish or coating subcomponent to the interior construction and exterior closure components, respectively. Consequently, opinion is divided. As BUILDER develops, the issue of whether to treat paint as a component or a subcomponent will need to be resolved. For the purpose of this initial report, paint is recommended to be treated as two components (interior and exterior).

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[12] E.S. Neely and R.D. Neathammer, "Worldwide Maintenance Prediction Model for the United States Army," *CIB 1986: Advancing Building Technology*, Vol 2, (1988) pp 490-497.

[13] U.S. Army Corps of Engineers (USACE), *Users Manual A-E: Computer Aided Cost Estimating System (CACES): Appendix E*, EP 415-345-6 (USACE, March 1984).

[14] FORSCOM Regulation 420-3, *Management of Maintenance and Repair Operation and Maintenance, Army (AOM) Operation and Maintenance, Army Reserve (OMAR) and Army Family Housing (AFH)* (Headquarters, Department of the Army [HQDA], March 1984).

[15] *Integrated Facilities System Mini/Micro (IFS-M) User's Manual: IFS-M Glossary--Interim Report* (USAEHSC, December 1988).

[16] Department of the Army, Technical Manual (TM) 5-610, *Preventive Maintenance Facilities Engineering Buildings and Structures* (HQDA, November 1979).

Table 2

Comparison of Proposed BUILDER Component Division With Existing Army Divisions

	COMPONENT DIVISIONS																								
	Sub Structure	Structural Frame	Structure	Roofing	Flat Roof	Sloped Roof	Ext Closure	Siding	Ext Painting	Int Construction	Int Finishes	Floor Covering	Int Painting	Mechanical	HVAC	Heating	Air Conditioning	Special Mech	Electrical	Special Elec.	Plumbing	Equipment	Equip & conveying	Specialties	Other
Proposed BUILDER Components			xxx xxx xxx	xxx xxx xxx			xxx xxx xxx		xxx xxx xxx	xxx xxx xxx			xxx xxx xxx		xxx xxx xxx				xxx xxx xxx		xxx xxx xxx				xxx xxx xxx
Uniformat	xxx xxx xxx	xxx xxx xxx		xxx xxx xxx			xxx xxx xxx			xxx xxx xxx	xxx xxx xxx				xxx xxx xxx			xxx xxx xxx	xxx xxx xxx	xxx xxx xxx	xxx xxx xxx		xxx xxx xxx	xxx xxx xxx	
Maintenance Resource Prediction Model (MRPM)				xxx xxx xxx			xxx xxx xxx			xxx xxx xxx	xxx xxx xxx				xxx xxx xxx				xxx xxx xxx	xxx xxx xxx	xxx xxx xxx				
Computer Aided Cost Estimating System (CACES)	xxx xxx xxx	xxx xxx xxx		xxx xxx xxx			xxx xxx xxx			xxx xxx xxx	xxx xxx xxx				xxx xxx xxx			xxx xxx xxx	xxx xxx xxx	xxx xxx xxx	xxx xxx xxx		xxx xxx xxx	xxx xxx xxx	
IFS-I Components			xxx xxx xxx	xxx xxx xxx					xxx xxx xxx			xxx xxx xxx	xxx xxx xxx			xxx xxx xxx	xxx xxx xxx		xxx xxx xxx		xxx xxx xxx	xxx xxx xxx			
Proposed IFS-M Components					xxx xxx xxx	xxx xxx xxx		xxx xxx xxx	xxx xxx xxx				xxx xxx xxx	xxx xxx xxx					xxx xxx xxx		xxx xxx xxx				xxx xxx xxx
Preventive Maintenance Facilities Engineering Buildings and Structures (TM9-610)			xxx xxx xxx	xxx xxx xxx			xxx xxx xxx		xxx xxx xxx	xxx xxx xxx	xxx xxx xxx	xxx xxx xxx	xxx xxx xxx			xxx xxx xxx	xxx xxx xxx		xxx xxx xxx		xxx xxx xxx	xxx xxx xxx	xxx xxx xxx		

Although the proposed component division is logical and convenient, further division of the building components into subcomponents is also required to properly identify building elements requiring unique inspection techniques and other management attention (see Table 3). This subcomponent division will ensure interfacing compatibility with existing Army systems. It will be continually reviewed, coordinated with existing EMSs, and revised as needed as inspection procedures and condition indexes are developed.

Dividing building components in ways different from established methods is permitted under current policy.[17]

Building Sections (Management Units)

Because of building complexity, use, age, different material types, and so on, subcomponents may not be uniform throughout a building. In addition, a given building subcomponent may sometimes address different functional, performance, and M&R requirements associated with particular areas within a building. For example, the interior finishes of a storage area are likely to be different from those of an office area. Because different areas may have differing M&R needs and thus may require different management actions, it is proposed that the BUILDER program will define management units for each building subcomponent. Each subcomponent would consist of at least one section (management unit).

Sections can be defined by dividing building subcomponents into logical sections according to the following criteria:

- Material type
- Construction
- Use
- Age.

The following example uses the exterior closure component to illustrate how component, subcomponent, and sectioning processes interrelate.

Figure 3 illustrates a building used primarily for warehousing. A small portion is devoted to administration use. The exterior closure component would consist of three subcomponent; cladding, doors, and windows. The cladding would be divided into two sections; one for the brick area and the other for the aluminum. The doors would likewise be divided into two sections; one for the personnel door and the other for the overhead door. The windows would only be divided into one section in this example because even though the windows are physically separated they are of similar age, type, and construction.

Inspection

The objective of the BUILDER inspection process will be to collect the minimum amount of data required both to define the condition of a building and its components and to develop annual and long-

[17]Chief of Engineers letter DAEN-MPO-M, Subject: Revised Facilities Component Inspection Policy, dated 23 July 1982.

Table 3

Tentative BUILDER Subcomponents

COMPONENT BREAKDOWN	PROPOSED SUBCOMPONENTS
STRUCTURE	Standard Foundations Special Foundations Slab on Grade Basement Walls Floor Construction Roof Construction Stair Construction Structural Frame Chimneys Exterior Canopies & Coverings Columns Load Bearing Walls
ROOFING	Roof Covering Roof Insulation Roof Flashing Roof Openings Parapet Firewalls
EXTERIOR CLOSURE	Exterior Cladding Exterior Doors Exterior Windows Exterior Sealants Perimeter Drainage
INTERIOR CONSTRUCTION	Stairs Interior Doors Interior Windows Interior Wall and Wall Finishes (except painting) Flooring and Floor Finishes Ceiling and Ceiling Finishes
EXTERIOR PAINTING	Trim Walls
INTERIOR PAINTING	Trim Walls Floor Ceiling
HVAC	Heating and Cooling Equipment Ventilation and Exhaust Systems Special Systems
ELECTRICAL	Service and Distribution Systems Lighting Systems Grounding Systems Sound Systems Alarm Systems Time Systems Television Systems Communication Systems
PLUMBING	Sanitary Systems Rainwater Drainage Special Plumbing Systems Special Plumbing Fixtures Domestic Water Systems
OTHER	Elevators & Escalators Loading Equipment Energy Supply Systems Fire Protection Systems Exterior Appurtenances Special Utility Distribution Systems

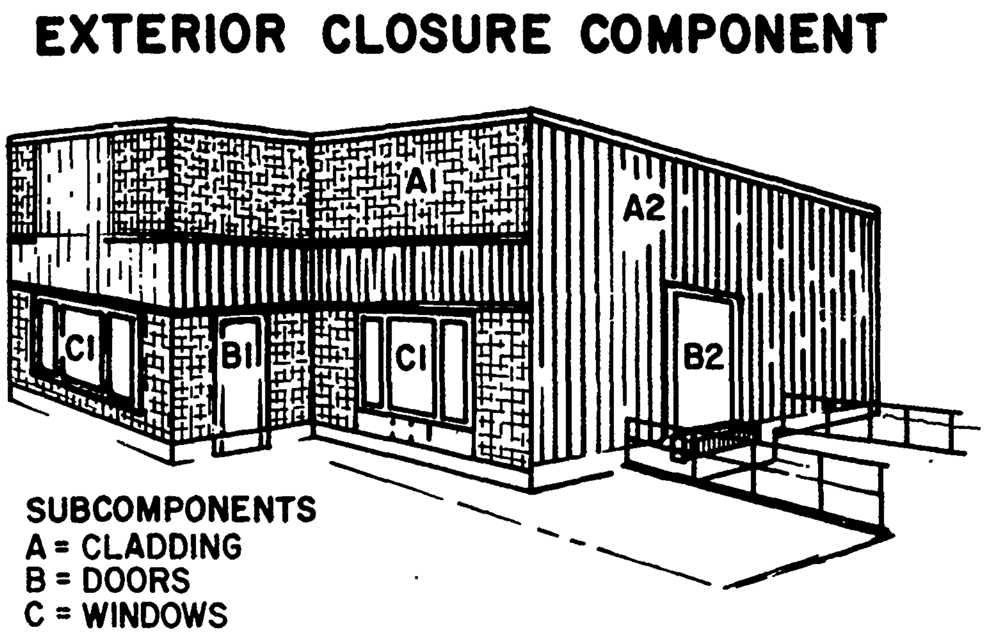

Figure 3. Example management units.

range work plans and budgets.[18] To ensure that this is accomplished and to facilitate computer usage, the inspection process must be structured so component deficiencies can be recognized and recorded in a repeatable fashion by trained technical personnel. Each component would be inspected in terms of its subcomponents.

Recognizing that adequate inspection resources may be lacking at some installations,[19] a comprehensive annual inspection effort would not be feasible. An inspection program can be accomplished with limited resources by using sampling, limited data collection for each sample, reduced inspection frequency, and automation.

Sampling

Sampling techniques can reduce the scope of component inspections, thus addressing the two major problems found in many inspection processes:

1. The amount of time required to perform building inspections.

2. The limited amount of human resources available to perform building inspections.

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[18] Department of the Army (DA) Pamphlet (PAM) 420-6, Facilities Engineering Resources Management System (HQDA, May 1978); Army Regulation (AR) 420-10, *Facilities Engineering Management of Installation Directorates of Engineering and Housing* (HQDA, August 1987); Chief of Engineers letter DAEN-MPO-M, Subject: Revised Facilities Component Inspection Policy, dated 23 July 1982.

[19] D. R. Uzarski, T. D. Tonyan, and K. R. Maser.

Sampling techniques allow the inspection process to become more efficient by reducing the inspection time required to collect information on each component. Through the proper selection of representative "sample units," enough information can be gathered and extrapolated, as necessary, to determine a condition rating and develop annual and long-range work plans. Only a relatively low sampling rate would be required for determining condition rating and developing the work plan. This procedure would, however, need to be sensitive to the need for gathering information from nonrepresentative samples, as required, to ensure overall accuracy.

It is anticipated that the sampling process would take the following approach. Since each subcomponent will be divided into appropriate sections, it is valid to assume that each section will be inspected. The sampling will occur through the selection of representative portions of each section for inspection. For example, in an office environment where many individual offices exist, only a representative number of offices needs to be inspected to gather defect information for the various subcomponents associated with interior construction. From that, the component condition can be determined. Of course, an appropriate level of detail needs to be reached in the inspection of each sample. That level will be determined during development of the component condition indexes, discussed later in this chapter.

It is also possible that when identical components exist in a group of similar buildings and those components have the same age, use, and so forth, the component sections themselves may be sampled; for example, the domestic water systems located within a group of barracks buildings constructed at the same time. If similar conditions are assumed, inspection economy should be greatly enhanced if the systems (each being a subcomponent section) are sampled. The validity of this approach will be discussed in *Condition Indexes*.

Inspection Checklist

Inspection checklist forms are needed for each building component and subcomponent. They should establish a consistent level of inspection detail and ensure that each inspection is comprehensive enough so meaningful ratings and work plans can be made. The inspection forms must be standardized and structured to permit condition index repeatability. Standardization will come from the specification of certain defect types. The severity, if appropriate, and quantity of each defect type would be recorded on the applicable component and subcomponent portion of the inspection checklist.

Inspection Frequency

Initial inspections will have to be performed on each building to identify maintenance deficiencies and determine current condition. The reinspection frequency for individual buildings and components may vary according to past condition ratings, expected rates of deterioration, construction type, or building age.

Automation

The potential for developing automated inspection techniques has been outlined elsewhere.[20] In addition, USACERL research projects started in FY89 to evaluate automated inspection devices for EMS, including voice recognition, are ongoing. If BUILDER can incorporate automated inspection techniques, then reliance on visual means and manual data transfer would be reduced and significant manpower savings could result.

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[20] D. R. Uzarski, T. D. Tonyan, and K. R. Maser.

The inspection process envisioned for BUILDER is intended to be rapid and collect just enough information to perform a condition assessment. It is also intended to be performed by properly trained technicians. In designing the inspection procedures, care must be taken to ensure that the telltale signs of impending problems are identified. If certain telltale signs are found during the inspection process, it may be necessary to follow-up the inspection with an engineering analysis by qualified personnel. For example, the facility inspector may note during the inspection that a particular crack pattern has occurred in a structural member. This information would be relayed to a structural engineer for further analysis through appropriate tests and procedures. This inspection follow-up would either confirm or disprove that a structural problem exists so that appropriate corrective actions, if necessary, are initiated to protect life and property.

Condition Indexes

Following inspection, each BUILDER-defined building component will be assigned a condition index rating, which will be similar to other EMS index ratings[21] to provide consistency for facility maintenance managers.

Component and possibly certain subcomponent condition index ratings will be determined from information gathered during inspection. The inspection checklists, described above, are key to the index computations. Severities and quantities of defined defects will be correlated and deducted to compute the index values. In addition, several individual defects cited on the inspection checklist can be aggregated into fewer, more genuine defects in the index methodology when their impact on conditions is the same as that of individual defects. The advantage of aggregating is that fewer deduct curves are required, thus simplifying the process. The validity of the aggregation process will be confirmed or rejected as the indexes are developed.

The index rating expresses the component's "health" based on the severity and extent of the deficiencies found during the inspection (Table 4). Where applicable, the component condition index would be a composite of appropriate subcomponent condition indexes, a concept similar to that currently used in determining the Roof Condition Index (RCI) for built-up roofs.[22]

The Building Condition Index (BCI) would be established by aggregating the component indexes into a single composite index for an entire building. Table 5 and Figure 4 illustrate the BCI concept. Note that a condition index is not envisioned for the "other" component category.

