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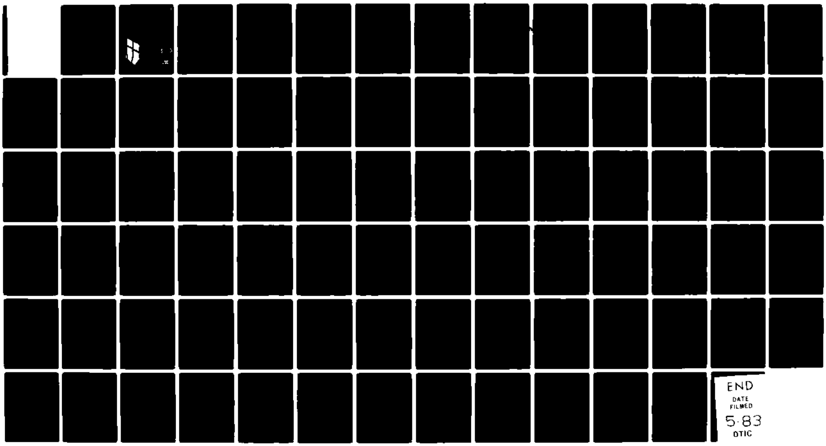

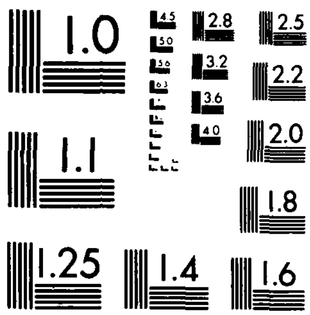

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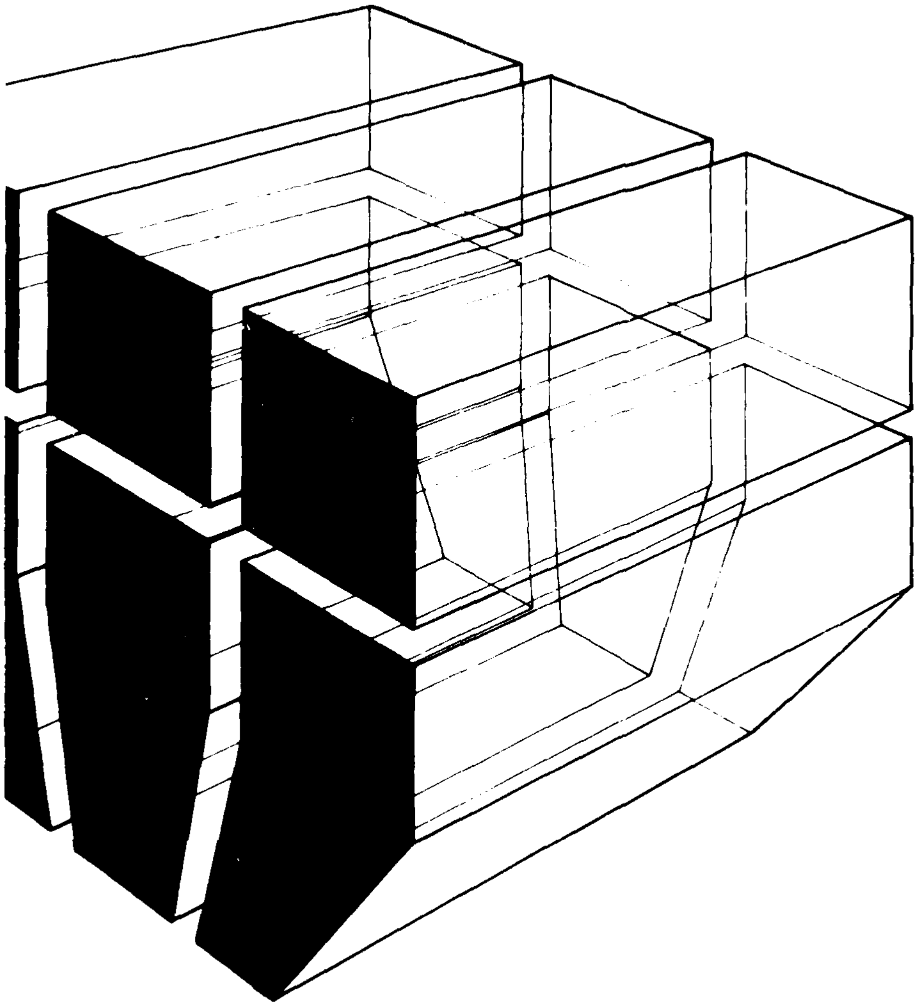
Technical Report P-139
January 1983

LIFE-CYCLE COST DATABASE: VOLUME I, DESIGN

by
R. D. Neathammer



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This report documents research conducted to design life-cycle cost (LCC) databases for selected building systems. These databases would be used by ~~(1)~~ a designers to compute LCC costs for design alternatives, ~~(2)~~ a installation and District personnel to generate maintenance and repair (M&R) data to justify new construction versus modification of existing facilities, and ~~(3)~~ a planners in the Office of the Chief of Engineers to provide summarized M&R cost data for various types of facilities.

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Databases were designed for heating, ventilating, and air-conditioning systems, roofing surfaces, interior finishes, and exterior finishes. When the data for them have been developed, they will be ready for use in actual projects.

The feasibility of using analytical methods to develop information for LCC databases was investigated. The analysis showed that use of Engineered Performance Standards is the best way to obtain the data.

Volume II of this report provides sample data development for heating, ventilating, and air-conditioning systems, floor covering systems, and cooling generating systems.

FOREWORD

This research was conducted for the Assistant Chief of Engineers, under RDT&E Program 6.27.31A, Project 4A762731AT41, "Military Facilities Engineering Technology"; Task A, "Planning and Design"; Work Unit 033, "Military Facilities Life Cycle Cost Data Base Design."

This work was performed by the Facilities Systems Division (FS) of the U.S. Army Construction Engineering Research Laboratory (CERL), and under contract by Bendix Field Engineering Corporation, Planned Maintenance, Inc., and Service Engineering Associates.

Dr. Larry Schindler, DAEN-ECE-G, was the Technical Monitor. Administrative support was provided by Mr. E. A. Lotz, Chief of FS.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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LIFE-CYCLE COST DATABASE: VOLUME I, DESIGN

1 INTRODUCTION

Background

Life-cycle cost (LCC) analysis is a costing technique used to evaluate alternative construction materials, systems, and designs. The Department of Defense (DOD) requires use of this technique during the design phase of any new military construction project;[1] documentation is required for projects exceeding $300,000. Engineer Technical Letter 1110-3-332[2] gives policy for conducting LCC-based economic studies as part of the design process. DOD implementation of LCC procedures requires analysis of all costs (before, during, and after construction) associated with selecting design materials, systems, subsystems, and components over a facility's life. These include maintenance, repair, operational, custodial, demolition, salvage, design, and construction costs.

Initial costs are generally available or can be computed from the architectural drawings. However, detailed estimates of maintenance and repair (M&R) costs are not readily available. Thus, there is a need for both an LCC database and cost-effective procedures for collecting and presenting M&R data for Army facilities. Such a database would consist of several small databases -- one for each building component. This would reduce the amount of time Army personnel need to spend collecting LCC data, and thus greatly reduce the amount of money spent for life-cycle cost analyses (LCCAs).

The first phase of the research to develop a database was done in FY79-80. This work identified the Army's LCC data needs and evaluated the feasibility of obtaining information needed for LCC databases from existing sources. This research is documented in CERL Interim Report P-120.[3]

Purpose

The purpose of the research documented in this report was to design LCC databases for selected building systems and to evaluate the feasibility of using Engineered Performance Standards (EPS) to develop information for LCC databases.

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1 Construction Criteria Manual, DOD 4270.1-M (Office of the Assistant Secretary of Defense, Installations and Logistics, 1 October 1972).

2 Economic Studies, Engineer Technical Letter 1110-3-332 (Office of the Chief of Engineers, 22 March 1982).

3 R. D. Neathammer, Life-Cycle Cost Database Design and Sample Data Development, Interim Report P-120/ADA097222 (U.S. Army Construction Engineering Research Laboratory [CERL], 1981).

Approach

Concepts for developing detailed M&R data using EPS were developed, and methods for obtaining data for a programming database were analyzed. Database formats were developed for heating, ventilating, and air-conditioning (HVAC) systems, floor coverings, roofing surfaces, interior finishes, and exterior finishes. Contracts were let to develop sample M&R data for part of the HVAC database and the entire floor covering database using EPS. A workshop was held to obtain input from Army personnel on the current results of CERL's LCC database research. Input from installation and District personnel was obtained on the sample data developed through EPS.

Outline of Report

Volume I defines the problem of database development; summarizes work prior to FY81-82; discusses the adopted EPS method of developing M&R data and the programming database; presents results of FY81-82 research; summarizes data collection problems at installations; gives the district office survey questionnaire; summarizes information on the 1979 and 1981 workshops; and gives conclusions and recommendations. Volume II contains reports by Bendix Field Engineering, Planned Maintenance, Inc., and Service Engineering Associates on development of M&R data for heating systems, floor covering systems, and cooling generating systems, respectively. These studies were done to demonstrate the feasibility of using EPS to develop information for LCC databases.

Scope

The most difficult aspect of designing the LCC databases is the data collection procedure. Design problems (format, level of detail, items to include) are trivial compared to the problem of actually collecting reliable data cost-effectively. Thus, most of this research concerns data collection methods.

Mode of Technology Transfer

It is recommended that the completed database be disseminated as part of a new Technical Manual in the 5-802 series.

2 PROBLEM DEFINITION

In FY81, the Army spent $794 million for M&R of buildings (including air-conditioning and heating plants).[4] This is 25 percent of the $3171 million spent by the Army to operate and maintain all of its facilities in FY81. Thus, it is obvious that M&R of buildings is a major expense and that reducing its costs will produce substantial savings.

Construction Criteria Manual 4270.1-M recognizes the problem of reducing ownership costs and requires LCC analyses on all new projects. Documentation is required in the project file for projects costing $300,000 or more. Engineer Technical Letter 1110-3-332 states policies for performing LCC economic studies; however, it does not give detailed procedures, such as equations, and contains no LCC data.

Thus, DOD regulations require LCC analyses, but designers/plan[illegible]s must develop their own estimates of M&R costs. This results in a time-c[illegible]ming and costly work effort and leads to inconsistencies when similar de[illegible] evaluations are done by different persons. Designers need a detail[illegible]tabase of M&R costs to compute LCC costs for design alternatives and to ma[illegible] consistency among analyses.

Planners at the installation and District levels also need M&R data to justify new construction versus modification of existing facilities. This requires an LCC analysis; however, the M&R data needed is at a less detailed level than that required by the designers. Planners in the Office of the Chief of Engineers (OCE) also require summarized M&R cost data for various types of facilities, both for planning and for responding to Congressional queries.

A database which can respond to the needs of OCE, District, and installation planners must contain M&R cost information for various building types. In fact, two or three different databases reflecting various levels of detail may be required. Once the design is formulated, the feasibility of obtaining the data must be addressed.

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[4] Facilities Engineering Annual Summary of Operations, Fiscal Year 1981 (Office of the Chief of Engineers, 1982).

3 SUMMARY OF WORK PRIOR TO FY81

Soon after Construction Criteria Manual 4270.1-M was published, OCE directed that LCCA be done for Corps projects. Computer programs to do LCCAs were developed. District designers used these programs to perform LCCAs on selected projects until the mid-1970s; since then, LCCAs have been performed only occasionally. A major problem encountered by District designers was lack of M&R data for the analyses. Only a very small amount could be obtained from Facilities Engineers (FEs), since M&R records had not been maintained. Therefore, designers used manufacturers' data and engineering judgment to determine the frequency and costs of M&R. The result was that data for similar projects was inconsistent among the various designers compiling it.

Work Prior to FY79

In FY71, the Corps began research on the life expectancy of its structures and on its life-cycle cost data needs. The following paragraphs summarize this work.

In FY75, a survey of 51 designers/planners in five Districts determined the type and availability of the LCC data needed. (Results of this survey and a similar one done in FY79 are discussed on p 12.)

The U.S. Army Construction Engineering Research Laboratory (CERL) studied the problem of obtaining very detailed M&R data from FEs at several installations. It was found that FEs did not have complete or detailed enough records to compute LCC. It was therefore concluded that someone would have to be stationed on an installation to coordinate data collection activities.

In 1975, a coordinator was stationed at Fort Ord, CA, to collect data on selected sample facilities for 1 year. Results of this effort showed that M&R data could be obtained at the installation level, but not without first modifying the existing FE work management system (as outlined in DA Pamphlet 420-6)[5] and the Integrated Facilities System (IFS).[6] There were three major problems with the data collection:

1. The work orders were deficient in LCC data.

2. Descriptions on the work orders of tasks performed were often ambiguous.

3. Work performed was not easily correlated to the facility components list.

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5 Resources Management System, DA Pamphlet 420-6 (Department of the Army, 15 May 1978).

6 Integrated Facilities System, 18-1-B-AKA (U.S. Army Computer Systems Commmand, 1978; changes 1 April 1979, 1 February 1979).

Although this trial data collection effort was not completely successful, such on-site collection is believed to be feasible. Coordinators could be stationed at eight installations (two in each of four geographic regions) to determine the effects of climate on degree and frequency of M&R. Evaluation of climate effects is needed to insure the validity of inferences drawn from the data. Detailed, highly accurate data could be collected on a sample group of buildings. To compare the effects of age and types of construction would require about 5 years of data. This would be a one-time program and would cost about $1 million. This cost, plus the major problem that M&R levels vary at different installations, makes this method unacceptable.

Contacts with other Government agencies and private companies showed that no LCC database existed elsewhere.

The UNIFORMAT method[7] of coding facility components and subcomponents was determined to be appropriate for a highly detailed database.

Obtaining data at a level below that of facility components (roofs, floors, heating system, etc.) would require modifying either the FE manual system or the IFS; i.e., obtaining data on various types of floor coverings or roofs within a building would require changing present data recording/collection systems. These changes would require more effort from the FE staff and would greatly change recordkeeping procedures for buildings with multiple types of one component.

