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QUALITY in the CONSTRUCTED PROJECT

A Guide for Owners, Designers and Constructors

Volume 1

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CHAPTER 20

PROJECT QUALITY THROUGH USE OF COMPUTERS

INTRODUCTION

Effective use of computers and computer systems assists design professionals, constructors, and owners when planning, designing, and constructing a project. Computer systems are capable of reducing the time required to perform many construction and design-related functions and, on many projects, computers and computer methods assist in improving elements of quality, including quality of the design and total life-cycle costs.

Computers are used in three basic areas:

1. Design applications,
2. Project coordination and data management,
3. Management and accounting, systems development, administration, and scheduling.

Computers, employed, managed, and maintained to their maximum, can give the project team considerable data processing powers, including:

- Analytical tools that allow simulation of the completed project's operation or performance to aid design decisions.
- Synthesis tools that allow automated selection of design variables using a volume and sophistication of computation not practical for manual methods.
- Graphics that allow visualization of the potential consequences of design decisions, rapid verification of input and output, explanation of design issues to nontechnical participants, and filing and retrieval of data used in the construction process.
- Shared databases that allow prompt, accurate, and economical exchange of information among participants in the design and construction process.
- Access to generic data bases providing accurate, economical, and timely ac cess to information required for design decisions.

This chapter gives guidance on computer usage to help realize the potential to provide quick and accurate computations, expeditious communications within the project team, fingertip data storage and retrieval, accurate design drawings and specifications, and facilitation of construction management activities/procedures.

1. EVALUATING FUNCTIONS

Typical considerations in selecting a particular function for computerization include:

- Does the function require complex mathematical calculations?
- How complex are the data-processing procedures?
- Does the task require storage and retrieval of large amounts of data?
- Can the data be stored and retrieved in standard formats that facilitate transfer and interpretation by different parties?
- Does reliable, economical, well-documented, "user-friendly" software exist?
- Do the benefits of computerization outweigh the several types of costs compared with acceptable alternatives?

If a computer or computer program is determined to be an appropriate tool to perform a specific function, the following questions should be answered:

- How difficult is it to develop acquire or customize the program?

- What is the best way to handle entry function?
- Are error-detection features a concern?
- How easily can the program be learned by a new employee?
- What are the risks associated with malfunction due to power failures, breakdowns, and human errors?

The answers to these questions result in the decision to use a specific program designed for the function, or a utility application such as an electronic spreadsheet, or in the selection of any numerous other programs that can be purchased for various custom uses.

1.1 Project Computer Systems

The greatest benefits of computers are achieved when data and analytical methods are planned and executed on a project-wide basis rather than as a series of disjointed tasks. Written procedures provide guidance to team members for operations within established criteria, for linking of hardware and assignment of responsibilities. If the project is complex, a procedures manual may be required. The overall objective is to be able to communicate information to all members of the project team in an effective manner.

1.2 Design Quality

Design professionals are well advised to use only those data processing and scientific application tools for which the functions and limitations are understood. Quality suffers, life safety may be threatened, and property may be damaged if the design professional is unsure of assumptions that form a computer program or of limitations that are imposed. Design professionals use appropriate analytical and design methods. "Appropriate" does not necessarily mean the most advanced or rigorous. Frequently, simple, less complex methods are appropriate.

1.3 Hardware and Software Requirements

Owners, design professionals, and constructors endeavor to select computer hardware and software with sufficient capacity and accuracy to meet the needs of typical projects being done in the office or in the field. Considerations for the appropriate hardware system and software programs are:

- Level of technology being used in projects.
- Level of communications desired by owner, design professional, and constructor.
- Flexibility in design.
- Sophistication of word processing.
- Compatibility with other systems.

In applications where team members are not experienced, experts in computer applications may be employed to give guidance on selection and installation of computer systems. The computer system is selected to meet the needs of the projects in a cost-effective manner. The system is structured to employ a mechanism of change control to determine in each case that the version of the software used is the one which has been tested and currently authorized for use. The rapidity with which software is enhanced or changed, particularly in the microcomputer field, makes it easy to confuse software versions. Revised versions may incorporate errors not present in previous versions.

1.4 Judging Software Results

Just as design assumptions only approximate reality, software models are only an approximation of reality. Except in trivial situations, different software employed by the same design professional, or the same software employed by different design professionals, may produce

different numerical results. The results are influenced by the methods and assumptions made by the design professional employing the model. While many different analyses could be "correct," because there is seldom a single correct answer, there usually will be one model that best fits a given situation. It is the duty of the design professional to select the appropriate model.