The development of these ratings will provide a standardized basis for rating current building and component conditions. A single set of rating criteria is envisioned for each component and the building as a whole. Different building uses (e.g., warehouses and administration buildings) would employ the same component rating criteria. That is, a BCI of 60 for both a warehouse and an administration building would indicate that they are in an equivalent condition. However, the index would be used differently

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[21] M.Y. Shahin and S.D. Kohn, *Development of a Pavement Condition Rating Procedure for Roads, Streets, and Parking Lots: Vol 1: Condition Rating Procedure*, Technical Report M-268/ADA074170 (USACERL, July 1979); M.Y. Shahin, D.M. Bailey, and D.E. Brotherson, *Membrane and Flashing Condition Indexes for Built-Up Roofs: Vol 1: Development of the Procedure*, Technical Report M-87/13/ADA190368 (USACERL, September 1987).

[22] M.Y. Shahin, D.M. Bailey, and D.E. Brotherson.

Table 4

Component Condition Index Concepts

INDEX SCALE:	DEFINITION:	CONDITION DESCRIPTION:
86 - 100	Excellent	Very few noticeable defects. Component function is not impaired. No immediate work action is required, but minor or preventive maintenance could be scheduled for accomplishment.
71 - 85	Very Good	Minor deterioration. Component function is not impaired. No immediate work action is required, but minor or preventive maintenance sould be scheduled for accomplishment.
56 - 70	Good	Moderate deterioration. Component function may be somewhat impaired. Moderate maintenance or minor repairs may be required.
41 - 55	Fair	Significant deterioration. Component function is impaired, but not critically. Moderate maintenance repairs are required.
26 - 40	Poor	Severe deterioration in localized portions of the component. Component function is seriously impaired. Major repairs required.
11 - 25	Very Poor	Critical deterioration has occured over a large portion of the component. Component is barely functional. Major repairs or less than total restoration is required.
0 - 10	Failed	Extreme deterioration has occured throughout the entire component. Component is no longer functional. Major or complete restoration is required.

for each building to prioritize work and establish minimum acceptable conditions. (This concept is discussed in Chapter 5.) The heart of the BUILDER system will be the capture and use of current and predicted conditions through the use of indexes.

Data Storage and Retrieval

Due to the large number of buildings on Army installations, a computer-based data storage and retrieval system is essential to efficient storing, organizing, analyzing, and reporting of inspection results. The computer data base system will aid in the manipulation of inspection results, including generation of condition indexes.

Table 5

Building Condition Index (BCI) Concept

INDEX SCALE:	DEFINITION:	CONDITION DESCRIPTION:
86 - 100	Excellent	Very few noticeable defects. Building function is not impaired. No immediate work action is required, but minor or preventive maintenance could be scheduled for accomplishment.
71 - 85	Very Good	Minor deterioration. Building function is not impaired, but appearance may be less than desirable. No immediate work action is required, but minor or preventive maintenance should be scheduled for accomplishment.
56 - 70	Good	Moderate deterioration. Building function may be and appearance will be somewhat impaired. Moderate maintenance or minor repairs may be required.
41 - 55	Fair	Significant deterioration. Building function is impaired, but not critically. Moderate maintenance repairs are required.
26 - 40	Poor	Severe deterioration in localized portions of the building. Building function is seriously impaired. Major repairs required.
11 - 25	Very Poor	Critical deterioration has occurred over a large portion of the building. Building is barely functional. Major repairs or less than total restoration is required.
0 - 10	Failed	Extreme deterioration has occurred throughout the entire building. Building is no longer functional. Major or complete restoration is required.

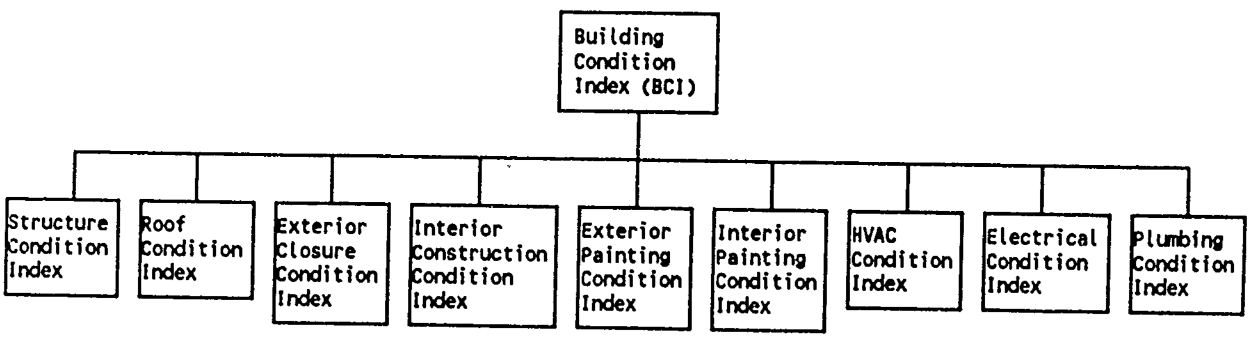

Figure 4. Building Component Index relationship to component indexes.

5 BUILDER EMS CONCEPTS

This chapter describes what the BUILDER system will be, what it will be able to do, how it will be used, how it will work with other Army systems, and how it may evolve and be fielded for use during the overall development process.

BUILDER Defined

The BUILDER Engineered Management System will combine engineering, architectural, and managerial methods with data base management technology to provide decision support so effective, efficient M&R of Army buildings can be planned and accomplished at an optimal level with the least possible cost, consistent with the Army's stated mission.

BUILDER would consist of three interrelated activities:

- Data collection in the field
- Data entry and other data management activities
- Use of a data base for decision support.

To facilitate these activities, the BUILDER system would incorporate three elements:

- Data base structure
- Procedures for data collection that are consistent with the data base structure
- Computer software for data base management and decision support applications.

What Will BUILDER Do for the DEH?

For BUILDER to help the DEH, certain system goals need to be established. At a *minimum*, these should include the following:

- Provide objective building evaluation through repeatable inspection procedures which leads to repeatable condition index ratings.
- Establish building maintenance, condition, and performance standards.
- Using condition indexes for components and key subcomponents to quantify the effectiveness of M&R and measure contractor performance by means of tracking condition index values.
- Be a means for developing annual work plans.

Network and Project Level Management

To explain how BUILDER will meet the above goals, a brief explanation of network and project level management is necessary.

Network Level Management

Network level management decisions are made at the following levels: installation, building group, building, component, subcomponent, or section. Management of this type tends to focus on the when, where, and budget aspects of building maintenance management. Network level management should be performed annually.

Condition indexes are critical at the network level. As was discussed earlier, current and predicted future condition assessments can be made using properly formulated condition indexes. These assessments lead to the identification of M&R candidate management units (discussed in Chapter 4). Once identified, the management units are prioritized for work accomplishment, which results in short- and long-range work plans. As a result, budgets can be optimized at this level through the best use of available or planned dollars. M&R program effectiveness will be measurable and required funding levels can be determined.

Network level "what if" management analyses are also possible using the condition indexes, for example, by estimating the costs (budgets) associated with establishing a minimum acceptable condition index at various target condition levels. "What if" analyses can lead to the establishment of minimum and optimal maintenance condition standards for buildings and building components. Also, effects of deferred maintenance or budget cuts can be determined in terms of index value reduction.

As was discussed in Chapter 4, inspection information is needed to enable this kind of analysis. Fortunately, component inspections at the network level need not be greatly detailed or extensive. Techniques of sampling (within components and among components within buildings of similar type and age), low sampling rates, appropriate inspection cycles, and proper inspection levels can keep these periodic surveys to a reasonable level of effort.

Project Level Management

Project level management focuses on how best to accomplish work decisions. Management at this level concentrates on building sections, subcomponents or whole components scheduled for M&R in the next annual work plan. The amount of personnel effort required for project level management depends on the type, cost, and scope of M&R work to be performed. For example, if the work is minor or preventive, the project would be planned, estimated, and scheduled through established job order or contract issuance procedures. These procedures include service orders, which by definition are of relatively small cost and scope and thus require little or no planning and estimating. Additional inspection information generally would not be required since enough information would be available from the network level inspections to plan and execute this type of work. However, if repairs, major M&R, or rehabilitation is to be accomplished, additional management actions are required. If severe deterioration, local failure, or complete component or building failure has occurred, diagnosing the cause of the failure or deterioration is critical so feasible M&R alternatives can be identified to solve the problem, not just treat the symptoms. The goal is to prevent a recurrence of the problem after repairs have been made. Ultimately, the best alternative should be selected according to life cycle costs and nonmonetary factors such as personnel comfort. This selection process permits project level budget optimization.

In general, Planners and Estimators (P&Es) need additional diagnostic and quantity information to properly estimate the job and prepare the job order. The information-gathering process consists of additional visual inspection, including nondestructive testing (NDT) and laboratory testing if necessary. Also, it may be necessary to perform an engineering analysis to determine the cause and possible solution, and an engineering design may be needed.

The visual effort will generally consist of a more detailed and thorough inspection of the component or section. NDT and laboratory testing may be needed when visual techniques are inappropriate or incomplete and additional information is needed for analysis. This inspection and testing effort may be performed by contractors or DEH personnel from the Engineering Plans and Services (EP&S) Branch or the Estimating and Facility Inspection Branch.

Use of BUILDER in Network and Project Level Management

BUILDER EMS Approach

For BUILDER to effectively aid the DEH in solving the problems described in Chapter 2, it must be capable of both network and project level management activities. Because building components use different technology disciplines (architecture as well as structural, civil, electrical, and mechanical engineering), BUILDER must be multidisciplined. Thus, appropriate technologies from those disciplines should be included. Moreover, because developing a complete system will take years, BUILDER should be created in steps or modules. This approach will get useful BUILDER components into the field at the earliest possible date, while overall development work continues. Add-on modules will enhance network level features and add project level capabilities.

Accordingly, the initial development approach to be taken with BUILDER is to establish network level procedures for determining when and where to best accomplish scheduled M&R. This can be done by using inspection and index rating procedures that assess current and predicted future conditions (Figure 5). The inspection and condition rating procedures outlined in Chapter 4 should be incorporated into the BUILDER EMS system. In fact, the condition indexes will provide the technological core of the system, and they will be the most important tools in the decision-making process. However, since it is likely that the component indexes will proceed at different rtes, some components could be put "on-line" before others.

Also, BUILDER should initially focus on the more common building types and materials. Thus, BUILDER could be implemented fairly early for at least some building types.

Based on the success of the initial system, perceived benefits, proponency, and available funds, an enhanced BUILDER system could then proceed further. A further discussion on both the network level BUILDER system and an Enhanced BUILDER system follow.

Network Level BUILDER System

A network level BUILDER EMS should improve management processes and add management techniques not currently in use. These changes would satisfy the *minimum* system goals listed earlier in this chapter. For clarity, these are expanded below.

Objective Condition Assessment. This will be accomplished through development and use of appropriate inspection procedures and condition indexes. Indexes will permit current and predicted conditions to be assessed for the building components addressed in Chapter 4. The indexes will be combined and result in a composite Building Condition Index (BCI) for each installation building. The average BCI can refer to groups of buildings or the installation as a whole. Having this information will allow facility managers to establish conditions of, and compare conditions between, a building's components, the buildings themselves, building groups, installation building components, and (at the Major Command level) various installations.

Establish Minimum Acceptable Condition Criteria. Establishing minimum condition index values will aid in work planning. By establishing minimums, buildings, building sections, and components can be flagged for early attention, when the repair costs are less. Minimum acceptable condition criteria could be based on building use as indicated by category code. Although a single index would apply to different building uses, the minimum acceptable index values would differ according to building uses.

Budgeting. Since condition indexes are a measure of deterioration, a relation between a component condition index and M&R cost can be established. In addition, the component M&R costs can be combined at the building level, and building M&R costs combined at the installation level to produce overall installation budgets.

"What If" Scenarios of Condition Versus Cost. By coupling condition prediction with cost and index values, many scenarios can be analyzed. Predicted conditions associated with certain budget targets can be studied, and the budgets needed to produce certain condition levels can be determined.

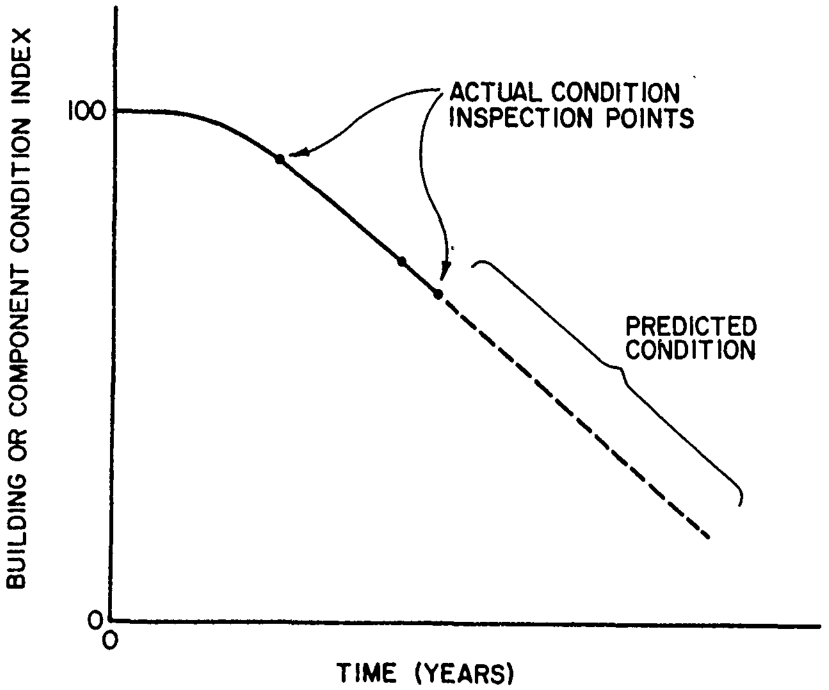

Figure 5. Building or component condition performance curves.

Work Prioritization. Prioritization techniques can be established to allocate funds where they are needed most. Possible criteria include condition, mission requirements, safety, building importance, building category code, interrelationship of one component to another, and so on. Work prioritization is a key management activity since funding rarely matches need at the installation level.

Annual Work Plan Development. Development of the annual work plan (AWP) is a key management activity. This can now be very time consuming, and the plan itself typically is not carried out because it rapidly becomes obsolete. However, BUILDER should make AWP development fairly rapid, and the resulting document should be dynamic and possess the flexibility needed by the manager. Also, since BUILDER would improve the overall facility management process due to the emphasis on planning, the AWP would become a much more effective document.

