

Microcomputer Configurations for Project Management

Productivity gains in construction project management can be realized via the use of estimating, scheduling and graphical software applications designed for microcomputers.

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Computers have long been used in the construction industry. However, up until the "microcomputer revolution" — brought about by both new hardware and software systems — only large mainframe computers were available for construction jobs. These computers were located most often at the company headquarters or major field offices, and required specialized staff for their operation and maintenance as well as special facilities for their housing.

The mainframe computer had usually been acquired for accounting and financial management purposes. A construction project manager who wanted to use the system for scheduling was very frequently forced to share time with

the primary users of the computer, a situation that often diluted the main value of the computer (*i.e.*, its ability to have data quickly input, to compute the results and provide updated reports that the manager could use for analysis). As a result, computer use for project management was restricted to constructing a detailed project schedule during the early project planning stage and then to periodically update the schedule for analysis, usually on a quarterly basis. However, often by the time the computer-generated scheduling reports were finished and back in the project manager's hands, the data had become outdated. Turn-around time was so long that the hand-drawn barchart still remained the most viable tool for the management of the project. Computer-generated reports and charts were retained to impress the client's representatives, showing how modern and up-to-date the construction firm was, or simply to abide by the scheduling requirements of the contract documents.

Estimating, however, remained a task whose productivity could be greatly improved through the use of such mainframes, since it requires manipulating vast amounts of basic data from historical and current records on unit costs and productivities. Interactive and computerized estimating systems are made operational by furnishing adequate computing

power that can deliver reasonable response times per transaction such as the extraction of data records or the computation of a bid item price.¹ However, since these mainframe systems required a sizeable staff base of trained operators and a large amount of capital investment for hardware and software, their use was limited to companies with sufficient resources to support the additional expenses.

In addition to the accessibility problem, mainframe systems did not allow for direct on-line inputs and tailored outputs. The system was not directly accessible by the project manager. All interaction with the system was with the staff of trained operators. Therefore, the system was of little use to the project manager, and even less to the project engineer and field staff.

The advent of the microcomputer changed much of that. The construction industry has realized the potential gain from microcomputer technology, and is applying it to such applications as estimating, scheduling and reporting.

Suckarieh cites three main microcomputer software applications systems that can benefit construction management: spreadsheets, database management systems and time management systems.² Word processing systems could be added to this list, since they are extensively used for the purpose of daily and weekly reports, memos and letters to suppliers, subcontractors, clients and management.

The use of spreadsheet systems for estimating is discussed by Lansford and McCullough, Suckarieh, and Herbsman.^{3,2,4} Although sophisticated interactive estimating systems such as those described by Herbsman have the advantages of both larger data storage and smaller response time, particularly for stand-alone systems, the simplicity and low cost of spreadsheet systems have made them a convenient way to enhance the productivity of estimators by automating the time-consuming calculations involved in estimating.⁴

Database management systems that furnish the means for storing, retrieving and sorting of data enhance the estimating function by providing convenient and systematic access to input data on historical unit prices and productivities. While spreadsheet systems can also be

used for data management (and many commercial spreadsheet applications do offer data management functions), they are put to better use in manipulating the data that can be supplied to the spreadsheet from data management systems. Since most commercial database management systems allow the transfer of information to popular spreadsheet systems, their combined use is a definite plus. Integrated database management and spreadsheet systems are also available today, as a response to the multiple needs for their combined use.

Microcomputer Scheduling

The availability of microcomputer scheduling systems has made it possible to "decentralize" the scheduling function, removing it from the exclusive domain of a trained staff of mainframe operators. The end user — *i.e.*, the project management team — can have a fully operational system at the project site or wherever else it is deemed suitable. The ability to input data, compute a solution, analyze reports on the screen or printed, and to modify input and test thoroughly different options represents an invaluable analysis tool for scheduling. The project manager no longer has to wait for data to be coded, entered into the mainframe system, computed and output. There is no longer any need to sort through reams of paper to find the required data, or to manually compare different outputs.

While the microcomputer does have its limitations, poses its own unique set of problems and cannot solve all of the problems of the past, it has to a large extent changed the way many construction managers and companies operate.

Project Management Software

The full value of the microcomputer for the project manager can be realized in software currently available for the management of time and resources involved in most projects. In selecting the appropriate software system, the user must carefully consider what the software is expected to do and what it actually can do. Extensive research suggests that a systematic approach to evaluating microcomputer project management software encompasses a range of factors that are discussed below.⁵

Network Input. There are basically two formats for the input of data into a project management system: activity-on-node (AON) precedence relationships and activity-on-arrow (AOA), i, j , node notation.

In the AON notation, once an activity has been entered into the system, a prompt appears asking for the activities that precede the entered activity. For example, for a concrete placing activity, the preceding activity would be the reinforcement placement activity. The chain of these activity relationships throughout the project defines the project length, critical path and floats.

The AOA notation relies on the start and end nodes for the activities to define the relationships and calculate the project duration. For example, if the reinforcement activity ended on node 20, then the concrete placing activity would begin at that node.

Although both formats produce the same final results, the precedence input has gained in popularity recently since it eliminates the need to have dummy or logic-only activities in the network. Ideally, a system would allow either of the two formats to be used, but that is not the case at the moment. While the decision between the two is largely a matter of individual preference, it should be recognized that some of the available software systems are better than others depending on the format selected. Current operating rules at a firm should be considered, since adjustments to a new system can result in inefficiency and low usage of the software.

Variable Calendar. The software chosen should have a means of setting the calendar for the project duration. It should be able to automatically forecast activity start and finish dates based on the overall project start date, durations of the activities and the non-work days that occur within the periods. It should also be able to calculate backwards from important milestone dates. The calendar should be able to accept holidays and variable work weeks, and to use them in the data computations. An advanced system should be able to adjust the work weeks for each activity. This ability to adjust periods is important since activities have different work-week periods. For example, adjustments need to be made for activities that

work on a five-day work week such as concrete placement and activities that occur on a seven-day work week such as concrete curing. If these concrete curing activities were on the critical path, it is easy to see how this factor could be an important consideration in the overall project duration, and one that could easily be overlooked in the planning stage.

Level of Detail. The project manager is interested in the details of the activities as well as in the overall duration and cost of the project. However, it is often impractical for the project manager to look at these details if the project is large and includes many activities. For this reason, many software packages avoid this problem by supplying the capability to break the project into sub-networks. The project manager interested in the details of a particular set of activities or a particular time period is thus able to recall that portion of the supernetwork for examination while also retaining the capability of watching the big picture of the overall project.