Work During FY79-80

The FY79-80 study was set up to design the database and develop sample data, using information from Districts, FEs, and private organizations. Results[8] are summarized below.

Literature Search

An exhaustive literature search revealed no available detailed database of M&R costs.

Contacts

Contacts with Government agencies and private organizations revealed that the only known detailed database was one at Cost Systems Engineer, Inc. Details about this database could not be obtained; however, it is known to be based on data from hotel and housing development operators.

The private sector typically either uses a percentage of initial costs to estimate annual operating and maintenance (O&M) costs or develops required data on a project-by-project basis.

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7 Uniform Building Components Format -- Automated Cost Control and Estimating System (General Services Administration, November 1975).

8 Details of this study are given in R. D. Neathammer, Life-Cycle Cost Database Design and Sample Development, Interim Report P-120/ADA097222 (CERL, 1981).

Questionnaire

In 1979, a questionnaire was sent to personnel at several branches of seven Corps District offices to dete: ine their opinions on LCC data. This survey was similar to the one done in FY75. Results of the two surveys were very similar. Appendix A provides a copy of the 1979 questionnaire and shows the percent responses given for each question. Results of the questionnaire indicated that the respondents prefer data to be:

1. Grouped by installation.

2. Categorized by facility type (BOQs, administration, etc.).

3. Given for type of component, such as LCC of vinyl asbestos tile, nylon carpet, oak strip floor, etc.

4. Given as an average cost ($/sq ft/yr).

5. Expressed in terms of per-unit cost of materials, installation, maintenance, and equipment rental cost.

In addition, the respondents felt that their current data sources do not have the potential for Corps-wide use. They believe that cooling systems, heating systems, exterior walls, and lighting fixtures have the greatest potential for M&R cost savings, and flooring, cooling systems, roof surfaces, and heating systems are the most expensive M&R items.

Workshop

The first LCC workshop was held in July 1979 at CERL with representatives from District offices, installations, other Federal agencies, private industry, universities, and OCE. The workshop was held to review progress on the research and to obtain a consensus on the database design and guidance for future efforts. Appendix B summarizes the workshop results. The most important conclusions were:

1. The databases should <u>not</u> be comprehensive for all types of building components and subcomponents.

2. Detailed databases should be designed and developed primarily for building components which (a) require large amounts of Army M&R dollars, and whose costs can be reduced through design, and/or (b) are high-quantity or damage-propagating.

3. The databases should not be computerized.

4. IFS data from sample installations and the 5-year MCA plan should be used to determine which components should be studied initially.

5. Detailed data may be obtainable from FE staffs or by use of EPS.

IFS Data Analysis

In FY80, IFS data was analyzed at two installations to ascertain (1) its potential for generating detailed LCC data, and (2) its effectiveness for use in summary form to determine high-cost M&R building components. The installations having the best working IFS packages and having the personnel most knowledgeable in its use were Fort Sill, OK, and Fort Knox, KY.

First, the IFS was examined to determine the level of detail at which data is available and can be made available. It was found that the Assets Accounting (AA) module contains detailed building component descriptions for roofing, structure, flooring, heating, and air conditioning; however, it does not contain detailed descriptions of plumbing or electrical components. The AA module also contains cost data for each facility's M&R. This data is accountable to a facility component (e.g., the roof), but not to a part of that component (e.g., the roof's structure, deck, or surface). A description of the work is also recorded on the historical file; this could be extracted and charged to the appropriate subcomponent in another computer system. However, when a building has two types of roofing, it is not usually possible to assign roofing repair costs to a specific type.

Another shortcoming of the IFS data is that contract data is not included; only in-house costs are input. These contract costs can be as much as 50 percent of all M&R costs. When contract files were examined to obtain M&R costs, three major difficulties were encountered: (1) when several components were repaired on the same contract, the costs for each were not always given; (2) sometimes, when several buildings were repaired on the same contract, costs for each building were not always separated; and (3) it was sometimes difficult to determine the fiscal year in which the work was completed. It was therefore concluded that the contract costs must be included in IFS if all M&R costs are to be reflected; however, some proration of costs would be required, which would result in less accurate data. Only an on-site employee could ever find all the contract data and assign costs to individual buildings, components, and subcomponents; even if such procedures were feasible, they would be expensive.

Many other problems are associated with collecting and using data from installations. Appendix C summarizes some of these.

Building Component Ranking

Data collected at Forts Sill and Knox over 2 years were combined with District questionnaire results to rank building components by M&R costs. The top five components were heating, cooling, flooring, electrical, and structure. Roofing is also considered a high-cost M&R item.

Electrical system components are a high-cost M&R item, and LCCA may be unable to reduce these costs much. This is especially true in the troop areas where vandalism may cause damage to lighting fixtures and switches.

Several major structural repair projects at Forts Sill and Knox contributed to its high ranking, since structures are not usually a high-cost M&R item.

Red Book Analysis

Red Book[9] data was analyzed to see if it would be useful for estimating M&R costs for programming purposes. However, data from neither the Red Book nor its source (Engineering Technical Data Report) is usable, because it is very summary in nature. All buildings for one category, such as training, are contained in one group, and an M&R cost figure and square footage are given for the group. Each group contains buildings of varying age, conditions, and construction type.

M&R costs for heating are kept in one account and those for air conditioning in another. The M&R cost and the tons of air conditioning or Btus of heating in each of these two accounts are for all building categories.

A final problem with Red Book data is that some costs for various building categories are of the indirect overhead type and are prorated over several buildings; e.g., up to 10 percent of the costs in the Red Book include charges beyond actual labor costs and regular overhead.

Database Needs Indicated by Previous Work

Results of previous work indicate that two distinct databases are needed for Corps LCCAs. Designers need a detailed database for building components to quickly compute accurate and consistent LCCs for alternative designs. Planners/programmers need a programming database for various classes, ages, and construction types of facilities to justify new construction and to evaluate M&R cost trends.

Designers Database (DDB)

Data collected from Army installations might be more reliable than private-sector data because it is based on real Army experience. The major drawback is that installations have different maintenance levels because of the amount of M&R funds available, FE philosophy, command philosophy, and user differences. Another problem is that historical data reflect only the M&R accomplished with available funds, and not the M&R that was required. Data collection would be best accomplished through IFS, since the system is now being used at all major installations. However, IFS files presently do not contain data for M&R done by contract. Also, when a building has several component types (e.g., concrete floor finish, wood flooring, and vinyl asbestos tile), costs cannot be assigned to the correct type.

Another way of collecting data is to employ someone to collect all data for a sample of buildings. This would involve checking the accuracy and completeness of all Service Orders, Individual Job Orders, and Standing Operations Orders. In addition, the buildings would be checked frequently to determine the value of any "self help" performed. An appropriate sample size is 320, computed as follows:

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[9] Facilities Engineering Annual Summary of Operations (published annually by the Department of the Army, Office of the Chief of Engineers). The "Red Book" is issued at the end of each fiscal year and contains financial accounts information submitted by each installation.

4 age groups x 8 facility types x 10 buildings = 320

(The four age groups would be 1950-59, 1960-69, 1970-79, and 1980-; these groups contain most of the permanent construction. The major classifications of facilities are maintenance, storage, medical, RDT&E, barracks and BOQs, admin/training/schools, industrial, and community. A sample of ten per combination will allow good estimates of the variation among individual buildings.)

To estimate time trends, the data would be collected for 5 years to allow replacement of one-third of long-life (15-year) components. It would also give 5 years of data for items requiring yearly M&R. An estimate of the cost is:

8 installations x $16,500 (GS-7 salary) x 1.40 (overhead) x 5 years = $924,000

(Two installations from each of four geographic regions would be sampled so that regional effects could be tested. The GS-7 level and the 1.4 factor are based on discussions with installations.)

No personnel are available in FE organizations for this work. OCE would either have to provide an additional personnel space or contract the data collection. Collection of <u>reliable</u> detailed M&R cost data is believed to be infeasible; therefore, this approach is not considered further.

A third way of obtaining data is to develop it using Engineered Performance Standards (EPS). This method is the one recommended and is discussed in Chapter 4.

Planners and Programmers Database (PPDB)

There are three ways to collect data for this database: (1) use IFS if and when contract data is included, (2) have data collected at a sample group of installations by a person on site and/or (3) use the EPS method.

The first method is not feasible at this time.

For the second method, a data collector would (1) collect data from contracts for the sample buildings for five years, (2) use IFS to collect data for buildings (since component-level detail is not required) and (3) also check on any "self help" performed. A sample of 480 buildings at each of eight installations would be required:

4 age groups x 8 facility types x 3 construction types x 5 buildings = 480

(The three construction types would be (1) brick/block/concrete single-story, (2) brick/block/concrete multistory, and (3) other.)

About one man-year would be required per installation, so the cost would be about $934,000 (as above for the DDB). Since the FE does not have the manpower available to perform this work, the best source of personnel would be a contractor or a retired employee. This method of collecting valid M&R data at the summary (building) level is feasible and can provide data for the PPDB.

Lastly, the EPS method could be used at the installation level to develop M&R data for existing buildings. This method is discussed in Chapter 5.

4 THE EPS METHOD OF DEVELOPING M&R DATA FOR THE DESIGNERS DATABASE

The idea of developing M&R data, rather than attempting to collect it, was discussed during the first workshop. CERL developed this concept more fully and tested it successfully.

FEs were consulted on the present and future availability of reliable, complete M&R data. It was found that little data is now or will be available, even after a new version of IFS is developed.

Lack of M&R field data led to the idea of developing it through use of EPS. However, even if field data were available, problems in using it would be formidable because:

1. Command and FE philosophies change with new personnel, resulting in uneven emphasis on maintenance.

2. Funding and staffing levels hinder or prevent good preventive maintenance programs at most installations.

3. Troop use/abuse of buildings can vary by type of installation, length of tour, and command philosophy on discipline.

4. Climate and physical environment would affect the data (e.g., mud, sand).

5. Data collection procedures are subject to the errors of data recording/entry.

Thus, a massive data collection effort would not be justified. However, small-scale sampling efforts could be used to collect data for verification purposes.

The EPS method outlined below is presently the best way to obtain detailed M&R data. For a building component:

1. A schedule of preventive maintenance (PM) is determined using the manufacturer's recommendations, the contractor's experience, and other sources.

2. Each PM job is broken into tasks, and the manpower requirements for each task are determined using EPS or other DA technical documents.

3. The expected failure rate of the component is used to determine frequency of repairs.

4. Each repair job is tasked as in No. 2 above.

5. Material requirements are calculated for each PM or repair job.

6. Yearly total manpower and material requirements are calculated.

Using EPS, the cost for developing data for heating and cooling systems, roofs, floors, interior finishes, and exterior finishes is estimated to be $280,000.

The EPS method does have a drawback. The contractor establishes a PM schedule, which provides an optimal M&R level. Given that FEs will probably not perform at this maintenance level, it is not known what impact this will have on failure frequency and component life. However, if this impact is about the same across the various alternatives of a building component, it can be ignored. (The major interest in comparing designs through LCCA is relative rankings of LCCs, not their magnitudes.)

The EPS method of developing LCC data operates as follows:

1. A system or subsystem is broken into its components and subcomponents. Those requiring maintenance are listed with the required maintenance actions. Expected failure actions are also listed.

2. Each M&R action is broken into tasks; the manpower requirements for each task are determined using Army Engineered Performance Standards as discussed in the Technical Bulletin 420 series. Concurrently, required quantities of materials and supplies are determined and their cost expressed in either manhours or percent of the component's initial cost.

3. Frequencies are established for the maintenance actions and for failures. These are based on manufacturers' data, available FE experience, ASHRAE and similar organizations' publications, and engineering judgment.

4. Yearly total costs are computed in manhours, or in manhours and percent of initial cost. If costs are expressed in manhours and percent of initial cost, the database will not require updating because of inflation.

5. Steps 1 through 4 are done for 25 years. The yearly information is useful for backup data, and the designers use the average yearly maintenance cost for their purposes. For cyclical repair actions, the cost and the cycle (years) must be put in the database.

5 OBTAINING DATA FOR THE PLANNERS AND PROGRAMMERS DATABASE

The PPDB will be used by installation and OCE planners and programmers. Installation personnel need M&R data to perform economic analyses of alternatives in the MCA program; i.e., when comparing the alternatives of renovating existing facilities versus constructing a new facility, an estimate of M&R for each alternative is needed. OCE personnel need estimates of M&R costs for programming and allocating current O&M funds and to project future Army requirements.

Installation Data Needs

Method Description

There are two ways of obtaining M&R data for installation needs:

1. With the first method, intensive data collection would be done at a sample of eight installations (two in each of four geographic regions). Data would be collected on a sample group of facilities for the various facility classes, for types of construction (components), for several ages of facilities, and for both temporary and permanent construction. This data would be obtained by a contractor using IFS, contract records, and self-help records. The contractor would check on each building (with key personnel) at least once every 2 months to insure that all M&R costs were reflected in the records. The data collection would be for 5 years so that cyclical M&R would be sampled. This program would require one person at each installation and would cost about $.9 million.

2. In the second method, FE personnel would only estimate M&R costs, as needed, in the MCA process. When an alternative in the economic analysis was renovation of an existing facility, an in-depth study of M&R costs would be conducted. The facility would be broken into components and the designers' database data and EPS methodology used to generate M&R cost estimates. There are about 200 projects in the annual MCA program which might entail an alternative of renovation. Assuming M&R data is needed for half of these 200 projects and that the 200 represent one-third of projects submitted, gives 300 projects for which M&R costs of renovated facilities are needed. At one man-week (GS-11 level) per project, this represents 300 man-weeks or about $198,000 per year. However, these costs would decrease over time, since estimates made for similar projects in prior years could be easily updated.

Discussion

Method 1 would produce data applicable to a specific geographic region. Thus, the data would have to be adjusted accordingly for each installation. For use beyond the 5-year collection period, adjustments for inflation would also have to be made. The data would reflect M&R performed, not M&R needed.

Method 2 would produce current data for a specific installation and would reflect M&R which should be done to properly maintain the facility. This method would use the designers' database and EPS methodology. Method 2 is the preferred method.