1.5 Generic Data; Data Retention and Retrieval

Project computer data are an extension of the paper records of a project and are treated with the same care as would be accorded other documents. This may require transferring the data to a nonvolatile archival medium such as magnetic tape. In the absence of contractual relationships to the contrary, project design data remain property of the design professional.

Over the years, checking and sign-off procedures have been developed for the paper design documents of record for a project. Similar procedures are possible for electronic records. In a manner similar to manual calculations, input data are checked for validity and consistency. That check is not performed by the developer of the information, but by an independent checker.

Data should be accessible and secure during the course of a project. If the project is developed with all parties sharing and using the project data, precautions may be necessary to maintain accurate data. Newly created information is identified by its "owner," the person who can rightfully revise the data. All others are merely granted permission to examine and use, but not to change, the data.

Multiple versions of what are supposedly the same data are dangerous. Making multiple private copies of data is not recommended. When possible, only one "official" copy of the data should exist except for backup files. Obsolete data should be replaced with more current information. Outdated data may have to be retained for purposes of historical documentation, but should be removed from active access.

Software and data should have adequate maintenance and backup. Loss of critical computer software or important data may have a significant effect on the cost or completion time of a project.

Computer data are stored at the conclusion of a project. Careful handling is necessary to prevent loss of information due to aging or contamination. Furthermore, the data should be stored in a way that will allow retrieval and manipulation by a later generation of computers. Outdated versions of software are retained if the software is significant for the project archives. In this regard computer data are treated no differently from paper records of a project.

2. SPECIFIC COMPUTER CONSIDERATIONS FOR DESIGN

Computer applications are useful in activities associated with design effort, including project programming, conceptual design, preliminary design, and final design, as well as reconciliation of as-designed and as-constructed data.

2.1 Project Programming

Esthetic, functional, environmental, safety, and economic criteria are formulated for the project. Some may be qualitative and others quantitative in expression. Effective computer use in project programming includes:

- Search of appropriate data bases to obtain pertinent and current regulations the project must meet (zoning, building codes, safety, environmental, etc.).
- Use of data bases and design study techniques to define benefit-cost functions for the project and to establish values for design criteria.

- Consultation with other participants in the project, using automatic or manual methods of information exchange, to identify and respond to conflicts in criteria and opportunities for synergy.

Responsible computer use entails testing the criteria established. Site visits are particularly helpful. At the site of the project, special environmental conditions, natural or human, can be identified and assessed. At the sites of similar facilities, the effectiveness of project programs can be assessed and special requirements for the current project identified.

2.2 Conceptual Design

Conceptual design identifies solution schemes consistent with the program and establishes the additional design criteria required for each scheme. Effective computer use in conceptual design includes:

- Use of graphics programs to sketch solution schemes and assess their fit to the program.
- Access to data sources and knowledge systems to define scheme-specific environmental actions.
- Access to data sources and knowledge systems to identify critical failure mechanisms and reliable techniques for predicting the system response.
- Use of graphics systems to test the fit of subschemes among the project team, and to assist nontechnical participants in evaluation of alternative schemes.

Responsible computer use entails testing the validity of the criteria required for each scheme to be considered. Quantitative consideration of each scheme's ability to satisfy project criteria is deferred to preliminary design.

2.3 Preliminary Design

A few critical design criteria, variables, and actions usually determine the validity of a particular solution to the project. In preliminary design, these controlling instances of design criteria, variables, and actions are identified by the design professional, and values of the design variables are found (if possible) to meet the design criteria. The scheme is extended to detailed design only if preliminary design results are promising. Effective computer use in preliminary design includes:

- Accessing data and knowledge systems that provide simple, transparent models for prediction of performance.
- Applying manual, simplified, computer or other analytical techniques to establish trial values of design variables that will nearly satisfy design criteria.
- Use of computer programs or knowledge systems to study the characteristics of the design and the agreemen with other design criteria.
- Exchanging preliminary design data with other participants in the project to identify and resolve inconsistencies.

Responsible computer use entails regular indendent review of preliminary design results for validity and consistency. In most areas of civil engineering, traditional, rational, approximate methods of analysis are highly effective in testing the results of computer methods.

