THE IMPLICATION OF DESIGN AUTOMATION OF CONSTRUCTION PROJECTS

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ABSTRACT

During the past several years, the automation of design of construction projects has taken major leaps that affected construction. Construction drawings are now produced with CAD programs using standard data, specifications are generated with expert systems that infuses requirements of testing standards, while construction contracts are derived from databases of documents tailored for specific projects. These changes have affected both, positively and negatively, the quality of construction projects. On one hand, computerization has lead to the enhancement of quality of information presented in the documents, hence reducing the possibilities of error resulting from the transfer of information to the field. On the other hand, the standardization used by computer software and design professionals sometimes lead to omissions and defects on construction projects.

This paper discussions the role that automation of the design process plays in quality of construction projects. It relies on a survey conducted at the local level for several A/E firms and on critical examination of some computer systems that are used in the design process.

1.0 INTRODUCTION

Automating the design of construction projects has become a priority for many architectural and engineering firms in the United States of America and around the world. The race for automation resulted primarily from convenient, usable, and affordable hardware and software programs. As a result, many design and construction drawings are now produced with computer aided design software. Similarly project specifications and contract documents are generated with specification database or even expert systems. Estimating and cost analysis are generated with software that interact with CAD systems to give fast and accurate results. Undoubtedly, automation has had a positive effect on productivity in the design phase of construction projects. Many firms, observing the benefits their competitors have derived from automation, rushed to adapt computerized design without careful planning. While

computerization, particularly in the CAD area, has improved productivity, enhanced the clarity of the drawings and often improved communication between various departments in the design firms, some problems emerged. In some instances, the pressure to increase productivity produced unsatisfactory results; haste resulted in lack of details and in omissions; poor assembly of information from various supporting efforts limited alternatives for major projects.

With the potential for productivity that automation promises not only in CAD applications but in determining project specifications, supervisors often underestimate the limitations of current expert specification software systems and create another problem. Expert specification systems operate under the classic "blackbox" process: information goes in and comes out without a clear indication of how that information is processed. Understanding the process is crucial to successful design. Added to that detriment, available specification programs have too many limitations and result in highly standardized documents. In projects that benefit from flexibility and multiple options, heavy reliance on computerized programs can actually inhibit document quality.

Both advantages and disadvantages of using automation in construction projects emerged in this study. Surveys of thirty A/E firms and their experience with automation, coupled with an examination of hardware and software systems, and generally accepted procedures in designing and implementing construction projects, revealed that computerization requires careful application to reap more benefits than detriments.

2. A/E AUTOMATION SURVEY

A preliminary telephone survey was conducted with thirty Architectural and Architectural Engineering firms of the Greater Cincinnati Area to determine the extent of automation of their design process and the year in which substantial automation was incorporated into the process. These thirty firms were selected at random to determine their computer use in three major areas:

a) Design/Construction Drawings (CAD),
b) Construction Specification and Contracts
c) Estimating and Quantity Survey/take-off.

This preliminary survey yielded the following results:

	Application	Number of Firms	% Sample
a.	Computer Aid Design	10	33%
b.	Computerized Specs	15	50%
c.	Computerized Estimating	5	18%

Table 1. A/E Automation: Preliminary Survey of 30 Firms

Thirty-three percent of the respondents indicated the

use of CAD in construction documents; fifty percent indicated the use of automated specification; eighteen percent indicated the use of computerized estimating in the design process. The preliminary survey did not include information about the specific CAD application, whether preliminary design or construction drawing; however, through discussion, most respondents indicated that CAD was used primarily for generating final design and construction drawings. For automation specification, the respondents employed word processing software, sometimes coupled with a large database such as Master Spec.... or similar systems. Some A/E firms, however, reported the use of more sophisticated computerized specification systems and some are even experimenting with "expert systems".

The preliminary survey of the thirty randomly selected firms indicated that automated application is proliferating at a rapid pace. In 1985, only two firms had CAD applications incorporated in the design process. By 1987, only two years later, six firms had opted to computerized design. Currently, ten of the thirty firms have fully operational CAD systems. Results of a follow-up survey are addressed in the following sections.

3. EFFECT OF COMPUTER AIDED DESIGN/DRAFTING (CAD) ON CONSTRUCTION

A follow-up interview with eight of the thirty firms was conducted to obtain more data on the extent and nature of their design and construction documents. This follow-up survey also indicated that A/E firms were aware of both positive and negative effects of automation. The benefits design firms derived from computer aided design and drafting (CADD) influenced the execution and quality of construction projects. However, the use of CAD in generating project documents also produced pitfalls, resulting primarily from lack of user experience and inadequately planned coordinating procedures.