OCE Data Needs

Method Description

There are three ways of obtaining data for OCE needs:

1. The first method is the same as Method 1 for installations, as discussed above.

2. The second method is the same as Method 2 for installations, except that a sample of buildings at each installation would be done; i.e., EPS or similar methods would be used to develop M&R costs on existing buildings. This would produce an estimated M&R cost for each facility class by type of construction by age group. This method would require at least 4 man-years to obtain data for 480 facilities at one installation. Thus, for 8 installations, about 32 man-years would be required at a cost of $1.1 million.

3. The third method would use Red Book data to estimate costs. The book contains all M&R costs for an installation; they need only be assigned to facility classes. A study would be required to develop algorithms for assigning costs to facility classes; i.e., prorate maintenance costs of central heating plants, maintaining the sewage system, maintaining electrical distribution systems, etc. Also, an operating cost algorithm would have to be developed; such an algorithm could be developed for type of installation (airborne training, airborne forces, armored training, armored forces, etc., or some other categorizing method). Costs to develop and program the algorithm would be about $110,000. Yearly costs to update the M&R data would be less than $10,000/year.

Discussion

Method 1 would require 5 years to implement.

Method 2 has the advantage that once it is developed, the M&R costs can be extended with little effort.

Method 3 has the advantage of using an existing data collection system and easily computed M&R costs, once the algorithms have been developed. The disadvantage is that age trends, differences between construction types, and differences between permanent and temporary construction are not possible. However, the importance of these for M&R programming purposes is questionable, since:

1. Older buildings may not require more maintenance than newer ones, since newer ones have more complex systems, and any high-maintenance components (e.g., wood siding) may have been replaced by low-maintenance ones (e.g., vinyl siding).

2. Temporary construction is a misnomer, since many facilities constructed as "temporary" during World War II may last indefinitely with proper M&R.

A more serious problem is that the data's accuracy and range of applicability would not be known. A sample of buildings at various locations would have to be monitored to collect M&R data for a check of the algorithms.

Method 3 is preferred since it is most cost-beneficial.

6 RESULTS OF CURRENT WORK

CERL's most recent research on developing LCC databases has provided the following:

1. Design of five building component databases: (1) HVAC, (2) floor covering, (3) roofing, (4) interior finishes, and (5) exterior finishes.

2. Development of sample data for some HVAC systems and all floor covering systems using the EPS method.

3. Holding a second LCC workshop to discuss database formats and data development.

4. Review by District offices and installations of the research results and sample M&R data developed by the EPS method.

5. Energy analyses to compare M&R costs versus energy costs for 25 years for certain buildings.

Database Design and Development

Database formats for HVAC, floor covering, and roofing systems (all high-cost M&R items) and interior and exterior finishes were developed (see Tables 1 through 7). The HVAC format is based on building fan-coil systems and equipment systems given in CERL's Building Loads and System Thermodynamics Program.[10] System sizes were selected for a wide range of possible M&R costs. A more detailed format at the system component level for HVAC was presented to designers at the second LCC workshop (see Appendix D). They noted that the design process requires information at the system level, not the system component level. However, M&R data is needed at the subsystem or system component level to expand and to provide a backup for system-level data.

The other database formats were developed by using (1) Army guide specifications, and (2) information provided by District designers on currently used components.

Sample Data Development

Bendix Field Engineering was contracted to develop M&R cost data for heating systems in a five-company administration building at Fort Gordon, GA. The purpose of this contract was to demonstrate the feasibility of using EPS to develop this type of data. A copy of the contractor's report was reviewed by ten installations, seven District offices, two Division offices, OCE, and three consultants; all agreed with the methodology (EPS) used to develop the data. Tables 8, 9, and 10 summarize the Bendix report data. This data will

[10] D. C. Hittle, The Building Loads Analysis and System Thermodynamics Program Users Manual, Volume I Technical Report E-153/ADA072272 (CERL, 1979); D. Herron, et al., Building Loads Analysis and System Thermodynamics Program: Supplement, Technical Report E-171/ADA099054 (CERL, 1981).

Table 1

M&R Database Format -- HVAC Systems

a. Fan Coil Systems.

System	Size (CFM)	Average Yearly Labor for M&R (Manhours)	Major Repair Replacement Costs (% of Initial Cost) Year	Cost
Multizone	6500			
	10000			
	25000			
	50000			
Dual-Duct	6500			
	10000			
	25000			
	50000			
Three-Deck Multizone	6500			
	10000			
	25000			
	50000			
Dual-Duct Variable Volume	6500			
	10000			
	25000			
	50000			
Variable Volume	6500			
	10000			
	25000			
	50000			
Terminal Reheat	6500			
	10000			
	25000			
	50000			
Two-Pipe Induction	6500			
	10000			
	25000			
	50000			
Four-Pipe Induction	6500			
	10000			
	25000			
	50000			

b. Boiler/Chiller Equipment.

System	Size (CFM)	Average Yearly Labor for M&R (Manhours)	Major Repair Replacement Costs (% of Initial Cost) Year	Cost
Single Zone Drawthrough	6500			
	10000			
	25000			
	50000			
Large Unit Ventilator	6500			
	10000			
	25000			
	50000			

Table I (Cont'd)

b. Boiler/Chiller Equipment.

System	Size (CFM)	Average Yearly Labor for M&R (Manhours)	Major Repair Replacement Costs (% of Initial Cost) Year	Cost
DX Packaged Unit	1200			
	3000			
	6500			
	10000			
Two-Pipe Fan Coil	400			
	1200			
Four-Pipe Fan Coil	400			
	1200			
Unit Ventilator/Heater	400			
	1200			

		Size	Average Yearly Labor for M&R (Manhours)	Major Repair Replacement Costs (% of Initial Cost) Year	Cost
Boilers		(KBTU/HR)			
	Gas	250			
		2000			
		10000			
	Coal	40000			
		100000			
	Oil	250			
		2000			
		10000			
	Dual Fuel	2000			
		20000			
	Electric	250			
Chillers		(TONS)			
	Air-Cooled Hermetic Reciproc	20			
		50			
		100			
	Water-Cooled Hermetic Reciproc	20			
		50			
		100			
	Hermetic Centrifugal	100			
		300			
		900			
	Double-Bundle Hermetic	100			
		300			
		900			
	Open Centrifugal	300			
		900			
	One-Stage Absorber	100			
		300			
		900			

Table 1 (Cont'd)

b. Boiler/Chiller Equipment.

	Size	Average Yearly Labor for M&R (Manhours)	Major Repair Replacement Costs (% of Initial Cost) Year	Cost
Two-Stage Absorber	300			
	900			
Two-Stage Absorber w/Economizer	300			
	900			
Heat Rejection System	(TONS)			
Cooling Towers	50			
	100			
	300			
	900			
Evaporative Condenser	20			
	100			
	300			
Air-Cooled Condenser	5			
	20			
	50			
DX Condensing Unit	(TONS)			
	5			
	20			
	50			
Furnaces (for Housing)	(KBTU/HR)			
Gas	25			
	100			
	200			
Oil	25			
	100			
	200			
Electric	25			
	100			
	200			
Air Conditioners for Housing	(TONS)			
Window	1,2			
Pad Mounted	4			

Table 2

Database Format for Floor Covering

	Type Covering	Surface Preparation	Type Use*	Obstruction Level	Yearly M&R Cost (Manhours)	Replacement Year	Replacement Manhours
01	Carpet	None	Admin/Personnel	Unobstructed			
02	Carpet	None	Admin/Personnel	Slightly Obstructed			
03	Carpet	None	Admin/Personnel	Obstructed			
04	Carpet	None	Admin/Personnel	Heavily Obstructed			
05	Carpet	None	Prod/Industrial	Unobstructed			
06	Carpet	None	Prod/Industrial	Slightly Obstructed			
07	Carpet	None	Prod/Industrial	Obstructed			
08	Carpet	None	Prod/Industrial	Heavily Obstructed			
09	Hard Flooring	Sealed	Admin/Personnel	Unobstructed			
10	Hard Flooring	Sealed	Admin/Personnel	Slightly Obstructed			
11	Hard Flooring	Sealed	Admin/Personnel	Obstructed			
12	Hard Flooring	Sealed	Admin/Personnel	Heavily Obstructed			
13	Hard Flooring	Sealed	Prod/Industrial	Unobstructed			
14	Hard Flooring	Sealed	Prod/Industrial	Slightly Obstructed			
15	hard Flooring	Sealed	Prod/Industrial	Obstructed			
16	Hard Flooring	Sealed	Prod/Industrial	Heavily Obstructed			
17	Hard Flooring	None	Storage	Obstructed			
18	Hard Flooring (Over 3,000 Square Feet)	Sealed	Prod/Industrial	Slightly Obstructed			
19	Resilient	Finished	Admin/Personnel	Unobstructed			
20	Resilient	Finished	Admin/Personnel	Slightly Obstructed			
21	Resilient	Finished	Admin/Personnel	Obstructed			
22	Resilient	Finished	Admin/Personnel	Heavily Obstructed			
23	Resilient	Finished	Prod/Industrial	Unobstructed			
24	Resilient	Finished	Prod/Industrial	Slightly Obstructed			
25	Resilient	Finished	Prod/Industrial	Obstructed			
26	Resilient	Finished	Prod/Industrial	Heavily Obstructed			
27	Resilient	Unfinished	Storage	Slightly Obstructed			
28	Resilient	Unfinished	Storage	Heavily Obstructed			
29	Resilient (Over 3,000 Square Feet)	Finished	Admin/Personnel	Slightly Obstructed			
30	Maple Floor, Unsealed	None	Storage	Slightly Obstructed			
31	Maple Floor, Sealed	Sealed	Gymnasium	Unobstructed			
32	Wood Parquet	Sealed	Lobbies	Slightly Obstructed			
33	Concrete, Untreated	None	Varied	Slightly Obstructed			
34	Concrete, Treated	Sealed	Varied	Slightly Obstructed			

*Admin = Administrative (offices)
Personnel = Barracks, BOQs
Prod = Production

Table 3

Maintenance and Repair Life-Cycle Analysis Chart for Hot-Applied Four-Ply Built-Up Roofing

Roof Type Description		Expected Service Life	Yearly Total Task	Craft Labor	Material Supplies Factor	Overhead	Total Yearly Manhours
Roof Material	Surface No.	a b c d e f g	a b c d e f g	a b c d e f g	a b c d e f g	a b c d e f g	a b c d e f g
Asphalt - Asbestos	Aggregate 1		*	*	*	*	*
	Mineral 2						
Saturated - Organic	Aggregate 3						
	Mineral 4						
Felt - Glass Fiber	Aggregate 5						
	Mineral 6						
Coal-Tar - Asbestos	Aggregate 7						
	Mineral 8						
Saturated - Organic	Aggregate 9						
	Mineral 10						
Felt - Glass Fiber	Aggregate 11						
	Mineral 12						

Insulation Types: a = none, b = cellular concrete, c = wood fiber board, d = composite board (Urethane + expanded perlite), e = cellular glass, f = urethane (on concrete deck), g=other.

*For each combination of roof material, surface and insulation costs in manhours are to be given.

Table 4

Maintenance and Repair Life-Cycle Analysis Chart
for Elastomeric, Shingle, and Metal Roofing

Roof Type	Surface No.	Expected Service Life	Yearly Total Task	Craft Labor	Material Supplies Factor	Overhead	Total Yearly Manhours
EPDM Sheet	13		*	*	*	*	*
Polyurethane With Silicone Coating	14						
Other	15						
Asphalt Strip	16						
Individual Asphalt	17						
Spanish Tile	18						
Slate	19						
Other	20						
Natural Aluminum	21						
Color-Coated Alum	22						
Galvanized Steel	23						
Alum-Coated Steel	24						
Color-Coated Steel	25						

*Costs in manhours are to be given for each cell.

Table 5

Multipliers for Special Conditions

Special Conditions for Roof Types		Multiplier for Roof Type Year 1	2	3	4	5	25
Slope:	None						
Preparation:	None						
	High						
Configuration	1:1						
	>1:5						
Traffic	Low						
	High						
Climate	Ideal						
	Extreme						
Maintenance Program	Excellent						
	Poor						
Flashing Material	Copper/Lead						
	Stainless Stl.						
	Asbestos W/Bitumen						
Drainage	To Interior						

NOTE: These multipliers to be used to adjust data in Tables 3 and 4.

*Low - No mechanical equipment on roof.
High - Mechanical equipment on roof.

