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Knowledge Base on Alternative Construction Methods

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Development of a Knowledge Base on Alternative Construction Methods

by
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Several building technologies and practices have emerged in recent years as alternatives to traditional design and construction in meeting cost, time, and quality goals of owners and builders. Some of these methods have been adopted within private industry, but have not yet seen wide use for military construction. However, legislation from Congress has mandated that the military services now consider using such methods when they have a potential to reduce Federal expenditures for construction.

The U.S. Army Corps of Engineers (USACE), which is responsible for construction within the Army and Air Force, has a limited background in using alternative methods due to the long reliance on traditional approaches to facility procurement. To expedite the learning process and capitalize on lessons learned from projects using alternative methods, USACE proposed that a knowledge base be prepared. The U.S. Army Construction Engineering Research Laboratory (USACERL) is responsible for its development.

This report describes the knowledge base concept and prototype. The prototype uses dBase III Plus software and IBM-compatible personal computers. Data will be both factual listings (e.g., project name, date, location) and informational (e.g., comments about a problem in the design phase). Access will be via a local data base containing installation-specific projects and through a centralized main-frame system containing USACE-wide projects.

Although useful by itself, the conceptual knowledge base would be a more effective tool if it were incorporated into an expert system. Such a system would provide decision support in addition to an advisory function. The knowledge base could be used to complement the expert system data base. It is recommended that the Army pursue development of an expert system for alternative construction methods; lessons learned and data collected for the prototype knowledge base can provide valuable input to the system.

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FOREWORD

This research was conducted for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Project 4A162734AT41, "Military Facilities Engineering Technology"; Work Unit BO-049, "Knowledge Base on Alternative Construction Methods." The HQUSACE Technical Monitor was T. Hodges, CEMP-EA.

The work was performed by the Facility Systems Division (FS) of the U.S. Army Construction Engineering Research Laboratory (USACERL). Savannah District personnel contributed to this study. The USACERL technical editor was Dana Finney, Information Management Office.

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DEVELOPMENT OF A KNOWLEDGE BASE ON ALTERNATIVE CONSTRUCTION METHODS

1 INTRODUCTION

Background

Several building technologies and practices have emerged in recent years as alternatives to traditional design and construction in meeting cost, time, and quality goals of owners and builders. Some of these methods are used frequently in commercial markets, but are not yet widely accepted within the U.S. Army Corps of Engineers (USACE) as standard practice.

The House of Representatives Committee on Armed Services (HASC) and Committee on Appropriations (HAC) have each explored alternative construction methods and have encouraged the military services to employ different construction techniques that may prove less costly than conventional practices. Both HAC and HASC reports since FY84 and the FY87 Military Construction Authorization (MCA) Act¹ include guidance on alternative construction methods. (These methods are described in Chapter 2 of this report.)

USACE has an enormous amount of expertise and experience in the traditional design and construction practices. However, the same background and depth of experience with alternative methods have not yet been established within USACE. If alternative construction methods are to be encouraged and used more widely within the Army, experiences, lessons learned, cause-and-effect relationships--i.e., "knowledge"--about these methods must be disseminated and institutionalized.

An automated knowledge base has been proposed as an effective means of expediting this process. This knowledge base will help persons with little experience in alternative construction methods make intelligent decisions when administering a project using these methods. USACE has asked the U.S. Army Construction Engineering Research Laboratory (USACERL) to develop this system.

Objective

The objective of this research is to develop a knowledge base to capture and disseminate experiences and knowledge about USACE projects that use alternative construction methods. The specific objective of this Technical Report is to describe the conceptual structure used in developing the prototype knowledge base.

Approach

The knowledge base concept was developed at USACERL by identifying USACE's specific needs and applying fundamental data base development theory. USACERL then monitored several Military

¹House of Representatives Committee on Appropriations Report No. 98-238, *Military Construction Appropriations Bill 1984* (June 9, 1983); House of Representatives Committee on Appropriations Report No. 99-275, *Military Construction Appropriations Bill 1986* (September 15, 1985); House of Representatives Committee on Appropriations Report No. 99-366, *Military Construction Appropriations Act 1986* (November 12, 1985); House of Representatives Committee on Appropriations Report No. 99-618, *Military Construction Appropriations Bill 1987* (June 1986).

Construction, Army (MCA) projects that used alternative construction methods in order to document experiences of USACE, its contractors, and other participants. For the prototype knowledge base, data from 18 of these projects were incorporated. The final knowledge base system will contain data from more projects; for this reason, USACERL is continuing to monitor alternative construction projects and collect data.

Scope

The knowledge base will ultimately represent each alternative construction method described in Chapter 2, as well as related methods not explicitly described in this report. Currently, the knowledge base includes fabric and modular construction and one-step acquisition procedures. These methods were selected as the prototype for the knowledge base development due to the high level of interest for them and a number of current projects within USACE. Other methods could be included as they are tested in MCA programs.

Project data from other sources (both Government and private) would be a worthwhile contribution to the knowledge base. However, current funding supports only the evaluation of MCA projects.

Mode of Technology Transfer

The final product of this research will be an automated knowledge base system to disseminate data, experiences, and lessons learned about MCA projects involving alternative construction methods.

2 PROGRAM DEVELOPMENT

Alternative Construction Methods

In House Report (HR) 98-238, 9 June 1983, HAC encouraged the military services to pursue "Alternative Construction Methods" on a selected basis. The following excerpt from the HR explains the position adopted:

The high cost estimates for many relatively simple construction projects have resulted in the Committee exploring initiatives to obtain construction goals at lower costs. The Committee held a special hearing this year to review construction alternatives that might help reduce military construction costs. Representatives from the business community testified on various methods that could be used instead of traditional construction. It is apparent that the use of nontraditional building methods on a selected basis can reduce Federal expenditures for construction.

