ENERGY AUDITS OF LOCAL GOVERNMENT BUILDINGS (LOUISIANA DNR)

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ABSTRACT

This paper describes innovations instituted in an ongoing energy auditing program for local government buildings in Louisiana. In order to provide as many audits as possible with the funds available, a two-pronged effort was initiated to reduce the cost of conducting audits and generating audit reports while maintaining high quality results: (1) senior mechanical engineering students were employed and trained as auditors and (2) a microcomputer-based software system was developed to automate much of the analysis, economic decision making, and composition required for the audit reports.

In addition to providing a valuable educational tool for the students and a streamlined cost effective means of generating audit reports for local governments, this project can potentially improve the energy efficiency by as much as 1,768 MMBTU/yr per building. These numbers are extrapolated from the results of this program performed in 1986 before the development and use of the microcomputer-based software system.

DESCRIPTION OF PROGRAM

The Local Government Building Energy Audit program is sponsored by the Louisiana Department of Natural Resources, Energy Division and funded by the U.S. Department of Energy. The purpose of the program is to reduce energy consumption in buildings owned by local governments in Louisiana. This is accomplished by providing local government building managers with energy conservation information pertinent to their buildings in the form of a written audit report resulting from an on-site survey of each building. The reports are provided at no cost to the local government.

Because funds available to local governments for implementation of energy conservation measures are limited, the audit reports concentrate on energy saving changes that can be implemented without large expenditures. The reports include an analysis of the energy consumption of the building based on data obtained from utility bills, data on building use schedules, energy consuming systems, and building envelope plus recommendations for reducing building energy consumption.

The design of an audit program in which available funding is limited involves a compromise between serving a small number of clients with detailed audit reports requiring a large number of professional and clerical man-hours per report, and serving a large number of clients with less detailed reports that require fewer man-hours for site visits, analysis, and report preparation.

In the latter case, the maximum number of clients is served by a program in which the auditor checks off items on a printed list of recommendations (also referred to as Energy Conservation Opportunities or "ECOs") as he inspects the building and gives the list to the building manager as he leaves the building. The cost per building surveyed is minimized in this case because the auditor spends a minimum amount of time on-site in the building since he does very little collection of data during his inspection. No time is spent performing an economic analysis of the energy conservation recommendations since recommendations are made based on general guidelines rather than the conditions that apply to a specific building. Once the audit visit is complete, no professional or clerical time is spent on preparation of the report. In the case when no analysis is performed, the auditor can be a person with limited training and experience.

The shortcomings of such a minimum cost audit report are obvious. The report is less accurate because it is based on general guidelines rather than an analysis of specific building conditions. Ideas that are economically attractive for a particular case may be omitted from the general guidelines because they are not attractive in all cases, while some ideas may be recommended based on the guidelines of an economic analysis for a particular building. In addition, the building manager is likely to put less faith in a checklist type report than in a more detailed report prepared specifically for a particular building, and implementation may not be accomplished.

The local government building audit programs sponsored by the Louisiana Department of Natural Resources have produced moderately comprehensive reports, based on data gathered during a site visit of one day or less, with recommendations based on data specific to each building. Building data and quantitative estimates of energy savings are contained in each report along with suggestions for implementation.

PROGRAM GOAL

A continuing goal in the Local Government Building Energy Audit program is to increase the benefit/cost ratio. Ways were then sought to increase the ratio of the savings in energy realized through the program, to the program cost.

CONSTRAINTS

The Local Governments Building Energy Audit

Program operates under a number of constraints. These constraints include the need to audit a wide variety of buildings ranging from small residential-type buildings of about one thousand square feet of floor area to large complex buildings of several hundred thousand square feet of floor area such as convention centers, arenas, and multi-story office buildings. In addition, the buildings to be audited are located throughout the state, requiring careful scheduling to minimize travel time and cost. Further complications occur since local governments in Louisiana are served by a large number of utility companies with a wide variety of rate schedules.