Table 6

Exterior Finishes and Materials: Maintenance and Repair Life-Cycle Analysis Chart

		Manhours for Refinishing					
Substrate or Surface*	Expected Life of Finish	Refinishing Total Task	Overhead 14%	Material, Supplies Factor	Craft Allowance	Total Refinishing	Manhours/Year for Repairs
Masonry							
Brick, natural							
Brick, 1 coat paint							
Brick, 2 coats paint							
Concrete, 1 coat paint							
Concrete, 2 coats paint							
Concrete Block, 1 coat paint							
Concrete Block, 2 coats paint							
Stucco/Plaster, 1 coat paint							
Stucco/Plaster, 2 coats paint							
Wood Siding							
Grooved Plywood, 1 coat paint							
Grooved Plywood, 2 coats paint							
Boards w/Batten, 1 coat paint							
Boards w/Batten, 2 coats paint							
Hardboard/Particle Bd, 1 coat paint							
Hardboard/Particle Bd, 2 coats paint							
Pine, 1 coat paint							
Pine, 2 coats paint							
Redwood/Cedar, 1 ct paint/stain							
Redwood/Cedar, 2 cts paint/stain							
Wood, 1 coat stain							
Wood, 2 coats stain							
Misc. Woodwork, Wood, Windows, and Doors							
Cornice, Narrow Surfaces, 1 coat paint							
Cornice, Narrow Surface, 2 cts paint							
Eaves/Exposed Rafters, 1 coat paint							
Eaves/Exposed Rafters, 2 coats paint							
Windows and Frames, painted							
Double Hung Windows -							
1 pane over 1 pane, 1 coat paint							
1 pane over 1 pane, 2 coats paint							
2 panes over 2 panes, 1 coat paint							
2 panes over 2 panes, 2 coats paint							
6 panes over 6 panes, 1 coat paint							
6 panes over 6 panes, 2 coats paint							
Sash, Hopper, Awning Types, 1 coat paint							

Table 6 (Cont'd)

Substrate or Surface*	Expected Life of Finish	Refinishing Total Task	Manhours for Refinishing: Overhead 14%	Manhours for Refinishing: Material, Supplies Factor	Manhours for Refinishing: Craft Allowance	Manhours for Refinishing: Total Refinishing	Manhours/Year for Repairs
Sash, Hopper, Awning Types, 2 coats paint							
Sliding Windows, 1 coat paint							
Sliding Windows, 2 coats paint							
Casement Windows, 1 coat paint							
Casement Windows, 2 coats paint							
Windows and Frames, Vinyl Covered							
Wood Door and Doorframe, 1 coat paint							
Wood Door and Doorframe, 2 coats paint							
Metal Siding							
Galvanized Steel, Flat Patterns							
Galvanized Steel, Corrugated							
Factory Coated, Type 1 Flat Pattern							
Factory Coated, Type 2 Flat Pattern							
Factory Coated, Type 3 Flat Pattern							
Factory Coated Steel, Type 1 Flat Pattern							
Factory Coated Steel, Type 2 Flat Pattern							
Factory C- -ed St-el, Type 3 Flat Pattern							
Nonferrous Metals, Corrugated							
Other Siding							
Aluminum Siding							
Asbestos Cement Shingles, 1 coat paint							
Asbestos Cement Shingles, 2 coats paint							
Asbestos Cement Siding, Corrugated, 1 coat paint							
Asbestos Cement Siding, Corrugated, 2 coats paint							
Asbestos Cement Siding, Flat, 1 coat paint							
Asbestos Cement Siding, Flat, 2 coats paint							
Vinyl Siding							
Misc. Metalwork, Windows and Doors							
Aluminum Windows and Frame							
Double Hung Window, 1 coat paint							
Double Hung Window, 2 coats paint							
Sash, Hopper, Awning Types, 1 coat paint							
Sash, Hopper, Awning Types, 2 coats paint							
Sliding Windows, 1 coat paint							
Sliding Windows, 2 coats paint							
Casement Windows, 1 coat paint							
Casement Windows, 2 coats paint							
Steel, Narrow Surfaces							
Steel Door and Frame, Soft Steel							

Table 6 (Cont'd)

Substrate or Surface*	Expected Life of Finish	Manhours for Refinishing: Refinishing Total Task	Overhead 14%	Material, Supplies Factor	Craft Allowance	Total Refinishing	Manhours/Year for Repairs
Steel Door and Frame, Galvanized							
Steel Door and Frame, Factory Coated							
Steel Window and Window Frame							
Double Hung Window, 1 coat paint							
Double Hung Window, 2 coats paint							
Sash, Hopper, Awning Types, 1 coat paint							
Sash, Hopper, Awning Types, 2 coats paint							
Sliding Windows, 1 coat paint							
Sliding Windows, 2 coats paint							
Casement Windows, 1 coat paint							
Casement Windows, 2 coats paint							

Note: Type 1, Baked Enamel; Type 2, Painted; Type 3, Laminated Vinyl.

*All bare surfaces must be primed before painting.
Aluminum and galvanized steel surfaces must be wash-primed before priming and painting.

Table 7

Interior Finishes and Materials: Maintenance and Repair Life-Cycle Analysis Chart

Substrate or Surface*	Expected Life of Finish	Manhours for Refinishing: Refinishing Total Task	Overhead 14%	Material, Supplies Factor	Craft Allowance	Total Refinishing	Manhours/Year for Repairs
Walls							
Brick, Natural							
Brick, 1 coat paint							
Brick, 2 coats paint							
Concrete, 1 coat paint							
Concrete, 2 coats paint							
Concrete Block, 1 coat paint							
Concrete Block, 2 coats paint							
Fabric Wall Cover							
Free Standing Partitions - Paintable - 2 cts paint							
Free Standing Partitions - Fabric-Covered							
Gypsum Board, 1 coat paint							
Gypsum Board, 2 coats paint							
Paneling, Wood, Factory Finish							
Plaster, 1 coat paint							
Plaster, 2 coats paint							
Plastic Wall Cover							
Wallpaper							
Wood, 1 coat paint							
Wood, 2 coats paint							
Wood Stained or Clear Varnish, 1 coat							
Wood Stained or Clear Varnish, 2 coats							
Ceilings							
Acoustical Ceiling (Porous suspended ceiling or ceiling tiles), 1 coat paint							
Gypsum Board, 1 coat paint							
Gypsum Board, 2 coats paint							
Plaster, 1 coat paint							
Plaster, 2 coats paint							

Table 7 (Cont'd)

Substrate or Surface*	Expected Life of Finish	Manhours for Refinishing: Refinishing Total Task	Manhours for Refinishing: Overhead 14%	Manhours for Refinishing: Material, Supplies Factor	Manhours for Refinishing: Craft Allowance	Manhours for Refinishing: Total Refinishing	Manhours/Year for Repairs
Doors							
Steel Door & Frame, Site-Painted							
1 coat paint							
2 coats paint							
Steel Door and Frame, Factory-Coated							
1 coat paint							
2 coats paint							
Steel/Metal Surfaces, Site-Painted							
1 coat paint							
2 coats paint							
Steel/Metal Surfaces, Factory-Coated							
1 coat paint							
2 coats paint							
Wood Door and Frame, Painted							
1 coat							
2 coats							
Wood Door and Doorway, Stained							
1 coat varnish							
2 coats varnish							

*All bare surfaces must be primed before painting.
Aluminum and galvanized steel surfaces must be wash-primed before priming and painting.

Table 8

Manpower Requirements (In Manhours) for Heating Systems -- Bendix Study

Description of Equipment	Years																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
Air Handling Unit (4-ton chilling & heating)	8.0	8.0	10.1	14.5	15.2	10.1	8.0	14.5	10.1	23.3	8.0	16.6	8.0	8.0	17.4	14.5	8.0	10.1	8.0	29.8	10.1	8.0	8.0	16.6	15.2	308.1
Unit Heater (10 Electric)	2.6	2.6	2.6	2.9	6.1	2.6	2.6	2.9	2.6	7.0	2.6	2.9	2.6	2.6	6.1	2.9	2.6	2.6	2.6	7.3	2.6	2.6	2.6	2.9	6.1	86.1
Exhaust Fan (Fractional hp w/ backdraft damper)	5.7	5.7	7.8	5.7	9.0	7.8	5.7	5.7	7.8	11.1	5.7	7.8	5.7	5.7	11.1	5.7	5.7	7.8	5.7	11.1	7.8	5.7	5.7	7.8	9.0	180.1
Heat Exchanger (550 water-to-water)	2.4	2.4	2.4	8.9	6.0	2.4	2.4	8.9	2.4	9.8	2.4	8.9	2.4	2.4	6.0	8.9	2.4	2.4	2.4	16.4	2.4	2.4	2.4	8.9	6.0	124.7
Pump (7-1/2 hp base-mounted centrifugal)	1.2	3.2	5.8	4.8	3.2	7.8	1.2	4.8	5.8	9.9	1.2	9.5	1.2	3.2	7.8	4.8	1.2	7.8	1.2	11.5	5.8	3.2	1.2	9.5	3.2	120.0
Hot Water Boiler (18.6 hp sectional CI)	9.3	11.2	9.3	11.2	17.2	11.2	9.3	11.2	9.3	19.1	9.3	11.2	9.3	11.2	17.2	11.2	9.3	11.2	9.3	19.1	9.3	11.2	9.3	11.2	17.2	294.8
Totals	29.2	33.1	38.0	48.0	56.7	41.9	29.2	48.0	38.0	80.2	29.2	56.9	29.2	33.1	65.6	48.0	29.2	41.9	29.2	95.2	38.0	33.1	29.2	56.9	56.7	1112.7

Table 9

Material Requirements for Heating Systems -- Bendix Study

Description of Equipment & Items (Replacement Kits)	Years																									Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
Air-Handling Units																										
Belts (sets)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	50
Filter (sets)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	100
Motor										1										1						2
Bearings			1			1			1			1			1			1			1			1		8
Pulley/Sheave										1										1						2
Thermostat										2										2						4
Actuator					4					4					4					4					4	20
Relay/Contactors				4				4				4				4				4				4		24
Unit Heater																										
Motor					1					1					1					1					1	5
Thermostat										1										1						2
Actuator					5					5					5					5					5	25
Relay/Contactors				5				5				5				5				5					5	30
Exhaust Fan																										
Belts	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	50
Motor					1					1					1					1					1	5
Bearings			1			1			1			1			1			1			1			1		8
Pulley/Sheave										1										1						2
Switch					1					1					1					1					1	5
Heat Exchanger																										
Actuator					2					2					2					2					2	10
Relays				4				4				4				4				4				4		24
Thermostat										2										2						4
Pump																										
Coupling		1		1		1		1		1		1		1		1		1		1		1		1		12
Seals & Bearings			1			1			1			1			1			1			1			1		8
Impeller & Shaft										1										1						2
Motor										1										1						2
Relay/Contactors				1				1				1				1				1				1		6
Hot Water Boiler																										
Section & Push Nipples					1					1					1					1					1	5
Tune-Up Kits		1		1		1		1		1		1		1		1		1		1		1		1		12

Table 10

Summary of M&R Data From Bendix Study

Description of Heating System Component	Average Yearly M&R Labor (Manhours)	Average Yearly M&R Materials Cost ($)
Air-Handling Unit (4-ton chilling and heating)	12.3	*
Unit Heater (10 MBH electric)	3.4	
Exhaust Fan (Fractional hp with backdraft damper	7.2	
Heat Exchanger (550 MBH water-to-water)	5.0	
Pump (7-1/2 hp base mounted centrifugal)	4.8	
Hot Water Boiler (18.6 hp sectional CI)	11.8	

*When performing an LCCA, use Table 9 to derive yearly costs for 25 years.

not be useful at the system level (Table 1), but will be used at the component level. The Bendix report is given in Appendix E (Volume II).

Planned Maintenance, Inc., was contracted to develop M&R costs for floor covering systems. Their report is given in Appendix F (Volume II). The database they developed (see Table 11) is now ready for use by designers.

A third contract was awarded to Service Engineering Associates, Inc., to develop M&R costs for selected cooling generating systems. Their report is Appendix G (Volume II). Part of the data they developed is ready for the final database (see Table 12).

Second LCC Workshop

The second LCC Database Design Workshop was held in Arlington, VA, on 1-2 June 1981. Twenty-seven attendees represented District and Division offices, installations (FE organizations), HQ FORSCOM, HQ TRADOC, FESA, the private sector, OCE, General Services Administration, and CERL. Appendix D summarizes the workshop discussion and results.

Major recommendations of the workshop were:

1. The EPS method should be used to develop M&R data.

2. Design databases should be at a more summary level, with detailed data for system/subsystem components serving as backup. For example, summary data should be given for each HVAC system and subsystem.

3. BLAST and TRACE[11] should be used to help define possible HVAC systems and subsystems.

4. Data for HVAC systems is needed for different operational requirements, not necessarily different facility classes.

5. Data for the planners/programmers database should be collected on-site, using IFS, contract data, and "self-help" data.

Review by Installations and District Offices

Copies of the Bendix report (which provided sample M&R data developed through EPS) and CERL Interim Report P-120 were distributed to six TRADOC installations, seven FORSCOM installations, and 11 District offices for review and comment. Eight of the installations and four Districts responded. Representatives from two other installations and three nonresponding Districts attended the workshop and had input to the discussions. Results of the installation survey were:

1. M&R data is not available at installations.

[11]Trace Air-Conditioning Economics Program (Trane Company).

Table 11

Database for Floor Covering

	Type Covering	Surface Preparation	Type Use	Obstruction Level	Yearly M&R Cost (Manhours) Per 1000 Sq Ft	Replacement Per 1000 Sq Ft Year	Replacement Per 1000 Sq Ft Manhours
01	Carpet	None	Admin/Personnel	Unobstructed	95	8	40
02	Carpet	None	Admin/Personnel	Slightly Obstructed	140	8	40
03	Carpet	None	Admin/Personnel	Obstructed	170	8	40
04	Carpet	None	Admin/Personnel	Heavily Obstructed	190	8	40
05	Carpet	None	Prod/Industrial	Unobstructed	20	8	40
06	Carpet	None	Prod/Industrial	Slightly Obstructed	25	8	40
07	Carpet	None	Prod/Industrial	Obstructed	25	8	40
08	Carpet	None	Prod/Industrial	Heavily Obstructed	25	8	40
09	Hard Flooring	Sealed	Admin/Personnel	Unobstructed	70	25	—
10	Hard Flooring	Sealed	Admin/Personnel	Slightly Obstructed	90	25	—
11	Hard Flooring	Sealed	Admin/Personnel	Obstructed	110	25	—
12	Hard Flooring	Sealed	Admin/Personnel	Heavily Obstructed	130	25	—
13	Hard Flooring	Sealed	Prod/Industrial	Unobstructed	60	25	—
14	Hard Flooring	Sealed	Prod/Industrial	Slightly Obstructed	80	25	—
15	Hard Flooring	Sealed	Prod/Industrial	Obstructed	95	25	—
16	Hard Flooring	Sealed	Prod/Industrial	Heavily Obstructed	120	25	—
17	Hard Flooring	None	Storage	Obstructed	25	25	—
18	Hard Flooring (Over 3,000 Square feet)	Sealed	Prod/Industrial	Slightly Obstructed	30	25	—
19	Resilient	Finished	Admin/Personnel	Unobstructed	75	18	40,60*
20	Resilient	Finished	Admin/Personnel	Slightly Obstructed	100	18	40,60
21	Resilient	Finished	Admin/Personnel	Obstructed	115	18	40,60
22	Resilient	Finished	Admin/Personnel	Heavily Obstructed	140	18	40,60
23	Resilient	Finished	Prod/Industrial	Unobstructed	60	18	40,60
24	Resilient	Finished	Prod/Industrial	Slightly Obstructed	85	18	40,60
25	Resilient	Finished	Prod/Industrial	Obstructed	100	18	40,60
26	Resilient	Finished	Prod/Industrial	Heavily Obstructed	120	18	40,60
27	Resilient	Unfinished	Storage	Slightly Obstructed	20	18	40,60
28	Resilient	Unfinished	Storage	Heavily Obstructed	30	18	40,60
29	Resilient (Over 3,000 Square feet)	Finished	Admin/Personnel	Slightly Obstructed	30	18	40,60
30	Maple Floor, Unsealed	None	Storage	Slightly Obstructed	40	25	—
31	Maple Floor, Sealed	Sealed	Gymnasium	Unobstructed	35	25	—
32	Wood Parquet	Sealed	Lobbies	Slightly Obstructed	45	25	—
33	Concrete, Untreated	None	Varied	Slightly Obstructed	80	25	—
34	Concrete, Treated	Sealed	Varied	Slightly Obstructed	85	25	—

*40 hours for 1,000 square feet for vinyl asbestos tile, 60 hours for sheet vinyl.