This feature can also be used to aid in the design of the network that encompasses the framework of the project — its activities and their relationships to one another. The design step discussed above lays out the network logic used for large projects. By using subprojects for a specific series of activities such as formwork, reinforcement and concrete placement, and then inserting the subproject into the framework of the superproject, the microcomputer can facilitate the network design process.

Updating. The project management software should not only be useful for project planning, but should also permit subsequent inputs for actual costs, resource usage and task durations. The project manager is concerned with the actual performance of the project and how it compares to the planned progress. It is also desirable to have a projection capability to update the planned progress using the cost and schedule variances to date. The capability to update will give the manager the earliest possible notification of indicated changes in project cost, activity completion dates and project completion date on a continuous basis.

Updated data is essential for periodic progress and cash flow reports. The earned value of the work to date forms the necessary

basis for requesting progress payments.

Evaluation of Schedule Changes. The software selected should enable the manager to evaluate the impact on the schedule of such factors as duration, unit costs resources. As an aid to decision making it is vital that the manager be able to ask "what if?" questions while maintaining the original schedule in the file. The software system should permit quick and easy updating of the project schedule and highlight the changes that had been made and the activities that have been impacted.

Report Generation. This factor is probably the most important consideration in evaluating a project management software system. The reports that the software can generate should be tailored to the needs of the manager. A rigid system that provides set reports with excessive amounts of information are of little use to the manager. The information that the manager needs should be readily available in a format that is easily readable. A well-constructed software system would have a set of easily usable report formats, plus a utility that permits the manager to create *ad hoc* or special reports. These report formats should be able to be permanently saved (usually on disk) so the manager will not have to recreate the format of a recurring report each time it is used.

The software should permit selecting what data, or data ranges, should be included in the report. It should also have the capability to let the manager choose how the data will be sorted. A manager concerned with cutting the project length should be able to obtain a list of the critical activities. A manager concerned with resource usage should be able to obtain lists of the activities that use those resources. Auxiliary inputs are quite useful for special sorting purposes, making it possible to design reports from the subnets as well as the project as a whole.

Graphical Output. Text or tabular reports are critical to detailed analysis of project, but a picture is worth a thousand words. Reports are enhanced by barcharts and network diagrams. The selected software should have facilities to tailor these outputs in the same fashion as the reports.

It is important to have the capability to produce barcharts that can depict resource

usage over time. Graphs displaying variances between projected and actual expenses, cash flow and task duration are beneficial.

In evaluating which software system to purchase, consideration must be given to the hardware requirements of the system. Will the software run on the microcomputers already installed in the office? Will the computers require more memory or different graphics subsystems? Will hard disk space need to be expanded? Will the software work with the printers available in the office or must special graphics printers or plotters be purchased? Can the costs of such purchases be justified?

Execution Speed. The execution speed of the software depends primarily on the programming techniques used to write the software, the number of activities in the network and the amount of information included in the program on each of the activities. The computer runtime to execute the necessary calculations for a project can vary from five minutes up to one hour for a 500-activity network. The importance of the execution speed will depend on the role that the manager plays. If the manager is located on the site, and is concerned primarily with that one project, the manager may be willing to accept a slower execution speed since the microcomputer is not needed immediately for calculations on other projects, or for other tasks. On the other hand, if the manager is handling multiple projects, or the microcomputer is needed for other functions such as word processing, the office may not be able to afford to tie up the computer for long periods of time.

Some of the currently available programs seem to update the program as each activity is input. This type of approach slows the input process, and requires more user time, but when the input process is completed, so are the calculations. Other programs provide rapid input speeds, but are followed by lengthy calculation periods. The update-as-entered-type software, while demanding more user time, seems to allow easier error detection. It is extremely inefficient to input a great amount of detail for a project, start the computations, and only to have them break off because a logic error has been detected by the computer. The amount of time spent searching back through the data to locate the error(s) may offset the savings gained