The audits must be performed at no cost to the local government, and the recommendations for energy savings must be those that can be implemented at no cost or low cost to the municipality. Finally, the reports must be written for the non-technical reader, since most of the people who receive and act on the reports do not have a technical background.

LOUISIANA DNR--LOUISIANA TECH UNIVERSITY APPROACH

In studying the goal of increasing the ratio of energy savings to program cost, it appeared that major cost reductions were possible in the area of salaries for professional personnel who conduct the audits, perform the analysis, and write the reports. Reduction of costs for professional services seemed possible through two avenues: reducing the time required by auditors in performing the analyses and writing the reports, and minimizing the use of experienced energy auditors who must be paid a high hourly rate.

The Department of Mechanical and Industrial Engineering at Louisiana Tech University proposed a two-pronged approach to building energy auditing aimed at reducing the costs for professional services. The proposed approach involved, first, employing as building energy auditors senior mechanical engineering students trained and supervised by faculty members experienced in energy auditing. It was felt that this approach would make use of the students' knowledge of engineering fundamentals as well as the knowledge and experience of the faculty members supervising the program in such a way as to reduce the cost of site visits, analysis and report writing without sacrificing the quality of the reports.

The second facet of the approach involved a commitment to automate the generation of the reports as much as possible to reduce the time required by auditors for research, calculation, and composition of report components. It was felt that an acceptable system of report generation must be based on auditor interaction in the construction of the report and provide for altering the calculations and text of a report to fit each particular building audited.

DETAILS OF THE APPROACH

The new approach was implemented in two stages. In the first year, student auditors were employed and the feasibility of using student auditors was demonstrated. The software system for automated report generation was implemented the following year. In both these years, the Louisiana Tech University was the contractor employed to carry out the Local Government Building Energy Audit program. All audits were performed during the summer months.

The students employed as auditors were mechanical engineering majors who had completed their junior year. These students had completed courses in thermodynamics, fluid mechanics, heat transfer, basic electrical circuits, and engineering economy. They thus had a knowledge of the engineering fundamentals required to perform analyses of energy conservation opportunities in buildings.

Each student auditor was required to complete a forty clock-hour course on the fundamentals of building energy auditing prior to beginning work as an auditor. At the end of the course, faculty members accompanied students on audits of four buildings so that the auditors gained confidence and experience before performing audits on their own.

As the auditing program progressed, faculty supervisors periodically accompanied students on audits as a means of verifying the quality of the work done on the site visit. When very large and complex buildings were audited, a faculty supervisor usually accompanied the auditor. Auditors performed the research and calculation required for the reports and composed the reports, consulting faculty members as necessary. In addition, each report was reviewed by a faculty supervisor before the report was issued.

During the initial phase of the project, word processors and "boilerplate" files were used extensively to minimize the clerical work required to prepare an audit report. In the second phase of the project, an integrated software system was devised to reduce not only the clerical work required to prepare a report, but the time required by the auditor in researching facts and data, performing calculations, and composing parts of the report.

This system consisted of a data base or library containing frequently encountered recommendations for energy conservation in buildings along with other components of a typical report. The entry for each recommendation contained the text of the recommendation, information screens containing data necessary for calculations that would otherwise have to be looked up in references, and programmed calculations for economic feasibility and energy savings.

After completing a site visit, the auditor sits at a microcomputer and enters site data in response to prompts by the software. Using a list of possible energy saving recommendations prepared during the building survey, he calls up each possible recommendation on his list. For each recommendation, he enters building data required by the programs that predict economic feasibility and energy savings. Reference data, equipment prices, etc. are either a part of the programs; or if the auditor needs to make a choice of the proper data values for the particular building which the report is being prepared, they can be displayed on the screen. If the calculations show the recommended action to be economically attractive, the auditor edits the text of the recommendation to the file. After the auditor has completed his work at the keyboard, the report file

can be turned over to clerical personnel for printing.