The Department is to pursue the use of nontraditional construction in the following manner:

- (1) Construction techniques. The Services are to explore alternative construction techniques for specific projects identified in the Service sections;
- (2) Turnkey. The Services, where appropriate, should consider turnkey (both one- and two-step) contracting;
- (3) Packaging. The Services should package similar small projects at the same site or proximity as a way of reducing repetitive contracting costs;
- (4) Standard design and one-step procurement. Repetitive projects, such as warehouses, covered storage and small maintenance facilities, should be evaluated in terms of their standard design and possible cost savings through one-step procurement;
- (5) Performance specifications. The Services are to select specific facilities in the fiscal year 1984 bill to be tested through the use of performance type specifications (sufficient exigent minor construction funds are available for this purpose);
- (6) Legislative actions. The Department is to advise the Committee on what legislative actions are necessary to allow for the use of nontraditional construction; and
- (7) Materials, modular and prefab. The Services are to take maximum advantage of the latest materials, techniques and technology of construction and off-site prefabrication of buildings and structural components, including modular construction.

The Committee wants the Department to be prepared to report during the fiscal year 1985 hearings on the results of the efforts described above.

In HR 98-166 (16 May 1983), HASC directed the military services to conduct demonstration tests of frame-supported architectural fabric structures on six projects in the FY84 MCA program. Three Army projects were designated in that report.

Subsequent HAC and HASC reports, as well as the FY87 Military Construction Authorization Act, include provisions regarding the military services' use of alternative construction methods. They direct the services to continue using these methods on a selected basis and to evaluate their effectiveness compared with traditional practices.

Clarification of the term "alternative construction methods" will be helpful in understanding the topic area and the objectives of this research. Congressional language describes alternative or nontraditional methods in essentially two areas: construction technology (e.g., modular construction) and facility acquisition procedures (e.g., One-Step "Turnkey" contracting). For the purposes of this Technical Report, "alternative construction methods" is understood to mean any method or technique relative to building technology, procedures, or other aspects of facility acquisition that are not regularly employed by USACE. Methods not explicitly described in the Congressional directives (such as third-party contracting) should also be considered alternative construction methods.

Knowledge Base Content

It was determined that the knowledge base should be developed using fabric and modular construction and the One-Step Facility Acquisition procedure as "prototype" alternative construction methods. It was anticipated that One-Step "Turnkey" procedures will be implemented in MCA programs on a wider basis in the near term than other methods described or implied by Congressional directives. Thus, there will likely be more examples from which to draw information and experiences as well as a wider potential for applying information on One-Step "Turnkey" projects.

The FY87 Military Construction Authorization Act authorizes the Army to initiate up to three One-Step "Turnkey" projects per year. It is anticipated that this language will remain in effect through the FY91 MCA program. The knowledge base will consist of these MCA projects and additional One-Step "Turnkey" projects that will be identified in subsequent MCA programs. Other One-Step "Turnkey" projects from different programs (e.g., Non-Appropriated Funding and Air Force projects) may also be entered into the knowledge base, as resources permit.

Alternative construction methods will be entered into the knowledge base as they are employed in MCA projects. Some projects using architectural fabric structures or modular construction have either been completed already or are in progress. Other Army projects also are being initiated that will involve third-party financing, design, construction, operation, and maintenance. The data structure for each alternative construction method will be unique to some extent, but will be similar enough that one conceptual knowledge base structure will be applicable to all such methods.

The knowledge base is being developed using specific projects as sources of input. Although it reflects interpretative information, it does not incorporate formal knowledge derived from expert input or other outside sources. Therefore, a distinction must be made between the knowledge base described in this report and a knowledge base within an expert system.

In computer science, the term "knowledge base" normally refers to a formalized collection of facts, rules, frames and relationships between objects, and is accessed and applied in solving difficult problems. This application of "knowledge" is usually performed using predefined methods of inference, such as backward chaining inference (for rules) or taxonomic inheritance (for frames). The knowledge is acquired from experts during interviews, problem-solving sessions, and similar interactions, and is then recast into the formal knowledge representation structure of rules and frames. This process, known

as "knowledge engineering," is extremely time-consuming due to the iterative nature of extracting knowledge from experts.

The term "knowledge base" as used in this report implies a data base management software package to store and retrieve information. The knowledge is being acquired from experts in the form of interviews and statements, but has not been formalized into a manipulatable form. However, this knowledge base is also more than just a traditional data base in that experiences and judgments are being stored. It would perhaps be more appropriate to use the term "information base" in describing the as yet unformalized knowledge in this "knowledge base"; however, for simplicity in achieving the goals of this report, "knowledge base" is used.

Users

The primary users will be personnel working at the District level in managing alternative construction methods on a day-to-day basis (e.g., preparing Requests for Proposal [RFPs], selecting proposals). Other potential users are HQUSACE and Major Commands (MACOMs) involved mainly with selecting adequate types of facilities for using alternative construction methods.

It is important to define the typical user as a person with little or no first-hand expertise in alternative construction methods. The lack of expertise in this area is due mainly to the small number of projects within the Army that have used alternative methods to date. As the number of projects increases in the future and alternative construction methods see wider use, this lack of expertise will diminish. The knowledge base is envisioned as a tool to expedite this process.