NOTE: Labor skill for yearly M&R cost is that of a janitor. Skill for replacement is carpet layer or vinyl flooring installer.

Admin = Administration (offices)
Personnel = Barracks, BCQs
Prod = Production

Table 12

Chiller and Heat Rejection Systems Data Developed by Service Engineering Associates

System Chiller	Size (Tons)	Average Yearly Labor for M&R (Manhours)	Major Repair/ Replacement Costs (% of Initial Costs) Year	Cost
Water-Cooled Hermetic Reciprocating	100	29.0	16	5%
			18	55%
			24	55%
Hermetic Centrifugal	280	39.8	16	5%
			18	75%
			24	25%
	980	64.4	15	5%
			18	75%
			24	25%
Open Centrifugal	300	41.3	16	5%
			18	35%
			20	45%
			24	25%
	900	66.8	16	5%
			18	25%
			20	45%
			24	25%
Heat Rejection				
Cooling Tower	100	18.0	20	95%
	300	25.3	20	95%
	900	30.7	20	95%
Evaporative Condenser	100	17.9	20	95%
	300	25.6	20	95%

Example: For a 280-ton hermetic centrifugal chiller, 39.8 manhours would be multiplied by the present wage rate for an air-conditioning mechanic at the installation. This would be multiplied by the appropriate discount rate to find the present value of labor M&R costs. If the original manufacturer's list price of the system (F.O.B.) was $100,000, then three replacement costs would be computed: $5000 discounted at year 16; $75,000 discounted at year 18; and $25,000 discounted at year 24.

2. IFS is not suitable to collect M&R data, although the Facilities Engineers Equipment Maintenance System (a module of IFS) could be used to collect some of it.

3. The EPS method appears to be a good way of estimating M&R data.

Results of the District survey indicated:

1. There is a need for more categories of components in the HVAC database format. (This was done.)

2. Costs should be separated into average annual and cyclical categories.

Comparison of Energy and M&R Costs

The importance of M&R costs relative to energy costs for HVAC systems is of interest, since designers need to know in which areas significant savings can be accomplished over the facility life. For cooling generation systems, the question was raised concerning how energy costs compared to M&R costs over 25 years; i.e., whether M&R costs are insignificant when compared to the energy costs. Energy and M&R costs were computed for eight cooling systems/components.

Table 13 shows the M&R data for initial costs, M&R manhours/year, labor costs, replacement costs, and 25-year LCC (without energy costs).

The following discussion describes the buildings and loads used in the BLAST analyses for energy consumption of sample cooling units. Two buildings -- a dental clinic and a type 64 barracks -- were used to generate the loads for the plants. Multiples of these loads were used to describe the loads of larger plants. The dental clinic is a one story, flat-roofed structure with walls of concrete block and brick; 15 percent of its area is glass and its total area is 9000 sq ft (18 chairs). The type 64 barracks is a three-story, flat-roofed building, with 8-in. concrete block walls and 38 percent glass area; its area is 31,122 sq ft (152 men).

In cases A through H, shown in Table 14, both buildings remain between 68°F and 78°F, 24 hours per day, every day of the year. In cases C1, D1, G1, and H1, described in Table 15 the cooling system is shut down from 16 October through 15 April. The dental clinic has a night and weekend setback schedule, during which the temperature remains between 68°F and 78°F for 10 hours per day, 5 days per week. There is no cooling on nights and weekends. The type 64 barracks are maintained between 68°F and 78°F 24 hours per day throughout the cooling season.

Table 13

Comparison of Cooling Systems -- M&R Data

	System	Size (Tons)	Initial Cost(IC)	Manhours/ Year for M&R	Labor Cost Year ($)	25-Year Discounted Labor($)	Replacement Total Discounted (% of IC)	25-Year LCC ($)
Heat Rejection	Cooling Tower	100	8570	18	540	4900	14.2%	14,690
	Evaporative Condenser	100	9210	18	540	4900	14.2%	15,420
	Cooling Tower	300	20,470	25	750	6810	14.2%	30,190
	Evaporative Condenser	300	22,000	26	780	7080	14.2%	32,200
Chillers	Hermetic Centrifugal	280	57,820	40	1200	10890	17.1%	78,600
	Open Centrifugal	300	55,860	41	1230	11160	16.6%	76,290
	Hermetic Centrifugal	980	134,880	64	1920	17430	17.2%	175,510
	Open Centrifugal	900	130,320	67	2010	18240	14.8%	167,850

Notes: Initial costs (IC) are as of August 1981 in Atlanta area; M&R is normal maintenance and repair. Major breakdowns and component replacements are expressed as a percentage of IC. Operating time was assumed to be 1000 to 1500 hours per year. Labor cost = $30/hour. Discount rate = 10%.

Table 14

Energy Consumption -- Year Round Operation, 24 Hours Per Day

		Columbia, MO		Fort Worth, TX		Phoenix, AZ		Raleigh, NC	
		Consumption (MWH)	Operating Hours	Consumption (MWH)	Operating Hours	Consumption (MWH)	Operating Hours	Consumption (MWH)	Operating Hours
A	100-Ton Evap. Cond.	48.94	8694	54.51	8760	57.15	8760	50.41	8760
	100-Ton Cooling Tower	48.65	8694	53.05	8760	54.81	8760	49.82	8760
	DIFFERENCE	.29		1.46		2.34		.59	
B	300-Ton Evap. Cond.	138.9	8694	150.9	8760	158.3	8760	149.2	8760
	300-Ton Cooling Tower	138.6	8694	148.3	8760	153.9	8760	146.8	8760
	DIFFERENCE	.3		2.6		4.4		2.4	
C	300-Ton Open Chiller	750.3	8694	762.0	8760	814.8	8760	765.0	8760
	280-Ton Chiller*	612.5	8694	656.5	8760	721.0	8760	644.8	8760
	DIFFERENCE	137.8		105.5		93.8		120.2	
D	900-Ton Open Chiller	2007.6	8694	2022.3	8760	2201.1	8760	2031.1	8760
	980-Ton Chiller*	1908.0	8694	1981.2	8760	2201.1	8760	1957.8	8760
	DIFFERENCE	99.6		41.1		0		73.3	
E	3 100-Ton Cooling Towers	141.6	8694@	152.4	8760@	158.6	8760@	150.6	8760@
	300-Ton Cooling Tower	138.6	8694	148.3	8760	153.9	8760	146.8	8760
	DIFFERENCE	3.0		4.1		4.7		3.8	
F	3 100-Ton Evap. Cond.	141.0	8694@	154.8	8760@	163.0	8760@	152.7	8760@
	300-Ton Evap. Cond.	138.9	8694	150.9	8760	158.3	8760	149.2	8760
	DIFFERENCE	2.1		3.9		4.7		3.5	
G	980-Ton Chiller*	1908.0	8694	1981.2	8760	2201.1	8760	1957.8	8760
	3 280-Ton Chillers*	1102.0	869,2209 8694	1368.7	1724,3437, 8760	1729.2	2503,4576 8760	1269.1	1310,2791, 8760
	DIFFERENCE	806.0	Ave=3924	612.5	Ave=4640	471.9	Ave=5280	688.7	Ave=4287
H	900-Ton Open Chiller	2007.6	8694	2022.3	8760	2201.1	8760	2031.1	8760
	3-300 Ton Open Chillers	1140.1	740,2070, 8694	1368.7	1485,3266, 8760	1685.2	2186,4384, 8760	1272.0	985,2554 8760
	DIFFERENCE	867.5	Ave=3835	653.6	Ave=4504	515.9	Ave=5110	759.1	Ave=4100

*"Chiller" means hermetic centrifugal type.

Table 15

Energy Consumption -- Operation 16 April Through 15 October
(10 Hours Per Day, 5 Days Per Week for Dental Clinics,
24 Hours Per Day for Barracks)

	Columbia, MO		Fort Worth, TX		Phoenix, AZ		Raleigh, NC	
	Consumption (MWH)	Operating Hours	Consumption (MWH)	Operating Hours	Consumption (MWH)	Operating Hours	Consumption (MWH)	Operating Hours
C1 300-Ton Open Chiller	230.1	2824	279.6	3528	336.4	4052	231.5	2986
280-Ton Chiller*	198.7	2824	253.5	3528	334.1	4052	200.8	2986
DIFFERENCE	31.4		26.1		2.3		30.7	
D1 900-Ton Open Chiller	600.8	2824	729.8	3528	976.0	4052	618.4	2986
980-ton Chiller*	583.2	2824	729.8	3528	993.6	4052	609.6	2986
DIFFERENCE	17.6		0		17.6		8.8	
G1 980-Ton Chiller*	583.2	2824	729.8	3528	993.6	4052	609.6	2986
3 280-Ton Chillers*	389.8	323,986, 2824	562.7	638,1688, 3528	838.2	1186,2581, 4052	433.8	410,1151, 2986
DIFFERENCE	193.4	Ave=1378	167.1	Ave=1951	155.4	Ave=2606	175.8	Ave=1516
H1 900-Ton Open Chiller	600.8	2824	729.8	3528	976.0	4052	618.4	2986
3 300-Ton Open Chillers	386.9	250,916 2824	545.1	528,1590 3528	806.0	961,2475, 4052	425.0	330,1038, 2986
DIFFERENCE	213.9	Ave=1330	184.7	Ave=1882	170.0	Ave=2496	193.4	Ave=1451

*"Chiller" means hermetic centrifugal type.

For cases A through H, C1, D1, G1, and H1, the loads were configured as follows (for cost comparisons use $30/MWH):

Size Unit	Raleigh No. Brks.	Raleigh No. Clinics	Columbia No. Brks.	Columbia No. Clinics	Fort Worth No. Brks.	Fort Worth No. Clinics	Phoenix No. Brks.	Phoenix No. Clinics
100 tons	1	1	1	1	1	1	1	1
300 tons	3	3	3	2	3	2	3	2
900 tons	10	9	9	8	8	8	9	8

In cases C2, D2, G2, and H2 (Table 16), loads for dental clinics at two locations were compared to analyze minimal cooling requirements on the equipment. The two locations were Columbia, MO (the location of least cooling needs) and Phoenix, AZ (the location of highest cooling needs). For the 300-ton equipment, 10 dental clinics were compared, and for the 900-ton equipment, 29 clinics were compared. In making the comparisons, the discount rate used for M&R costs was 10 percent. The discount rate used for energy consumption was 7 percent in accordance with Department of Energy methods.

Tables 14, 15, and 16 give the energy consumption for various operating profiles.

Table 17 shows energy consumption data for the eight systems/components used to compare LCC and energy costs and for certain combinations of these systems. Four different geographic locations were used for the analysis. Table 17 also allows comparisons between systems which are of similar size, different types, large systems and several small ones, and M&R and energy costs. Example: a 300-ton open chiller has a 25-year energy cost at Fort Worth of $327,580 for full-year operation, and seasonal operation cost of $120,200. Its 25-year M&R cost is $20,430. Thus, the energy cost for seasonal operation over 25 years is more than five times the M&R cost (including partial replacement). Example: using three 300-ton open chillers instead of a 900-ton open centrifugal chiller will cost $61,020 more in LCC, but will cost $280,990 less for energy at Fort Worth in a full-year operational mode ($79,400 less in a seasonal mode).

For each chiller, the full-year operation energy costs for 25 years are at least 12 times the 25-year M&R cost. For seasonal operation of a mixture of barracks cooled 24 hours every day and clinics cooled on a 10-hour 5-day week basis, the ratio is at least four to one. For seasonal, 10-hour, 5-day operation, the ratio varies from 2.5 to 3.9 at Columbia, MO, and from 2.9 to 4.4 at Phoenix, AZ. This limited analysis indicates that in many cases M&R costs are small compared to energy costs and that for those cases, the most promising area for reducing Army ownership costs of cooling systems during design is in energy, not M&R.

Table 16

Energy Consumption -- Operation 16 April through 15 October (Dental Clinic, 10 Hours Per Day, 5 Days Per Week)

		Columbia, MO		Phoenix, AZ	
		Consumption (MWH)	Operating Hours	Consumption (MWH)	Operating Hours
C2	300-Ton Open Chiller	137.7	1246	156.2	1270
	280-Ton Chiller*	140.3	1246	164.4	1270
	DIFFERENCE	2.6		8.2	
D2	900-ton Open Chiller	354.5	1246	401.4	1270
	980-Ton Chiller*	380.9	1246	439.5	1270
	DIFFERENCE	26.4		38.1	
G2	980-Ton Chiller*	380.9	1246	439.5	1270
	3 280-Ton Chillers*	386.8	1246	471.7	1270
	DIFFERENCE	5.9		32.2	
H2	900-Ton Open Chiller	354.5	1246	401.4	1270
	3 300-Ton Open Chillers	363.3	1246	445.4	1270
	DIFFERENCE	8.8		44.0	

*"Chiller" means hermetic centrifugal type.