Contractor Performance Monitoring. Contractors perform some or all M&R work at many installations. Work that exceeds the capabilities of the in-house work force may be contracted, or the contracts may have been established through the Commercial Activities (CA) program. Management has recently shown a preference for performance, instead of process or method, specifications in M&R contracts. By specifying required condition index values in the contract, these values can be monitored as a measure of contractor performance.

Condition History. Condition indexes can be used to record condition variations over time, and thus past trends can be a factor in predicting the future. As a result, budget requests can be objectively justified.

Component Reinspection Scheduling. Based on the condition index values of the previous inspection, the rate of deterioration, and the maximum desired interval between inspections, a building-by-building reinspection schedule can be developed and used for planning the future component inspection program. Establishing such a reinspection schedule will help allocate limited inspection resources where they can be most effective.

Presentation Graphics. A certain amount of graphics is necessary for managers to assimilate, analyze, and present information. This would include items such as bar graphs and pie charts that take BUILDER numerical output and put it into a picture format that can be easily viewed and understood.

Enhanced Network and Project Level System

Many system enhancements would make BUILDER capable of performing complete network and project level activities. These enhancements would emphasize optimization and efficiency in decision making. They are briefly described below.

Automated Inspection Procedures. The development of automated inspection procedures could significantly reduce personnel effort associated with component inspections. When such procedures are developed, they would be incorporated into BUILDER.

Benefit Analysis. A benefit analysis procedure would provide a means for evaluating different M&R strategies at the network level and different M&R alternatives at the project level.

Budget Optimization. BUILDER would use operations research techniques to combine benefit analysis procedures with network level cost and index procedures. This approach would provide the user with a method to allocate funds optimally at both network and project levels.

Component Level EMSs. Four building components have individual EMSs under development. These are low-sloped roofs (ROOFER), interior water piping and condensate return lines (SCALER), and both interior and exterior painting (PAINTER) (Appendix G). Once BUILDER is in use, these component EMSs will have their greatest value at the project level. Thus, their integration into BUILDER would provide a fully capable system to the user. Development and integration of other component EMSs for project level management activities would add to BUILDER the capabilities necessary for a complete system. A further discussion of this integration is discussed in the next section of this report. It should be noted, however, that the true need for additional component level EMSs has yet to be established.

As a minimum, should the need for additional component level EMSs not be deemed necessary, BUILDER could simply expand to include those project level capabilities that would be most useful to the user community.

Engineering Analysis Procedures. Incorporation of engineering analysis technologies into BUILDER for evaluating various components may be possible. This would place within one software package a complete range of features useful for project level work.

Enhanced Graphics. As microcomputer software for representing buildings and building information pictorially becomes available, strong consideration should be given to integrating those capabilities with BUILDER. For example, the "network" of buildings could be represented on a computer-based installation map. Then, those buildings could be represented in different colors to reflect conditions of the different components throughout the installation. Each component could be displayed on an "overlay" basis. Also, details of individual buildings could be represented pictorially. Specific sections could be called up with appropriate information displayed. The interaction of the various components could also be represented.

Other graphics capabilities, discussed elsewhere,[23] have additional potential.

Data Base, Software, and Interface With Other Systems

Data Base

The BUILDER system requires its own structured data base. Included would be inventory, inspection, and other pertinent data needed for effective maintenance management. The proposed data base structure is represented by Figure 6. Although the specific data elements have not been defined for this concept report, the intent is to use data available from other data bases to the extent possible and to collect data only as needed.

Software

It is expected that BUILDER will run on IBM compatible microcomputers available in local offices. The software will be developed to operate like existing EMS software (menu driven, help features, etc.). This would expedite development and have BUILDER match, as closely as possible, other EMS software (PAVER, RAILER, etc.) developed to improve maintenance management capability.

[23]Uzarski, Tonyan, and Maser.

The software will consist of more than just data base management with menu features; it will also offer the decision support applications associated with network and project level management. BUILDER software will be an engineering tool for condition evaluation and rating procedures (condition indexes), condition predictions, and remaining tasks and analyses associated with work plan development.

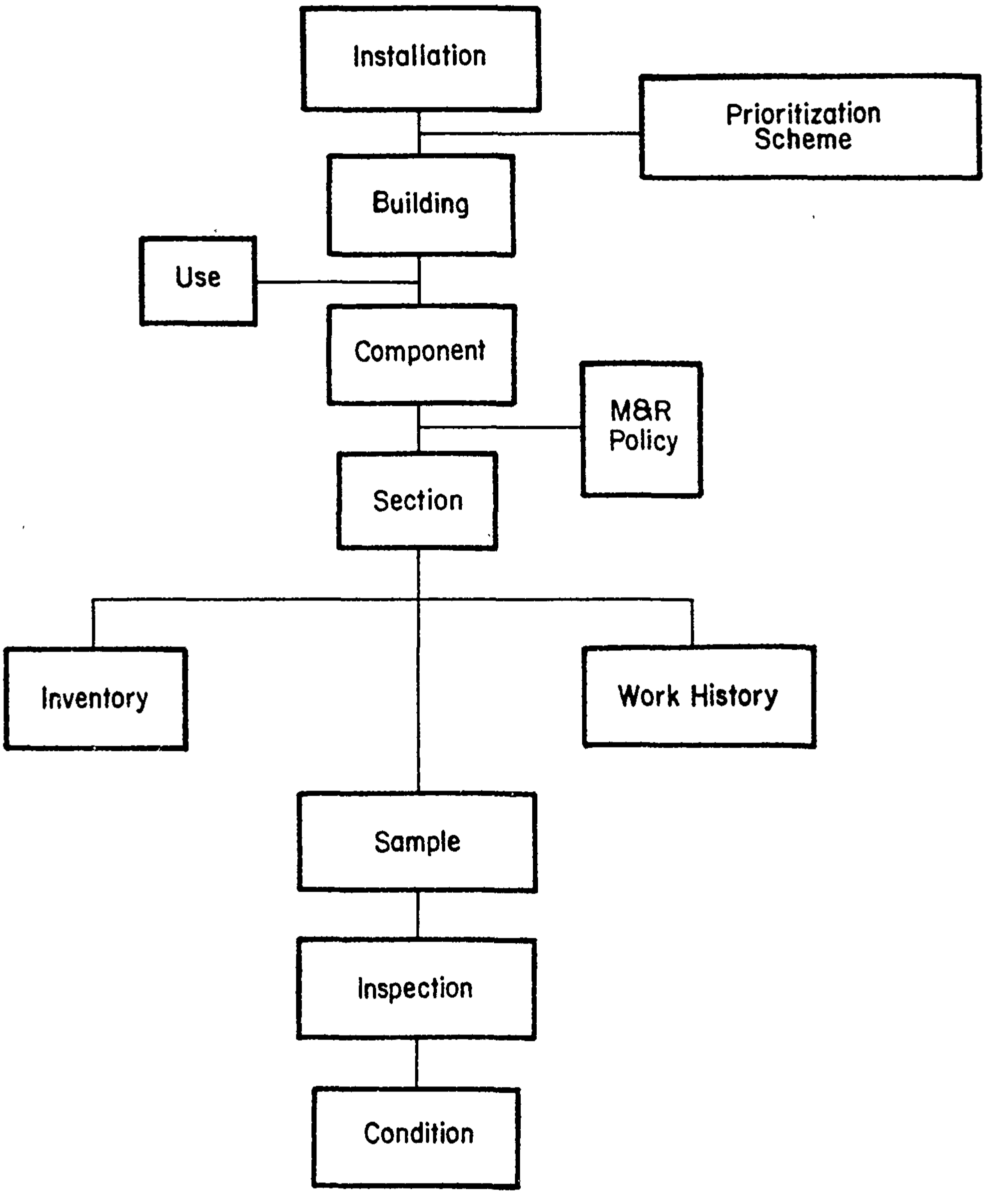

Figure 6. Proposed BUILDER data base structure.

Interface with Other Systems

When completed, a network/project level BUILDER will be able to interface with various existing and developmental systems including IFS-M, MRPM, building component EMS systems, other facility EMS systems, and Computer Aided Drafting and Design (CADD) systems. However, the initial network level BUILDER system described earlier will only interface with IFS-M, MRPM, and existing component EMSs. Interfacing with the other systems would occur as warranted by developments.

IFS-M. IFS-M is the primary system available to the DEH for performing a variety of required management tasks. Several modules are used in this effort.[24] USACERL and USAEHSC, formerly the Facilities Engineering and Support Agency (FESA), recently outlined and approach for interfacing the EMS family into IFS-M by treating the entire family as an IFS-M module. Data modeling has occurred for several of the EMSs to aid in this interface process. When developed, BUILDER will be added to the module, as shown in Figure 7. IFS-M data, particularly certain inventory elements, could be downloaded into BUILDER, and data such as condition information could be uploaded. Also, other IFS-M modules, such as the Facilities Engineering Job Estimating (FEJE) module, could probably be used for estimating costs when performing project level analyses through BUILDER EMS. If that interface is possible, BUILDER would not need project level cost-estimating capabilities.

MRPM. The Maintenance and Repair Prediction Model and BUILDER serve different functions. MRPM may be used to develop budgets at the installation level and higher (discussed in Appendix B). BUILDER will be used for determining M&R needs and costs at the specific building level and for prioritizing among buildings. However, even though they serve different purposes, they both deal with buildings and their components, and savings in data collection for one or the other could result if common data needs were transferable.

Component EMSs. The component EMSs (ROOFER, PAINTER, and SCALER) apply to building components that will be part of BUILDER, so interchange between them and BUILDER is anticipated. For the network level BUILDER system, the desired interchange initially would be that BUILDER accept data from the component systems. The BUILDER data will probably be too general for downloading into a more data-specific, project level component EMS. BUILDER and the component EMSs are planned to be separate systems because of their different management functions. This separation will provide maximum implementation flexibility at installations because implementing any of the systems will be possible independently on a schedule that best fits local needs.

The enhanced network and project level BUILDER system will look at integrating all building EMSs into one software package (Figure 8). When this is accomplished, maximum use of common data files and transfer could be made. This will facilitate data collection and transfer and make it easier for the user to put all available information to work. However, even when this is accomplished, ROOFER, PAINTER, and SCALER will still be available as stand-alone systems.

Facility EMSs. No exchange between BUILDER and the facility EMSs (PAVER, RAILER, BRIDGER, PIPER) is required. However, all facility EMSs need to be combined on an installation level so optimal facilities M&R decisions can be made. BUILDER needs to be developed with that goal in

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[24] *Functional Description, Prototype Development Methodology, Integrated Facilities System, Mini/Micro (IFS-M), Executive Summary,* Internal FESA Document (Facilities Engineering and Support Agency [FESA], 1987).

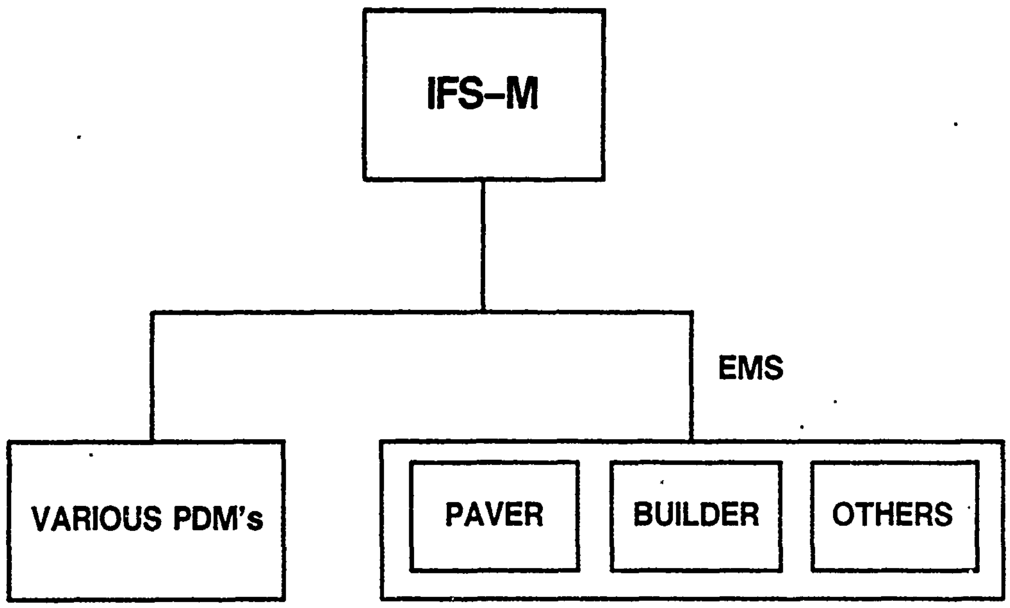

Figure 7. BUILDER interface with IFS-M.

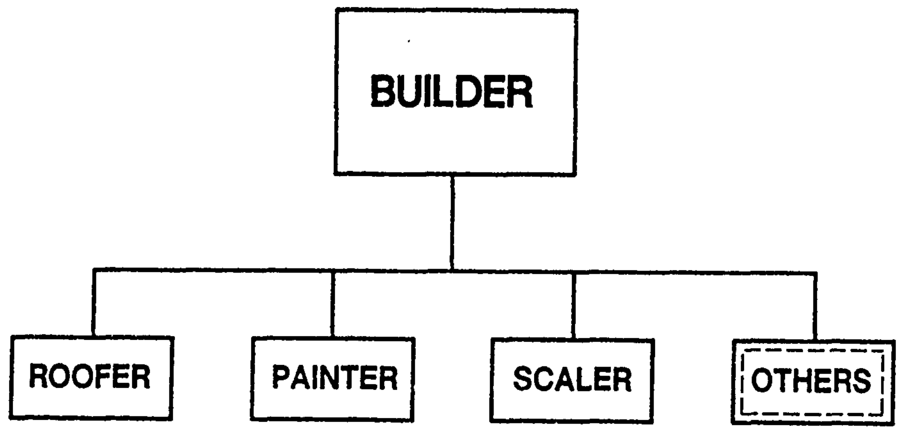

Figure 8. BUILDER interface with component EMSs.

mind. The installation level decision-making process is currently under study as a separate USACERL work unit.

CADD. Incorporating CADD graphic features into EMS is very appealing. The ability to display drawings of exterior walls, floor layouts, etc., will permit the user to visualize the building as part of the decision-making process. Also, the physical relationship of one component to another will be easily seen. Condition index values, defect types and locations, and other pertinent information could be superimposed to clarify problems and simplify solutions.