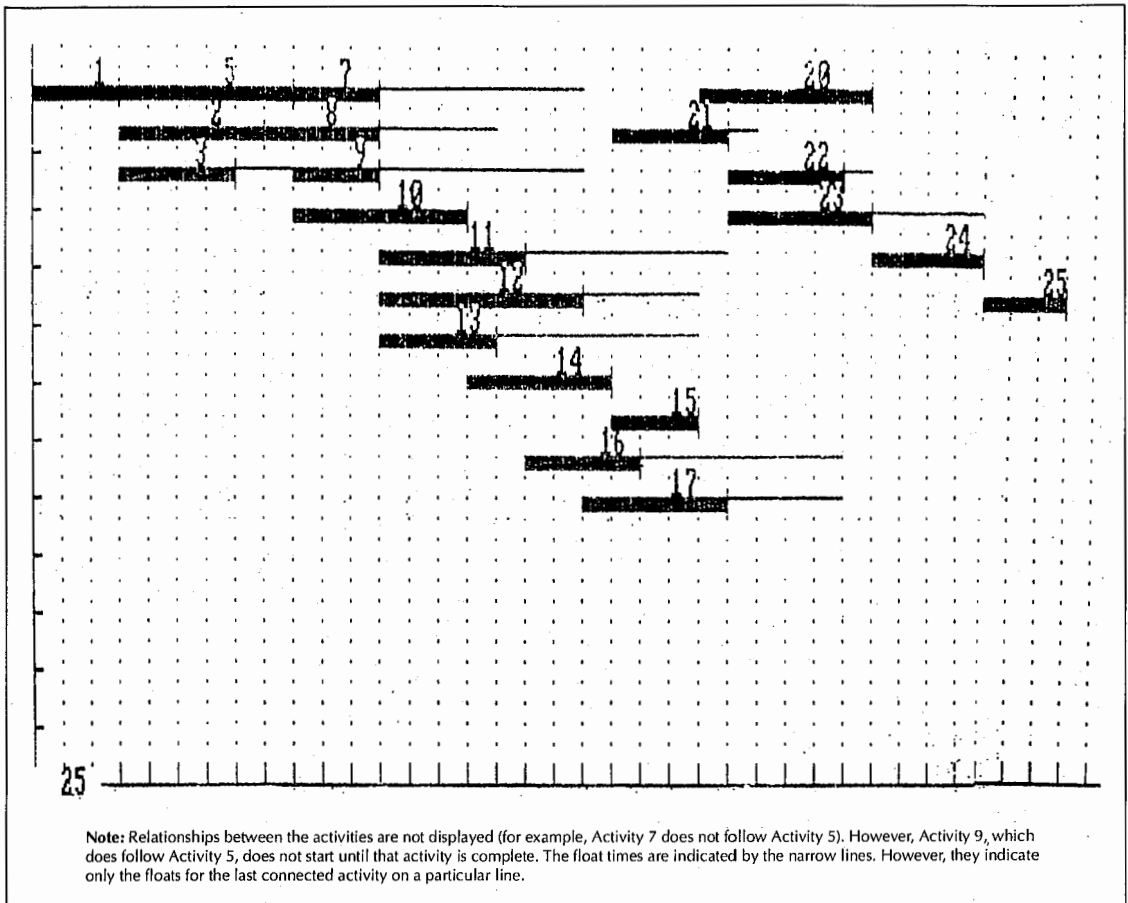


FIGURE 1. BASIC barchart diagram.

initially during the much shorter input sequence.

The purchase decision in this area should focus on the capabilities of the available hardware and the personnel available for inputting data. Execution speed is generally a function of price — the more expensive the system, the greater the speed.

Flexibility. Input sequences, and report and graph generation, must be adaptable to the needs of the office. No single software system will completely satisfy every requirement that will be placed on it. However, the manager must decide early on in the evaluation process whether the computer will drive the office or will the office dictate how the computer is to be used. In terms of the hardware the project management software might run on, consideration should be given to the other sorts of application software that might be run on the

microcomputers and how all of the pieces fit. In terms of the project management software itself, a wide range of functions might make it suitable for all sorts of projects, or even for other tasks (e.g., its database functions might be used to maintain small databases that might not be worth acquiring a large database software program for; or its graphic output facilities might be used to provide graphs occasionally of non-project data).

User Friendliness. There are certain traits to look for in software (and to a lesser extent in the system hardware for microcomputers since the user works with and interfaces primarily with the software) that will make it more adaptable and easy to use:

- **Documentation:** Is the reference material provided with the software complete and easy to understand? Are help screens

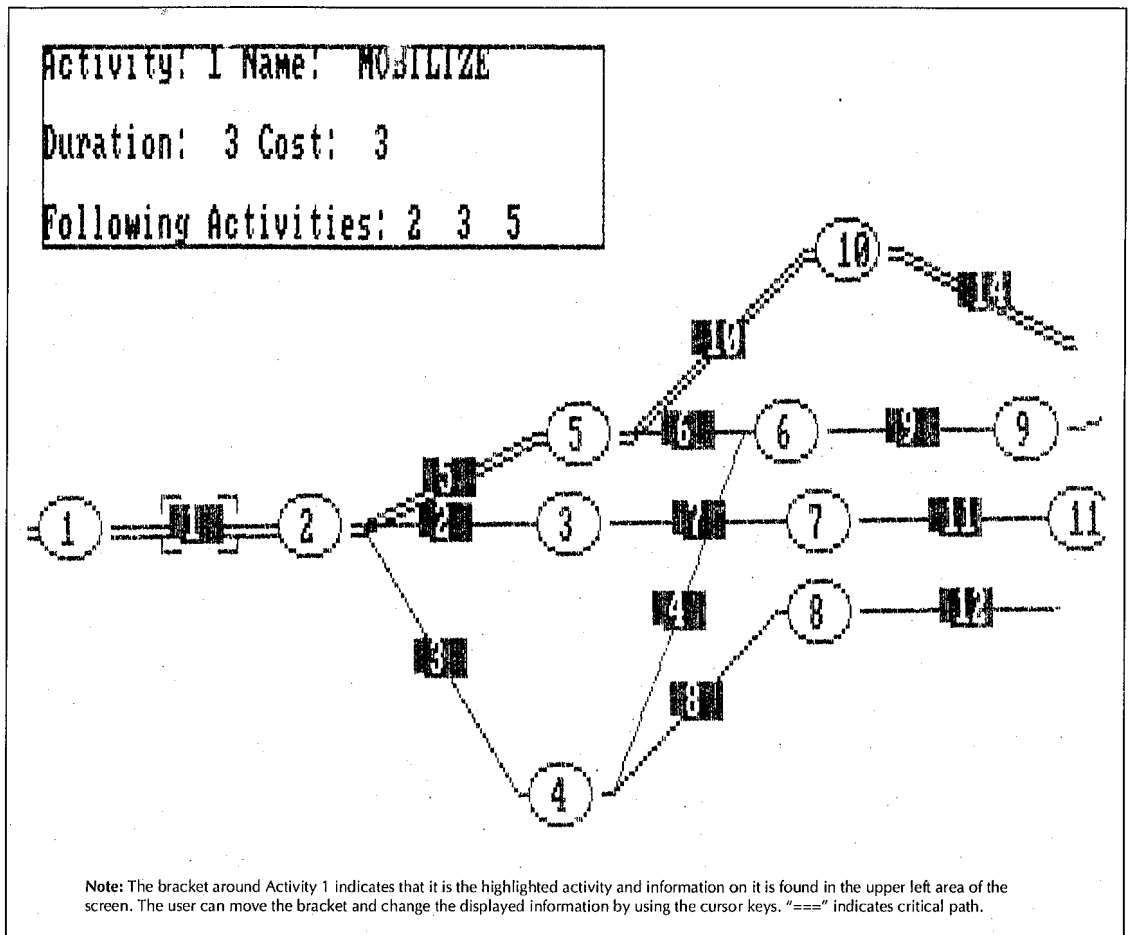


FIGURE 2. Partial BASIC AOA network diagram.

provided and are they easily retrieved? Is there an on-disk tutorial with accompanying documentation.

- Command Structure/Interface: A wide variety of command input techniques are available, from typing in commands or selected abbreviations, to moving a cursor or highlighted bar. Some programs require selecting a letter followed by pressing the return key. As the software is updated, these techniques tend to become more and more sophisticated, which translates to simpler commands for the user. The important considerations here are that the commands be consistent through the program, and that the command system be easy to use and intuitive (e.g., the command for saving a project file is, for example, typing the letter "s" and

not typing "\$IOD").

- Compatibility: Programs obviously must be compatible with the hardware already present in the office. File transfer capability between database, spreadsheet, time management and word-processing software is highly desirable. Another consideration would be compatibility with the office's peripheral equipment for microcomputers such as printers, video monitors, plotters, networking systems, etc. A major consideration in some offices will be compatibility with a mainframe computer. Access to the database and to data previously input to the mainframe is obviously an advantage, but one that is sadly not available as of yet for the majority of project management systems.