Table 17

Comparison of LCC and Energy Costs

System	Initial Cost ($)	25-Year M&R Costs ($)	25-Year LCC ($)	Year Roun Columbia	Fort Worth
100-Ton Evap. Cond	9210	6210	15420	1470-20340	1640-23430
100-Ton Cooling Tower	8570	6120	14690	1460-20210	1590-22810
300-Ton Evap. Cond.	22000	10200	32200	4170-57710	4530-64870
300-Ton Cooling Tower	20470	9720	30190	4160-57590	4450-63750
300-Ton Open Chiller	55860	20430	76290	22510-311750	22860-32758
280-Ton Chiller	57820	20780	78600	18380-254490	19700-28223
900-Ton Open Chiller	130320	37530	167850	60230-834160	60670-86939
980-Ton Chiller	134880	40630	175510	57240-792770	59440-85172
3 100-Ton Cooling Towers	25710	18330	44040	4250-58830	4570-6552
300-Ton Cooling Tower	20470	9720	30190	4160-57590	4450-6375
3 100-Ton Evap. Cond.	27630	18600	46230	4230-58590	4640-6655
300-Ton Evap. Cond.	22000	10200	32200	4170-57710	4530-6487
980-Ton Chiller	134880	40630	175510	57240-792770	59440-8517
3 280-Ton Chiller	173460	62340	236800	33060-457880	41060-5884
900-Ton Open Chiller	130320	37530	167850	60230-834160	60670-8693
3 300-Ton Open Chillers	167580	61290	228870	34200-473710	41060-5884

NOTE: The 25-year energy cost present value was calculated using the UPW published 18 N
"Chiller" means hermetic centrifugal.

*LCC here means initial plus 25-year discounted M&R cost. It does not include energy co

Year Round Operation				Operation: 16 April - 15 October, Barracks and Clin			
lumbia	Fort Worth	Phoenix	Raleigh	Columbia	Fort Worth	Phoenix	Raleig
70-20340	1640-23430	1710-23160	1510-22560	----	----	----	----
60-20210	1590-22810	1640-22210	1490-22300	----	----	----	----
70-57710	4530-64870	4750-64160	4480-66840	----	----	----	----
60-57590	4450-63750	4620-62380	4400-65710	----	----	----	----
10-311750	22860-327580	24430-330080	22950-342410	6900-95610	8390-120200	10090-136340	6940-103
80-254490	19700-282230	21630-292220	19340-288610	5960-82560	7600-108980	10020-135400	6020-89
30-834160	60670-869390	66030-892110	60930-909120	18020-249630	21890-313740	29280-395570	18550-27
40-792770	59440-851720	66030-892110	58730-876310	17500-242320	21890-313740	29810-402710	18290-27
50-58830	4570-65520	4760-64280	4520-67410	----	----	----	----
60-57590	4450-63750	4620-62380	4400-65710	----	----	----	----
30-58590	4640-66550	4890-66060	4580-68350	----	----	----	----
70-57710	4530-64870	4750-64160	4480-66840	----	----	----	----
40-792770	59440-851720	66030-892110	58730-876310	17500-242320	21890-313740	29810-402710	18290-27
60-457880	41060-588400	51880-700840	38070-568050	11700-161960	16880-241900	25150-339720	13010-19
30-834160	60670-869390	66030-892110	60930-909120	18020-249630	21890-313740	29280-395570	18550-27
00-473710	41060-588400	50560-683010	38160-569350	11610-160760	16350-234340	24180-326670	12750-19

e UPW published 18 November 1981 in the Federal Register.

ot include energy costs.

ber, Barracks and Clinics		Operation: 16 April - 15 October, Clinics Only	
Phoenix	Raleigh	Columbia	Phoenix
----	----	----	----
----	----	----	----
----	----	----	----
----	----	----	----
10090-136340	6940-103620	4130-57200	4686-63310
10020-135400	6020-89880	4210-58310	4930-66600
29280-395570	18550-276800	10640-147360	12040-162660
29810-402710	18290-272860	11430-158310	13180-178060
----	----	----	----
----	----	----	----
----	----	----	----
----	----	----	----
29810-402710	18290-272860	11430-158310	13180-178060
25150-339720	13010-194170	11600-160660	14150-191170
29280-395570	18550-276800	10640-147360	12040-162660
24180-326670	12750-190230	10900-150960	13360-180490

7 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

LCC databases for HVAC systems, roofing surfaces, interior finishes, and exterior finishes have been designed and are ready for data development. The floor covering database is complete.

Collection of valid M&R data at the detailed subcomponent level using IFS and existing records is impractical because these records do not include contract data or self-help data, and because data cannot be matched to a portion of a building component.

Developing M&R data by EPS is the best way to obtain consistent, analytically valid data. This method was shown to be feasible by generating sample data.

A programmer's database could be developed by contracting the collection of IFS, contract, and self-help data for a sample of buildings at each of eight installations. This data could be analyzed to compare M&R costs across building type, to determine geographical effects, and to evaluate the effect of building age on M&R costs. A second method is to use EPS or similar methods to develop M&R data at each of the installations. This data would be analyzed in a manner similar to the first method. A third feasible method is to use Red Book data and apportionment models.

Recommendations

Designers Database

The HVAC systems, roofing surfaces, exterior finishes, and interior finishes data should be collected by contract, using the EPS method. Scopes of work for these contracts were developed and forwarded to OCE and should be used when awarding these contracts.

When the databases are completed, they should be tested by two or three Districts for several projects. Results of these tests would indicate whether any modifications are needed before requiring use of the databases by all Districts.

Once the DDB data have been developed, final implementation should be done in the following manner:

1. The summary tables which list yearly M&R for components should be included as an appendix to the applications volume of the TM now being developed on LCCA procedures. The backup data for the yearly numbers and the detailed data on which the backup and yearly numbers are based should be provided to District and Division office libraries for reference use by designers.

2. Occasionally, a designer will need data not included in the database. Detailed instructions for use of the EPS method should be given in the

applications volume of the TM on performing LCCAs. These procedures, plus the detailed data provided by the TM, will allow a designer to develop M&R data when needed.

3. The database should be updated every 4 years. Two aspects should be examined: if any additional building components should be added to the database, and if technological advances have made any of the data obsolete. The updating can be done by an FOA or by contract.

Planners and Programmers Database

Installation Planners. It is recommended that FE personnel use the EPS method to develop M&R costs as needed for renovation alternatives in their economic analysis in the DD Form 1391 submissions for MCA projects. (No database would be maintained.)

OCE Programmers. Method 3 (p 20), which uses information from the Red Book, should be used to develop the M&R data. Yearly updates would be required. The data should be disseminated by yearly letters.

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APPENDIX A:

DISTRICT OFFICE SURVEY QUESTIONNAIRE

DISTRICT LIFE CYCLE COST (LCC) QUESTIONNAIRE

PART I - DATA TYPE AND FORMAT

An effective data collection, storage, and retrieval system to support LCC analysis can only be developed if CE district data needs are identified. This portion of the questionnaire is designed to identify the desired LCC data type and format.

A. Cost Breakdown

1. Which of the following types of cost data do you feel would be most useful (circle letter)?

34% a. Total cost expressed on a per unit basis ($/SF of alternate).

66% b. Cost expressed in terms of the per-unit cost of materials, per-unit cost of installation, per-unit cost of maintenance, and the equipment rental cost, normalized to a per-unit basis.

Comments:____

____

____

____

2. What would be the best way of presenting the cost figures (circle letters)?

45% a. Average: example: cost = $.08/SF/yr

30% b. Range of values: example: cost = $.02 - .08/SF/yr

24% c. Average with confidence interval:

Example: Cost = $.05/SF/yr ± .03 at 95% confidence

(95% of the time the true maintenance cost will be within the interval .03 and .08 $/SF.)

Comments:____

____

____

____

B. Location.

1. Would it be desirable to have data available by geographic location?
Yes *97%* No *3%*

2. f yes, specify grouping (circle choice).

1% a. by installation

32% b. by district

6% c. by division

Comments:

C. Facility Type.

Would it be desirable to have data available by facility type (BOQ's, administration, family housing, etc.)
Yes *88%* No *12%*

Comments:

D. Alternate.

Which level of detail do you feel would be most useful to you in performing life cycle costing (circle number)?

22% 1. Least specific detail which describes the alternate. Example: life cycle cost of flooring type, such as tile floor, carpet, wood floor, etc.

69% 2. Description of type of alternate. Example: life cycle cost of vinyl asbestos tile, nylon carpet, oak strip floor.

9% 3. Description of manufacturer's data for alternate. Example: life cycle cost of Footstrong "Solarina," no-wax asbestos tile, sunburst pattern, yellow.

Comments:

PART II - CURRENT DATA SOURCES

The identification and estimated occurrence of currently used LCC data sources will be surveyed with the following questions. A single source of LCC data references will be created by this portion of the questionnaire.

List of Building Categories

1. Foundations and footings
2. Structural system
3. Exterior walls
4. Roof structure
5. Gutters and downspouts
6. Roof surface
7. Exterior doors
8. Exterior door hardware
9. Windows and glass
10. Interior partitions
11. Ceilings
12. Interior doors
13. Interior door hardware
14. Flooring
15. Bathroom fixtures
16. Plumbing other than fixtures
17. Heating system
18. Cooling system
19. Air-handling system
20. Steam-water system
21. Electric circuitry
22. Lighting fixtures
23. Insulation
24. Other ____________
25. Other ____________
26. Other ____________

A. Data Per Type of Cost.

Is there any difficulty obtaining reliable estimates for the four types of life cycle costs (custodial, annual, cyclical and operating)? Please indicate degree of difficulty by placing the category number in the appropriate column.

	Great Difficulty						Moderate Difficulty					
	17	18	19	20	21	22	17	18	19	20	21	22
Custodial	1	1	1	1	0	0	0	0	0	0	1	2
Annual	2	2	2	1	1	1	0	0	0	1	1	1
Cyclical	2	2	2	1	0	0	1	1	1	2	2	2
Operating (HVAC)	3	3	3	3	0	0	2	2	1	1	1	1

Comments: ____

____

____

____

____

B. Category Potential.

Please indicate which of the categories have the greatest and least potential for cost savings. Place the number on the appropriate line. If you believe a category has greatest or least potential for cost savings <u>only</u> for certain facility types or utilizations, please indicate this limitation in parentheses.

Great potential *Listed in decreasing order of importance: cooling, heating, exterior walls, lighting fixtures, air handling*

Least potential *Exterior door hardware, interior door hardware, interior doors, bathroom fixtures, electric circuitry*

List of LCC Estimate Sources

1. Facility Engineer
2. Trade association
3. Manufacturer's data
4. Professional society
5. Government research
6. University research
7. Private research
8. Government publications
9. Information from architects/ engineers
10. Other ____________
11. Other ____________

C. From the preceding list of cost estimating sources, indicate how often you use each source in making LCC estimates by placing the source's number on the appropriate line.

	1	2	3	4	5	6	7	8	9
Extensively used	48%	17	69	6	19	0	17	10	33
Moderately used	16	30	23	28	19	14	22	30	33
Only used a little	32	30	4	11	29	24	39	50	29
Not used at all	4	22	4	56	33	62	22	10	5

Comments:

D. Do you feel that any of the sources of cyclical and annual maintenance information you use have the potential to provide a CE-wide source of cost data for a particular category? Yes *19%* No *81%*

If yes, name the source and the category.

E. For each of the LCC estimate sources, indicate the credibility and/or applicability of each source by placing the source letter on the appropriate line below.

Source	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Very credible	*48%*	*12*	*46*	*31*	*29*	*24*	*18*	*29*	*22*
Credible	*22*	*59*	*38*	*38*	*35*	*29*	*50*	*29*	*56*
Not credible	*22*	*6*	*4*	*6*	*0*	*6*	*0*	*0*	*6*
Unknown credibility	*9*	*24*	*12*	*25*	*35*	*41*	*31*	*41*	*17*

Comments:

F. In addition to developing a data collection scheme that will fill the districts' LCC needs, CERL must determine which categories to give priority for collecting LCC data. One means of establishing priorities may be to base priority on current maintenance expenditures. Please indicate below which five categories (refer to list of categories) cost the Army the most money to maintain.

Listed in decreasing importance:

flooring, cooling, roof surface, heating, windows and glass.

APPENDIX B:

SUMMARY OF THE LIFE-CYCLE COST DATABASE WORKSHOP,
23-24 JULY 1979, CHAMPAIGN, ILLINOIS

Attendees

The LCC Database Workshop was held 23-24 July 1979 at CERL; Table B1 lists the attendees, who included:

1. Personnel from the private sector who provided current experience in LCC analysis and state-of-the-art concepts in LCC database development.

2. A representative from the Facilities Engineering Support Agency who provided information on IFS and its current and future capabilities.

3. A Veterans Administration representative who provided a view of the problem with different emphasis than the Army's.

4. Representatives from the Districts, Divisions, and installations who provided detailed information about their LCC approaches and available data.

Problem Statement

There are requirements that economic analyses be performed during the MCA process. At the programming phase, justification of decisions such as renovation vs. new construction should normally have some economic basis. At concept design, decisions such as brick walls vs. concrete panels should have an economic basis. In final design work, decisions such as vinyl asbestos tile

Table B1

Workshop Attendees

Atkinson, J.	Southwest Division	Dallas, TX
Fleming, H.	Veterans Administration	Washington, DC
Gagliano, J.	Fac. Engrg. Support Agency (FESA)	Fort Lee, VA
Grulich, R.	Savannah District	Savannah, GA
Haviland, D.	Rensselaer Poly. Inst.	Troy, NY
Kirk, S.	Smith, Hinchman & Grylls	Washington, DC
Kubo, K.	Norfolk District	Norfolk, VA
Lotz, E.	CERL-FS	Champaign, IL
McGee, C.	Master Planning Branch	Fort Bragg, NC
Motichko, M.	Engrg. Resources Division	Fort Sill, OK
Murphree, L.	University of Illinois	Urbana, IL
Neathammer, R.	CERL-FS	Champaign, IL
Schindler, L.	OCE, DAEN-MPE-T	Wash DC
Smith, H.	Engrg. Plans Branch	Fort Benning, GA
Wright, A.	Engrg. Resources Division	Fort Campbell, KY

vs. sheet vinyl floor covering requires an economic basis. In each case, the economic analysis incorporates LCC considerations.

