

Current Survey of Computer Status in the U.S. Construction Industry

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Computer technology changed drastically during the 1980s. Microcomputers now perform functions that only large, expensive mainframe computers performed a decade ago. Computers are used by a rapidly growing majority of construction firms. A study was conducted to investigate computer applications in various aspects of the construction industry, such as planning, surveying, design, graphics, prebidding, budgeting, scheduling, quality and cost controls, and equipment management. A questionnaire was sent to various companies in the construction industry concerning (a) the type of construction, (b) the annual dollar volume of business, (c) the types of computers used, (d) the types of software used, (e) the percent of time a computer is used to perform various construction tasks, and (f) the effect of computers on the advancement of the construction industry. The results indicated that minicomputers are used predominantly in all types of construction tasks. Commercial software is more commonly used and requires constant revision and improvement. Software problems are the major cause of user dissatisfaction. In general, the computer has benefited the construction industry, and the number of users is increasing. The computerization of scheduling techniques and construction material codings has helped improve the speed and accuracy of computer data entry. The construction industry needs to enhance user capabilities to save costs.

The main objective of this study was to identify the extent to which the computer has enhanced business in the construction industry. Additional objectives were to identify (a) reasons why some businesses do not use computers, (b) the percent of computer use in various aspects of construction activities, (c) the types of computers and software being used, and (d) problems with available software.

The construction industry is fragmented, sensitive to economic cycles, and highly competitive. A contractor is far more at risk in this industry than in almost any other (1). The number of yearly business failures in the construction industry increased by 484 percent between 1978 and 1986 (2). Because of the competitiveness that exists in the construction environment and the concern for time and cost savings, computers are being used by a rapidly increasing majority of construction firms.

The availability of microcomputers with increased capacity, low cost, user-friendliness, and a menu-driven nature encourages those in the construction industry to use computers in various activities of construction projects. Costs range from under \$1,000 for an XT-compatible machine to \$2,000 for an AT, and up to \$10,000 for a 386-based machine. Price depends on the computer's standard features, such as the central processing unit (CPU), size of the random access memory (RAM), and disk operating system (DOS). The applications of a per-

sonal computer (PC) range from word processing to running simple design programs. A PC system is expandable and can thus meet the changing needs of its user.

A literature search was conducted, along with a telephone interview, to identify computer applications in performing different construction tasks. A questionnaire was then prepared and mailed to various U.S. construction firms.

The questionnaire results indicate that construction firms predominantly use minicomputers. The commercial software commonly used requires constant revision and improvement. Software problems are the major cause of user dissatisfaction. The computer has helped the construction industry, and the number of users is increasing. Computer training is essential for users in the construction industry to optimize their computer skills.

LITERATURE SEARCH

The purpose of the literature search was to identify computer applications in various aspects of construction activities. In the past, engineering and construction applications of the computer were adaptations of manufacturing and business management programs. These programs did not take into account the unique site-specific nature of design and construction. As a result, commercial software never fully met the needs of the construction industry.

With sales of computer-aided design and drafting (CADD) applications reaching \$120 million annually, vendors of hardware and software systems have recognized the potential in other areas of construction (3). Bookkeeping was one of the earliest applications because it is a basic business need. But with growing demand, more versatile programs have become available, especially for the small computer. A major difficulty in buying a software package for a particular need is finding out what programs are available. User groups, newsletters, and current reference books are excellent sources of information.

A variety of computer applications for the construction industry are described in the following subsections. Commercial software is not yet available for some of these applications (3).

Planning

In the construction industry, computers are used for a number of planning activities, including financial feasibility analysis, traffic flow studies, optimizing land or structure use, space

requirement projections, mathematical modeling, and geophysical and seismic data analysis.

Construction Management

A major area in construction applications is construction and project management. Construction management software is available through the University of Florida's McTrans Center, a software distributor and user support center for FHWA. Some examples of the construction-related programs at this center are Quality Level Analysis (QLA), Highway Design and Maintenance (HDM), and Project Tracking System (PTS). Construction scheduling software include Primavera, Harvard Total Project Manager, Microtrak, Timeline, Superproject Plus, Pertmaster Advance, and Quicknet Professional. Each of these software packages allows importing, exporting, and data modification in a dBase or LOTUS 1-2-3 format. This capability allows the owner to perform additional analysis or modification to the project data and then import this information back into the source scheduling software. These software packages can handle 1,000 to 10,000 different activities and all of them can generate bar charts.