Potential Benefits

The user will receive direct and immediate benefit from using the knowledge base. The ultimate system will be designed to allow project managers to record events that will be useful for analyzing progress, reporting, and supporting decisions. To summarize, the knowledge base will:

1. Provide data base management
2. Generate customized reports
3. Aid in decision-making.

The knowledge base will organize and store data (names, dates, text) in the same way for all projects. This method of organizing will help the project manager enter and retrieve information since the storage format will be similar for all projects.

The knowledge base will be able to generate reports automatically at any time. Users will have the option of printing any or all information, depending on their needs. Also, the project managers will have the opportunity of selecting an existing report format or generating their own to include only those elements desired.

The decision-making function will allow users to retrieve information concerning specific problems. They will be able to compare all data from each project and make a decision based on this past experience. Managers will have a way to support their decisions by citing these similar projects.

3 DATA ACQUISITION AND CONTENT

Data Acquisition

The traditional method of obtaining information for a data base is to go into the field and talk to personnel involved in construction projects. This convention has not been the most practical, however, due to the time required for field personnel to gather the requested information or to spend interviewing.

For the knowledge base, data are being compiled as a coordinated activity between project managers for different projects and the personnel who will maintain the system. The final system will be designed such that project managers will feed the data base while recording facts during day-to-day work. Information retrieval for the local project will be a direct interaction between the project manager and the knowledge base in his/her computer, whereas the information from other projects will be searched through a communication system or from diskettes.

Data Elements

The knowledge base consists of basic components called "data elements." These elements define the pieces of information required for documenting the project. Data elements for the knowledge base are divided into nine different levels. These levels are defined in chronological order:

- Project identification
- A/E selection
- RFP development
- Advertisement
- Proposal development
- Proposal evaluation and selection
- Construction document review and approval
- Construction
- Occupancy.

Project identification contains general project information, such as project name, location, number, and fiscal year (the four key items), and names of project managers. The four key items as a group must differ for each project since they are used to discriminate among projects. This information is supplied by the District and the project managers.

A/E selection is the second level and, if applicable, contains information about the architect/engineer (A/E) firm hired to produce the RFP. This information is provided by the project manager.

The next level in the data structure is RFP development, which includes dates for all stages of RFP development, the cost, a description of all specifications, and amendments. Information for this level can come from three sources: the A/E contract, the RFP, and the project manager.

Another level of the data structure provides information on advertisement, including the dates for fund authorization and advertisement, a description of the advance notice, and the actual advertisement. The project manager supplies this information.

Proposal development is the fifth level of the data structure. The types of information at this level are all dates associated with the proposal, the proposers' submittal requirements, any remarks concerning the preproposal meeting, and any new, innovative technologies used. Data can be sought from the RFP, the project manager, proposers, and the proposals.

The proposal evaluation and selection level contains data such as the proposers' names, the evaluation point distribution, values of all proposals, a description of the evaluation team, the length of time for evaluation, and any comments made by the proposers. Information is provided by the project manager, evaluation team, and proposers.

The next level of the data structure is construction document review and approval. Information contained here includes all dates for review and approval, the contents of the construction documents, descriptions of any modifications, and various costs for document completion, review, and approval. The project manager enters this information.

Construction is the next level of the data structure, and contains information about the construction schedule, contractor performance, claims, start and end dates, and various costs. Information is provided by the project manager.

The final level covers the occupancy of the facility. Here the quality of the facility and any other post-occupancy opinions are described. Most of the information is supplied by the end-user.

Two types of information are stored in the system: quantitative and qualitative. The quantitative data are elements such as names, dates, and numbers. Qualitative elements include any type of descriptive or narrative (memo) information. It is in these "memo" elements that the cause-effect relationships, lessons learned, and experiences of the project manager will be recorded.

The content of each data element is described briefly below (with data base field type in parentheses).

Project Identification

Project Name. (Character.) The name of the facility, taken directly from the RFP (Key item).

Project Number. (Character.) (Key item.)

Fiscal Year. (Number.) (Key item.)

Project Scope. (Number.) The size of the project by number of square feet, tons, barrels, etc.

Project Scope Units. (Character.) The unit of measure for the size of the project. For example, square feet, persons, barrels, gallons, or tons.

Project Location. (Character.) The name of the military base or other location (Key item).

Program Amount. (Number.)

District. (Character.) The city of the District office.

Type of Acquisition Used. (Character.) Indication of One-step, Two-step, or traditional acquisition.

Facility Type. (Character.)

User Name. (Character.) The occupant of the facility.

Command Name. (Character.) MACOM or other agency affiliated with the user.

Project Manager, Engineering. (Character.) Name and telephone number.

Project Manager, Construction. (Character.) Name and telephone number.

Resident Engineer. (Character.) Name and telephone number.

A/E Selection

Scope of Work. (Memo.) This field will describe: the A/E services required, including site investigation; a market survey; design; specification development; the percentage of design shown in the RFP; the construction ceiling; the estimated size of the project; a recommendation of specifications to the A/E firm or in-house staff; and comments on the RFP organization.

Criteria for Selecting A/E Firm or In-House Personnel. (Memo.) Reasons for electing to produce the RFP in-house or by an A/E firm will be recorded in this field. Also, if the project is turnkey, the A/E firm's past experiences with writing RFPs will be included. Project managers will be able to compare their needs with the recorded solutions to select an approach with the highest potential for success.

List of Firms Applying for A/E Work. (Memo.) This field will contain a short list--including names and addresses--of all firms applying for the project.