LCC analyses are required by Congress and are necessary to insure that Army facilities are designed economically.

LCC analyses require valid data for which uncertainties (variation) are known.

Conclusions and Observations

Overall, the workshop accomplished its objective of providing guidance for future R&D needed to design/develop the database.

The following conclusions have been made on the basis of information gained during the workshop.

A comprehensive database for all types of building components and subcomponents would be too expensive and is not needed.

A computerized database is not needed.

At least two databases are needed:

1. A database with a gross level of detail for programming/justification purposes. Data would be given for different facility categories and types of construction within categories. This database would be used by installation and OCE personnel.

2. A very detailed database for use by District and installation personnel in final design.

A third database having a level of detail between that of the two databases listed above may also be required by District and installation personnel during concept design.

Detailed databases should be designed and developed primarily for (1) those components requiring large amounts of Army M&R dollars which may be reduced through design, and (2) components which are high-quantity or damage-propagating. Selection of these high-cost items can best be achieved by using data from IFS (and installation records) and the 5-year MCA program. IFS installation tapes with at least one year's valid data can be used to determine those components with high M&R costs for each major facility category. (Check with the installation to verify the costs, since installations may vary somewhat in costing procedures, or some unique occurrence may have inflated the M&R costs.) Through LCC analyses, these high-cost facilities can be compared with planned future construction to select facility types with high potential for M&R savings. A constraint on this procedure is that some high-cost components may not have cost reduction potential through LCC analysis (e.g., plumbing).

MACOMs and installations (through OCE) can use data from IFS for program justification.

The detailed component/subcomponent level database may be obtainable from (1) a survey of FE staffs about their experience with various components/ subcomponents, and (2) use of maintenance standards (Army, Navy, Postal Services, GSA, etc.). The questionnaire can also be used to evaluate climatic/geographic differences among installations for components M&R.

The database should have some logical accounting system (such as UNIFORMAT) for building components. The IFS classification system should also be considered for use with the database when this classification is devised.

Some building components/subcomponents interact; the database structure should contain a cross-index system of such interactions.

Labor costs should be expressed in manhours, rather than dollars, to avoid the inflation problem and to avoid varying regional labor rates.

One way of providing benefit cost data to justify the database is to conduct an LCC analysis of a sample of existing CE designs for which no LCC analyses were performed previously. The high-cost components would be LCC analyzed, and the LCC for several alternates compared. This would show what savings could have been made if an LCC analysis had been performed during the original design. Several project cost ranges and design agencies should be sampled. Potential savings can then be estimated by projecting the sample results to the MCA program.

APPENDIX C:

PROBLEMS IN DATA COLLECTION AT INSTALLATIONS

One problem with collecting M&R data at Army installations is that it represents M&R performed rather than M&R needed. Thus, if $100 were spent on M&R for a building's floors, possibly $1000 should have been spent. M&R emphasis varies among installations because of building conditions, geographical factors, and command/FE philosophies. Allocation of M&R dollars is therefore quite arbitrary and may have little to do with the buildings' actual M&R requirements. To use such cost data, one must assume that this is the best data available and that it represents what is being done and probably will continue to be done. However, it is <u>Army</u> data and represents <u>Army</u> facility use. Use of private-sector data (if it were available) would require development of conversion factors.

Another problem is motivating the craftsmen to record job charges accurately. Most of these workers are not paperwork-oriented, and errors do occur; in addition, there must be some apportionment of hours for small jobs.

Although contract data are not input to the IFS now, there are plans to do so in the future. However, there are several difficulties. The FE staff does not have manpower available to enter the data. Requiring the contractor to do this would increase the recordkeeping and thus increase the M&R contract price. Allocation of costs to building components will be arbitrary; for example, to repair a floor and adjoining wall requires entering costs for two building components (floor, structure). Contractors do not normally keep such detailed cost data. On general maintenance contracts, the FE representative and contractor walk through a building and note what maintenance should be done. The contractor may work on several components in a single building. In this case, no detailed cost record is kept; the inspectors' records show only what work was done.

Self-help data is not entered into IFS. The value of self-help accomplished is not readily available.

Sometimes the estimators do not break a job into sufficiently detailed tasks to allow cost accruals to be made to individual buildings or building components. For example, changing filters and oiling motors on heating systems in 50 similar buildings may be considered as one task and charged to one building.

The K9000 account is a major problem since as much as 8 percent of the charges made against building types listed in the Red Book can not be assigned to individual buildings. The K9000 account is used to distribute labor costs chargeable to more than one detailed account (e.g., costs of awards, interns, and some benefits; acquisition, maintenance, and repair of hand tools and personnel safety equipment; and some equipment rental). These costs cannot be entered into the IFS by specific building; thus, the IFS data will not reflect "cost of doing business," but only direct charges to the building.

Another problem is the Commercial Industrial Type Activity (CITA) contracting now being done. Functions of the FE are being contracted. It is not known how, if at all, M&R data for their services will be entered into the IFS.

One final problem is that FE organizations are understaffed. Thus, there is little they can do either to collect M&R data or to help others do so.

APPENDIX D:

SUMMARY OF LIFE CYCLE COST DATABASE DESIGN WORKSHOP, 1-2 JUNE 1981, ARLINGTON, VA

The Life Cycle Cost (LCC) Database Design workshop was held 1-2 June in Arlington, VA. Twenty-seven representatives from District and Division offices, installations (FE organizations), HQ FORSCOM, HQ TRADOC, FESA, the private sector, OCE, GSA, and CERL attended. Table D1 lists the persons attending.

The purpose of the workshop was to present results of CERL research on the database to future users, interested organizations, and experts in LCCA. Input from these groups would be used in the final phase of the research.

The following sections summarize the discussions and results of the workshop.

Review of the Problem

Dr. Larry Schindler discussed requirements for LCCA and the database and future plans in the Corps of Engineers. LCCA is required by the Construction Criteria Manual, DOD 4270.1-M. ETL 1110-3-296 gives policy and criteria for performing LCC-based economic studies. Various laws and Congressional directives also require economic/LCC analyses.

The planners/programmers need a database which shows M&R costs for existing facilities by age, type of construction, and facility classification. This data is needed for both as-built and renovated facilities. Designers need a database of M&R costs to help them compute LCC for various facility design alternatives. A two-part designers' manual is being developed: a handbook for direct use, and a source book with general supporting information. The database will be used with these manuals. A training program for performing LCCA and using these tools will be developed if it is required. A new ETL on economic analysis is nearly completed.

Progress to Date

Earlier research noted three ways to obtain information for the database. The first -- manual recording of data -- was tried unsuccessfully at Fort Ord. The second option -- IFS -- was considered a source of M&R data, but changes to the data entry format would have been required to obtain IFS outputs at the subcomponent level (i.e., type of floor covering, roofing, plumbing item repaired, etc.). These changes were not considered feasible because of excessive costs and the additional effort required of FE personnel for FE data input. The third option was to purchase an existing database and adapt it for Army uses; however, no database was found.

Table D1

List of Attendees

Atkinson, Jim	ME, Electrical Mechanical Sec	Southwest Division, Dallas, TX
Averyt, Joe	CE, Systems Engineering Branch	Huntsville Division, Huntsville, AL
Bacon, Tony	IFS Officer, Eng Res Mgmt Div of FE	Ft. Stewart, GA
Borton, Leonard	Arch, Eng Div, Design Br	Savannah District, Savannah, GA
Burroughs, Ed	IE, Chief, Installation Br of FE	Eng. Activity, Capital Area, Ft. McNair, Washington, DC
Carter, Don	Installation Br of FE	Eng. Activity, Capital Area, Ft. McNair, Washington, DC
Cranbo, Bill	Prog Div, Prog Dev & Budget Br	Office of Chief of Engineers, Washington, DC
Czsimadia, Tibor	Arch, Facilities Systems Div	USA CERL, Champaign, IL
Deacon, Ron	O&M Div, Management Br	Office of Chief of Engineers, Washington, DC
Ellis, Dan	ME, Mechanical Section	Ft. Worth District, Ft. Worth, TX
Finkemeier, Ted	Arch, Chief, Architectural Sec	Kansas City District, Kansas City, MO
Hammerschmidt, Ted	IET, Acting Chief, Eng Res Mgmt Div	Ft. Polk, LA
Jaekley, Richard	IE, Chief, Mgmt Eng Systems Br of FE	Ft. Sill, OK
Kirk, Stephen	Consultant, Smith Hinchman and Grylls	Washington, DC
Muller, Gus	Chief, Civil and Env Eng Br of Eng Div	Office of Chief of Engineers, Washington, DC
Murphree, Lile	Consultant, Sage Systems Inc	Urbana, IL
Neathammer, Bob	OR Analyst, Facilities Systems Div	USA CERL, Champaign, IL
Ostrander, Virgil	Program Director, Operations & Maintenance	Public Bldg Service, GSA, Washington, DC
Ralph, Ken	Facilities Eng Supp Agency, Supp Impl Br	Ft. Lee, VA
Reardon, Robert CPT	Engineering Mgmt Div	HQ, TRADOC, Ft. Monroe, VA
Roberts, Charles	Chief, Resources Mgmt Div of FE	Ft. Knox, KY
Schindler, Larry	ME, Technical Monitor, Eng Div	Office of Chief of Engineers, Washington, DC
Small, Henry	ME, Chief, Env control Sec. EM Br	Mobile District, Mobile, AL
Stoudenmire, Ray	GE, Resources Mgmt Div	HQ, FORSCOM, Ft. McPherson, GA
Witherspoon, Ray	Consultant, Hanscomb Associates	Atlanta, GA
Wright, Arlin	IE, Supervisor, Mgmt Engr Systems Br of FE	Ft. Campbell, KY
Zulkofske, Ed	Eng Div, Electr & Mech Sys Br	Office of Chief of Engineers, Washington, DC

One phase of the earlier work was to survey District Office designers to determine their needs. The survey established the desired level of data detail, that a range of values was desirable, that designers' available data sources were not usable Corps-wide, and that little LCCA was being performed (1979).

Progress since the first workshop held in July 1979 is summarized below:

Planners and Programmers Database (PPDB)

Data from the Red Book was thoroughly analyzed to see if it or the installation data used to compile the Red Book could be used. This data was not usable. The accounting system used for this data was not designed to yield total M&R costs by facility class and/or age.

Designers Database (DDB)

M&R data from the IFS system was found unsatisfactory because:

1. Subcomponent level detail is lacking

2. M&R costs performed by contract are not included

3. Certain prorated overhead costs are not included

4. Errors are caused by improper entries by workers and because times must sometimes be apportioned

5. Task levels for work orders may have insufficient detail.

Ranking of Components

Data collected at Forts Knox and Sill in FY80, along with the results of the District designer questionnaires were used to rank building components in terms of database importance. Figure D1 shows the ranking. HVAC systems ranked highest, followed by floor coverings and electrical. Use of the 5-year MCA plan for predicting which facilities would be built, and thus which components would be important, was discarded after a check showed that line items on the plan changed 50 percent in 1 year.

Data Collection

IFS showed potential for PPDB development. If M&R costs incurred by contract and data on M&R work done through self-help can be collected with the IFS data, then all of this data can be developed and used for the PPDB. However, changes required in IFS and the effort required by the FE staff make using IFS impractical.

Engineered Performance Standards (EPS)

The steps for using EPS to develop M&R cost data are:

1. A preventive maintenance schedule is developed, and each job is broken into tasks.

RANKING OF COMPONENTS BY POTENTIAL LCC SAVINGS, SURVEYS 1 & 2 COMBINED	RANKING OF HIGH COST M&R COMPONENTS, SURVEYS 1 & 2 COMBINED	IFS & CONTRACT DATA, FY78-79 FORTS KNOX & SILL	OVERALL
1 COOLING	1 FLOORING	1 HEATING	1 HEATING
2 HEATING	2 COOLING	2 STRUCTURE	2 COOLING
3 EXTERIOR WALLS	3 ROOF SURFACE	3 PLUMBING	3 FLOORING
4 LIGHTING FIXTURES	4 HEATING	4 INTERIOR PAINT	4 ELECTRICAL
5 AIR HANDLING	5 WINDOWS & GLASS	5 FLOORS	5 STRUCTURES
6 WINDOWS & GLASS	6 LIGHTING FIXTURES	6 ELECTRICAL	
7 FLOORING	7 EXTERIOR WALLS	7 COOLING	
8 STEAM-WATER SYSTEM	8 INTERIOR PARTITIONS	8 ROOFS	
9 ROOF STRUCTURE	9 AIR HANDLING	9 EXTERIOR PAINT	
	10 GUTTERS & DOWNSPOUTS		

Figure D1. Ranking of building components.

2. Frequencies of component failure are estimated, and each repair job is broken into tasks.

3. EPS are used to develop manhours required for the task, and to estimate the quantities of materials and equipment needed for each year over a 25-year life.

Figures D2 through D7 give the formats for four EPS databases. Contracts were awarded for three sample databases:

1. A heating system for a five-company administration building -- Bendix Field Engineering Corp., completed in March 1981.

2. Floor covering systems (all types of systems for all facility classes) -- Planned Maintenance, Inc.; completed in July 1981.

3. Cooling generation systems (some types of systems) -- Service Engineering, Inc.; completed in July 1981.

| | | Manhours/Year | | | | | | | | | | | | | | | | | | | | | | | | |
Component Alternative		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
01	FURNACES																									
0101	Gas Fired																									
0102	Oil Fired																									
0103	Coal Fired																									
0104	Electric																									
02	STEAM BOILERS																									
0201	High Pressure-Gas Fired																									
0202	High Pressure-Oil Fired																									
0203	High Pressure-Coal Fired																									
0204	Low Pressure-Gas Fired																									
0205	Low Pressure-Oil Fired																									
0206	Low Pressure-Coal Fired																									
03	HOT WATER BOILERS																									
0301	Gas Fired																									
0302	Oil Fired																									
0303	Coal Fired																									
0304	Electric																									
04	AUXILIARY EQUIPMENT																									
0401	Burners and Stokers																									
0402	Tanks and Tank Heaters																									
0403	Pumps and Deaerators																									
0404	Heat Exchange/Recovery																									
0405	Boiler Breaching and Draft Control																									
0406	Boiler Water Treatment																									

Note: (1) If M&R requirements vary among facility classes, a table will be developed for each class.
(2) A similar table will be developed for materials, supplies and equipment requirements.