For instance, the QLA program statistically estimates the degree of conformity of construction materials to specification requirements. Quality control test results are entered as well as specification requirements and tolerance levels. QLA can predict whether construction materials and methods will meet owner specifications.

An example of quality assurance is the production of concrete through automated concrete-batch plants, which enable the operator to request any of several predefined mixes. The computer operates the plant until the correct mix is discharged into a waiting concrete truck. Batch information is then printed out, and copies are given to the truck driver to take to the point of delivery for an inspector's approval before the concrete goes into the pourer. Copies are attached to the samples made at the pour site. The loop is closed after testing, when sample results are logged and sent back to the quality assurance department. Similar applications are gaining acceptance in such areas as welding and asphalt paving.

For high-quality concrete in batch plants with higher volume, such as nuclear power stations, a computer controls the selection, transport, weighing, charging, and mixing of cement, sand, aggregates, water, and admixtures for batches that must meet specified design criteria for a specified structural component. The computer simultaneously handles administrative reporting for delivery, quality, and cost control.

Another area in construction management is cost estimating. The difficulty in this application is establishing and maintaining an accurate data base of construction materials, labor, and equipment cost (or in-place cost). Software is available to allow some sophisticated applications for material take-off. One estimating system automates the drawing of take-offs through the use of a sonic digitizer, which replaces conventional scales, tape measures, and measuring wheels. The digitizer calculates coordinates from the sound impulses of a stylus drawn across the drawing, feeding the data directly into the computer. Once the drawing is digitized, the cut-and-fill volumes and costs, site-preparation costs, and preliminary building estimates are automatically calculated (3).

A similar system solicits information from the estimator by asking questions to be answered from construction drawings. Questions are grouped around the pertinent sets of dimensions to save computer memory. The system lists possible answers for each question, with the most likely choice starred; the answer is usually entered by typing a single digit. Once the cost estimate is produced, bid solicitation postcards are printed automatically for each phase of the project using the system's file of eligible subcontractors. Other programs allow firms to work totally with their drawings on the screen for material take-offs (4). Cost-estimating programs range in a broad spectrum of capability and are available for all sizes of computer systems.

Job-site cost control is another area of concern in construction management. Small, on-site computers can organize a job's lost-time information on Friday afternoon, allowing the project managers and supervisors to determine problem areas before quitting time. Appropriate information is produced for each level of management, summarizing the week's assessment on a single-page printout (4).

A wide range of bar code applications in construction has recently been developed by member firms of the Construction Industry Institute. Specific areas of applications are quantity take-off, field material control, warehouse inventory and maintenance, tool and consumable material issue, time keeping and cost engineering, purchasing and accounting, document control, and office operations (5).

Other computer applications for construction management include budgeting and scheduling, CPM/PERT schedules and charts, manpower schedules, progress payment requisitions, change orders, color selection devices for matching building painters' materials inventories, manpower and machinery allocations, operation and phase scheduling, record keeping, and progress reports.

Equipment Management

Computer applications for equipment management include equipment scheduling, replacement allocation, service and repair scheduling, ordering and inventory of replacement parts, and small tools and hardware distribution.

Most major construction equipment manufacturers are experimenting with, and even producing, machines that include on-board microprocessors for monitoring performance, maximizing engine power and fuel economy, optimizing gear shifts, and keeping loads within safe tolerances.

Surveying

Computer programs are used for such surveying activities as distance and bearing traverse measurements, coordinate geometry, radial distance calculations, contouring, cross-sectioning and profiling, and cut-and-fill calculations.

Survey data gathered by mechanical means or aerial photographs can be entered into a program with subdivision designs. Area maps can then be generated, corrected, and computer drafted.

Automated excavation grade control is now possible through the use of laser surveying equipment combined with elec-

trohydraulic feedback control systems mounted on bulldozers, motor graders, scrapers, and so forth. In applications such as highway grading, constructing large parking lots, and constructing canals, these techniques have reduced costs (in some cases by over 80 percent) and improved quality (6).