2.4 Final Design

Final design involves determining the value ot each design variable, satisfying design criteria, and preparing data bases, plans, and specifications to transmit the results of the design professional's efforts to other project participants. Requirements for effective and responsible computer use include the following steps:

- Select analytical modeling techniques for their ability to input efficiently and test input, and to emphasize critical response results.
- Use data sources or knowledge systems to guide formulation of the analytical model for each subsystem, to achieve necessary accuracy economically.
- Evaluate critically the results of analysis with the corresponding results of the independent analytical method used in preliminary design.
- Use appropriate techniques for the design, considering factors such as reliability and life-cycle cost.
- Use computerized representations of the designs of the various subsystems. Employ automatic interference checking, when available, and review by the project team to identify and remove inconsistencies. (Production of drawings at a common scale, and overlaying to identify interferences, are effective tests for consistency.)
- Use computerized master specifications to formulate job specifications that are consistent with recognized practice for the type and location of the project. Review the results manually for credibility. Emphasize the special, project-specific elements of the specification so that these elements are not lost in routine application of master specifications. Conform the master specification to reflect any changes dictated by updated codes and standard use.
- Use computerized quantity takeoff techniques to prepare bills of materials in formats consistent with recognized practice for the type and location of the project. Test the results with independent manual or automated calculations.
- Provide data files on analytical models, bills of materials, plans and specifications to facilitate regulatory reviews and approvals, and preparation of bids. Check these with manual review of key drawings or views of the data.
- Establish procedures for updating data files on design and construction documents as changes occur during design, review and approval, contracting and construction.

2.5 Reconciliation of As-Designed and As-Constructed Data

In construction projects, deviations may develop between the contract documents and the as-constructed project. Such deviations are a consequence of field conditions which are different from those envisioned during design, and construction problems whose resolution results in a contract change.

Reconciliation of as-designed and as-constructed data may involve the development and implementation of a procedure to determine compliance with design documents by the material supplier, fabricator, erector, constructor, etc., and the review and approval of any necessary changes.

Using computers in their data-base management mode may help eliminate, record, and track design or field-changes to their resolution and incorporation into the project documentation.

3. COMPUTERS IN CONSTRUCTION - ADMINISTRATIVE USE

The functions that computer applications perform in the management of construction can be categorized into the following areas: corporate accounting, project management and administration, and special applications. This section discusses how project team members can use certain computer systems for administrative functions. A description of desirable features and available software is included.

3.1 Corporate Accounting

- General ledger. As the ultimate repository of all financial activity of the business, certain computer systems can integrate diverse accounting transactions into a single file, or data base, from which reports can be accessed. This is used to manage and analyze

accurately the profitability of the company and provide reports to satisfy government audit requirements.

- Accounts payable. This system monitors open invoices, or bills, the company owes its creditors. It can be used to print checks and help to analyze cash requirements by department, vendor, job, age, or payment priority.
- Accounts receivable. This system monitors open receivables and can generate monthly statements, invoices, and aging reports.
- Payroll. Appropriate computer systems can produce checks and calculate withholding amounts, union deductions, and overtime amounts based on union agreements. It also permits allocation of employee time to various projects and produces year-end W-2s and government-required electronic tapes.

3.2 Project Management (Cost Control, Scheduling, Material Control, Contracting) and Project Administration

- Change-order estimating. This allows for the immediate identification of the cost impact of events potentially affecting the cost to complete the project. In a construction management environment, it can be used to identify and track costs as scope or field conditions change.
- Requisitioning. This system can produce formatted worksheets for the payment-application process. It can be implemented as a subset of the job-costing system.
- Accounts payable. This performs tasks similar to those described for corporate accounts payable. However, in a general or subcontracting environment the data flow to the job-cost and the general-ledger systems.
- Job-cost reporting. This is a data base file management system that receives data from the cost-control systems for timely monitoring of all costs. It produces reports with an end-user, free formatting report-writing feature, identifies cost to complete, and compares actual versus estimated costs.
- Cash-flow reporting. This is utilized to forecast, monitor, predict, and compare original versus actual out-of-pocket cost requirements or earned value, or both. It accurately reports job status.
- Action lists. These are unrelated tasks that can be monitored in tabular format and accommodated in a spreadsheet format. Integrating listed and logical field activity is possible with scheduling software that provides for the reception of data from spreadsheets.
- Network-scheduling logic. This is used for planning, monitoring, and reporting. Systems are widely available in personal computer applications. Systems that provide custom free-format reports and easy-to-read bar-chart graphics are readily available.
- Quantity takeoff. This quantifies the scope of work indicated on design drawings. Blue-line drawings are quantified with an interactive interface, light pen, or digitizing tablet. Computer generated drawings developed with a CAD system may generate bills-of-materials.
- Cost estimates. This allows the preparation of estimates that are uniform and free from mathematical errors. It maintains a pricing catalog with "standard" default values or special unit costs input by the estimator, permitting rapid recalculation of extensions.
- Bid solicitation. This system helps constructors select, notify, and solicit bids from appropriate subcontractors.
- Bid evaluation. This provides a comparative spreadsheet of the bids submitted. It allows for an item-by-item review of submissions by bidders.
- Control of materials. This tracks flow of materials from purchase to delivery to job site to installation.
- Letters. Word-processing packages automate the processes of creating, storing, sorting, retrieving, and merging large quantities of information. These packages can maintain contracts, standard agreements, and office forms, and can be used for name and address management.