TABLE 1
Time Scheduling Macro:
Menu & Data Entry

```
/XMenu~
Add Quit Sort CompuErase Barchart
Add an ActivSort CompuErase BCreate a Barchart
(GOTO)A/xq /xgo/xgo/xmMenu(barchart)~{loop1}~
/xnActivity Number ?~{riBarchartTable
/XnStart Node ? ~{rightErase BErase Table
/XnEnd Node ? ~{right}~{goto}z{goto}a10~/rea10.50~
/XnDuration ? ~{right}~{for counter,1,50,1,loop50}
/XnCost ? ~{end}{left}~{right 2}~{re.pgdn}{pgdn}~
```

- **Training/Ease of Use/Support:** Is it difficult to learn how to use the software? A powerful and fast program might be one that is more difficult to learn. Does the software publisher, or do third-party vendors, provide training seminars? Does the software publisher provide technical support? Is this support free or paid? What is the level of service provided should there be problems with using the software down the line? Is the software publisher a "solvent" company that will be around to support and upgrade its product, or is it a company that might disappear, leaving users without a solid basis of technical support to solve any problems that might occur?

Cost/Performance Trade-off. Costs of available basic project management software systems for microcomputers vary widely, from under \$500 to over \$3,000. Other features, including software for utilities and additional functions, as well as special peripheral equipment such as graphics printers, may add several hundred to thousands of dollars to the cost of the system. The best approach here is to determine as much as possible beforehand what uses the system will be put to when it is used. Complicated resource usage tables, reports and graphs, while potentially a great aid to managing the project, are worthless if no one uses them. Their use requires that someone spend time designing the inputs to the system, inputting the initial plans and updating the data as the project goes on. Whether the potential benefits of a larger type of system are promising enough to justify the higher costs of equipment, operation

TABLE 2
Time Scheduling Macro:
Network Computations

```
/rnddatb~/mctest1~/mrcfin~/mrcf~/mrcst{goto}c10~
{goto}a10~/mrcdatb~{end}{down}{right}~{c~b26~
/mrccount~a1~
/mrccounter~b1~/mrccounter2~c1~
{right}~
{for counter,1,count,1,strch}
{goto}datb~/mrcfin~/mrcf~/mrcst{right 2}~
{for counter,1,count,1,loop4}
{goto}datb~{right 6}~/mrcmaxlf~
{for counter,1,count,1,loop8}
{goto}maxlf~{left 4}~/mrcnode~/mrcnode~
{goto}datb~{right 2}~
{for counter,1,count,fick}
{goto}datb~{end}{down}~{right}~/mrcstr~/mrc
{for counter,1,count,1,loop10}
{barchart}
```

and maintenance is a challenging question that the company management should face intelligently.

Special Features. Aside from the management features described above, the marginal benefits of certain "add-on" functions can be immense and help in deciding which software system to purchase. Two of these features that would aid in project management are optimization and calculation routines. Optimization routines are available that can supply the manager with what combination of durations, costs and resource usage would provide the optimum results in terms of money and time. However, this type of function often takes a lengthy period of time to execute and requires considerable time for the calculations involved in determining the optimum situation. Although the results often turn out to be impractical, they can be of valuable assistance in "brainstorming" and "what-if" analyses.

Calculation capability exists for figuring costs and durations in a free format. Conducting calculations separate from the set input format found in most software, and transferring the data to the required input field, allows the manager to correct or analyze minor changes in the data without leaving the microcomputer or the basic program that is running.

The evaluation of project management software systems can best be undertaken by running a sample project on different systems, and noting their performance according to

Activ Number	Start sNode	End fNode	Duration rncduRes	Early Start	Early Fin	Late lStart	Late lfin	SlackFol1 slackFol1	fol2 fol2	fol3 fol3	#fol #fol		
1	1	2	3	1	0	3	0	3	0	5	3	2	3
2	2	3	5	1	3	8	10	15	7	7			1
3	2	4	4	2	3	7	7	11	4	8	4		2
4	4	6	0		7	7	16	16	9	9			1
5	2	5	6	2	3	9	3	9	0	10	6		2
6	5	6	0		9	9	16	16	7	9			1
7	3	7	4	4	8	12	15	19	7	11			1
8	4	8	5	4	7	12	11	16	4	12			1
9	6	9	3	4	9	12	16	19	7	13			1
10	5	10	6	5	9	15	9	15	0	14			1
11	7	11	5	6	12	17	19	24	7	16			1
12	8	12	7	7	12	19	16	23	4	17			1
13	9	14	4	8	12	16	19	23	7	20			1
14	10	13	5	3	15	20	15	20	0	21	15		2
15	13	14	3	3	20	23	20	23	0	20			1
16	11	18	4	3	17	21	24	28	7	23			1
17	12	15	5	3	19	24	23	28	4	19	18		2
18	15	17	0		24	24	29	29	5	24			1
19	15	18	0		24	24	28	28	4	23			1
20	14	17	6	7	23	29	23	29	0	24			1
21	13	16	4	7	20	24	21	25	1	22			1
22	16	17	4	1	24	28	25	29	1	24			1
23	18	19	5	1	24	29	28	33	4	25			1
24	17	19	4		29	33	29	33	0	25			1
25	19	20	3		33	36	33	36	0				0

Note: This data table is based on a 25-activity project. The start and end nodes, resources and activity numbers were entered using a macro. Another macro was used to compute the early and late start and finish dates, and other activities.

FIGURE 3. Spreadsheet output of network processing.

selected criteria. The project run would be representative of the projects normally encountered. In this evaluation process, a good way to quantify the evaluation would be to give a "weight" in numeric terms to the factors mentioned above (based on the company's or manager's estimation of the importance and value of the factor) and rate the software's performance in each factor. In an earlier report, several systems were evaluated according to the aforementioned factors.⁵

Simple Development Options

Two development options were considered:⁵ a program was written in BASIC using AOA or AON notations, and a program was con-

structed using the macro programming techniques within the spreadsheet software that provided time analysis and reporting functions.