BUILDER Development Steps

Time Frame

It is estimated that the network level BUILDER system will require 4 to 5 years for development; however, some modules or phases should be available sooner. Condition indexes do not exist for all components, and experience has shown that approximately 3 years are needed for research and development, which includes completing inspection procedures. Software development can begin simultaneously, but a considerable refinement will be required after the indexes are completed.

User Group and Research Group Involvement

User input was incorporated in the background work that went into this concept study. The users who provided input have functioned as a user group, and this report largely reflects their views and needs. This group needs to continue its work as BUILDER moves into the full development phase. In addition, researchers should continue to meet at the users' installations; this permits researchers to evaluate DEH problems fully, share ideas with field personnel, and test developments in the field. User group meetings are needed to allow group dynamics to play a part in establishing the BUILDER EMS. Since a system like BUILDER does not exist and since the Navy and Air Force face similar facility problems, their participation in BUILDER development through personnel involvement and research funding should be invited. This would result in a system that would be accepted and used throughout the Department of Defense. This approach would facilitate technology transfer and result in the broadest benefit. Likewise, liaison with the American Public Works Association (APWA) and the Building Research Board could reap positive development feedback and provide the future technology transfer medium to the non-Federal public and private sectors.

Since BUILDER will be composed of various technologies, experts from these disciplines should work together in its development. USACERL experts have provided initial input for this study and these various research teams should continue to develop appropriate parts of the system. BUILDER's development will follow the flow diagram shown in Figure 9.

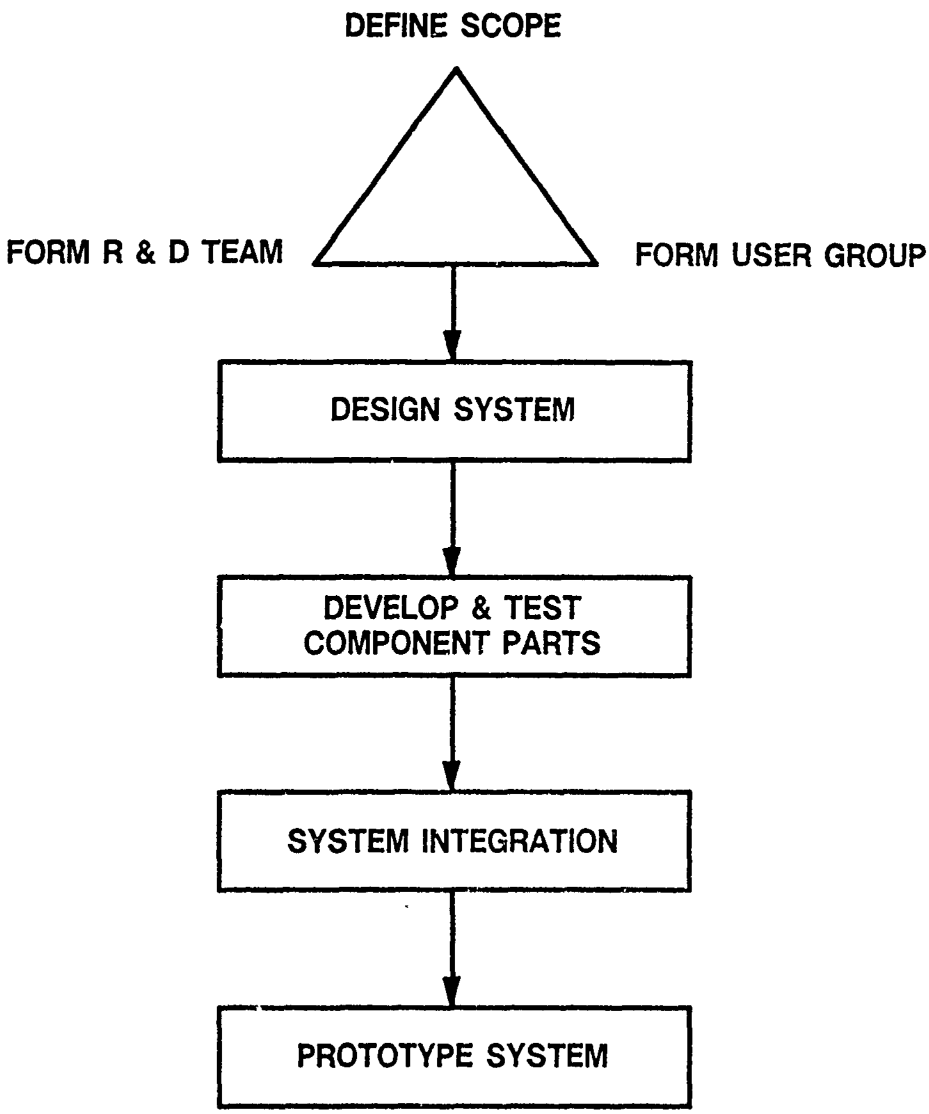

Figure 9. BUILDER development steps.

6 CONCLUSIONS AND RECOMMENDATIONS

Nearly 55 percent of all DEH M&R is devoted to buildings. Management tends to be ad hoc, with strong reliance on service calls and work requests from building occupants. M&R funds are expected to be limited in the future, and M&R funding needs are expected to outpace budget growth. Accordingly, an effective structured maintenance management system, or BUILDER EMS, is needed by DEH managers to improve decision making.

Although no BUILDER-like system is now available, the study identified methods and procedures in existing programs and systems that could be useful in developing BUILDER.

Any structured system intended for Army use must be compatible with existing management systems, such as IFS-M and available EMSs. The system must be technologically sound and account for the various components found in buildings. The use of condition indexes for components and buildings is essential for proper management. Condition indexes are essential for evaluating current conditions and predicting future conditions. This approach will lead to timely and effective work accomplishment through active management, budget requests based on realistic predictions, and the ability to use inspection resources optimally.

An effective BUILDER system should be developed for network level use initially. Additional benefits will be attained if development is expanded to include project level features and network level enhancements consisting primarily of automated inspection features and optimization techniques. These features could be added later to an initial network level system.

The following recommendations are made:

1. Develop BUILDER as an EMS complete with condition indexes and software similar to other EMSs.

2. Develop BUILDER initially as a network level system; enhancements to BUILDER should include project level features or other component EMS systems.

3. Include existing programs and systems that have methods and procedures useful to BUILDER; their incorporation will save R&D effort.

4. Continue to involve user groups as well as the Navy and Air Force in the R&D process to ensure user needs are met.

5. Continue liaison with the APWA and BRB as a means for fostering technology transfer to the non-Federal and private sectors.

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APPENDIX A:

SURVEYED FIRMS PRODUCING BUILDING OPERATIONS-RELATED SOFTWARE PROGRAMS

ABC Technologies International, Inc.

Burke & Associates, Inc.

Cochrane Associates, Inc.

Creative Maintenance Systems, Inc.

Datastream Systems, Inc.

DFM Business Software Systems, Inc.

JB Systems, Inc.

Johnson Controls, Inc.

Locke Systems, Inc.

Maintenance Automation Corporation

Maximo Maintenance System

MIT's INSITE Facilities Management System

Owen Engineering & Management Consultants, Inc.

RMS Systems

APPENDIX B:

BUDGET PREDICTION METHODS

Maintenance Resource Prediction Model[25]

The Maintenance Resource Prediction Model (MRPM) was developed by the U.S. Army Construction Engineering Research Laboratory (USACERL) for the U.S. Army. The purpose of the MRPM is to predict specific recurring maintenance tasks based on the expected life cycles of the various building components/ subcomponents. No inspection procedure is included. These predictions, along with their associated costs, are designed to be used by Headquarters Department of the Army (HQDA) and the Major Commands (MACOM) to predict maintenance resources and estimate annual maintenance budgets.

In the MRPM program buildings are divided into systems, subsystems, and components (Table 2). Specific recurring maintenance tasks have been established on a statistical basis for each component and subcomponent to enable predictions of specific future maintenance requirements. By predicting specific maintenance tasks requirements and their associated costs, HQDA and MACOMs will have a greater ability to predict the annual maintenance budgets for each installation. They will also be able to predict the Army's annual maintenance budget at the MACOM and Department of the Army (DA) level by aggregating the installations' associated maintenance costs upwards. Even though specific component/ subcomponent level tasks can be predicted by year, they are not intended to be work plan input. The intent is that they be used for any given period to predict high-cost items, determine areas requiring inspection, and aid in predicting and planning maintenance budgets.

The MRPM program does not have the capability to define an installation's current condition and specific maintenance requirements or the backlog of maintenance and repair (BMAR) needs found at many Army installations.

Historical Records Analysis

Historical records analysis is a budget prediction process based on records of past maintenance requirements and costs associated with a building or group of buildings. Annual maintenance budgets are generated using maintenance predictions made from the historical records.

Many organizations use historical records analysis to compare past maintenance requirements and expenditures with planned maintenance budgets. For example, the Indian Health Service (Appendix E) uses historical analysis and a building inspection process to develop its annual maintenance budgets.

[25] E.S. Neely and R.D. Neathammer.

APPENDIX C:

CONDITION ASSESSMENT METHODS AND AGENCIES SURVEYED

Sampling techniques:

U. S. Air Force (Project SNAPSHOT)

Dutch Housing Condition Survey

Comprehensive inspections:

U. S. Navy (Controlled Inspection Program)

North Carolina Department of Administration

Florida Department of General Services

Missouri Division of Design and Construction

The University of North Carolina at Chapel Hill

National Park Service: Historic Landmarks Assistance

Veterans Administration: Medical Centers

Indian Health Service (Project Deep Look)

Bohm-NBBJ, Architects and Planners

Mell Simon & Associates

Canadian Park Service

Transport Canada: Toronto, Ontario

English House Condition Survey

Scottish Special Housing Association

Royal County of Berkshire: Berkshire, England

Engineered Management Systems, USACERL

APPENDIX D:

SAMPLING TECHNIQUES

United States Air Force (Project SNAPSHOT)[26]

Project SNAPSHOT is a condition assessment program conceived by the Air Force to aid in the allocation of capital resources. The conceived program is modeled around similar building types defined within 20 building category code groups (Table D1). Each category code group would be assigned a required statistical representative building sample grouping. Building inspections would be performed only on the representative buildings of each category code group to reduce the time and costs involved in the inspection process.

The building inspection process is planned around eight building components (see Table 1). Each component would be inspected by a team of trained technical level personnel. Because the project's designers anticipated that team members might lack a complete knowledge of building problems, the level of inspection detail is low, and the inspection forms are a series of yes/no questions and identifications of specific building component deficiencies (Figure D1).

After the inspection is completed, the inspection team would determine the percentage of building components requiring replacement, rehabilitation, and maintenance. These results would then be aggregated and extrapolated from each representative building to produce the percentage of replacement, rehabilitation, and maintenance required for each component at the installation level.

Deduct values would be assigned to each component so installation level component replacement, rehabilitation, and maintenance percentages could be aggregated into a single percentage of replacement, rehabilitation, and maintenance required on an installation. These three percentages would be finally summarized at the total installation level by referring to the Facility Condition Index (FCI), which would represent the entire installation condition. Although acceptable FCI ratings have not been established, the use of the FCI rating does provide a way of comparing installations' general facility conditions without having to refer to the Backlog of Maintenance and Repair (BMAR).

Budget projections are based on the Total Base (installation) Value (TBV) (i.e., the base replacement cost) and the corresponding percentage of replacement, rehabilitation, and maintenance work required on the base.

The development of Project SNAPSHOT has not been completed. Its future is uncertain.

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[26] Hazardous Waste Remedial Actions Program (HAZWRAP), *Project: SNAPSHOT*, Phase 1 Summary Report (HAZWRAP, Martin Marietta Energy Systems, Inc., undated).

Dutch Housing Condition Survey[27]

The Dutch Housing Condition Survey method was established in response to the inability to accurately predict maintenance and repair needs of its housing assets based on the 1975 Qualitative Housing Survey. Due to limited annual budgets, the current inspection method uses a sampling technique in which detailed information is collected on only 10 percent of the dwellings. The remaining 90 percent receive a limited inspection.

The detailed inspection involves examining approximately 50 building components, which are categorized by material types. Each component is inspected to determine the amount of material needing replacement. The inspection form has areas to indicate the amount of material needing replacement, notes of possible defects and their seriousness, and repair cost estimates when defects can be repaired immediately. A detailed cost of replacement is also estimated by recording computer data on the specific component replacement amounts determined during the inspection process.

Table D1

Project SNAPSHOT: Building Category Code Groups

1. Airfield Pavements
2. Operating Buildings
3. Other Operations Structures
4. Laboratories
5. Maintenance, Industrial, & Production
6. Storage with Environmental Controls
7. Storage without Environmental Controls
8. Medical
9. Administrative
10. Training
11. Living Quarters
12. Food Preparation / Dining
13. Sales Facilities
14. Community Facilities
15. Indoor Recreation
16. Outdoor Recreation
17. Utilities
18. Fuel Systems
19. Roads & Parking Areas
20. Other / Miscellaneous

[27] A.A.J. Damen and J.M.J.F. Houben, "The Dutch Housing Condition Survey," *Journal of the CIB Building Research and Practice* (March/April 1987), pp 113-117.

MECHANICAL

HEATING EQUIPMENT
1 Month Maintenance Cycle

BOILER

	1.	Does system use one of the following type boilers?		
		(A) Fire Tube (B) Water Tube (C) Cast Iron	This is useful to know to establish life and maintain frequency and cost	(Info.)
	2.	Is the system comprised of:		
		(A) Hot Water (B) Steam	Same as above	(Info.)
Yes/No	3.	Does boiler leak water?		
Yes/No	4.	Is the boiler chimney corroded or rusted?		
Yes/No	5.	Is some of the pipe insulation damaged or missing?		0-25% 26-50% 51-75% 76-100%
Yes/No	6.	Are the steam and condensate pipes sloped?		
____ Years	7.	What is the approximate age of the boiler?		(Info.)
____ Years	8.	What is the approximate age of the piping?		(Info.)
Good Fair Poor	9.	What is the estimated condition of the boiler? (Circle One)		

Figure D1. **Project SNAPSHOT: boiler inspection form.** (Source: Hazardous Waste Remedial Actions Program (HAZWRAP), Project SNAPSHOT, Phase 1 Summary Report [HAZWRAP, Martin Marietta Energy Systems, Inc., undated.)

The limited inspection involves the assessment of 12 building components (see Table 1). For each building component, data is recorded on the presence of certain defects, and the inspector assigns a condition and cost of improvement (repair) rating to the component (Figure D2).