Experience has shown that the system does reduce the time required by auditors, supervisors, and clerical personnel for each report. Less keying, proof-reading, calculation, checking of calculations, and consulting of references is required. The resulting reports are more uniform, technically correct, and more detailed than reports generated using a manual system. In fact, the completeness and detail of a building audit report is now limited by the time available for gathering data at the building site rather than the time available for analysis and writing of the report. Details of the software system and its use are given below.

REPORT GENERATION

The past decade has seen a revolution in the computer industry with the introduction of the microcomputer and minicomputer. The availability of these machines and high level applications software for them has fostered a new look at traditional ways of handling problems in engineering and all areas of the business world. In engineering the computer has always been utilized as a number cruncher, and its role in this area continues to expand with the development of new methods of handling larger and more complicated problems. In a similar manner new applications are now being found in other areas for basic applications such as word processing, spreadsheets, graphics, desktop publishing, and data base management. Each area of new application is having to adjust to some extent to the impact of the change that is forced upon it by the new tools; but many new concepts and techniques are evolving to handle traditional tasks. Some of these tasks may now be performed in a revolutionary manner; and in most cases, the role of the individual in completing the task is changed markedly.

More complicated tasks are addressed using integrated applications which require simultaneous use of several of the basic applications. The choices of methods available to perform these tasks vary with the different packages available. Some packages allow one to perform each basic application individually and combine the results at the end, while others utilize an application package that will integrate the basic applications into a more general and flexible tool. The present paper deals with a powerful integrated microcomputer software package that prepares data for publishing a number of engineering reports.

The selection of an acceptable integrated application package was based upon the requirement that it was to be used as a tool by the individual report author to assist him in report generation; it was in no way to replace his function in the reporting procedure. Essentially the package was required to have capabilities to perform acceptable word processing, spreadsheet calculations, and basic graphics presentations for data display. Some data base capabilities for providing a batch or base of known input information, both numeric and alphanumeric was desired. Additionally, in keeping with the desktop philosophy of many of the better computer applications, it was felt that the handling of data input and output should correspond to whatever mode, interactive or batch, was convenient for and natural to the user. Finally, it was deemed important to be able to prepare and publish these reports without unnecessary expenditure of time and talent; the report was to be easily duplicated for a number of similar situations.

THE INTEGRATED SOFTWARE PACKAGE

The software contains a word processor with a spelling checker, a spreadsheet, an outliner, graphing and data management capabilities, plus telecommunications. Additionally, it contains a programming language that allows creation of custom applications, and it also provides macro capability. The latter two features are not inherent in all similar application packages. The package is not copy protected, thus allowing its easy use on macros with hard disks. The hard disk capability is mandatory.

The package works in a desktop environment simulated on the computer screen. The desktop contains a menu bar, a disk file, a library file, and trays to store documents for ready access to the desktop. The main document on the desktop is contained in a frame. It may be any type of document of basic application for word processing, spreadsheets, etc.; and, there may be more than one frame of different types present. The frames may be nested, resized, or relocated on the screen. Frames may be put within other frames for maximum flexibility to organize any combination of spreadsheet, database, graph or text data. The number of frames is limited only by computer memory.

Word processing in the software is conducted in a word frame. The basic editing and text manipulation features are performed using the cursor, command keys, and menu selections. Cut, copy, and paste are effected with the function keys.

A data base structure is made up of records and fields to correspond to rows and columns on the computer screen. Data may be entered or viewed in either table or form view; and frames containing the latter may be used to design custom forms for suitable data entry or presentation. Sorting, searching and filtering functions are available.

The spreadsheet is typical of most spreadsheet structures and capabilities. It centers around the cell identified by row and column number of English name reference. A useful complement of functions are available plus the capability to create custom functions.

The software draws a variety of graphs from the data in spreadsheets or data base frames. Choices are made typically from menu selections and many options are available for enhancing the graph's appearance. Automatic or manual updating of the graph with changes in input data are possible.