The BASIC program had the following capabilities:

- output report on activities, their early start and finish times, cost and duration, and floats.
- modification and updating of activities and their sequence.
- the ability to produce a bar chart (see Figure 1)
- the ability to produce a network diagram in both AOA and AON notations. A sec-

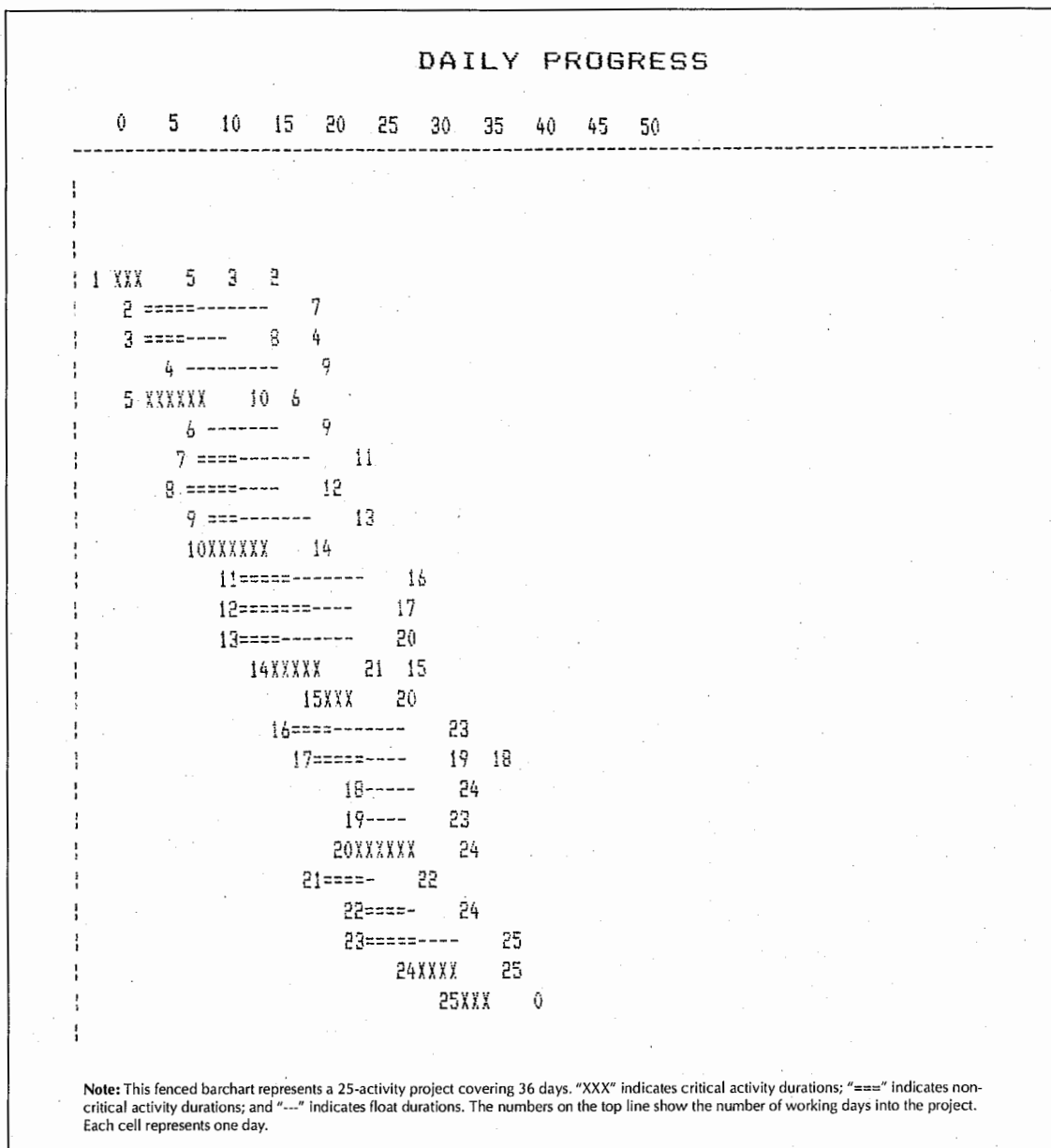


FIGURE 4. Spreadsheet version of the barchart.

tion of a sample AOA diagram is shown in Figure 2.

A major advantage of using spreadsheet software to develop a project management application program is the ability to tailor the spreadsheet to the format that the user desires. Another advantage is that there are a large number of special-purpose spreadsheet software systems that are commercially avail-

able and that are adaptable to this end.⁶

The use of macros in spreadsheet software allows the development of a user-friendly, menu-driven project management system. Reporting and graphing are very well performed by spreadsheets. The disadvantages to using spreadsheet software is the relative complexity of macro programming, and a lower speed of execution than some of the sophisticated commercial project management sys-

Date: 1/ 1/80
 Project Id: HOSPITA
 Project Start: 1/ 1/86
 Project Currency: 1 US\$
 base: newclass

 * PALM WEST HOSPITAL *
 * P R O M I S *

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 Last Acc: 1/ 1/80
 Last Upd:

Report #: 541-1

ACTIVITY INPUT LISTING

Selection: All

ACT. ID	SUBPROJ. ID	ACTIVITY DESCRIPTION	EST DUR	PLANNED S/F	SCHED DATE	CONC.	WMC	RESP	AUX1	AUX2	AUX3
01		START	0	1/ 1/86	SNLT	5d					
02		MOBILIZATION	2	1/ 1/86	SNLT	5d	GC				
03		MACHINE EXCAVATION	5			5d	GC				
04		HAND EXCAVATION	4			5d	GC				
05		BACKFILL/COMPACTION	16			5d	GC				
06		FORMWORK/SPREAD FOOTING	12			5d	GC				
07		FORMWORK/CONTINUOUS FOOTINGS	1			5d	GC				
08		GRADE BEAM FORMS	7			5d	GC				
09		FORMWORK/FOUNDATION WALL	3			5d	GC				
10		FORMWORK/SLAB ON GRADE	2			5d	GC				
11		FORMWORK/RETAINING WALLS	5			5d	GC				
12		REINFORCEMENT/SPREAD FOOTING	5			5d	GC				
13		REINFORCEMENT/CONT. FOOTING	1			5d	GC				
14		REINFORCEMENT/GRADE BEAM	4			5d	GC				
15		REINFORCEMENT/FOUNDATION WALL	1			5d	GC				
16		WELDING WIRE FABRIC	44			5d	GC				
17		REINFORCEMENT/RETAINING WALL	1			5d	GC				
18		CAST/SPREAD FOOTINGS	4			5d	GC				
19		CAST/CONTINUOUS FOOTINGS	1			5d	GC				
20		CAST/GRADE BEAM	1			5d	GC				
21		CAST/FOUNDATION WALL	1			5d	GC				
22		CAST/SLAB ON GRADE	8			5d	GC				
23		CAST/RETAINING WALL	1			5d	GC				
24		TROWEL FINISH SLAB	12			5d	GC				
25		CURE AND HARDEN	14			5d	GC				
26		CURE VERTICAL SURFACE	13			5d	GC				
27		FINISH	0			5d					

FIGURE 6. Activity input listing for a time and resource scheduling system.