So comparisons can be drawn between the detailed and limited investigations, the detailed inspection also includes a section where the inspector rates the 12 components considered in the limited inspection. The inspector rates each of the 12 components on the rating scale of the limited inspection.

By using both limited and detailed inspections for condition assessment, inspectors check the accuracy of the limited inspection process, and the often costly and time-consuming aspects of a comprehensive, detailed inspection are minimized.

External components	Front	Back
1 External walls		
- cracks in brickwork		
- imperfect paintwork	X	X
- other defects		
Condition	1 2 3 (4) 5 6	
Cost of improvement	A B (C) D E F G H J K	

Figure D2. **Dutch Housing Condition Survey: inspection form for external walls.** (Source: A.A.J. Damen and J.M.J.F. Houben, "The Dutch Housing Condition Survey," *Journal of the CIB Building Research and Practice* [E & FN Spon, London, March/April 1987], pp 113-117.)

APPENDIX E:

COMPREHENSIVE INSPECTIONS

United States Navy: Controlled Inspection Program[28]

The U.S. Navy requires that each Naval installation annually inspect, assess, and report the condition of its facilities to reduce the critical M&R backlog.[29] The buildings at each installation are assigned to one of 18 investment categories (Table E1). These categories aid decision makers by grouping similar building types. Each building is divided into four building components (see Table 1). A facility inspection report (Figure E1) is completed and inspection reports are produced for each component. The building component inspections are performed by trained inspection personnel to identify deficiencies present in a building.

Table E1

U.S. Navy: Investment Categories

1.	Aviation Operation Facilities
2.	Communications Operation Facilities
3.	Waterfront Operation Facilties
4.	Other Operational Facilities
5.	Training Facilities
6.	Aviation Maintenance/Production
7.	Shipyard Maintenance/Production
8.	Other Maintenance/Production
9.	Research, Development, Test & Evaluation
10.	POL Supply/Storage
11.	Ammunition Supply/Storage
12.	Other Supply/Storage
13.	Medical
14.	Administrative
15.	Troop Housing/Messing Facilities
16.	Other Personnel Supply & Services
17.	Utilities
18.	Real Estate and Ground Structures

[28] Naval Facilities Engineering Command (NAVFAC) Maintenance and Operation Manual (MO) 322, Vol 2, *Inspection for Maintenance of Public Works and Public Utilities* (NAVFAC, June 1975); NAVFAC MO-322, Vol 1, *Inspection of Shore Facilities* (NAVFAC, July 1977); NAVFAC MO-323, *Inspection Maintenance and Operations Manual for Naval Reserve Centers (NRC)* (NAVFAC, April 1986); NAVFAC MO-321, *Facilities Management* (NAVFAC 1985); NAVFAC MO-321, *Maintenance Management of Shore Facilities for Small Activities* (NAVFAC, November 1978).

[29] Office of the Chief of Naval Operations Instruction (OPNAVINST) 11010.34B, *Instructions for Preparation and Submission of the Type "A" Annual Inspection Summary and Narrative Assessment* (Department of the Navy, Chief of Naval Operations [DNCNO], 1987); OPNAVINST 11010.23E, *Management of Shore Base Maintenance of Real Property (MRP) Functions* (DNCNO, 1987); OPNAVINST 3501.167B, *Shore Base Readiness Report (BASEREP)* (DNCNO, 1987).

FACILITY INSPECTION REPORT

1 ACTIVITY	2 LOCATION	3 UIC	4 SPC AREA	5 FACNO
SSC	G-30			621

6 DEF NO	7 DEF DESC	8 EST CST
	STRUCTURAL FY8	

9 DC	10 TYP	11 FSC	12 PROJ NO	13 LST EST (YYMMDD)	14 FUND DT (YYMMDD)

☐ ELECTRICAL ☐ MECHANICAL ☐ ROOFING ☒ STRUCTURAL ☒ SPECIAL

16 EST CD	17 DESCRIPTION OF WORK

REQUEST WAS MADE BY LT. KRONE TO CHECK STRUCTURAL CRACKS IN COLUMNS, BEAMS AND WALLS AT THE NORTHEAST CORNER OF THE 2ND & 3RD DECKS.

THESE STRUCTURAL CRACKS WERE REPORTED TO LT. KRONE BY T. CHEESEMEN OF THE PUBLIC WORKS CENTER - BLDG. 104.

THE AREA IN QUESTION WAS INSPECTED BY THE UNDERSIGNED ALONG WITH Q. YOUNG OF THE ENGINEERING DEPT.

THE INSIDE OF THE BUILDING ON THE 2ND & 3RD DECKS NORTHEAST CORNER SHOWS MINOR CRACKS ALONG THE CONCRETE COLUMNS AND BEAMS MEET CEMENT BLOCK WALLS AT ITS MORTAR JOINTS. THERE IS A SMALL EDGE BROKEN OFF OF THE CONCRETE COLUMN ON THE 2ND DECK EXACTLY IN THE NORTHEAST CORNER AT THE TOP. THE OUTSIDE OF THE BUILDINGS CONCRETE COLUMNS, BEAMS & BRICK ARE IN GOOD CONDITION:

	LABOR COSTS	MATERIAL COSTS	TOTAL COSTS
18 TOTAL THIS PAGE			
19. TOTAL FOLLOWING PAGE(S)	$180.00	$40.00	$220.00
20 TOTAL DEFICIENCY COST ESTIMATE			

21 PREPARED BY (Inspector)	22 REVIEWED BY	23 DATE
JOE INSPECTOR		10/88

PAGE 1 OF 3

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Figure E1. U.S. Navy: facility inspection report.

After inspection of these components, the inspector assigns a subjective condition rating (poor, fair, good, or excellent) to each component. The inspector also assigns an estimate of repair cost to each deficiency. The list of all deficiencies and their estimated repair costs are consolidated in an annual inspection summary (AIS) report,[30] which is used at various command levels within the Navy to plan, prioritize, and justify annual M&R budgets.

North Carolina Department of Administration[31]

North Carolina is developing a Facility Condition Assessment Program (FCAP) to aid in the management of its 11,102 buildings. The program will be used only on buildings larger than 3000 sq ft. The inspection and maintenance planning process will be developed around 17 building components (see Table 1). Experienced inspection teams, made up of architects, engineers, and maintenance operations personnel, will conduct the inspections, which gather inventory, assessment, and deficiency data. From this data, deficiency correction costs will be computed and a correction priority rating will be established for each deficiency. A computer data base will be established to store data collected during inspection, produce budget planning reports, and process current work requirements. Reinspection will occur, on average, every 3 years; buildings with a poor condition rating may be inspected annually.

Florida Department of General Services[32]

Florida has developed an inventory and condition assessment program that includes six building components (see Table 1). The program is used on all building types larger than 3000 sq ft within all state agencies, except those included within the university system. The inspection teams consist of architects employed by the department. During the inspection process, deficiencies are identified and described and corrective actions along with their corresponding costs are recommended. The information is stored in a microcomputer data base where it linked via modem to a central microcomputer at the state capitol, where it is used directly in the state budget process. Inspections are performed on a 3-year cycle.

Missouri Division of Design and Construction[33]

Missouri has developed the Land and Buildings System (LABS) which is an inventory and condition assessment system. LABS is used to report the use and condition of state-owned facilities. A subjective condition rating system has been developed that reflects the physical state of repair of various building components (see Table 1). The ratings are: A = Good, B = Fair, C = Poor. An overall condition rating is determined from the individual component ratings. Components rated at less than "good" are given a cost estimate as to what it would take to restore the component to a "good" condition. Inspections are performed annually. Figure E2 is completed as part of the inspection process.

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[30] OPNAVINST 11010.34B.

[31] DSA Group of N.C. Inc., *Facility Condition Evaluation and Maintenance Planning Program*, State of North Carolina, Phase 1 Report (North Carolina Department of Administration, May 1988).

[32] Building Research Board, *Committing to the Cost of Ownership. Maintenance and Repair of Public Buildings*, Draft Report (National Research Council, 1990).

[33] State of Missouri, *LABS Agency Procedures Manual* (Land and Buildings System [LABS], April 1982).

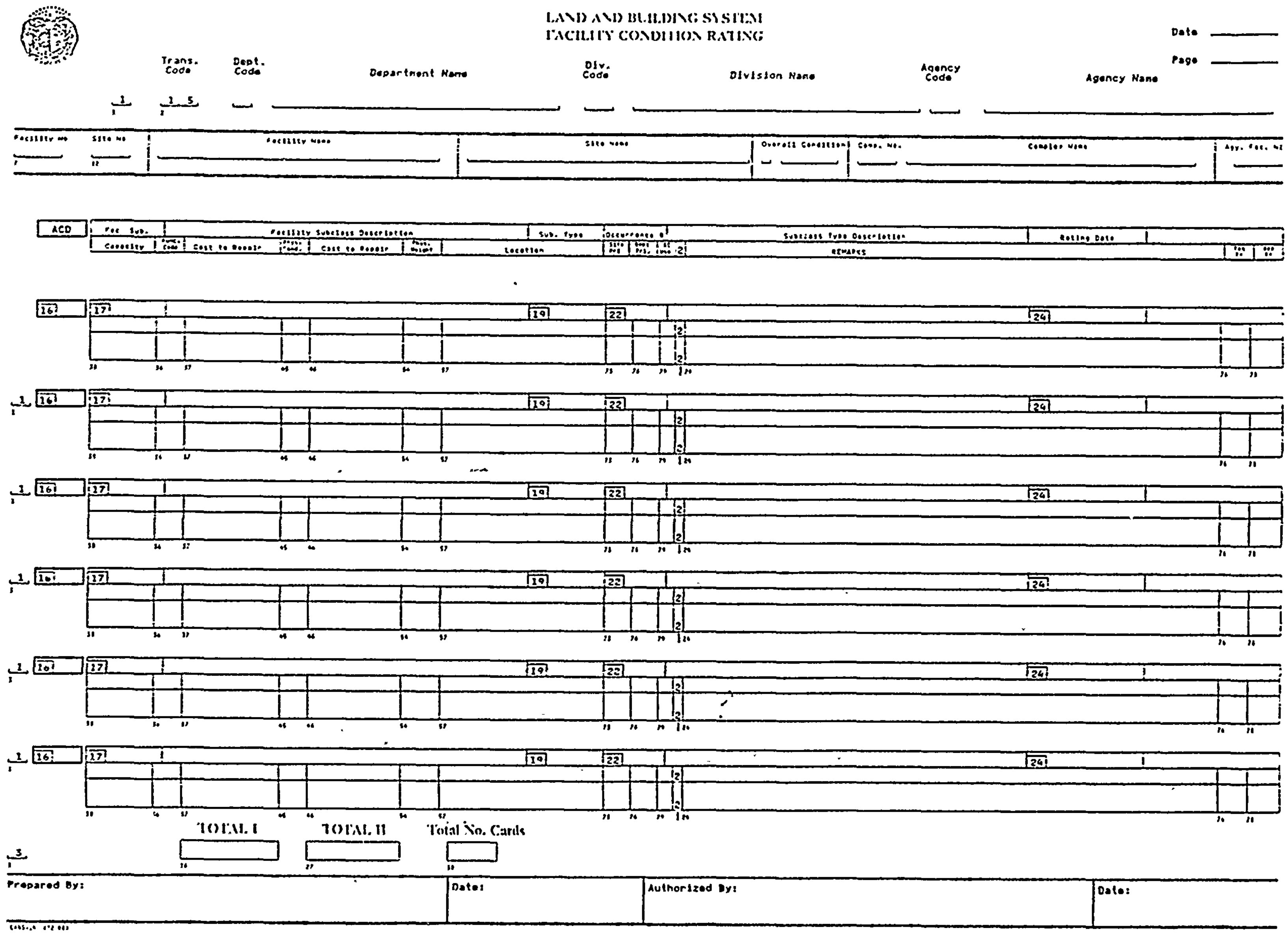

Figure E2. **LABS Facility Condition Rating Form.** (Source: State of Missouri, *LABS Agency Procedure Manual*, [Land and Buildings System April 1982).

The LABS data base contains a considerable amount of information. In addition to the condition information, LABS contains inventory, construction, and acquisition costs, major facility functions, age, replacement costs, and maintenance history. LABS data are used by various state agencies as well as the state General Assembly and the Executive Branches for capitol improvement planning, cost analyses, and support budget requests for maintenance and reapir funds. The interfacing with other systems and software is planned.

University of North Carolina (UNC) at Chapel Hill[34]

In 1986 physical plant staff began collecting information on all university facilities for input into a central data base system. This information would be used to aid in producing maintenance budgets, verifying the condition of the University's facilities, and prioritizing required maintenance or capital improvements. The system uses a dBASE III data management program. Information on building deficiencies is collected by an inspection team consisting of building inspectors, trade technicians, and specialists and then manually loaded into the microcomputer data base. Inspectors collect data on 23 building component deficiencies (see Table 1). The facility (building) inspections are performed at a subcomponent level identified for each building component. Each subcomponent is inspected to determine maintenance deficiencies, and a subjective condition rating is assigned by the inspection team in one of five categories: satisfactory, routine, urgent, emergency repairs, or not rated. The inspection team roughly estimates correction costs for each identified maintenance deficiency, which are used until a formal estimate can be created by a Planner/Estimator. The resulting cost estimates are identified as a maintenance deficiency report (MDR).

Following the identification of the MDR value and the subcomponent condition ratings, the computer assigns a building component Condition Rating (CR) based on the requirements to bring the component to a satisfactory condition (MDR = 0). The component condition ratings are satisfactory, maintenance repairs (<$75,000), capital repairs (>$75,000), unsatisfactory, or not rated.

The computer also assigns a Facility Rating (FR) based on the total estimate to correct identified maintenance deficiencies (MDR) and the facility's current replacement value (CRV). The facility condition rating is determined by dividing the MDR by the CRV (MDR/CRV). The computer assigns a facility condition rating based on the resulting percentage: satisfactory (0 percent CRV), renovations (<25 percent CRV), remodeling (25 to 50 percent CRV), or restoration (>50 percent CRV). The resulting MDR values and condition ratings are summarized in a facility audit/condition evaluation summary form (Figure E3).

Initial inspection of Chapel Hill University buildings is expected to be completed in 1990, with a three year reinspection cycle subsequently being performed.

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[34] E. Sanders, *The Solution to Facilities Management Planning?* Facilities Audit (University of North Carolina at Chapel Hill, March 1988).