A/E Qualification Factors. (Memo.) If an A/E firm is used instead of in-house personnel, this field will be used to list the qualification factors from the *Commerce Business Daily (CBD)*.

RFP Development

Material Provided to the A/E Firm. (Memo.) This field will list the material from the A/E contract (Appendix A). Information will indicate if the following items were provided: a previous design or plan, previous RFP material, and guidance or instructions with respect to USACE specifications or criteria.

Preliminary RFP Concept. (Memo.) The function and design of the facility and any other special instructions will be recorded. This element will also mention whether the project was started with One-Step, Two-Step, or traditional acquisition.

Technical Specification Contents. (Memo.) This field will contain an outline of the table of contents from the technical specifications. This information will help the project manager choose specifications based on similar cases.

For the following descriptions of specifications for different systems, the field contents will include the performance criteria or design standard and, the material or equipment specification required, and will indicate the use of USACE guidance specifications.

Description of Architectural Systems. (Memo.)

Description of Exterior Systems. (Memo.)

Description of Interior Systems. (Memo.)

Description of Mechanical Systems. (Memo.)

Description of Plumbing Systems. (Memo.)

Description of Electrical Systems. (Memo.)

Description of Other Specifications. (Memo.) To be used for additional specifications.

Description of Criteria Waivers. (Memo.) This field will contain a list of waivers and the justification for each. This information will help clarify any questions the project manager may have during the revision process and is particularly useful in cases of personnel turnover and when the A/E firm is not local.

A/E or In-House Used. (Character.) This field will indicate whether the A/E firm or in-house staff wrote the RFP.

Direct RFP Cost. (Number.) This field is a numerical value equal to the A/E fees plus supervision and administration (S&A).

Description of Cost of RFP Development. (Memo.) This field will contain the breakdown values for A/E fees and S&A.

RFP Directive #1 Date. (Date.)

RFP Design Start Date. (Date.)

Preliminary RFP Submittal Date. (Date.)

Preliminary RFP Approval Date. (Date.)

Final RFP Start Date. (Date.)

RFP Review and Responses. (Memo.) Any major issues arising during the Government's review of the RFP will be recorded.

Final RFP Submittal Date. (Date.)

Final RFP Approval Date. (Date.)

Amendments to the RFP. (Memo.) The number of amendments and the major items with their reasons will be listed.

General Remarks About RFP Development. (Memo.) This field will be used to list any other remarks about the RFP development.

Advertisement

Ready to Advertise (RTA) Date. (Date.)

Fund Authorization Date (Code 1). (Date.)

Fund Authorization Date (Code 2). (Date.)

Fund Authorization Date (Code 6). (Date.)

Fund Authorization Date (Code 9). (Date.)

Authority to Advertise (ATA) Date. (Date.)

Current Work Estimate (CWE). (Number.) The estimate of final cost, including construction contract, S&A, and contingencies.

Current Work Estimate Basis (A/E). (Character.)

Method of CWE Estimate. (Memo.) This field will be used to describe the method by which either the District or the A/E computed the CWE (calculated by square feet of project, compared with similar projects, calculated quantities with costs, etc.).

Release for Award Date. (Date.)

Advance Notice Date. (Date.)

Advance Notice Comments. (Memo.) Any comments about the advance notice for the project will be described. Information should include any efforts by the District to identify sources not typically notified and describe the type of medium used (e.g., CBD, local contractor organizations, local A/E organizations, bidders' list).

Advertisement Date. (Date.)

Advertisement Date(s). (Memo.) If it is necessary to readvertise the project, the dates and reasons will be listed.

Proposal Development

Submittal Requirements. (Memo.) This field will contain an outline of information the proposers are required to submit in their proposals. (This can be taken directly from the RFP.) Also included should be a record of the proposers' (winning and losing) costs to develop the proposal and an indication of whether the proposers' design services were in-house or by an A/E firm.

Preproposal Meeting Date. (Date.)

Preproposal Meeting Comments. (Memo.) This field will list the names of proposers who attend the meeting and describe the composition of the firms (i.e., general contractor, A/E, D-B firm). Any meaningful comments made by proposers about the RFP or the project with regard to time, budget, RFP requirements, and competitive environment should be recorded.

Proposal Due Date. (Date.)

Proposal Submittal Date. (Date.)

Proposal Submittal/Resubmittal Comments. (Memo.) This field will describe any important comments made by the Government about the RFP and the project concerning time, budget, RFP requirements, and competitive environment. Also included should be the proposers' viewpoints concerning requests made in the RFP (e.g., were these requests reasonable?).

Building Technologies. (Memo.) For any proposal, the innovations or atypical features that may not have been used in an A/E or USACE design should be described, including the proposer's reason for using them.

General Remarks About Proposal Development. (Memo.) This field will indicate the proposers' feeling about whether turnkey is a fair way for the Government to obtain services. (Would the proposers participate in turnkey projects in the future?)

Proposal Evaluation and Selection

Proposer Names. (Memo.) This field will list the proposer names and contacts. Included should be general contractors, A/E firms (if other than proposer), and fabricators of major building systems.

Proposal Evaluation Factors. (Memo.) This field will compare the evaluation scheme as described in the RFP with the scheme used at the evaluation. (Were evaluation points listed in the RFP, or only ordered by importance?)

Additional Information Required of Proposers. (Memo.) Any areas in which the proposals were lacking or nonconforming will be described.

Number of Submitted Proposals. (Number.)

Cost/Quality Points. (Memo.) This field will list the dollar values of the proposals in order of success, starting with the winning proposer. If known, the quality points given to each will also be listed.