Figure D2. Heat generation systems -- less than 750K Btu/hr.

Manhours/Year

Component Alternative		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
01	FURNACES																									
0101	Gas Fired																									
0102	Oil Fired																									
0103	Coal Fired																									
0104	Electric																									
02	STEAM BOILERS																									
0201	High Pressure-Gas Fired																									
0202	High Pressure-Oil Fired																									
0203	High Pressure-Coal Fired																									
0204	Low Pressure-Gas Fired																									
0205	Low Pressure-Oil Fired																									
0206	Low Pressure-Coal Fired																									
03	HOT WATER BOILERS																									
0301	Gas Fired																									
0302	Oil Fired																									
0303	Coal Fired																									
0304	Electric																									
04	AUXILIARY EQUIPMENT																									
0401	Burners and Stokers																									
0402	Tanks and Tank Heaters																									
0403	Pumps and Deaerators																									
0404	Heat Exchange/Recovery																									
0405	Boiler Breaching and Draft Control																									
0406	Boiler Water Treatment																									

Note: (1) If M&R requirements vary among facility classes, a table will be developed for each class.
(2) A similar table will be developed for materials, supplies and equipment requirements.

Figure D3. Heat generation system -- 750 K -- 3.0 million Btu/hr.

Component Alternative		Manhours/Year																								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
01	FURNACES																									
0101	Gas Fired																									
0102	Oil Fired																									
0103	Coal Fired																									
0104	Electric																									
02	STEAM BOILERS																									
0201	High Pressure-Gas Fired																									
0202	High Pressure-Oil Fired																									
0203	High Pressure-Coal Fired																									
0204	Low Pressure-Gas Fired																									
0205	Low Pressure-Oil Fired																									
0206	Low Pressure-Coal Fired																									
03	HOT WATER BOILERS																									
0301	Gas Fired																									
0302	Oil Fired																									
0303	Coal Fired																									
0304	Electric																									
04	AUXILIARY EQUIPMENT																									
0401	Burners and Stokers																									
0402	Tanks and Tank Heaters																									
0403	Pumps and Deaerators																									
0404	Heat Exchange/Recovery																									
0405	Boiler Breaching and Draft Control																									
0406	Boiler Water Treatment																									

Note: (1) If M&R requirements vary among facility classes, a table will be developed for each class.
(2) A similar table will be developed for materials, supplies and equipment requirements.

Figure D4. Heat generation systems -- more than 3.0 million Btu/hr.

Manhours/Unit of Linear Ft

Year

Component Alternative		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
01	AIR DISTRIBUTION																									
0101	Fans																									
0102	Motors and Drives																									
0103	Plenums and Casings																									
0104	Coil Sections																									
0105	Ductwork																									
0106	Duct Accessories																									
0107	Mixing Boxes; Pressure, Reheat																									
0108	Filters																									
0109	Humidity Control																									
0110	Heat Recovery Equipment																									
0111	Anti-Vibration Equipment																									
02	EXHAUST VENTILATION																									
0201	Air Exhausters																									
0202	Ventilators																									
0203	Air Make-up Fan																									
0204	Air Make-up Motor and Drive																									
0205	Air Make-up Plenums and Casings																									
0206	Air Make-up Filter Section																									
0207	Air Make-up Motorized Damper																									
0208	Air Make-up Heating Section																									
0209	Ductwork																									
03	STEAM DISTRIBUTION																									
0301	Pipe and Fittings																									
0302	Valves																									
04	WATER DISTRIBUTION																									
0401	Pipe and Fittings																									
0402	Valves																									
0403	Expansion Joints and Specialties																									
05	TERMINAL UNITS																									
0501	Baseboard Heating Unit																									
0502	Convector Heating Unit																									
0503	Induction Unit																									
0504	Enclosures and Cabinets																									
0505	Fan Coil Units																									
0506	Radiators																									
0507	Duct on Unit Mounted Coils																									
0508	Finned Tube Elements																									
0509	Radiant Water Heating system																									
0510	Unit Heater																									
0511	Grills																									
0512	Registers																									
0513	Diffusers																									
06	PACKAGED UNITS																									
0601	Space Heaters																									
0602	Heat Pumps																									
0603	Dehumidifiers																									
07	CONTROLS																									
0701	Thermostats																									
0702	Control Valves																									
0703	Relays																									

Note: A similar table will be developed for materials, supplies and equipment requirements.

Figure D5. Heating/cooling distribution systems.

Manhours/Unit

Year

Component	Alternative	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
01	COMPRESSORS																									
0102	Reciprocating																									
0103	Centrifugal																									
0104	Screw																									
02	CONDENSERS																									
0203	Water Cooled																									
020301	Shell & Tube Horizontal																									
020302	Shell & Tube Vertical																									
020303	Shell & Coil																									
020304	Double pipe																									
020305	Atmospheric																									
0204	Air Cooled																									
0205	Evaporative																									
03	EVAPORATORS/LIQUID COOLERS																									
0301	Flooded Shell & Tube																									
0302	Spray																									
0303	Direct Expansion																									
0304	Double Tube																									
0305	Shell & Coil																									
04	AUXILIARY EQUIPMENT																									
0401	Motors - Open or Hermetic																									
0402	Pumps																									
0403	Expansion Valves																									
0404	Controls																									
0405	Piping																									
0406	Refrigerant																									
0407	Purge Units																									
0408	Oil Heaters																									
0409	Lubricating Systems																									
0410	Bearings																									
0411	Seals																									
05	COOLING TOWERS - FACTORY ASSEMBLED OR FIELD ERECTED																									
0501	Direct Contact - Non Mechanical Draft																									
050102	Spray Towers																									
050103	Ejector Towers																									
050104	Hyperbolic																									
0502	Direct Contact - Mechanical Draft																									
050201	Induced Draft																									
050202	Forced Draft																									
050203	Special Purpose (Wet/Dry)																									

Note: A similar table will be developed for materials, supplies, and equipment requirements.

Figure D6. Cooling generation systems.

Manhours Per Square Foot
Average Use/Severe Use

Year

Component		1	2	3	4	5	6	7	8	9	10	11	12	13	14	14	15	16	17	18	19	20	21	22	23	24	25
01	TILE AND TERRAZZO																										
0101	Ceramic Tile, MUDSET																										
0102	Ceramic Tile, Thinset																										
0103	Ceramic Tile, Overwood																										
0104	Quarry Tile, MUDSET																										
0105	Quarry Tile, Thinset																										
0106	Terrazzo Finish																										
0107	Precast Terrazzo																										
02	WOOD FLOORING																										
0201	WoodStrip																										
0202	Hardwood Parquet																										
0203	Maple floor																										
0204	Other																										
03	RESILIENT																										
0301	Asphalt Tile																										
0302	Vinyl tile																										
0303	Vinyl Asbestos Tile																										
0304	Linoleum Sheet																										
0305	Vinyl sheet																										
0306	Nylon Carpet w/rubber Padding																										
0307	Nylon Carpet w/Integrated Padding																										
0308	Wool Carpet w/Padding																										
0309	Wool Carpet w/Integrated Padding																										
0310	Other																										
04	MASONRY																										
0401	Concrete																										
0402	Brick																										

Note: A table will be developed for each building type:

219 - Maintenance Facilities	610 - Administrative Buildings
310 - Research, Development and Test Facilities	710 - Family Housing
	721 - EM Barracks
442 - Storage	722 - Bachelor Housing - Mess Facilities
510 - Hospitals	723 - Bachelor Housing - Detached Facilities
540 - Dental Clinics	723 - BOQs
550 - Dispensaries	740 - Community Facilities

Note: A similar table will be developed for materials, supplies, and equipment requirements.

Figure D7. Floor covering systems.

Results of the Workshop

After discussion of recent progress, attendees were split into two discussion groups. The FE personnel, FESA representative, MACOM personnel, and some OCE personnel discussed data collection at installations. The District/Division designers, private consultants, and some OCE personnel discussed the database formats and use. Results of these two meetings were then presented to the whole group.

FE Group

The FE group assessed the feasibility of collecting PPDB data at the installations. IFS summarizes inhouse costs by building. Contract M&R data could either be added to the IFS files or added in a separate analysis. A special effort would be needed to collect information on M&R work accomplished through self-help. The Facility Engineer Supply System (FESS) could be used to identify supplies/materials and users. Normally, self-help is in the area of painting, faucet repair, filter changes, etc. No repairs to HVAC systems, structures, floors, etc., are done through self-help. Most self-help is done in troop areas where many soldiers are available for these tasks. However, the group noted that industrial-funded installations compute overhead differently, so an adjustment would be necessary if FESS was used. The amount of time required to monitor a maximum of 480 buildings at a post and collect IFS data, contract data, and self help data was discussed. Based on the discussions, it was estimated that one person would be required to monitor the buildings and collect the data.

The Facility Engineers Equipment Maintenance System (FEEMS) is used for M&R of the critical equipment in a hospital. It was suggested that FEEMS could be used to monitor M&R of buildings in general rather than hospital equipment. However, this would involve more FE staff time and additional installation computer time, both of which are scarce resources.

Another suggestion was to derive failure rates by monitoring building component failures. This would provide DDB input data that would be based on actual experience.

The ranking of building components according to M&R costs was also discussed. The ranking in Figure D1 is satisfactory, except for roofing, which is considered a high-cost M&R component.

The IFS system is currently undergoing major revision, so any recommended changes should be discussed with FESA now.

One problem is that partial or entire FE operations are contracted out on various posts. Thus, since no detailed records are required of the contractor, valid data collection at these posts would be nearly impossible.

District/Division Group

This group assessed how usable sample databases developed by CERL would be to designers. The concept and design of the sample databases shown in Figures D2 through D7 were discussed. A general suggestion was that information be presented in the simplest and most usable form possible. Designers need data at the system/subsystem level; this data can easily be adjusted for inflation at the time of a study. The consensus was that installations should not provide cost information. Four major changes in the database were suggested:

1. Present the data on a system or subsystem rather than a component basis, since once concept design is complete, it is too late in the design process to do LCCAs, (i.e., systems and subsystems should correspond to designer thinking.)

2. Give an annual average for 25 years of all continuing or regularly recurring costs; itemize each special one-time item.

3. List the averages per year plus special items for each labor skill.

4. Give the material supplies and equipment cost as a percentage of initial construction cost.

These suggestions were specifically for the HVAC databases; however, whether they are applicable to other design features, such as electrical, architectural, etc., must be determined. The reason for change 1 (above) was that the HVAC *designers'* "*design process*" is in *system* terms. It was suggested that BLAST and TRACE be examined for guidance in summing components to subsystem or system levels. The HVAC databases were put in their present form to allow designers to assemble a virtually unlimited number of component combinations. The consensus was that there is not an unlimited number of combinations; i.e., the number of systems that designers consider as possible design solutions is reasonably finite (perhaps 20 to 50). Some of those systems require similar M&R. Major decisions on system and subsystem selection are made early in the design process (first, second, or third decision points). Decisions on components are made too late in the design process to make effective use of LCCA.

It was suggested that CERL check applicable guide specifications to insure that all relevant components in these documents were included; in addition, components that are used often, but which are not listed should also be in the databases.

The same HVAC systems databases can be used for different facility classes; however, different ones are needed for different operating load profiles. Separate databases might be needed for different facility classes if HVAC systems were used for applications other than space conditioning (e.g., heating domestic hot water).

All Districts represented at the workshop are now conducting LCC studies routinely; however, these studies are limited almost entirely to the building's energy-consuming portions. M&R data is now guessed at rather than known.

CERL should determine current criteria on size versus type limitations in an HVAC area. Also, several additions were suggested to the lists of HVAC components shown. Units used for the components/systems should agree with those contained in BLAST.

The cooling generation systems database may have to be broken into various system sizes as done on the heat generation systems.

Combined Groups Session

Following the discussion groups, the attendees discussed the overall work unit. The following points were made:

The EPS method of developing M&R cost data is best. The Bendix report on a heating system (based on EPS) was very good.

The EPS method could also be used to develop M&R costs for existing facilities; i.e., the PPDB could be developed analytically, rather than through data collections from installations.

A check on the failure frequencies of EPS-developed databases can be made by sampling failure rates of building components at installations.

There was concern that inaccuracies would result if system or subsystem M&R costs were developed by combining M&R component costs. Such inaccuracies would result from tertiary effects; for example, a failure of one component could cause others to fail, or failures can occur in component assemblies that do not occur in individual components, etc.

The numbering system in the proposed databases is now arbitrary. UNIFORMAT is considered best for the database, although it was pointed out that the cost-estimating system currently being developed by the Middle East Division for Corps-wide use is based on the Construction Specifications Institute format.

Conclusions

The EPS method of developing M&R cost data is presently the best way of obtaining the DDB. The first use of the method (the Bendix report) was satisfactory.

HVAC designers cannot easily use current database formats.

With some exceptions, design databases are needed more for different operating load profiles than for different facility classes.

Data for the PPDB can be collected at the installation level by on-site personnel (or by contractor) from existing records and by checking the self-help program.

Recommendations

The EPS method of developing M&R cost data for the DDB should be continued.

Design databases should be provided at a more summary level, with detailed databases such as those shown in Figures D2 through D7 serving as backup. The summary databases should show M&R costs in terms of average labor (manhours per year per labor skill). Costs that are, in essence, one of a kind (i.e., not continuous or regularly occurring) should be separated from the yearly average. Materials, supplies, and equipment costs should be expressed as a percentage of initial cost when possible.

For HVAC systems, the component concept should be used for backup data, but system and subsystem databases should be given. BLAST and TRACE should be used to help define possible HVAC systems and subsystems.

Separate data should be developed for HVAC systems for different operational requirements but not usually for different facility classes.

Guide specifications should be checked to verify the component lists.

Data for the PPDB should be collected on-site, using IFS, contract data, and self-help data, and adjusting for M&R backlog.

The possibility of developing PPDB data by means of the EPS method should be examined.

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