UNC FACS FORM F1A.0 FACILITY AUDIT/CONDITION EVALUATION SUMMARY

SECTION I AUDIT INFORMATION

FAC# 199/X FAC Name TEST BUILDING

DATE INSPECTED: TEAM LEADER: ES
LOCATION: AIRPORT ROAD YEAR CONSTRUCTED: 1952

GROSS SQUARE FEET: 100000
NET SQUARE FEET: 90000 RATIO: NET SQ FT/GROSS SQ FT: 0.90

ORIGINAL COST: $ 2000000 CURRENT REPLACEMENT VALUE (CRV): $ 5000000

SECTION II CONDITION EVALUATION

		MDR TOTAL	RATING
OVERALL FACILITY SUMMARY		$ 218500	FR = 3

RATIO OF MDR/CRV = 0.04

BUILDING COMPONENT SUMMARY

		MDR TOTAL	RATING
EXTERIOR			
F2.1	FOUNDATION	$ 4000	CR = 3
F2.2	WALLS	$ 0	CR = 4
F2.3	PAINTING	$ 9000	CR = 3
F2.4	DOORS/HARDWARE	$ 1000	CR = 3
F2.5	WINDOWS	$ 0	CR = 4
F2.6	ROOF	$ 100000	CR = 2
F2.7	SITE	$ 1000	CR = 3
INTERIOR			
F3.1	CEILING	$ 0	CR = 4
F3.2	WALLS	$ 0	CR = 4
F3.3	WINDOWS	$ 0	CR = 4
F3.4	DOORS/HARDWARE	$ 2500	CR = 3
F3.5	FLOOR	$ 0	CR = 4
F3.6	PAINTING	$ 0	CR = 4
ELECTRIC/MECHANICAL			
F4.1	AIR CONDITIONING	$ 2500	CR = 3
F4.2	PLUMBING	$ 5000	CR = 3
F4.3	ELECTRICAL	$ 17000	CR = 3
F4.4	EMERGENCY GENERATOR	$ 2500	CR = 3
F4.5	CONVEYING	$ 0	CR = 4
F4.6	ALARM/DETECTION	$ 0	CR = 4
F4.7	WATER DISTILLATION	$ 29500	CR = 3
F4.8	HEATING	$ 0	CR = 4
SPECIAL			
F7.1	ANIMAL QUARTERS	$ 2000	CR = 3
F7.2	CLASSROOMS	$ 16500	CR = 3

FACILITY RATING	COMPONENT RATING
FR4 = Satisfactory	CR4 = Satisfactory
FR3 = Renovations (<25%CRV)	CR3 = Maintenance Repairs (<$75,000)
FR2 = Remodeling (25%-50%CRV)	CR2 = Capital Repairs (>$75,000)
FR1 = Restoration (>50% CRV)	CR1 = Unsatisfactory
	CR0 = Not Rated

Figure E3. **UNC at Chapel Hill: facility audit/condition evaluation summary.** (Source: E. Sanders, *The Solution to Facilities Management Planning?* Facilities Audit [UNC at Chapel Hill, March 1988].)

National Park Service

The building condition assessment program for historic landmarks of the National Park Service (NPS)[35] divides the building into nine component categories (see Table 1). These categories establish the basis for the inspection format performed by an architect/engineering inspection team. During inspection the nine categories are subdivided into approximately 150 specific building elements which are inspected in each building. The results are recorded on an inspection form (Figure E4). Notes are made for each element identifying specific characteristics and deficiencies. Inspectors will also assign each element an appropriate treatment rating, a subjective condition rating (good, fair, or poor), a deficiency priority (critical, serious, or minor), and identify the quantity of each deficiency.

After the inspection is complete, the inspection team prepares a report listing deficiencies, appropriate work recommendations, and repair or replacement cost estimates. Included in the inspection team's building report to the NPS Regional Coordinator is general information about the building, the building's component conditions, deficiency lists and work recommendations, single-line floor plans of the building, and photographic documentation of the building.

The initial inspection of the National Park Service's historic landmarks is in the process of being completed; future reinspection cycles have not yet been determined.

The NPS also has an Inventory and Condition Assessment Program (ICAP).[36] Using the same building components as for the historic landmarks program (see Table 1), ICAP applies to all buildings regardless of size and use. Trained inspectors use standardized procedures to perform a condition assessment. The inspectors visually inspect and perform limited nondestructive testing (e.g., test electrical circuits) to describe up to 227 standard features within the components. Feature descriptions, deficiencies, recommendations for corrective action and costs are recorded, prioritized and reported. No set reinspection frequency is established. Rather, accomplishment is performed as required to support an effective program. The ICAP program is microcomputer based. Data can be retrieved for a single building or for groups of buildings.

Veterans Administration Medical Centers[37]

In 1984 the Veterans Administration (VA) began development of an evaluation and management information system that would be used in the technical assessment of its 131 medical centers throughout the United States. Standardized inspection and evaluation techniques were established so that short- and long-range capital asset planning activities could be monitored and compared among the medical centers. For the assessment process each VA medical center facility is divided into buildings, systems, and components. Each building has 13 potential systems (see Table 1) and 118 potential components.

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[35] Center for Architectural Conservation, College of Architecture, Georgia Institute of Technology, *Draft of the Building Condition Assessment Program, Field Operations Manual, Vol 1* (Georgia Institute of Technology, undated).

[36] National Research Council, 1990.

[37] *Capital Facilities Study: Vol 2: CFS/MIS Operations Manual for Architects and Engineers* (Veterans Administration, March 1985).

EXTERIOR ENVELOPE

	ELEMENT	RATING	QUANTITY	CONDITION	PRIORITY
71	ROOF: SURFACE MATERIAL 1 Hexagonal asphalt shingles - approx 19" x 16" laid over orignal wood shingles NOTES:	4	5679 SF	POOR	CRITICAL
72	ROOF: SURFACE MATERIAL 2 Asphalt roll roofing over rear porch / see work recommendation for #71 NOTES:	4	23 SF	FAIR	
73	ROOF: SURFACE MATERIAL 3 NOTES:				
74	ROOF: VENTS / OPENINGS Wood louvered vents at gable ends / gap in soffit / plumbing vents NOTES: Wood vents rated 2. Plumbing vents rated 4.	2 / 4		FAIR	
75	ROOF: FLASHING Tar over original metal / lead at plumbing vents / see work recommendation for #71 NOTES:	4		POOR	
76	Painted metal gutter + downspouts / w parlor octagonal bay has new (1984) copper downspouts + lined wood gutter NOTES: Metal gutters rated 5 - to be removed. Copper rated 2 - to be preserved	2 / 5	474 LF	POOR	CRITICAL
77	ROOF: DECKING / SHEATHING 1 ca 1883: Spaced sawn 1" x 3" wood decking boards / see work recommendation for #71 NOTES:	3	2947 SF	POOR	

Figure E4. National Park Service: roofs inspection form.

The inspection and evaluation process of each building is organized around the 13 potential systems and each system is inspected at the component level. An architect/ engineering inspection team performs the building inspection. Using survey forms (Figure E5) for each building component, the inspectors identify deficiencies and assign a subjective component condition rating of good, fair, poor, failing, or critical.

Inspection results are entered into a computer data base system, which determines the costs to repair or replace a specific component. A priority ranking is assigned for each component based on its condition rating and estimated cost to correct. Short- and long-range budgets and work plans are then established.

Indian Health Service: Project Deep Look[38]

The Indian Health Service (IHS) uses historical records analysis (discussed in Appendix B) and inspection results to determine required annual budgets for building maintenance. Inspections are performed by IHS personnel every year to identify deficiencies and develop annual work plans. However, after every fourth year, comprehensive building inspections are performed by third-party architect/engineering consultants to define the backlog of maintenance and repair (BMAR) for each building.

Bohm-NBBJ, Architects and Planners[39]

Bohm-NBBJ Architects and Planners have developed a facility assessment and cost projection system that they market for use. This system has two major programs: the inspection and recording of deficiency information in the facility assessment program; and the computer-based cost variance factors (location, degree of replacement difficulty, etc.) and cost estimates produced for replacing or correcting building problems associated with the cost projection program.

The facility assessment program consists of eight building system evaluations (see Table 1), including development of 52 element condition ratings. Data is collected by institutional staff and architect/engineering consultants and recorded on inspection survey forms (Figure E6) noting the deficiencies for each element, additional comments on element condition, and an estimate of the element's remaining useful life. An assessment of each element's condition is also made by the inspection team by assigning one of six deficiency levels to each element. These deficiency levels include adequate for future use, maintenance needed, minor improvement needed, major improvement needed, replacement needed, or not applicable.

To aid the accuracy of the cost estimates developed in the cost projection program, each of the 52 building elements is weighted according to its contribution to the total building cost, and each building system is weighted according to the building's occupancy.

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[38] This information was presented by Tom Bedick, Indian Health Service, to the Building Research Board's Committee on Advanced Maintenance Concepts for Buildings, Washington, DC, September 1988.

[39] Bohm-NBBJ, *The Facility Assessment and Cost Projection System* (Bohm-NBBJ Architects and Planners, undated).

VETERANS ADMINISTRATION
CAPITAL FACILITIES STUDY
PROJECT NO. 101-

COMPONENT: EXTERIOR WALLS AND TRIM

CHAP. 0 2 PARA. B 1 a

FACILITY ____
BUILDING ____
COMPONENT LOCATION ____
AREA SERVED ____

(INITIALS)
BY: ____
____ QUAN. SURVEYED
____ OF TOT QUAN.

PAGE NO. ____
OF TOTAL ____
SURVEY DATE (MO./YR) __/__

1. AVG. COST/COMPONENT — SEV.
2. TOT. COST THIS SET. — RTG.
$____ X 1,000. -3
$____ X 1,000. -2
$____ X 1,000. -1
$____ X 1,000. 0
$____ X 1,000. +1

ACTION REQUIRED:
__ (ACT. REQ.)
A REPLACE
B REPAIR
C ADD (NONE EXISTING)
D NO ACTION REQUIRED
E OTHER: ____

____ OVERALL SEVERITY
____ WORST SEVERITY
SEVERITY RATINGS: (SEV.)
+1 GOOD; 5 YR LIFE
0 FAIR: 3 TO 5 YEARS
-1 POOR; 2 TO 3
-2 FAILING; 1 TO 2
-3 CRITICAL

ANY LIFE THREATENING CONDITIONS?
Y - YES __
N - NO
IF YES, COMMENT BELOW.

MATL - MATERIAL SEV - SEVERITY

LOCATION BLDG #	WALL		TRIM		AVG. SEV	LIFE THREAT Y/N	ACT. REQ.	REMARKS (LIMIT TO 1 LINE)
	MATL	SEV	MATL	SEV				
N								
E								
S								
W								
N								
E								
S								
W								

MATERIAL: (MATL)

AL - ALUMINUM
AS - ASPHALT SHINGLES
CB - CONCRETE BLOCK
BR - BRICK
CT - CERAMIC TILE
CA - CLAPBOARD
CO - CONCRETE
CR - COPPER
GL - GLASS
GB - GLAZED BLOCK
HD - HARDBOARD
MR - MARBLE
PL - PLASTIC
PD - PLYWOOD
PC - PRE-CAST CONCRETE
ST - STEEL
SO - STONE
SU - STUCCO
WS - WOOD SHINGLES
XX - OTHER: ____
YY - OTHER: ____

COMMENTS: ____

NOTES:

Figure E5. Veterans Administration: exterior walls and trim inspection form.

System Element (Check all types that apply) Rating Factors

5. Interior Walls and Partitions

Check	Type	Check	Rating Factor
X	a. Plaster on lath	X	Cracked
	b. Plaster on masonry or stone		Excessive maintenance required
	c. Dry wall on studs		
X	d. Masonry		
	e. Stone		Generally obsolete or worn out
	f. Wood panel		
	g. Structural glass		
X	h. Ceramic tile		Inappropriate to building function
	i. Carpet on plaster		
	j. Other ______		Other ______
			% Needing replacement

Comments: BASEMENT - TILE. 1ST CMU. 2ND CORNER BASE AT STAIR. 4TH MAJOR CRACK AT ABOUT 1 1/2" WIDE. CRACK ABOVE DOOR FRAMES AT PLASTER WALL.

Useful Life Expectancy: Element Evaluation: Major Improvement Required

6. Ceilings

Check	Type	Check	Rating Factor
X	a. Plaster on lath	X	Cracked
X	b. Suspended acoustical	X	Sagging
	c. Acoustical tile		
	d. Metal pan	X	Water-marked
	e. Exposed structure		
	f. Wood		Generally inadequate
	g. Gypsum board		
	h. Other ______		Non-code conforming
			Other ______
		50	% Needing replacement

Comments: 4TH FLOOR - EXTENSIVE WATER DAMAGE, MATERIAL IS OBSOLETE.

Useful Life Expectancy: Element Evaluation: Major Improvement Required

Figure E6. **BOHM-NBBJ: interior building structure and finishes inspection form.** (Source: Bohm-NBBJ, The Facility Assessment and Cost Projection System [Bohm-NBBJ Architects and Planners, undated]).

Mell Simon & Associates

Mell Simon has established a computer data base maintenance management system to monitor the buildings and rental spaces which make up its shopping center facilities. Each facility receives a visual inspection approximately every 6 months. The local operations director makes the visual inspection according to guideline specifications set up by the company's headquarters. The visual inspection is not very detailed, and results are provided mainly as a reminder system of maintenance and repair needs. Information from a facility's inspection is loaded manually into a personal computer and then transferred to the headquarters mainframe computer system for analysis and approval.

Additional inspections performed at each shopping center facility include a detailed electrical inspection every 3 years, a roof inspection conforming to a 6-year replacement program, and an HVAC inspection (Table 1).

Canadian Park Service[40]

The Canadian Park Service is researching the possibility of developing a system to forecast recapitalization expenditures to aid in the management of its aging building asset base. The proposed system would include a standardized regular inspection of the major building assets. Inspection would establish building condition and estimate the time and cost of recapitalization. Following inspection, a method would be devised for rolling up the inspection information so recapitalization trend forecasting could take place at park, region, and headquarters levels. After developing a recapitalization planning system, the Park Service could, through effective planning and prediction, reduce the number of emergency maintenance repairs, receive asset condition information, and develop evidence to substantiate increasing maintenance funding levels.

Transport Canada: Ottawa, Ontario[41]

Transport Canada does a condition inspection survey for each of its major airport buildings and tunnels on a 3-year cycle. For the inspection process the building is broken down into 18 components (see Table 1). During inspection the inspectors follow a building structures handbook that reminds them what items need inspection and what tasks are required to correct deficiencies. Deficiencies are noted on the inspection form, and photographs are taken. Following inspection, the inspectors prepare a written report which addresses in detail the required maintenance needed for each component.