The software programming language is not unlike any other programming language such as FORTRAN or COBOL. It is a general purpose language that consists of various commands for control, for operators to perform functions on variables of different types, for functions of the spreadsheet variety,

and for variables or constants. Its power lies in the fact that its capability extends beyond number crunching and spreadsheet manipulations. Practically any data handling operation may be performed, including word processing functions, printing functions, spreadsheet calculations, data base manipulation, and e graphic display. In essence, data handling capability is extended to all portions of a report and the program may be directed at generating the entire report, piece by piece, from pertinent data consisting of numerical and/or alphanumerical information supplied either interactively or batch inclusion. The flexibility that is accessible in performing a job is nearly unlimited. It would seem to approach the various choices available to calculate, cut and paste on a real desktop. An additional advantage is that the language syntax or rules for combining language elements is not complicated but is relatively easy to learn.

REPORT STRUCTURE

The overall structure of all reports involved in this program follows the same format; and many portions are generic and duplicated in each report. These common portions are simply supplied as fixed data in word frames and are output in proper sequence to the printer on command from the report program.

Similarly, some data is generic in form but may differ in number of description from one audited location to another. Such data as name of location, date audited, etc. falls into this category. This data may be supplied interactively to a data base which is accessed during report compilation or during a preprocessing period before report generation.

Audit data may fall into a category similar to the above generic data except that each location will not have similar equipment or building layout. This data will usually be unique to the facility being audited. Some of this type of data may be supplied to a preprocessing program prior to running the report program, while some may be required of an ECO program embedded within the overall report program. A preprocessing treatment is required in the latter case as the ECOs are the most important portion of the reports. The auditor who made the site visit must tailor each ECO for a specific application, check its text and calculations, and insure that it is both appropriate and correct.

The ECOs will fall into two general classes. First, many ECOs will be commonly applicable to a number of sites. These ECOs will be already prepared and available in a library in a format that will allow appropriate data to be filled in, appropriate spreadsheets to be called, and desired results to be tabulated and included. The ECO is then attached to the report, and the data is assembled into a summary report data base.

Other ECOs that are not available in the library will have to be constructed individually in a standard format (for inclusion in the library) and then attached to the report as above.

Report summary data in the form of energy and dollars savings projected will be developed in spreadsheet form for appropriate totaling and also for consideration of various options available. A word summary must be provided by the auditor as a final check on the audit results.

REPORT PUBLISHING

The report is published or generated by processing with the standard report program. A main objective of the present approach to the audit program is to save unwarranted time and money in the production of the audit visits as well as the audit reports. The final printing of the reports is thus automated and does not require operator intervention. The integration of the data for both input and output into preprocessing tasks conducted by the auditor provides opportunity for the auditor to check for completeness and correctness prior to the report generation. Thus relieving him of the possibility of having to redo the report. Effectively, the report is published in, as nearly as possible, an automatic procedure.

ADVANTAGES

Experience with the approach to building energy auditing described has shown that the combination of employing senior mechanical engineering students as auditors combined with a microcomputer based automated report generating system can decrease the cost per building audited while maintaining high quality reports. Interactive use of the system by the auditor is an essential factor in insuring that the recommendations contained in the report are correct for the specific conditions observed by the auditor during the site visit.

The two facets of the approach complement each other. A substantial turnover in auditors is expected as students graduate. The automated report generating system reduces the amount of time required to train the auditors since new auditors do not have to be shown where to find needed data in a large number of references. Most of the data they will need is contained in the data base.

In addition to providing a needed service for local governments in Louisiana, the current program provides a valuable educational experience for the students employed as auditors. The students gain not only experience in the technical area, but valuable experience in dealing with the many local government officials they encounter in the course of their work. Finally, the program provides financial assistance in the form of summer jobs for the students.

FUTURE WORK

The next area of building energy auditing cost targeted for reduction is the time spent by the auditor in taking field notes during the site visit and later keying this data into the computer. The possibility of keying data and notes into lightweight, portable, laptop computers during the site visit and later transferring this information electronically to the computers in the office is being explored.

Also, an area for future work is anticipated

along the lines of returning to a sampling of audited sites and collecting implementation data. This follow-up will provide real data on energy savings achieved as a result of this program effort.