A. Major Benefits Reported

1. Improved productivity
2. Improved drawing quality
3. Improved information retrieval and assembly from previous projects.
4. Improved interaction between design departments
5. Improved overall design and value engineering/ analysis function
6. Improved construction functions (estimating and other) in the A/E firm

Most firms cited improved productivity of construction drawings as a significant motivation for using CAD systems. The timely delivery of information to construction sites and the reduction in cost of drawing production for A/E firms with no major negative consequences to construction constitute the major benefits. Improved productivity of construction drawings is particularly important for fast track projects. CAD systems can deliver timely and "crisp"

information and reduce delays and errors. One firm, for example, cited reduced change orders as a result of CAD use.

Many of the surveyed firms also cited improved quality of construction drawings as a major benefit. The "crisp print" clear letterings and dimensions of CAD drawings omit on-site guessing. As a result, defects resulting from poor quality drawings are reduced. An added advantage is in delivering design to the jobsite. The drawings can be delivered by telecommunication systems, thereby allowing constructors in the field and designers in the office to discuss the details and problems as they arise in the jobsite. Although this feature of CAD, coupled with telecommunications, is not widely used, more firms, particularly design-built firms, can be expected to adapt it to enhance communication to the field and, thereby, reduce costly mistakes.

A major benefit of CAD cited by small A/E firms is the ease of assembling information and details from previous projects. When applicable, details and drawings of previously executed projects can be used to generate drawings for new projects. As an example, details of beam connections, cladding attachments, window and doors can be retrieved from the database of previous projects, or from a library of standard details, adapted for current projects and thereby minimize errors, reduce cost and save time.

In large A/E firms where structural, mechanical, architectural and construction management departments share the same database, various designers can retrieve and update drawings as they develop the design. John D. Maultsby, President of Construction Computing, confirms our findings that this, in turn, enhances the communication between the designer and construction teams and reduces the chance of interference between the structural and mechanical elements of the projects and results in a lessoned opportunity for costly field errors.(2) The increased communication also expedites the task of various construction managers since they can maintain up-to-data information on all their projects.

During the design phase of construction projects, value engineering/value analysis improves the owner's project quality. Computer Aided Design allows the team to attempt alternatives to optimize the benefits of the projects. Computer Aided Design allows designers and construction managers, for example, to try various structural grid combinations, or to change the skin of the building and immediately evaluate the effect on the project cost and value. The structural and material data available in the computer database allows rapid evaluation of alternatives. This flexibility results in improved design quality.

Finally, many firms reported an expanding benefit of CAD use in improving the interaction between CAD and other

construction functions. Estimating, for example, was cited as one of these benefits where the database used i CAD provides ease of recording, collating and evaluation project costs.

B. Due to the relative newness of CAD in A/E firms, the pitfalls of CAD are less obvious; however, the reported pitfalls can be categorized as follows:

1. Omissions
2. Delays
3. Psychological Over-Dependence on Computerized Processes
4. Infringement on Creativity

In fast track projects, the timely delivery of construction drawings and the clarity of drawings supplied by CAD systems can cause omissions in the drawings to go unnoticed. The psychological effect of CAD drawings on the constructors might lead them to believe that these drawings are thorough and error-free. However, improved clarity of drawings does not guarantee the thoroughness and quality of information presented in the drawings. CAD-generated drawings are particularly susceptible to omissions when drawing and documents entails copying details from libraries of from other CAD-generated projects. Often these omissions are not detected until construction time, resulting in defects and costly change orders in the field. One major source of error in CAD systems is in the editing phase of details pertaining to other projects or the drawing of the projects interrelated details. During production, the size of the CAD video and the resulting size of data (numbers and letters), cause many errors to go unnoticed. Ironically, the variety of colors used on the screen to highlight various layers and help coordinate between various designers are a source of ambiguity when the drawings are transformed to blue prints. They result in congested drawings with many intersecting blue lines that need modification and clarity.

Another problem can occur when interfacing with construction estimating and planning functions. Any error in computer-aided design drawings will transfer directly through the interfacing functions to the construction projects. An error in dimensioning one structural element, for example, can result in error in estimating the cost of the element and may result in field delays due to improper fabrication of the element.

In the value engineering phase of design, the limited amount of information available in the database could restrict the value engineering. If a certain material of alternative is not available within the database, the designer, thinking purely of CAD optimization, deprives the project of certain valuable alternatives. This is particularly true when the designer is working on many projects of when timely delivery of design is required, forcing the project into a single alternative.