Office Administration

In office administration, computers help with general accounting, payroll, record keeping, progress payments, financial statements, progressive cost analysis, cash flow control (cumulative labor and materials costs, time and materials costs, profitability reports, expense and budget monitoring, actual versus estimated cost assessment, and project status), materials and supplies purchasing, delivery scheduling, and inventory control.

An example of computers' estimating expenditures during construction is a program based on double-entry accounting, with the added feature of tracking retainage cash flow. This program provides a monthly balance sheet, a profit-and-loss statement, a list of charges to each account (established by the user), and a list of checks written and journal entries made each month. By interactively entering payroll data (question-and-answer entry), a record of costs for the particular job is automatically created, along with an automatic backup record of the postings on a separate floppy disk to prevent loss of data. Accounts payable and payroll transactions are automatically posted to the job cost and general ledgers. Reports track labor, material, and subcontractor costs by category and by job. One report shows the status of every unpaid charge, not just the current month's transactions. Social security and unemployment taxes, both state and federal, are produced in a report and can be automatically charged to the accounts defined by the user. The program also produces a report for each job that itemizes income and expenditures. It indicates the amount that can be billed for work accomplished and the amount in retainage, and can flag any items over the designated budget (7). These are the types of features most contractors need in a business application. This particular program is designed for a small computer; however, the same type of software can be found in larger systems.

Another example is a time-sharing system, in which multiple users rent computer time and the user's microcomputer is tied into a distant, larger computer by telephone and modem. This system provides expanded memory capacity, enabling customers to use the service for many jobs. It is especially advantageous for large jobs so that the job's complete financial history can be followed. Some smaller computers simply do not have the necessary memory.

Design and Graphics

In the construction industry, design applications include analysis for shear, moment distribution, axial force, and side-sway; selection of structural members (reinforced and prestressed concrete, steel, or composite sections); design of beams, columns, slabs, frames, arches, foundations, footings, formwork, and shoring; load analysis for conveyors, chutes, piping, scaffolding, and other construction support systems; design

of heating, ventilating, and air conditioning systems; and pipe network balancing. Computer graphics programs are used for such applications as plot maps, topographic maps, project layouts, as-built drawings, project plans, schematics, detail drawings, shop drawings, and materials tables.

For example, a computer-aided design (CAD) system allows a drafter to develop drawings through the use of commands. Results are displayed on the terminal screen and can be printed for a hard copy.

Through the interactive control of the user, CAD provides the means to compose original maps and designs, encode existing base maps and drawings, and store, retrieve, and modify maps and drawings. The graphics workstation consists of a digitizer combined with a graphics display (cathode ray) screen, a command menu and input devices, a table, and a keyboard. A number of engineers and technicians can work simultaneously at various terminals, all sharing the minicomputer's memory, storage, and processing capabilities, which include plan preparation, photogrammetric mapping, bridge and roadway design, and other drafting (8). CAD produces plans at a faster rate than manually, with higher quality and lower construction costs due to improved and more accurate design (9).

It has been claimed that CAD saves as much as 90 percent in conceptual design time, 25 percent in design cost, 30 percent in bidding time, 15 percent in construction cost, and 40 percent in construction loan interest expense (10). A CAD program can plan a highway profile by use of topographic data along a right-of-way. Once complete, a graphic view is presented of what the final road will look like when traveling on it.

The New Hampshire Department of Transportation has divided its 16,000-mi highway system into more than 100,000 segments and is entering the data into a Graphics Design System (GDS). These data include hundreds of common attributes, such as pavement type and conditions, traffic volume, accident statistics, maintenance records, geometry, and physical features. The GDS has cut manual drafting time in half, and many jobs are now handled in-house instead of using an outside consultant (11).

Word Processing

A final application in construction is word processing, which takes advantage of the computer's ability to manipulate words and characters. The computer can store text, allow editing, and print quality letters, forms, and reports. Word processing programs are ideal for retaining specifications and bid documents, which can be edited later to conform to a new job.