- Shop-drawing control. This monitors all submittals required on the project, which submittals have been made, and the status of each submittal.
- Forms and agreements. These word processing systems and advanced laser printers provide a complete and convenient inventory of standard agreements, office forms, payment requests, etc.
- Desk management. This system automates the storage, retrieval, and processing of large volumes of information relating to clients, consultants, constructors, and other organizations that are involved on many constructed projects. It provides fast retrieval and mailing-list capabilities with sort and search functions.

Computer systems can be used effectively in all phases of the project by each of the team members to produce timely and accurate reports and to enhance the communication process.

3.3 Special Applications

In addition to administrative functions, computer systems can assist team members in many types of projects, such as:

- Telecommunications. Special computer programs can easily connect remote sites and permit access to time-sharing systems by use of modems or multiplexers and dial-up telephone lines.
- Computer-aided design (CAD). This permits planning, cost estimation, cost allocation, space allocation, and maintenance planning. A CAD system maintains a data base of standard planning elements that can be incorporated into design. Summary and detailed lists of equipment and material quantities can be made quickly.
- Income property analysis. This produces a complete financial package (pro-forma) that can determine the financial feasibility of a proposed project.

CONCLUSION

Effective use of computers and computer systems can assist owners, design professionals, and constructors when planning, designing, constructing, and operating the project. Computer systems help to reduce the time required to perform many construction and design-related functions and, properly managed, computers and computer methods can assist in achieving quality.

Computers are influencing design practice by greatly increasing speed and accuracy of computation and increasing options (alternatives) considered. Indeed, effective use of computer methods may become essential to remaining economically and technically competitive. Computer methods are used responsibly when design professionals maintain professional control of their decisions, understand the technical basis for those decisions, provide adequate training, and independently evaluate significant data upon which the design decisions are based.

Specific computer programs can perform many time-consuming and administrative functions quickly and efficiently. For example, computers allow construction personnel to monitor accurately and rapidly changes in contract commitments, costs, schedules, impact of change orders, subcontractor relationships, material deliveries, and many other aspects of complex projects. As the job progresses, profit and loss can be monitored. Resource productivity can be greatly improved, and potential problems can be identified early. Organizational efficiency can be fine-tuned, job estimating can be made more accurate, and out-of-sequence work curtailed.

Computers can also improve communications and teamwork within the project team by providing access to project information, helping the project team to function with greater efficiency.

BRIEF HISTORY OF DEVELOPMENT OF *QUALITY IN THE CONSTRUCTED PROJECT*

The editors considered hundreds of pages of comments and suggestions in preparing the current edition. As each chapter was revised it was sent to its original authors, the steering committee, the Legal Forum, ASCE counsel, and representatives designated by the presidents of ACEC and NSPE for review. The construction chapters had the added benefit of review by representatives of AGC who produced much useful comment in a very brief turnaround time.

The Steering Committee is deeply grateful for the time, effort, and contributions made by the numerous authors and reviewers. They have performed an invaluable service to their profession and industry. We are also indebted to the hundreds who read the Guide, applied it to their practice, and gave us the benefit of their comments.

ASCE plans to maintain the Guide as a living document. A Committee on Quality in the Civil Engineering Profession has been appointed and charged, in part, with ongoing review and revision of the Guide at regularly scheduled intervals. Readers are urged to participate in this continuing process by addressing their comments to the Manager of Professional Services, ASCE, 345 East 47th Street, New York, New York 10017.

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