The inspectors also assign a condition rating to each component to aid in maintenance planning and prioritizing. Thereafter, a predetermined weighting for each component's contribution to the building is multiplied by the assigned condition rating to determine a weighted condition rating for each component. A rated condition for a building (facility) is then computed by summing the weighted condition ratings and dividing by the sum of the building component's weight. Then by using the rated condition of a facility and a predetermined average physical life of the building, a mathematical calculation is made to determine the recommended restoration year of the building (Figure E7).

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[40] J. Burrows, *Case Study for Recapitalization Planning* (Canadian Park Service, May 1988).

[41] Airports Authority Group, *Appendix F: Building Structures Maintenance Guidelines*, AK-74-15-199 (Transport Canada, Nov 1985); Airports Authority Group, *Airport Buildings*, AK-76-04-400 (Transport Canada, January 1984).

Transport Canada Air — Transports Canada Air

Airport Facilities Branch
Direction des Installations Aeroportuaires
AK No. 76-04-018

AIRPORT BUILDINGS AND TUNNELS CONDITION SURVEY REPORT

BUILDING NAME AND NUMBER ____________________

SITE NAME ____________________

SITE NUMBER ____________ YR. CONSTRUCTED ____________

INSPECTION NO. ____________ DATE ____________

INSPECTED BY: ELEMENTS	WEIGHT OF ELEMENT A	CONDITION RATING B	WEIGHTED RATING AxB C	Remarks on Rating or Maintenance Required
Structural Frame	9			
Stairs and Handrails	6			
Floors	5			
Foundations	9			
Doors, Frames & Hardware	5			
Ceilings	3			
Walls (interior)	4			
Walls (exterior)	7			
Painting (exterior)	1			
Painting (interior)	1			
Windows, Skylights & Hardware	6			
Roof Systems	6			
Electrical Systems	7			
Mechanical Systems	8			
Fire Exits & Lights	9			
Life Safety	9			
Insulation/Energy Conservation	6			
Energy Consumption	6			
	A =		C =	

CALCULATION OF RESTORATION YEAR

D. Rated condition of facility = $\frac{C}{A}$ = ____________ =

E. Average Physical Life of facility =

F. Expected Life = $\frac{D \times E}{10}$ =

G. Recommended restoration year ____________

Feb. 83

Figure E7. Transport Canada: condition survey report. (Source: Airports Authority Group, Airport Buildings and Tunnels Condition Survey Report, AK-76-04-018 [Transport Canada, February 1983].)

English House Condition Survey[42]

The English House Condition Survey was established in 1967 to provide a method for surveying the condition and analyzing the maintenance needs of its housing assets. The assessment method uses two condition survey forms: one for houses and one for apartments. Table 1 lists areas the assessments address. The survey forms are set up as combinations of yes/no rating questions and percentages of surface areas affected to establish the dwelling's condition and repair costs (Figure E8). The resulting condition assessment relies heavily on the inspector's knowledge of buildings and inspection assessment skills. Inspections are performed on a 5-year interval, and established conditions are used to plan maintenance needs and expenditures for the years between inspections.

Scottish Special Housing Association[43]

The Scottish Special Housing Association (SSHA) currently owns and manages approximately 90,000 houses. Because of the large amount of property maintenance required to preserve such an asset, the association began in the early 1970s to develop a computerized property information system which could be used to plan maintenance needs by predicting events in the life of a property.

Today the property information system stores data from the 5-year inspection/ supervision frequency of each house. During the 5-year cycle of each house, comprehensive internal and external inspections are performed, and a supervisory stage is allocated for reviewing contract work and reporting defect liability. Inspectors are aided in their work by a guidance manual. The inspector reports defects and indicates possible work requirements for each component (Table 1). This information later aids in producing an estimate of repair cost.

Once the estimate is established, the inspection form is given to the technical staff; they fix the work priority and formulate a work program. A profile of each component's performance and condition can be plotted with the aid of the property information system and the technical archives (Figure E9). Based on the performance and condition profile, a prediction of likely events can be entered, and a graphic representation of predicted life can be shown (Figure E10). The continued use of historical data provided by the property information system and the technical archives is expected to improve the predictions of element and component life.

Royal County of Berkshire: Berkshire, England[44]

The Royal County of Berkshire is implementing a computerized strategic property management system. The system is designed so both property professionals and service managers can monitor the property assets. The system now operates interactively with digital maps, computer aided design (CAD) graphics, and a central property data base. The digital maps and CAD graphics provide a graphical display of information that can be used for property management. This information may include site areas, land values, and floor plans of each building showing usable and circulation areas, along with detailed listings of building elements. The central property data base stores text information on physical, operational, and financial attributes of each building.

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[42] *English House Condition Survey: 1986: Forms 1 and 2* (Building Research Establishment, Garston, Watford, England).
[43] *Maintenance Planning: The Long-Term Care of Housing Stock*, (SSHA, Edinburgh, Scotland, 1984).
[44] D. Murray, *Strategic Property Management Systems* (Royal County of Berkshire, undated).

8. Exterior (continued)

Front / **Back**

Chimney Stacks

Front: Seen 1 — Front only 1, With left 2, With right 3; Not seen 2 — Left only 4, Right only 5

Back: Seen 1 — Back only 1, With left 2, With right 3; Not seen 2 — Left only 4, Right only 5; Does not exist 8

Masonry | Masonry

Number
Faults (Y N | Y N)
Rebuild
Part rebuild
Repoint/flashings/refix
Leave
Urgency (U F B)
Replacement period

Roof Structure

Pitched, Mansard, Flat, Mono, Chalet, Unknown

Tenths of area
Faults (Y N)
Replace
Strengthen
Leave
Urgency (U F B)
Replacement period

Roof Covering

Slate, Plain tile, Single lap tile, Felt, Metal, Concrete screed, Unknown

Tenths of area
Faults (Y N)
Renew
Isolated repairs
Leave
Urgency (U F B)
Replacement period

Walls

Windows doors, Void, Wall

Tenths of area

Wall structure

Masonry cavity, Masonry solid<9", Masonry solid = 9", Masonry solid>9", In situ concrete, Prefab concrete, Timber

Net tenths of area
Faults (Y N)
Rebuild
Repair
Leave
Urgency (U F B)
Replacement period

Wall Surface

Brick face, Stone face, Rendered, Timber, Tile hung, Concrete panel, Metal/plastic

Net tenths of area
Faults (Y N)
Renew/repoint
Isolated Repairs
Surface finish
Leave
Urgency (U F B)
Replacement period

Figure E8. **English House Condition Survey: partial house and apartment inspection form for building exterior.** (Source: English Housing Condition Survey: 1986: Form 1 [Building Research Establishment, Garston, Watford, England, 1986].)

PERFORMANCE PROFILE

CONTRACT – 150 NO FINES COTTAGES AND FLATS CALSTANES.

YEAR BUILT 1950

CONTRACT CODE 00 00 00

	TYPE		COTTAGES 1 STOREY	COTTAGES 2 STOREY	FLATS 2 STOREY	FLATS 3 STOREY	T	COMMENT
COMPOSITION	HOUSE SIZE (PERSONS)	1						
		2	20		20		40	
		3						
		4	[illegible]	30		30	[illegible]	Average Dwelling Size = 3.8
		5		30			30	Dwelling Mix Acceptable
		6						
		7						
		8		5			5	
	Houses Sold		0 [illegible]	0 10 0	[illegible]	0	[illegible]	90% of Sales from cottage stock
	Totals		30	[illegible]	[illegible]	30	133	
USE	Tenant's Age Pattern		[illegible]	[illegible]	[illegible]	[illegible]		1 Storey cotts show high level over 60
	Occupancy		[illegible]	[illegible]	[illegible]	[illegible]		3 Storey flats consistently under occupied
	Lettings Turnover		[illegible] L	L L [illegible]	[illegible]	[illegible]		Medium turnover in 3 st flats & 2 st cotts
	Existing Special Amenity							Need indicated for amenity & sheltered
	Needs	Sheltered						Facility in 1 st. cotts also for some
		Disabled	5	[illegible]	5			wheelchair houses
		Wheelchair						
	Vandalism			L [illegible]	[illegible]	[illegible]		Increasing on 3 st access stairs & surrounding areas
PERFORMANCE		PAR					[illegible]	
	Space Standard	8	[illegible]	9 9 [illegible]	[illegible]	[illegible]		Poor performance in heating insulation
	Plan Performance	7	[illegible]	7 6 5	[illegible]	[illegible]		Condensation and flat accesses reduce
	Access	7	[illegible]	[illegible]	6	[illegible]		standard to an unacceptable level of an
	Heating	7	[illegible] 3	3 3 3	3	[illegible]		otherwise good scheme. Upgrading parking
	Insulation	8	3 3	3 3 3	3	[illegible]		and landscape would help also
	Condensation	9	[illegible]	5 [illegible]	[illegible]	[illegible]		
	Parking	8	[illegible]	[illegible] 3 4	[illegible]	[illegible]		
	Landscape	7	6 6	6 6 6	[illegible]	[illegible]		
	Layout (Site)	6	6 6	6 6 6	[illegible]	[illegible]		
	Location (Site)	6	[illegible]	[illegible]	5	[illegible]		

STRATEGY

Priority
1. Insulation
2. Heating and Ventilation
3. Convert 1 st. cotts to sheltered investigate wheelchair adaption
4. Upgrade stair & close entry system to flats. Maintain lettability of 3 storey flats by alternative forms of accommodation (shared singles)
5. Improve landscape and parking

Housing Management Department SSHA

ACCESSED	1981	AREA H.M.	[illegible]
REVIEW	1986	REGIONAL H.M.	[illegible]

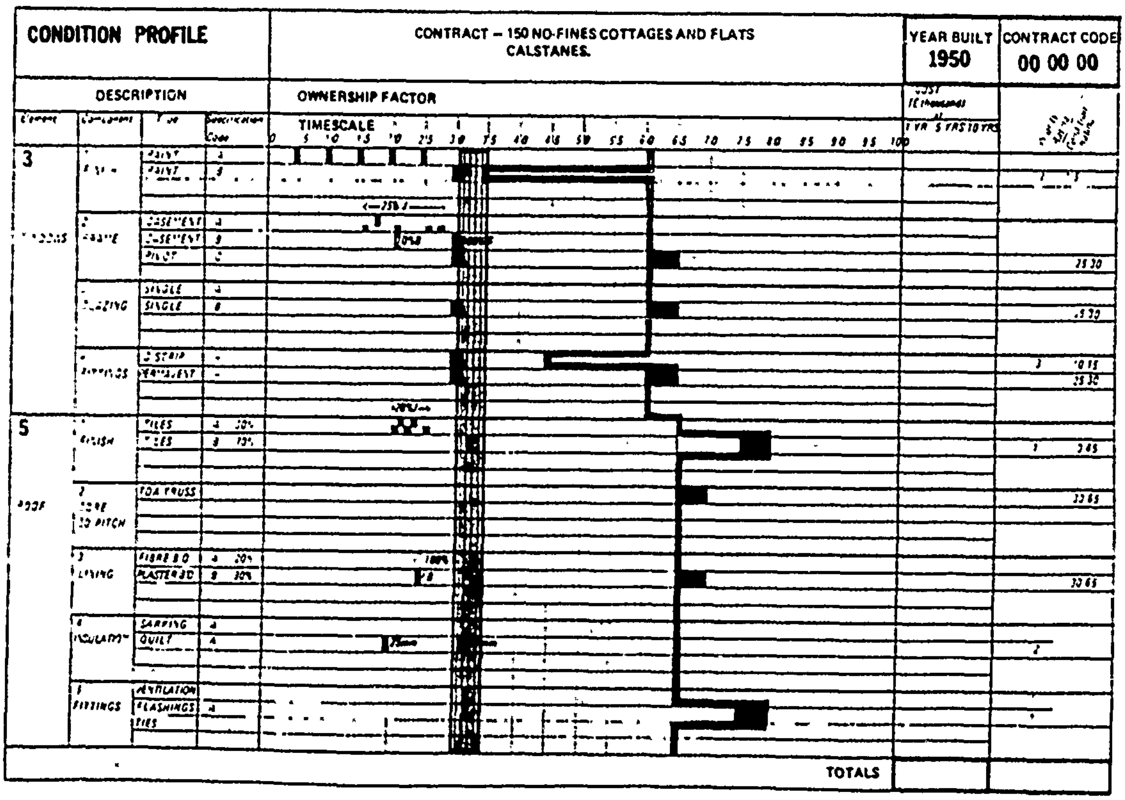


Figure E9. SSHA: performance and condition profiles. (Source: SSHA, Maintenance Planning: The Long-Term Care of Housing Stock [SSHA, Edinburg Scotland, 1984].)

Taken together, the graphics and text provide a comprehensive decision-making tool for budgeting and planning building maintenance. Future development of the system will be aimed at interfacing with expert systems so day-to-day decision making can be enhanced.