- a fenced barchart (see Figure 4)
- a daily resource usage barchart for a given resource code using the spreadsheet's sorting capability
- different graphics outputs (for example, a graph of a resource versus time as depicted in Figure 5)

Figure 4 presents a barchart printed out from the information contained in Figure 3. The barchart is fenced by the activities that follow. The number of the activity is listed in front of the symbol for the activity. The duration of the project is indicated by "===" or "XXX" for critical activities. The floats for the activities are

indicated by "---". While the printouts are not particularly fancy, they do provide the manager with a visual display of the project progress.

Figure 5 reveals a barchart for activities utilizing a particular resource required for a sample project, electricians in this case. The data table was reselected to display only activities using the specified resource. The barchart was then reprinted.

The real value of using spreadsheet software for this purpose is the flexibility that the user has in designing the system and designating the inputs, the data to be used and the selection and sorting criteria, as well as the ability to

Date: 1/ 1/80 ***** Page 1
 Project Id: HOSPITA * PALM WEST HOSPITAL * Last Acc: 1/ 1/80
 Proj Start: 1/ 1/86 * P R O M I S * Last Upd:
 Proj Currency: 1 US\$ *****
 Database: newclass Report #: 543-2

PROJECT RESOURCE TABLE

Selection: All

RESOURCE ID	DESCRIPTION	UNITS OF MEASURE	STANDARD RATE	OVERTIME RATE	DEF. OH. PROFIT	MAX DAILY AVAILABLE
1	REINFORCING STEEL	TON	480.00	0.00	10.00	50.00
2	WELDING WIRE FABRIC	SQ. FT.	7.65	0.00	10.00	7500.00
3	CONCRETE	CU. YD.	46.00	0.00	10.00	0.00
B-10A	COMPACTION	CREW-DAY	289.85	434.78	10.00	0.00
B-12N	EXCAVATION	CREW-DAY	788.00	1182.00	10.00	0.00
BLAB	BUILDING LABORER	MAN-DAY	122.00	183.00	10.00	0.00
C-1	FORMWORK	CREW-DAY	605.00	907.00	10.00	0.00
C-2	FORMWORK	CREW-DAY	936.00	1404.00	10.00	0.00
C-6	CONCRETE FINISHING	CREW-DAY	824.30	1236.45	10.00	0.00
C-9	CONCRETE FINISHING	CREW-DAY	175.90	263.85	10.00	0.00
CFW	CONT. FOOTING FORM	SQ. FT.	0.48	0.00	10.00	300.00
FWW	FOUNDATION WALL FORM	SQ. FT.	0.77	0.00	10.00	1050.00
GBW	GRADE BEAM FORMS	SQ. FT.	0.73	0.00	10.00	3000.00
RDMAN	RODMAN	MAN-DAY	166.40	249.60	10.00	0.00
RWW	RETAINING WALL FORMS	SQ. FT.	0.86	0.00	10.00	1700.00
SFW	SPREAD FOOTING FORMS	SQ. FT.	0.55	0.00	10.00	4500.00
SWH	SLAB ON GRADE FORMS	LIN. FT.	0.17	0.00	10.00	850.00

FIGURE 7. Project resource table generated by a time and resource scheduling system.

perform "what-if" analyses. However, considerable time might be spent by the user in writing and revising the programs to suit his needs. In fact, the macros might need to be revised for each different project. Another disadvantage is the amount of time that spreadsheets use to complete calculations. For example, the macro utility from the spreadsheet software used here was intended for short operations. Calculations for construction project management often require long macro scripts and repeated calculations, posing distinct problems in debugging. Still, writing efficient macro programs is possible and it does have certain advantages in its customization capability.

Other capabilities that are available on most commercially available spreadsheet software programs can also be used in construction management. The graphical outputs are an obvious addition to any reports that the program generates. There are also various statistical packages that could be adapted and used in conjunction with spreadsheet programs for aiding in the computation of overtime, and in

developing production estimates.

Standard Sophisticated Systems

Another project management software option is to use one of the commercially available sophisticated standard time and resource scheduling software systems. This type of software can handle very large projects, and provides a wide variety of features such as subnetworking, reporting of progress-to-date performance as well as projecting time and cost performance.

A sample project consisting of a hospital substructure was run on one of these dedicated application programs. The activity listing is shown in Figure 6. The software maintains resources and costs, which can be used to create a project resource table as shown in Figure 7. After the network has been processed, a wide variety of standard reports and graphs are available, such as the resource requirements listing and costing reports (see Figures 8 and 9), time analysis reports, and graphs such as a barchart (see Figure 10), network diagram, cash

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 Project Id: HOSPITA
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 Project Currency: 1 US\$
 base: newclass