SURVEY ON COMPUTER USE

In an attempt to understand the extent to which the use of computers has enhanced business in the construction industry, a set of questions was prepared to survey computer users within various states (see Figure 1). The literature search helped in the development of the questionnaire by focusing on those construction-related areas in which computers have been used extensively.

QUESTIONNAIRE

1. Please mark the following areas in which your business construction activities are closely related.

a. Building Construction

1) residential _____ 2) commercial _____

b. Highway Construction

1) local roads, _____ 2) collector roads, _____
3) arterial roads, _____ 4) interstate, _____
5) other _____

c. Heavy Construction

1) bridges, _____ 2) tunnels, _____
3) dams _____ 4) other _____

d. Industrial Construction

1) light industry _____ 2) heavy industry _____

e. Municipal Construction _____

f. Railroad Construction _____

2. Are you a foreign construction firm? a. Yes _____ b. No _____

3. Do you use your own computer? a. Yes _____ b. No _____

4. Are you a builder only? a. Yes _____ b. No _____

5. Are you a design firm only? a. Yes _____ b. No _____

6. Are you both a design firm and builder? a. Yes _____ b. No _____

7. Are you a construction management firm only? a. Yes _____ b. No _____

8. Are you going to purchase another computer? a. Yes _____ b. No _____

9. Do you currently rent a computer? a. Yes _____ b. No _____

10. Are you using a computer? If so, please indicate the percentage of computer application in the following areas of your business.

Computer Application	Percent of Use
Bookkeeping	%
CPM/PERT (Scheduling)	%
Cost Estimating	%
Bid Computation	%
Budget Tracking	%
Designing	%
Surveying Calculations	%
Personnel Listings	%
Equipment Management	%
Project Material Status	%
Project Material Inventory	%
Graphics	%
Job site cost control and time-lost information	%
Pre-bidding	%
Quality Control	%
Quality Assurance	%
Construction Material Mixing	%
Construction Material Coding	%
Grading (e.g., computer mounted on construction equipment)	%
Other, please state _____	%

11. Indicate the extent to which you are dissatisfied with computer application.

Reasons	Percent of Users Not Satisfied
Software Problems	%
Hardware Problems	%
Lack of Programmer	%
Poorly Trained Personnel	%
Other Reasons	%

12. If computer utilization has advanced your construction business activities, please complete the following:

Size of Company* (please circle)	Answers by Percentage		
	Yes	No	Partially
Small			
Medium			
Large			

* Circle appropriate company size which is based on the following annual \$ volume of business:

Small refers to business volume of \$0 - \$5M/year

Medium refers to business volume of \$5M - \$50M/year

Large refers to business volume of over \$50M/year

13. Indicate the reason and extent you are not using a computer in your business.

Reason	Percent of Non-Users
Expense	%
Lack of Workload	%
Inadequate Training	%
Employees Adequately Handle Workload	%
Other Reasons	%

14. Do you use any of the following computer software?

- a. Primavera®
- b. MicroTrak
- c. Harvard Total Project Manager II®
- d. TIMELINE 3.0®
- e. SUPPERPROJECT PLUS®
- f. PERTMASTER ADVANCE®
- g. QWICKNET® Professional
- h. Survey 3.0
- i. ROAD RUNNER
- j. SURFER
- k. Draftsman
- l. LOTUS 1-2-3®
- m. VisiCalc
- n. QLA
- o. HDM
- p. PTS
- r. Other (please state):

_____* _____*
_____* _____*
_____* _____*

15. What type of computer(s) do you have?

16. Are you satisfied with your hardware? a. Yes _____ b. No _____

17. Have you changed your hardware? a. Yes _____ b. No _____

18. If yes to #17, please state the reason you changed your hardware.

FIGURE 1 Construction industry questionnaire.

The questionnaire identified the respondents by their type of business, their dollar volume of business, and the percent of time their computer performed different tasks. Table 1 presents a breakdown of the responding firms by their business classification.

The survey achieved a 48 percent response, of which 83 percent used computers and only 13 percent rented a computer through time-sharing.

Twenty-two percent of the respondents had annual sales of under \$5 million, classifying them as small. Forty-seven percent did \$5 to \$50 million in annual sales and were classified as medium-sized, whereas 31 percent had annual sales of over \$50 million and were classified as large-sized.