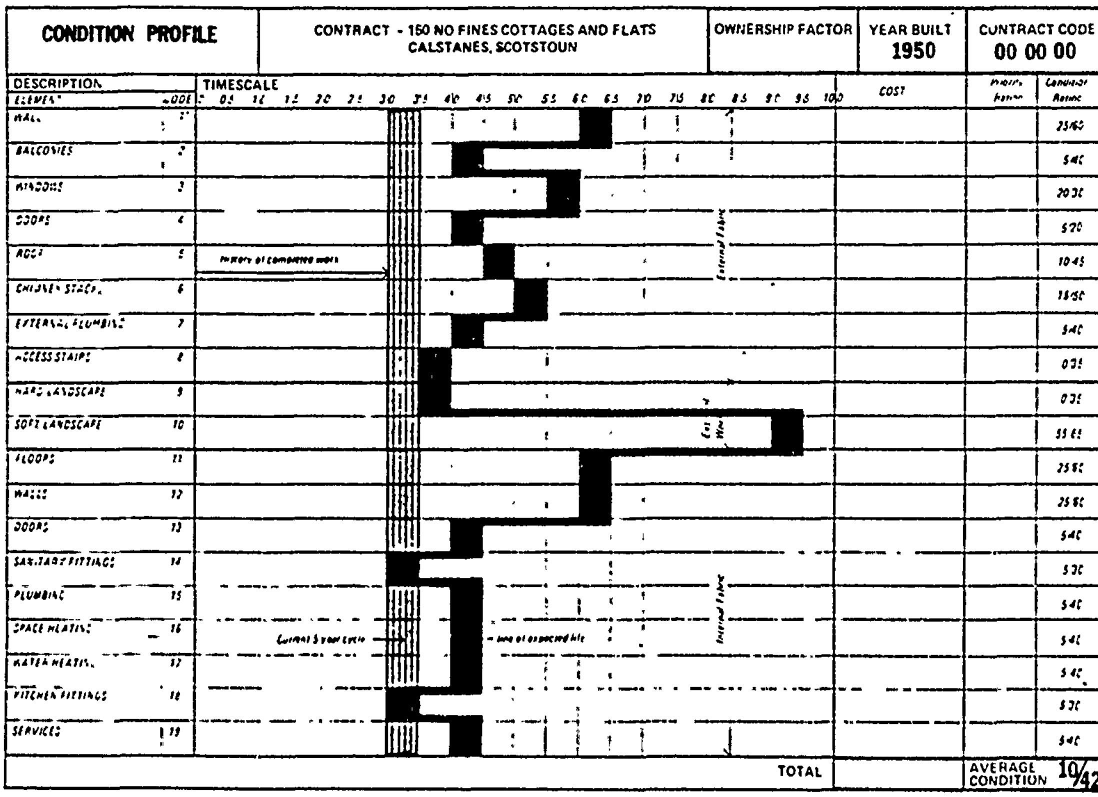


Figure E10. **SSHA: predicted life profile.** (Source: SSHA, Maintenance Planning: The Long-Term Care of Housing Stock [SSHA, Edinburgh, Scotland, 1984].)

APPENDIX F:

EMS CONDITIONS ASSESSMENT AND INSPECTION PROCEDURES FOR BUILDING COMPONENTS

USACERL has now developed, or is developing, three engineered management systems (EMS) building condition assessment and inspection procedures to aid in effective maintenance management of buildings. These procedures have been incorporated into microcomputer-based EMSs. These EMSs include ROOFER[45] (low sloped roofs), PAINTER (interior and exterior painting), and SCALER (interior water piping and condensate return lines).

ROOFER

ROOFER is a roofing maintenance management system that provides the facilities engineering staff with a practical decision-making procedure for identifying cost-effective M&R on low sloped roofing systems. The key feature of the ROOFER system is the development of an objective Roof Condition Index (RCI) generated following a comprehensive evaluation procedure. This procedure includes a thorough inspection of each roof section using inspection worksheets (Figure F1). The inspection is performed by facility engineers who note distresses and specific defects of the membrane, insulation, and flashing. The inspection results are loaded into a microcomputer, which processes the information to produce a condition index rating for the membrane (MCI), insulation (ICI), and flashing (FCI). These three subcomponent condition index ratings are then aggregated to produce the RCI rating.

ROOFER will give the engineer the ability to store and retrieve information on roofing inventory, perform roof condition inspections, rate roofs on a standardized scale using the RCI, generate reports for inspection scheduling, determine present roof network condition and M&R needs, and perform economic analysis of alternatives.

ROOFER enables the user to set priorities, gain funding for identified projects, predict roof condition, and optimize budgets. It will also provide a means to later analyze the effects and consequences of M&R decisions.

PAINTER

PAINTER is a paint maintenance management system for interior and exterior applications over wood, metal, concrete, and masonry substrates. The key feature of the system is the Coating Condition Index (CCI). The CCI is an objective rating of a paint's or coating's ability to cover or protect a substrate. Separate CCI ratings are established for interior and exterior painted surfaces following an inspection of all painted surfaces. Trained inspectors follow interior and exterior inspection checklist forms to determine the percentage of painted area not covering or protecting the substrate, primer, and surface (Figure F2). Appropriate CCI ratings are then determined for each percentage of painted area not covering or protecting

[45] M.Y. Shahin, D.M. Bailey, and D.E. Brotherson, *Membrane and Flashing Condition Indexes for Built-Up Roofs,* Technical Report M-87/13/ADA190367 (USACERL, September 1987).

ROOF INSPECTION WORKSHEET	INSTALLATION FT. JONES

BUILDING 68 PER. FLASHING 527 FT DATE ____
SECTION G CURB FLASHING 36 FT NAME ____

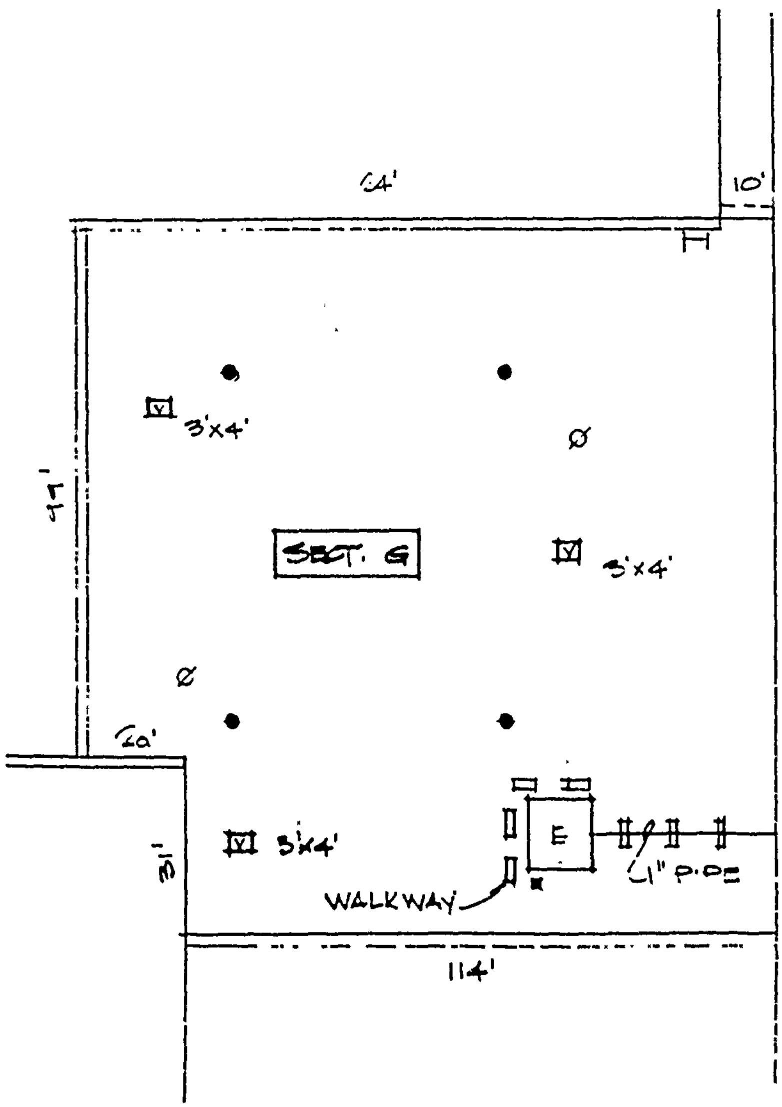
BF - BASE FLASH
MC - METAL CAP
EM - EMBEDDED MET
FP - FLASHED PEN
PP - PITCH PANS
DR - DRAIN & SCUPPER

DISTRESS TYPE

BL - BLISTERS
RG - RIDGES
SP - SPLITS
HL - HOLES
SR - SURF DET

SL - SLIPPAGE
PA - PATCHING
DV - DEBRIS & VEG
EQ - EQ SUPPORTS
PD - PONDING

IDENT NO	DISTRESS	SEVERITY	DEFECT	QUANTITY



SCALE: 1" = 30'

NORTH

Figure F1. ROOFER: roof inspection worksheet.

CONDITION ASSESSMENT FOR EXTERIOR PAINTED SURFACES

UIC # ________ BLDG # ____________ DATE ______________ INSPECTOR ______________________________

SUBSTRATE TYPE ______________________ PAINT SYSTEM/CATEGORY ______________________________________

FILM THICKNESS (mils): N ___/___ E ___/___ S ___/___ W ___/___ ROOF ___/___

SURFACE AREA (ft^2): WALLS ________ ROOF ________ WINDOWS ________ OTHER ________

SUBSTRATE	EXTERIOR WALLS				EXTERIOR TRIM				EXTERIOR ROOF				OTHER MISC SURFACES				REMARKS
	N	E	S	W	N	E	S	W	1	2	3	4	1	2	3	4	
% TOTAL AREA																	
% TO RUST																	
% TO SUBSTRATE																	
% TO PRIMER																	
% TO SURFACE																	
SURFACE AREA																	
CCI																	

CONDITION OF BUILDING COMPONENTS REQUIRING REPAIR: TYPE AND EXTENT OF DETERIORATION

LOCATION:

NORTH ______________________________ EAST ______________________________

SOUTH ______________________________ WEST ______________________________

ROOF ______________________________ OTHER ______________________________

COMMENTS ____

Figure F2. PAINTER: exterior paint inspection form.

the substrate, primer, and surface. These CCI ratings can then be aggregated using deduct values to determine CCI ratings for specific wall surfaces or total interior or exterior painted surfaces.

The PAINTER program includes storing inspection results in a microcomputer data base, inspection scheduling, historical recordkeeping, project prioritizing, paint or coating condition rating, estimating the costs associated with recoating or cleaning structures, projecting maintenance requirements, and budget planning.

With this system the user can store painting records, determine labor resources and funding needs, plan inspection schedules, and predict budget requirements.

SCALER

SCALER is a corrosion mitigation and maintenance management system which will assist the maintenance manager in making cost-effective maintenance decisions regarding internal potable water piping systems and condensate return lines. SCALER includes a complete inventory of each section of a facility's internal potable water piping system. The inventory includes information such as installation date, operating temperature and pressure, pipe size and material, and location (Figure F3). Information is also collected on the water chemistry of the piping system (Figure F4). All information is entered into a microcomputer data base following the inspection process. This information, when used with predictive mathematical models, can help determine the corrosion status of galvanized steel and copper piping systems and condensate return lines. A Corrosion Status Index (CSI) and estimated date of failure are then calculated by the computer for each piping section.

The program is used to store and retrieve information on piping systems, perform piping system condition inspections, rate piping systems on a standardized scale using the CSI, and generate printed inventory reports, corrosion status prediction reports, pipe condition rating reports, and economic analysis reports.

SCALER enables the user to perform life cycle cost analysis of various maintenance and repair alternatives and optimize budgets.

PIPE SECTION DATA

* = data from real property records
** = data from plumbing shop records

Section ID _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
(bldg.no) (other description)

Water Quality Name: ____________________

Description of location: ________________________

Pipe Type (circle material and type or schedule):

Copper: K L M   Galvanized: Sch. 40 Sch. 80

Black Steel   Fiberglass

Pipe Size: ____________   Length (feet): __________

* Date Installed: ______ .___ .___
year mo. day

** Date Rehabilitated: ______ .___ .___
year mo. day

** Date of First Leak: ______ .___ .___
year mo. day

** Are there As-Built Drawings? Y N

Repair difficulty (0 to 5): _______

* Building Category Code: __________

* Mission Priority Code (1 to 9): __________

Fixture units (enter total from attached sheet): _______

Water temperature (°F): __________

Water pressure (PSIG): __________

Average building usage (from meter, gpd): __________
(OPTIONAL)

Workmanship:	Unreamed tube ends?	Y	N
	Excessive solder flux?	Y	N
	Solder globules?	Y	N
	Dented, kinked, bent?	Y	N
	Abrupt diameter change?	Y	N

Water type (circle one): Potable Condensate

Figure F3. SCALER: pipe selection data sheet.

WATER CHEMISTRY DATA SHEET

**** ALL UNITS ARE MG/L UNLESS OTHERWISE NOTED ****

Water Quality Name ____________________

Description ____________________

* pH ______ Temperature(°F) ______ Silicate ____________________

* Oxygen ______________ * Sulfate ______________

* Carbon Dioxide ______________ * Sulfide ______________

* Aluminum ______________ Carbonate Hardness ______________

* Calcium ______________ * Total Hardness ______________

Copper ______________ * Total Alkalinity ______________

Iron ______________ Methyl Orange Alkalinity ______________

Magnesium ______________ Phenolphthalein Alkalinity ______________

* Manganese ______________ Hydroxide Alkalinity ______________

Molybdnum ______________ Bicarbonate Alkalinity ______________

Sodium ______________ Carbonate Alkalinity ______________

Tin ______________ Total Dissolved Solids ______________

Zinc ______________ Conductivity (micromhos) ______________

* Chloride ______________ Tannin ______________

Chlorine ______________ Causticity ______________

Fluoride ______________ Langelier Index ______________

Nitrogen ______________ Ryznar Index ______________

Phosphates ______________ Aggressiveness Index ______________

Phosphonate ______________

Silica ______________

Figure F4. SCALER: water chemistry data sheet.

APPENDIX G:

NATIONAL SURVEYS

Association of Physical Plant Administrators

The Association of Physical Plant Administrators of Colleges and Universities (APPA) and the National Association of College and University Business Officers (NACUBO) have recently completed a National Survey of Capital Renewal and Deferred Maintenance Costs. This study had three objectives:[46]

1. Quantify, in dollars, the magnitude of the higher education deferred maintenance and capital renewal/replacement problem in the United States.

2. Obtain a better sense of the overall condition of higher education's physical plant.

3. Identify the gap between current funding levels and needed funds.

To accomplish these objectives a survey was developed and distributed to 750 randomly selected institutions. The survey was developed to obtain, from a number of different sources, a variety of information on an institution's statistical, financial, and operational data. The results of the survey will be analyzed and extrapolated to produce information on the 3300 colleges and universities in the United States.

State of the American Schoolhouse[47]

A survey, consisting of a statistical sampling of school districts in each state, to determine the amount of deferred building maintenance at the state and local levels of our educational system is being completed. This survey was indirectly initiated through a number of state and local governments now requiring data collection on the schools and facilities under their jurisdiction. The study is aimed at learning the amount of planning being done by schools, the information being collected by school districts, the age of the nation's school buildings, and the investment, reinvestment, and budgetary approaches used by school districts to determine maintenance requirements. The study's results will be used to identify problems and solutions within our educational system, study the growth of school districts and the amount of investment required, and identify a level of information each school district should maintain on its educational facilities.

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[46] Coopers & Lybrand, National Survey of Capital Renewal and Deferred Maintenance Costs (Association of Physical Plant Administrators of Colleges and Universities, April 1988).

[47] This information was presented by Lisa Walker, Executive Director, Education Writers Association, to the Building Research Board's Committee on Advanced Maintenance Concepts for Buildings, Washington, DC, September 1988.

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