Manpower To Evaluate Proposals. (Number.) The number of manhours for evaluation.

Roster of Proposal Evaluation Team Members. (Memo.) This field will list the actual and desired qualities for evaluation members. The list should contain the name of each team member, agency, or office, and area of expertise.

Proposal Evaluation. (Memo.) The activities and sequence for each phase of evaluation will be described. The list should include who participated in: logging proposals, the general conformity review, the technical and/or management review, quality point scoring, price per point calculation, and recommendation for award.

General Remarks About Proposal Evaluation. (Memo.) This field will describe the proposers' past experiences with turnkey projects and give the evaluators' feelings as to whether the proposal selected reflects the best choice. This field will also describe the quality of material provided in the proposals. In other words, were the proposals good enough to make a proper evaluation?

List of Proposal Evaluation Dates. (Memo.) The list of evaluation dates will be recorded here, along with any reasons for a particularly short or long evaluation. The project manager will be able to see how long an evaluation should take and avoid any of the problems that occurred in the past.

Proposal Evaluation Schedule. (Number.) The number of days taken to evaluate the proposals.

General Remarks About Negotiation and Award. (Memo.) This field will note whether negotiations were necessary and indicate which proposers participated.

Final Selection Date. (Date.) The date the evaluation team selected the winning proposal.

Award Date. (Date.) The date the contract was signed.

Winning Proposal Price. (Number.)

Design NTP Date. (Date.)

Construction NTP Date. (Date.)

Winning Proposer's Responses. (Memo.) The winning proposer's comments about the RFP, proposal submittal, negotiations, and award will be recorded here.

Losing Proposers' Responses. (Memo.) The losing proposers' comments about the RFP, proposal submittals, negotiations, and award should also be recorded. It should also indicate if any losing proposers requested a debriefing. This information will be vital in improving RFPs to ensure a wide range of participants for healthy competition.

Any Other Responses. (Memo.) This field will describe any responses from firms that expressed interest in or received the RFP but did not respond with a proposal.

Losing Proposers' Notice Date. (Date.)

Notification to Losing Proposers. (Memo.) This field will indicate how the losing proposers were notified (by letter or direct contact), and describe the contents of the notification. This information can be used later as a model for future notifications.

Construction Document Review and Approval

Contents of Construction Documents. (Memo.) The table of contents will be listed in outline form. It should also describe all materials provided for design analyses, construction documents, and specifications.

Cost To Complete Construction Documents. (Number.)

Construction Document Preliminary Submittal Date. (Date.)

Construction Document Preliminary Approval Date. (Date.)

Review Comments of Construction Documents. (Memo.) This field will list documents that were resubmitted and the reasons. It should describe elements of the proposal that were changed during design and record any major disagreements between the contractor and the Government. The stages of review for the documents should also be listed.

Contract Modifications and Reasons. (Memo.) Any modifications to the construction documents and their reasons will be listed here.

Documents' Final Submittal Date. (Date.)

Documents' Final Approval Date. (Date.)

Corrected Final Date. (Date.)

A/E Fees. (Number.) The proposer's A/E fees for design.

Cost To Review and Approve Construction Documents. (Memo.) The cost of review and approval will be recorded as man-effort. Any differences in effort when comparing this project to a traditional MCA project should be shown.

Shop Drawing Submittals. (Memo.) Any major differences in shop drawing submittals compared with those of a traditional project will be indicated. This field should show a comparison of what was submitted with what was required.

Construction

Construction Time (Days.) (Number.) The number of days allotted for construction; can be taken from the RFP.

Contract Amount. (Number.)

Construction Start Date. (Date.)

Original Construction Completion Date. (Date.)

Current Construction Completion Date. (Date.)

Actual Construction Completion Date. (Date.)

Quality Control. (Memo.) Any major differences in QC procedure compared with that of a traditional project will be recorded.

Construction Process. (Memo.) The construction schedule will be described along with any major activities or conditions that affect the progress of work (e.g., design changes or subsurface conditions). Any consequence of a change order should be recorded to support a possible future claim.

General Remarks About Construction. (Memo.) This field will record any comments on contractor performance, the relationship with USACE, the quality of work, and similar information not recorded elsewhere. Claims made by the contractor will be listed.

Closeout Date. (Date.)

Comments About Fast-Tracking. (Memo.) If fast-tracking was used, its effectiveness to this project compared with a traditional project will be recorded. For each submittal phase, the time for review and approval and actions included in each phase should be described, along with any impacts on the District's workload due to review and approval.

Cost Growth. (Number.) The percentage of growth.

Final Construction Costs. (Number.)

Occupancy

Overall Design Quality. (Memo.) USACE and the user reactions to the general layout and esthetics such as the floor plan, lighting, mechanical systems, color scheme, and general appearance will be recorded.

Material and Detail Quality. (Memo.) This field will list any opinions about the materials or quality of construction.

User Opinion or Other Comments. (Memo.) After occupancy, any comments the user makes concerning callback items, repair and maintenance, design, materials, and detail will be described.

4 PROTOTYPE KNOWLEDGE BASE

Hardware

The prototype system runs on an IBM or compatible personal computer (PC). Necessary hardware features are one diskette drive, a hard disk of at least 10 MB, 640K RAM, and possibly a modem.

The final system is proposed to have two locations, labeled "local" and "centralized." The local sector would contain data from the individual projects under development at a specific District. The local user would enter and extract information from a PC. This component would be the active part of the system where information is produced, transferred into data, and manipulated in a variety of ways.