Ninety-nine percent of the respondents performed construction activities, which averaged 91 percent of their business workload. Eleven percent conducted design activities, averaging 6 percent of their business workload. Twenty-six percent were involved with construction management, which averaged 30 percent of their business workload, and 7 percent conducted other types of business, averaging 23 percent of their workload.

Thirty-eight percent of the small businesses did not use computers, 13 percent used time-sharing, and 50 percent owned computers. Of those small businesses owning computers, 75 percent had small computers, averaging one per firm. No small businesses owned large computers.

Fifteen percent of the medium-sized businesses did not use computers, 15 percent used time-sharing, and 70 percent owned computers. Of the medium-sized businesses owning computers, 24 percent owned small computers, averaging two per firm. Seventy-six percent of those owning computers had

minicomputers, averaging one per firm. No medium-sized businesses owned large computers.

Only 5 percent of the large-sized businesses did not use computers, 2 percent used time-sharing, and 94 percent owned computers. Of the large businesses owning computers, 41 percent owned small computers, averaging eight per firm, 73 percent owned minicomputers, averaging eight per firm, and 32 percent owned large computers, averaging two per firm.

Sixty-three percent of the small businesses, 85 percent of the medium-sized businesses, and 96 percent of the large businesses used computers. Seventy percent of the computer users had purchased commercial software, with 30 percent writing their own programs. Table 2 presents the percentage of use for various computer applications. Only 6 percent of the users indicated that their computer was not being used for its original purpose.

Fifty-eight percent of the users reported that their computer had met their expectations, 33 percent said it had only partially met expectations, and 8 percent said it had not met expectations. Table 3 presents the reasons why users were dissatisfied with their computer. Some of the other reasons for dissatisfaction that were cited included (a) the lack of requirements identification in selecting a turnkey solution,

TABLE 1 BUSINESS CLASSIFICATION OF RESPONDING FIRMS

Location	Members Surveyed	Business Category*						
		Sub-Totals						
		B	H	HV	I	MU	RR	F
Northeast FL	19	15	2	7	5	6	0	1
South FL	20	17	3	5	7	3	0	2
Mid-FL	24	16	5	12	7	10	0	0
Northwest FL	18	10	5	6	6	7	0	0
East Coast FL	29	16	9	9	5	14	0	1
Georgia	16	10	5	6	6	7	2	0
Alabama	24	14	10	16	13	12	5	0
TOTAL	150	98	39	61	49	59	7	4
Percent of TOTAL		65	26	41	33	39	5	3

* Business Category abbreviations:

- B - Building construction
- H - Highway construction
- HV - Heavy construction
- I - Industrial construction
- MU - Municipal construction
- RR - Railroad construction
- F - Foreign construction firms

TABLE 2 COMPUTER APPLICATIONS BY USERS

Application	Percent of Use
Bookkeeping	90
CPM/PERT (Scheduling)	30
Cost Estimating	42
Bid Computation	13
Budget Tracking	63
Design	7
Surveying Calculations	3
Personnel Listings	38
Equipment Status	35
Project Material/Status	20
Project Material Inventory	22
Other tasks	13

TABLE 3 REASONS FOR USER DISSATISFACTION WITH COMPUTERS

Reason	Percent of Users Not Satisfied
Software Problems	38
Hardware Problems	15
Lack of Programmer	17
Poorly Trained Personnel	10
Other Reasons	20

(b) incorrect cost information provided by superintendents on each phase of the work, (c) a lack of appreciation of the capability of computers, (d) the limited flexibility of software, (e) the amount of lead time needed to get answers and the restrictive format of answers, (f) project managers' lack of knowledge concerning computers and accounting procedures, and (g) software delivery delays.

Forty-eight percent of the computer users indicated that they would purchase another computer in the future to expand their capabilities, and 52 percent of the users said they would not buy another computer in the future. Eighty-three percent of the computer nonusers indicated that they would purchase a computer in the future, and 17 percent said they did not plan to buy a computer. Table 4 presents various reasons for computer nonuse.

Table 5 presents the respondents' views concerning the computer's role in the advancement of the construction industry. Sixty-nine percent believed that the computer had advanced their business, 4 percent believed it had not, and 26 percent said it had a partial effect.