In summary, computer-aided design and the production drawing process influence the quality of construction projects both ion a positive and sometimes negative manner. Proper management of CAD in the design firms, coupled with carefully applied procedures, are key elements for its successful application.

4. EFFECT OF COMPUTERIZED SPECIFICATION SYSTEMS ON CONSTRUCTION

Similarly to Computer Aided Design, computerized specification systems affect productivity of design documents of A/AE firms. The survey indicated that most firms with automated specifications use word processing software coupled with a large database of prepared specs for their automation process. Texts are retrieved from the database and edited with the word processor to apply to specific projects. Increasingly, expert system vendors encourage architects to use expert systems to generate specs rather than write their own. Regardless of the method firms choose, computerized specifications should be carefully applied. Product research is always essential and computerized specs might in some instances limit this research. The limited information on products in a computer database might inhibit thorough research.

Ironically, the major benefit of computerized specifications, improved productivity, also contains pitfalls. In computerized specification, the specifier, working with the computer directly, generates the specification documents from the database. In a few cases, however, firms entrusted clerical staff with the major responsibility and consigned the designer to a less involved role. The practice of making clerical staff responsible for generating automated specification contains hazards. It limits the role of the architect/engineer to reviewing rather than to composing the specifications, which lead t less thorough documents.

Added to the potential for careless use of specification programs, the systems themselves present an inherent disadvantage. Michael Chusid concurs that some expert systems operate as the classic "black box" and conceal the process (1). In these cases, information goes in and comes out without any indication of how that conclusion resulted. If architects and engineers are to specify a product and be responsible for it, they must be able to evaluate the logic of the decision-making process. Without that ability, future field problems and possible litigations will haunt the specifier.

In summary, this study demonstrated that automated specification is a source of improved productivity that should not be abused or underestimated. Automation systems must be regarded as tools, not primarily instruments of design. In large A/E firms with specification departments, knowledgeable project designers can work diligently with

project specifiers to coordinate automated specifications. In small A/E firms, designers can produce automated specifications that are well coordinated with the drawings, using minimal clerical assistance. In both cases, professional designers, experienced in research and in critical thinking, must control outputs to generate highly valued projects and defect-free construction.

5. RECOMMENDATION

Careful management is required for proper automation of architectural engineering firms. System planning, procedure setting and standardization can maximize the productivity and minimize the pitfalls of the construction document automation process. In automation, the first consideration should be given to the designers, specifiers and project staff who form the basic resources. The object is not to optimize the machine output, but to maximize productivity of the project staff using the systems.

To make the best use of A/E automated systems, the designer and specifier need to interface with the system. The transfer of design information to a CAD operator and the specification texts to word processing staff result in additional steps before the completion of the construction documents. This, in turn could mean loss of information, and errors in interpretation, resulting in construction problems. To lesson the chance for error, a strong interface should exist between the project designer and the specifier to develop value documents for constructable projects. In large firms, professional design assistants familiar with design concepts and skilled in operating computer systems, can enhance the productivity of the firms. The same principle is valid for specification writers. It should be emphasized therefore that maximizing the output of automated systems is achieved by effectively interfacing design professionals with the systems. Careful procedures smooth workflow and standard methods will further improve the productivity of the team and reduce construction problems. A workflow in some large design firm can start with a project designer generating schematics on the CAD systems from simple sketches; assistant designers can then complete the design and construction drawings while interfacing with the construction staff. Meanwhile, the specifiers are researching products and writing in specifications. Standard procedures for construction document generation can include a checklist for major functions that are possible sources of errors. One checklist can be made for assembling details from previous projects, another can be used for cross-referencing between drawings. These checklists are verified at the end of each phase of the documentation process or every time significant editing is made. Standardizing methods for application in generating symbols, grouping related items, assigning attributes and filing conventions could further improve productivity and reduce errors.

By following procedures in a smooth workflow,

designers, construction managers and specifiers will improve their productivity in automated environments. The pre-established procedures need to include frequent check-points for human input: is the computer giving all the options for a structural grid system?; is the specification database requiring unnecessary testing?; is a certain drywall thickness, and so on.

In summary, automation in architectural engineering firms, is the substantial benefit in improved design and construction documentation and project value; however, managers must recognize and control potential hazards.

6. CONCLUSION

Automation of design and construction documents has become an increasingly significant factor in construction projects. A carefully managed automation process enhances the quality of information, reduces the margin of error, and improves the value of construction projects.

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