The centralized storage would house all project data from all Districts and could be accessed directly through a mainframe or via a PC (by exchanging diskettes). The final approach will depend on the advantages and drawbacks of each possibility. If the solution is to use a mainframe computer, the information will be transferred from different projects through a communication system such as a modem.

Data would be retrievable from both locations, but the process of accessing it would differ. Also, until it is made "public," the local data could be retrieved only from the project manager's PC. When the information becomes public, the data would be transferred to centralized storage. Any user would then be able to retrieve this information, but could not edit or otherwise change it.

Software

The basic software required by the system is a programmable data base management system. This data manager provides the ability to sort and retrieve organized information about specific projects. It permits quick access to data specified by the user and is also important in generating reports containing selected information.

The final system will also use the data base management system's programming capability. Thus, the knowledge base will be accessible in two ways: directly, using the data base management commands, or indirectly, using the program written in the data base management language. This "program" is menu-driven and easy to use by persons with no computer background.

The current prototype knowledge base is being developed using dBase III Plus. This software application was selected for its high data storage capacity and fast computational speed (which has been increased over that of earlier versions). dBase III Plus also offers more programming options than other packages on the market. (Other products might be more user-friendly, but are usually best confined to small-scale applications.)

The software that will be used for the final system has two processing modes: interactive and batch. In interactive mode, the user can select the appropriate menu options, or manipulate data files by typing easy-to-use, English-language commands directly onto the keyboard. The batch-processing mode will be a vital feature of this application because it will provide the opportunity to send files to and from the centralized storage area.

Other software that could be used in the knowledge base is a word-processing program; this application would make it easy for users to record data that require extensive comments. (dBase III Plus has its own word-processing capability for memo fields, but is limited to 5000 characters.)

File Structure

The data base structure for this system consists of two parts, with information held in two areas: one file contains character, numerical, and date fields (which will be referred to as "alphanumeric") and the other contains text (memo fields). Each of the two files consists of records that correspond with the projects. In other words, each project will have two records of information--one in the alphanumeric file and one in the memo file (Figure 1).

Program Structure--Menuing Features

The system uses several menus to facilitate use by novice computer operators. These menus are designed to give maximum flexibility in searching, reporting, and other functions. The user can choose the options by pressing the appropriate numbers or letters.

The main menu contains the following options: input a new project, update an existing project, generate a report, send data to general storage area, and exit the system (Figure 2).

Input a New Project

When Input a New Project is selected, the system will display four questions to be answered (Figure 3). These questions are the prompts (key items) for identifying a particular project. The system needs to know the name of the project, the fiscal year, the project number, and the project location.

After the system has verified that this information has not been entered previously (to prevent duplicates), it will take the user through all of the data elements. If, at any time after entering the four key items, the user wants to stop, he/she can respond appropriately at the bottom of the screen. This option is useful when only a small amount of information is known about the project, so that time is not wasted in continuing through all of the data elements (Figure 4).

The user is shown elements in different ways for the type of field. For alphanumeric elements, the information is typed directly into the field prompt. For memo data elements, the prompt is marked with a "Y" (for yes), and the actual text is entered later with the use of other screens. Once the inputting is finished, the information that has been entered is then stored in the system and can be accessed.

Update Menu--Updating an Existing Project

Updating an existing project will be the project manager's most commonly used function. This option will be needed each time some new transaction in the process must be recorded. It thus provides primary support to the project manager in recording and tracking the project.

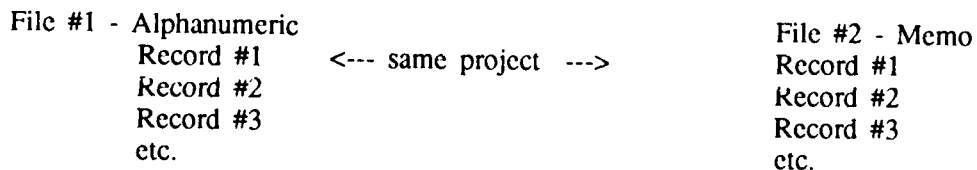


Figure 1. Knowledge base file structure.

Input New Project	- A
Update Menu	- B
Report Menu	- C
Help Menu	- D
Send Data to General Storage	- E
EXIT to System	- X

MAKE SELECTION A, B, C, D, E or X, then <return>

Figure 2. Main menu.

Please enter the following information:

Project Name:
Project Number:
Fiscal Year:
Project Location:

Figure 3. Data element key fields.

```
***** GENERAL PROJECT INFORMATION *****  
  
Project Name: Sample Project  
Project Number: 12345  
Fiscal Year: 1988  
Project Scope Quantity: 0.00  
Project Scope Units (SF, ton, etc.):  
Project Location: Fort Smith  
Program Amount: 0.00  
District:  
Type of Acquisition Used:  
DO YOU WANT TO STOP?, ENTER Y/N:
```

Figure 4. Example input screen.

After the Update Menu has been selected, a submenu is shown and the user must decide whether to work with memo or alphanumeric information (Figure 5). After the selection is made, the system continues similarly for both options.

For either submenu selection, the user must enter the four key items that the system requires for retrieval. These are the same key fields that were used when inputting the project. Once entered, the system will search for this project, and, if it is not found, will notify the user. This can occur if the project was never input or if any of the four keys were incorrect. At this point, the user has some options: alter the four keys, go back to the main menu, or print some information about all projects' key fields. Once a matching project is found, the next submenu appears. The user is shown a menu with the nine different levels of information described in Chapter 4 (Figure 6). The system continues similarly for alphanumeric and memo elements.