Sixty-five percent of the respondents commented on the type of software programs they would like to see developed. Some comments clearly came from inexperienced users, whereas other respondents were intimately familiar with computer applications. The major theme in these responses was for better accounting programs, that is, programs that are not as rigid in format and content. Many users asked for basic programs in accounting, cost estimating, and cost scheduling.

Users also indicated the need for software that could handle such functions as (a) accessing historical data, including lost bid comparisons; (b) cost estimating for heavy and highway construction; (c) printing end-of-year government returns; (d) making minor payroll deductions without modifying the program; (e) tracking cost and maintenance

scheduling of heavy equipment; (f) tracking work backlog status; and (g) preventing double billing.

Sixty-nine percent of the respondents attributed better project cost control to the ability of the computer to quickly condense large volumes of information, allowing constructive management action. Some respondents indicated that CADD systems have improved working efficiency. Apparently, the computer's major benefit is its ability to provide better job control.

FUTURE USE OF THE COMPUTER IN CONSTRUCTION

New technology is already emerging with magnetic bubble memory, which is envisioned as plug-in modules with far greater capacity and faster access than traditional floppy and hard disks (secondary memory). Primary memory will grow, eventually requiring that only data be stored in secondary memory. This feature is becoming possible with the emerging 256K RAM chip (3). User-oriented features will continue to be added to simplify understanding and operation, with voice and handwritten input being implemented routinely (3).

As a result of these technology advances, small computers will be increasingly available and in greater demand, especially by the construction industry. Integrated data bases will become possible on small computers, allowing design, construction, and accounting from a single source. Computers at the job site will likely become commonplace in the construction industry, which is especially significant considering the advancements being made with CAD and the new technology of integrating various software programs. Satellite-linked networks for international firms will become more advanced. There will be no need for hard-copy drawings because field terminals or systems will provide the necessary information. Engineering and construction students will routinely be trained in the computer's use and conversant in its applications.

The trend toward lowering cost may gradually be reversed because of increased sophistication and capabilities (12,p.108). The cost for software programming will increase. It will eventually be possible to place 20,000 activity networks on a small computer, with mainframe computer scheduling programs becoming obsolete (12,p.108). Programs will proliferate in the industry for every phase and aspect of construction, with construction management receiving more and better tools to increase productivity.

CONCLUSION

The majority of construction firms use computers, and this trend is increasing. Small computers and minicomputers predominate in this industry. Clearly, computer use increases with the dollar volume of business. Commercial software is more commonly used. Bookkeeping is the most predominantly used function of computers, followed by budget tracking, cost estimating, personnel listing, equipment status, and project scheduling.

The majority of users reported that the computer had met their expectations, with very few reporting that it had not. For those not completely satisfied with their computer, soft-

TABLE 4 REASONS FOR COMPUTER NONUSE

Reason	Percent of Non-Users
Expense	0
Lack of Workload	31
Inadequate Training	8
Employees Adequately Handle Workload	46
Other Reasons	15

TABLE 5 EFFECT OF COMPUTERS ON ADVANCEMENT OF CONSTRUCTION INDUSTRY

Size of Company	Answers (By Percentage)		
	Positive Effect	No Effect	Partial Effect
Small	94	0	6
Medium	62	3	35
Large	64	9	27

ware problems were the major cause. The majority of computer users indicated that they would not buy a computer in the future, but nonusers clearly planned to do so. The majority of respondents stated that the computer has benefited construction by providing financial information faster, allowing better cost management. A few added that CAD systems had further improved the industry.

The major reason cited for the nonuse of computers was that employees adequately handled the work load, with lack of work load being second. This response indicates either a lack of knowledge about the computer's ability to increase productivity or a fear of the unknown.

The 1980s were considered by many to be the decade of the computer. A firm's ability to function effectively in the future will greatly depend on its ability to harness computer technology.

The low cost of PCs (approximately \$500) is attractive to minority contractors and small businesses. These firms are slowly moving toward the use of computers in their businesses.

In general, contractors must first decide the types of programs they need. A professional can be helpful in configuring a system that meets those needs.

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