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Report #: 541-3

RESOURCE REQUIREMENTS LISTING

Selection: All

ACTIVITY ID DESCRIPTION	ESTIMATED DURATION	WORK WEEK CODE	RESOURCE		QUANTITY NEEDED	UNITS OF MEASURE	DAY OF ACT	NO. S OF / DAYS	JOB CODE	OH & PROFIT (%)
			ID	DESCRIPTION						
03 MACHINE EXCAVATION	5	5d	B-12N	EXCAVATION	5.00	CREW-DAY	1	5 S		10.00
04 HAND EXCAVATION	4	5d	BLAB	BUILDING LABORER	40.00	MAN-DAY	1	4 S		10.00
05 BACKFILL/COMPACTION	16	5d	B-10A	COMPACTION	16.00	CREW-DAY	1	16 S		10.00
06 FORMWORK/SPREAD FOOTING	12	5d	C-1	FORMWORK	12.00	CREW-DAY	1	12 S		10.00
			SFW	SPREAD FOOTING FORMS	4424.00	SQ. FT.	1	12 S		10.00
07 FORMWORK/CONTINUOUS FOOTINGS	1	5d	C-1	FORMWORK	1.00	CREW-DAY	1	1 S		10.00
			CFW	CONT. FOOTING FORM	288.00	SQ. FT.	1	1 S		10.00
08 GRADE BEAM FORMS	7	5d	C-2	FORMWORK	7.00	CREW-DAY	1	7 S		10.00
			GBW	GRADE BEAM FORMS	2820.00	SQ. FT.	1	3 S		10.00
09 FORMWORK/FOUNDATION WALL	3	5d	C-2	FORMWORK	3.00	CREW-DAY	1	3 S		10.00
			FWW	FOUNDATION WALL FORM	997.00	SQ. FT.	1	2 S		10.00
10 FORMWORK/SLAB ON GRADE	2	5d	C-2	FORMWORK	2.00	CREW-DAY	1	2 S		10.00
			SGW	SLAB ON GRADE FORMS	750.00	LIN. FT.	1	1 S		10.00
11 FORMWORK/RETAINING WALLS	5	5d	C-2	FORMWORK	5.00	CREW-DAY	1	5 S		10.00
			RWW	RETAINING WALL FORMS	1646.00	SQ. FT.	1	3 S		10.00
12 REINFORCEMENT/SPREAD FOOTING	5	5d	1	REINFORCING STEEL	29.90	TON	1	5 S		10.00
			RODMAN	RODMAN	40.00	MAN-DAY	1	5 S		10.00
13 REINFORCEMENT/CONT. FOOTING	1	5d	1	REINFORCING STEEL	0.30	TON	1	1 S		10.00
			RODMAN	RODMAN	2.00	MAN-DAY	1	1 S		10.00
14 REINFORCEMENT/GRADE BEAM	4	5d	1	REINFORCING STEEL	10.20	TON	1	4 S		10.00
			RODMAN	RODMAN	16.00	MAN-DAY	1	4 S		10.00
15 REINFORCEMENT/FOUNDATION WALL	1	5d	1	REINFORCING STEEL	0.60	TON	1	1 S		10.00
			RODMAN	RODMAN	2.00	MAN-DAY	1	1 S		10.00
16 WELDING WIRE FABRIC	44	5d	2	WELDING WIRE FABRIC	7260.00	SQ. FT.	1	44 S		10.00
			RODMAN	RODMAN	440.00	MAN-DAY	1	44 S		10.00
17 REINFORCEMENT/RETAINING WALL	1	5d	1	REINFORCING STEEL	2.00	TON	1	1 S		10.00
			RODMAN	RODMAN	2.00	MAN-DAY	1	1 S		10.00
18 CAST/SPREAD FOOTINGS	4	5d	3	CONCRETE	392.00	CU. YD.	1	2 S		10.00
			C-6	CONCRETE FINISHING	4.00	CREW-DAY	1	4 S		10.00
19 CAST/CONTINUOUS FOOTINGS	1	5d	3	CONCRETE	4.00	CU. YD.	1	1 S		10.00
			C-6	CONCRETE FINISHING	1.00	CREW-DAY	1	1 S		10.00
20 CAST/GRADE BEAM	1	5d	3	CONCRETE	134.00	CU. YD.	1	1 S		10.00
			C-6	CONCRETE FINISHING	1.00	CREW-DAY	1	1 S		10.00
21 CAST/FOUNDATION WALL	1	5d	3	CONCRETE	8.00	CU. YD.	1	1 S		10.00
			C-6	CONCRETE FINISHING	1.00	CREW-DAY	1	1 S		10.00
22 CAST/SLAB ON GRADE	8	5d	3	CONCRETE	1178.00	CU. YD.	1	4 S		10.00
			C-6	CONCRETE FINISHING	8.00	CREW-DAY	1	8 S		10.00
23 CAST/RETAINING WALL	1	5d	3	CONCRETE	27.00	CU. YD.	1	1 S		10.00
			C-6	CONCRETE FINISHING	1.00	CREW-DAY	1	1 S		10.00
24 TROWEL FINISH SLAB	12	5d	C-9	CONCRETE FINISHING	12.00	CREW-DAY	1	12 S		10.00
25 CURE AND HARDEN	14	5d	BLAB	BUILDING LABORER	140.00	MAN-DAY	1	14 S		10.00
CURE VERTICAL SURFACE	13	5d	BLAB	BUILDING LABORER	52.00	MAN-DAY	1	13 S		10.00

FIGURE 8. Resource requirements listing output by a time and resource scheduling system.

flow and resource profiles, and earned value analysis. Resource-constrained scheduling is also possible from some of these dedicated programs which provide an integrated project

management environment.

Make or Buy Decisions

From the preceding discussion, it is quite clear

Date: 1/ 1/80
 Project Id: BEACH
 Project Start: 1/ 1/86
 Project Currency: 1 US\$
 Database: GROUP2

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RESOURCE COSTING REPORT - TARGET SCHEDULE

Selection: All

RESOURCE ID	DESCRIPTION	UNITS OF MEASURE	REQUIREMENTS			NO. OF DAYS	COST	CUMULATIVE COST
			FROM	TO	COST/DAY			
B10A	MECH EXC	CREW DAYS	1/16/86	1/17/86	289.85	2	579.70	579.70
			1/20/86	1/24/86	289.85	5	1449.25	2028.95
			1/27/86	1/31/86	289.85	5	1449.25	3478.20
			2/ 3/86	2/ 6/86	289.85	4	1159.40	4637.60
			TOTAL:		16	4637.60		
B12N	MACH EXC 2	CREW DAYS	1/ 3/86	1/ 3/86	788.00	1	788.00	788.00
			1/ 6/86	1/ 9/86	788.00	4	3152.00	3940.00
			TOTAL:		5	3940.00		
BL	BUILDING LABORER	MAN DAYS	1/10/86	1/10/86	1220.00	1	1220.00	1220.00
			1/13/86	1/15/86	1220.00	3	3660.00	4880.00
			3/17/86	3/21/86	488.00	5	2440.00	7320.00
			3/24/86	3/28/86	488.00	5	2440.00	9760.00
			3/31/86	4/ 2/86	488.00	3	1464.00	11224.00
			6/13/86	6/13/86	1220.00	1	1220.00	12444.00
			6/16/86	6/20/86	1220.00	5	6100.00	18544.00
			6/23/86	6/27/86	1220.00	5	6100.00	24644.00
			6/30/86	7/ 2/86	1220.00	3	3660.00	28304.00
			TOTAL:		31	28304.00		
C1	CARPENTERS1	CREW DAYS	2/ 7/86	2/ 7/86	1210.00	1	1210.00	1210.00
			2/10/86	2/14/86	605.00	5	3025.00	4235.00
			2/17/86	2/21/86	605.00	5	3025.00	7260.00
			2/24/86	2/24/86	605.00	1	605.00	7865.00
			TOTAL:		12	7865.00		
C2	CARPENTERS2	CREW DAYS	2/10/86	2/12/86	1872.00	3	5616.00	5616.00
			2/13/86	2/14/86	936.00	2	1872.00	7488.00
			3/13/86	3/14/86	1872.00	2	3744.00	11232.00
			3/17/86	3/21/86	936.00	5	4680.00	15912.00
			TOTAL:		12	15912.00		