Update names, dates or numbers	- 1
Enter and update memos	- 2
EXIT to MAIN MENU	- X

MAKE SELECTION 1, 2 or X, then <return>

Figure 5. Update menu.

- 1 - Project Identification
- 2 - A/E Selection
- 3 - RFP Development
- 4 - Advertisement
- 5 - Proposal Development
- 6 - Proposal Evaluation & Selection
- 7 - Construction Document Review & Approval
- 8 - Construction
- 9 - Occupancy
- X - EXIT to Update Menu

Make selection 1 - 9, or X, then <return>

Figure 6. Nine levels of information menu.

Updating Alphanumeric Elements. The user selects the level and can change any or all of the elements. Figure 7 shows an example of one screen.

At each prompt, the user can alter the element with new data or can skip down to the next one. The user can continue to update elements until Exit is selected from the Nine Levels Menu. When Exit is chosen, the system deletes the old information and replaces it with the new, updated data. The user is returned to the Update Menu.

Updating Memo Elements. The user makes a selection and is shown a list of memo topics within that level (Figure 8). He/she then chooses one of the topics and updates the memo. When a memo is chosen, the monitor will show the four key items, some instructions, and the memo's topic. From this point, the user can alter the memo (or enter a new one). He/she must follow the instructions on the screen. The user can continue to select topics until Exit is chosen. After exiting the Memo Menu, the user is returned to the Update Menu.

```
*****PROPOSAL EVALUATION AND SELECTION*****  
  
Manpower to Evaluate Proposals (man-hrs):                6.00  
  
Proposal Evaluation Schedule (days):                    520  
  
Final Selection Date: 09/08/87  
  
Award Date: 09/08/87  
  
Winning Proposal Price:   3000000.00  
  
Design NTP Date: 10/09/87  
  
Construction NTP Date: 12/15/87  
  
Losing Proposers' Notification Date:  /  /
```

Figure 7. Example of updating alphanumeric elements.

```
*****UPDATING MEMOS FOR*****  
  
*****A/E SELECTION*****  
  
1 - Scope of Work  
  
2 - Criteria for Selecting A/E or In-house  
  
3 - List of Firms Applying for A/E Work  
  
4 - A/E Qualification Factors  
  
X - EXIT  
  
Make selection 1 - 4, or X, then <return>
```

Figure 8. Example of updating memo elements.

Report Menu

Reporting will also be a commonly used feature of this system. The project manager can produce a report at any time to view different information about a particular project, all projects, or memos. There are several reporting options from which to choose (Figure 9).

After the user makes a selection, some information may be required. The system may ask for the four key fields, a choice of memo topic, or other information. In some cases, the user is also asked whether to send the information to the printer or the monitor. This choice is helpful if a report is lengthy so that the project manager can view the information on the monitor before sending it to the printer.

Help Menu

To give the user some information about the different menus, a Help Menu is available through the Main Menu. This menu provides the user with a description of each menu selection.

Send Data to General Storage

This system feature allows the project manager to save the data as a batch file in the general (central) information base. The data can be sent in this way only after the project manager has elected to make it public. The system will ask whether to send the file to general storage or to quit and return to the main menu. In other words, it will ask the project manager to confirm that he/she wants to send it. In addition, some type of password should be a requirement for sending the data.

Future Direction for Development

To provide the most efficient tool to USACE, the prototype knowledge base should be transformed into an expert system. It is proposed that a system be developed called the "Alternative Construction Advisor," which would incorporate the prototype knowledge base into a true knowledge-based expert system.

The architecture of the Alternative Construction Advisor would be defined within the expert system concept. There are four basic components of an expert system: knowledge base, context, inference engine, and user interface (Figure 10).

The knowledge base (explained in Chapter 2 as a set of rules or frames) could be developed using some portions of the current "information" base. A knowledge engineer would work with an expert to write these rules from the narrative elements of the current information base.

The context would be the local memory describing the current problem to be solved. The inference engine would compare the context to the knowledge base and execute the appropriate rules. The user interface would be the interaction between the user and the system.

The difference between the knowledge base on alternative construction methods and the Alternative Construction Advisor is that the prototype provides information that the user must process in order to make a decision, whereas the expert system will generate a recommended solution and give the rationale. The current knowledge base is passive: the user asks to see information and must derive an answer from it. The expert system will be active: the user will pose a question and the system will return with an answer supported by explanations. The user can then decide whether to use this advice.

- 1 - Report key fields for all projects
- 2 - Report memo topics for one project
- 3 - Report key fields for selected memo topic
- 4 - Report memos for a selected facility type
- 5 - Report character or numeric info for one project
- 6 - Report memos for one project
- 7 - Report all info for one project
- 8 - Report memos for a selected topic
- X - EXIT TO MAIN MENU

MAKE SELECTION 1 thru 8 or X, then <return>

Figure 9. Report Menu.

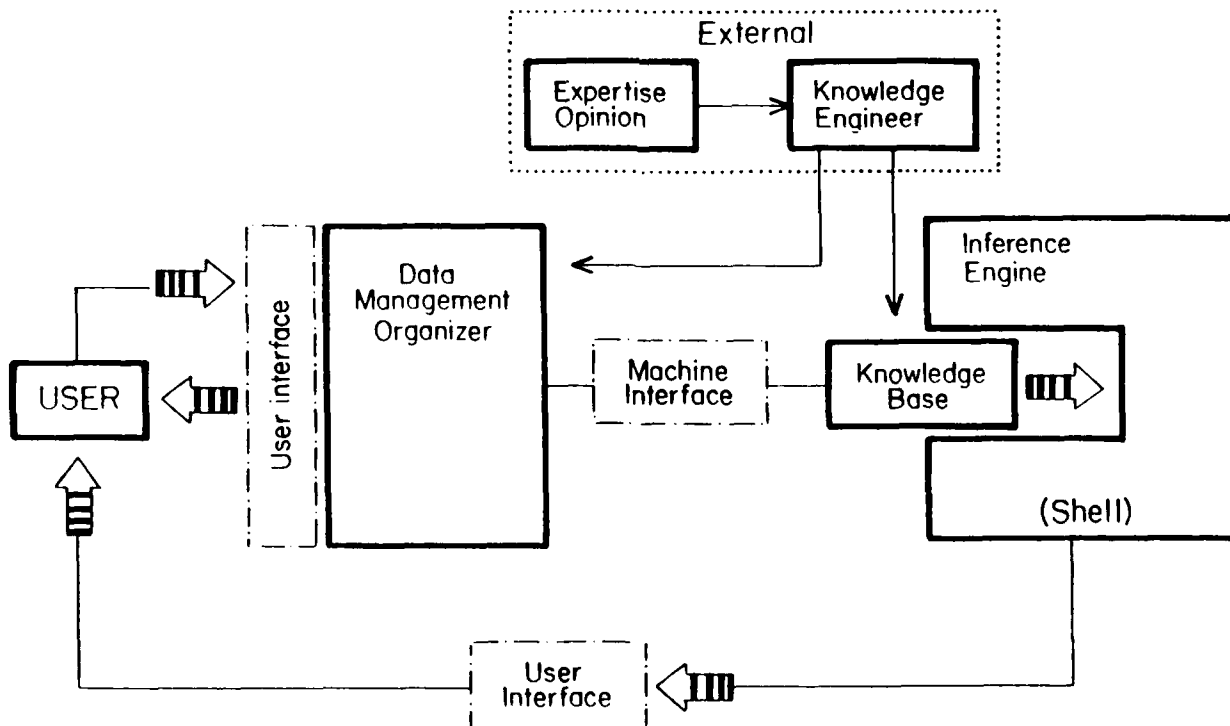


Figure 10. Architecture of the Alternative Construction Adviser.

5 CONCLUSIONS AND RECOMMENDATIONS

A conceptual approach has been developed for a knowledge base on alternative construction methods. The primary functions of the knowledge base are to:

1. Manage factual data and comments acquired from projects that use alternative construction methods.
2. Facilitate documentation and reporting on projects that involve alternative methods.
3. Provide interpretive information (project experiences, cause- and-effect relationships, and lessons learned) to USACE personnel managing subsequent projects using these methods.

This knowledge base will help project personnel become better informed and thus able to make intelligent decisions without having had a great deal of first-hand experience with the methods.

A distinction must be made between the knowledge base for alternative construction methods and a "knowledge base" that supports a rules-based expert system. The current knowledge base (actually an information base) contains only project data and information about specific projects. No other generalized expert input or outside information source will be represented.

The basic hardware for the knowledge base is a simple PC, IBM-compatible with at least 10 MB hard disk storage and 640K RAM. For the final system, a mainframe computer may be used to store the central data base. Characteristics of this computer will be determined when the expert system is developed.

The prototype knowledge base uses dBase III Plus data management software. Comparable software could be used as long as it is compatible with expert system shell software.

In addition to providing a general source of information, the knowledge base will enable project personnel to manage data for individual projects and expedite the development of project reports and summaries. Users will be able to retrieve selective information, depending on what they need for a specific situation. The users will have access to data, experiences, and precedents related to all aspects of a project and will be able to use this information to support decisions throughout the project's execution.

The method by which data are acquired and input into the knowledge base is critical to the system's success. The knowledge base must eventually be self-supporting in data acquisition; neither USACERL nor HQUSACE should have to monitor projects indefinitely. However, the imposition on field personnel administering the projects must also be kept to an absolute minimum. A definitive data acquisition strategy has yet to be developed.

Data on each project represented in the knowledge base must contain basic elements such as costs, durations, and numbers of change orders. Qualitative and interpretive information must also be included, such as descriptions of events or documents, opinions of participants in the projects, conclusions, and cause-and-effect relationships that should be observed in future applications of the alternative construction method.

The prototype knowledge base has been programmed to be menu-driven, which makes it easy to use by those with little computer experience. Menus are provided for all aspects of use: entering information, reporting, and sending data to general storage.

A rules-based expert system could potentially provide guidance for a wider spectrum of situations than the current knowledge base. However, the existing knowledge base would be used to develop rules in the expert system, providing an advisory tool. Generalized "rules" describing "if/then" situations could be introduced into the decision-making process to afford the advisory capability. Such an expert system, called the Alternative Construction Advisor, has been proposed.

It is recommended that the prototype knowledge base be further developed as an expert system type of decision-support tool (e.g., the proposed Alternative Construction Advisor). Such a system would provide greater depth and variety of expertise along with an advisory capability, which are lacking in the current knowledge base. However, if another type of automated system is chosen, it should provide, as a minimum, a decision support capability, enabling project personnel to weigh information and their own professional judgment in reaching decisions. Developing the expert system will entail the following steps:

- Determining the problem characteristics
- Finding concepts to represent expertise and knowledge
- Designing a structure to organize knowledge
- Formulating rules that embody knowledge
- Validating the rules.

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