FIGURE 9. A resource costing report that has been generated by a time and resource scheduling system.

that the implementation of a simple project management software system is feasible. In particular, the combination of database management software and spreadsheet software is particularly advantageous, and provides the benefits of customized reporting.

However, the computational power of dedicated time and resource management software can be fully exploited only with a significant in-house investment in supplementary software development that far exceeds the purchase price of the basic system.

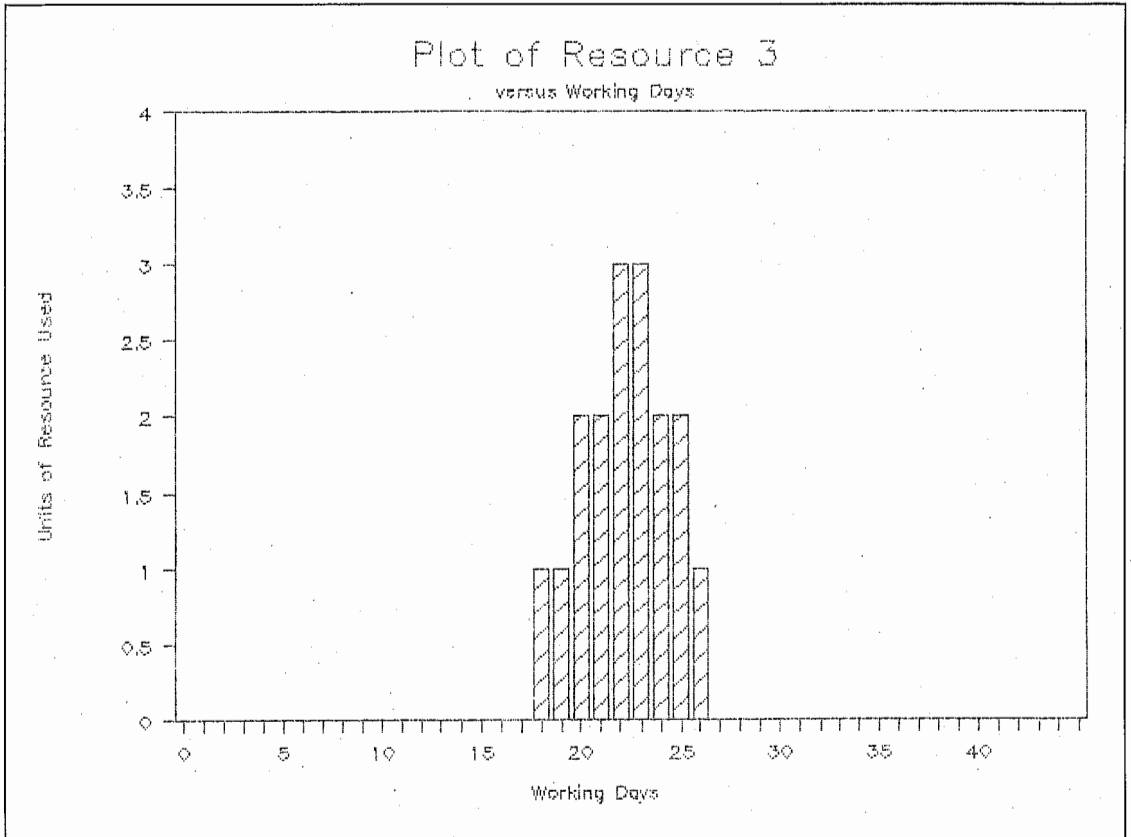


FIGURE 10. Resource profile produced using the graphics capabilities of spreadsheet software.

In Table 3, database management, spreadsheets, integrated time and resource management systems, and word processing software are evaluated for different functions such as estimating, time management, standard/customized reporting, *etc.* The only areas of relative weakness of integrated project management software are in estimating (often performed by specialized software), and customized report and graph generation. Spreadsheets, and possibly database management software, can be used in conjunction with a sophisticated time and resource management system. Some of these dedicated programs provide a file transfer feature that simplifies interchanging data with other spreadsheet and database management programs. Using macros such as those described above, customized reporting or inputting capabilities can be created by reading from, or writing to, the time and resource management system.

Conclusions

The company that is about to select a microcomputer project management system is faced with a wide variety of choices of software with varying prices and capabilities. The quality and features of this software are undergoing continuous improvement and change.

Developing programs in-house can be considered for simple applications. A combination of commercially-available sophisticated project management software, spreadsheet and database management software can enhance overall system performance significantly, particularly when supplemented by customized reporting and input utilities developed in-house. This latter approach is generally the most cost-effective development option, unless the advantages of compatibility with other functions such as job costing and cost control dictate the development of a costlier, more fully

TABLE 3
Usefulness of Different Software Systems for Construction Management Functions

Function	Software System			
	Database Management	Spreadsheet	Integrated Time & Resource Management	Word Processing
Estimating	UC	U	L	S
Network Design	N/A	L	U	N/A
Time Management	N/A	L	U	N/A
Resource Management	N/A	L	U	N/A
Standard Reports	N/A	N/A	U	N/A
Standard Graphics	N/A	N/A	U	N/A
Customized Reports	U/UC	U	L	S
Customized Graphics	U/UC	U	L	S

Key: U = Useful UC = Useful when combined with other systems L = Limited use S = Support N/A = Not applicable

customized system, with the associated need for a much more expensive and time-consuming in-house programming and debugging effort.

NOTES — The spreadsheet software used for this article was Lotus 1-2-3, by Lotus Development. The dedicated project management system was PROMIS, by Strategic Software Planning Corp. The term, "network," as used here refers to the interrelated elements encompassed within a project and not to the linking together of computers, peripherals, instruments and other devices.



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REFERENCES

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