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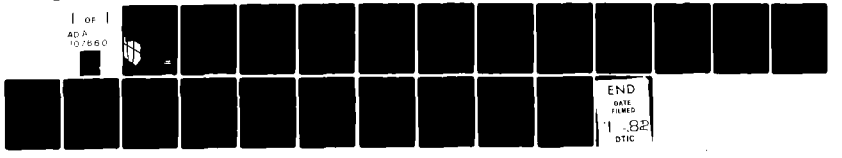

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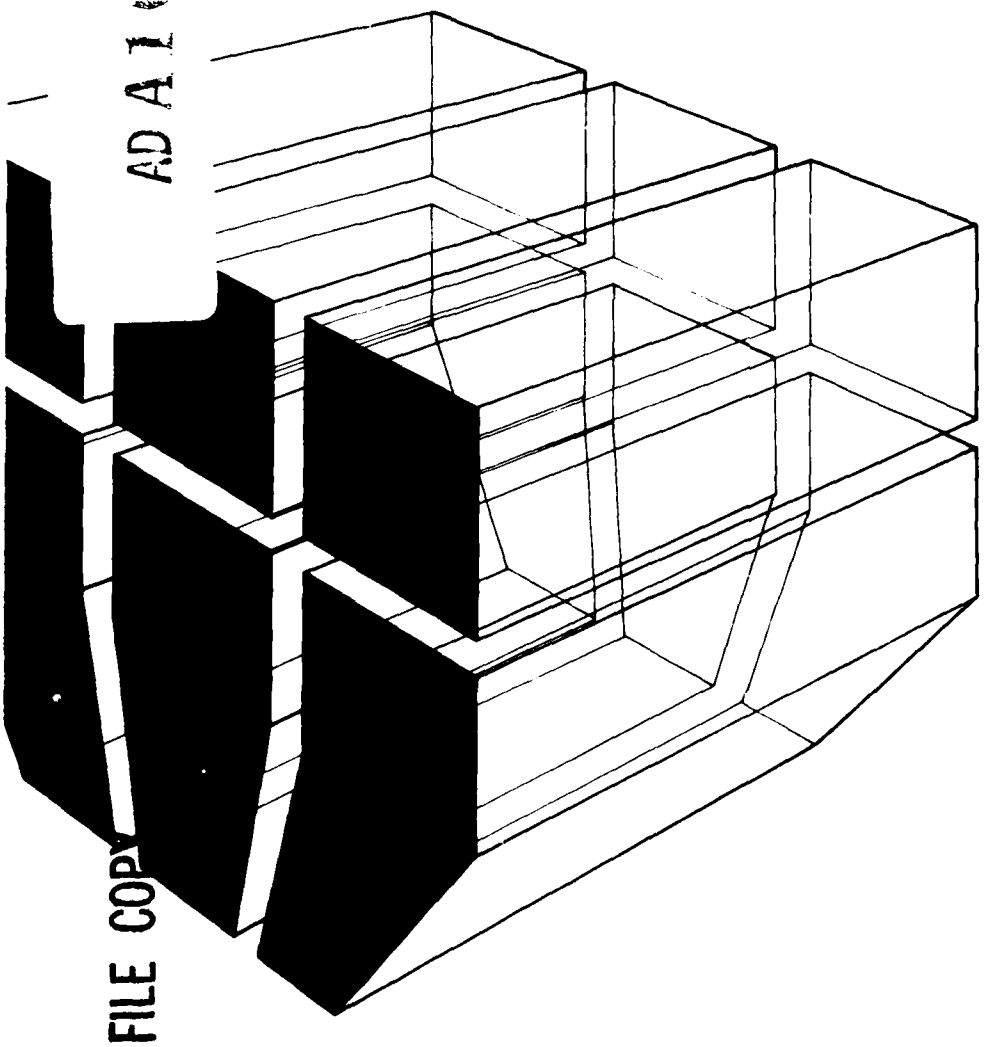

by
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Over the next decade, engineers have an excellent opportunity to use available low-cost, micro-based hardware. Network analysis is a suitable software tool for managing small and large, simple and complex project networks even on the small machines. One may ask whether and how engineers will use micro-based network analysis given its limited use in the past. Data on the current construction projects indicate that engineers will not quickly and easily adapt these micro-based tools. The same data also suggest that

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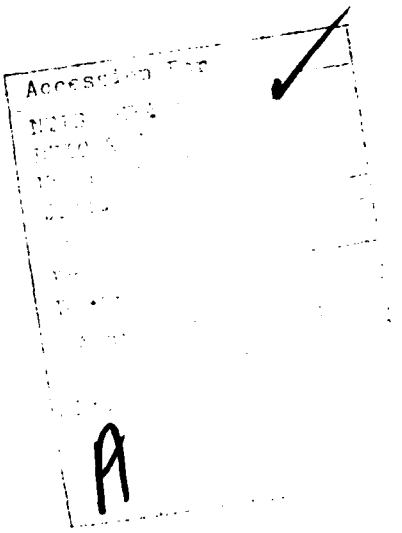
FOREWORD

This manuscript was presented at the First International Computer Conference in Civil Engineering, New York, 12 May 1981.

The work was performed for the Directorate of Military Programs, Office of the Chief of Engineers, under Project 4A762731AT41, "Design and Construction of Fixed Military Facilities"; Task A, "Design and Construction"; Work Unit 35, "Microprocessor Applications to the MC Process." The applicable QCR is 303.006. The OCE Technical Monitor was Mr. Phil Pinol.

The research was conducted at the U.S. Army Construction Engineering Research Laboratory (CERL) by the Facility Systems (FS) Division. Mr. Edward Lotz is Chief of FS.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.



ABSTRACT

Expected Use of Micro-Based Network Analysis

by

Carl E. DeLong
Janet H. Spoonamore

Over the next decade, engineers have an excellent opportunity to use available low-cost, micro-based hardware. Network analysis is a suitable software tool for managing small and large, simple and complex project networks even on the small machines. One may ask whether and how engineers will use micro-based network analysis given its limited use in the past. Data on the current construction projects indicate that engineers will not quickly and easily adapt these micro-based tools. The same data also suggest that established users will more and more depend on their micro computers.

Vita

Ms. Janet Spoonamore has been an operations researcher with the Corps of Engineers, Construction Engineering Research Laboratory, Champaign, Illinois, since 1973. She has designed and developed micro-based tools for use in construction management and architectural design. Prior to her Corps research, Ms. Spoonamore developed parallel numerical methods and econometric models at the University of Illinois Center for Advanced Computation.

Mr. Carl DeLong has been with the Corps of Engineers since 1969. After three years of civil works field construction experience, he served as an office engineer in a military construction area office. In 1972, he transferred to CERL, where he has developed computer-based construction management techniques. In addition, he has been heavily involved in the functional analysis of Corps of Engineers organizations. Prior to his Corps employment, he worked for the Bureau of Public Roads and the U.S. Geological Survey. Mr. DeLong is currently president of the Central Illinois Section, ASCE.

Expected Use of Micro-Based Network Analysis

Background

The development of microprocessors during the 1970's and the resulting decrease in computational costs made it feasible to consider putting microcomputers in Corps field offices. By the end of the 1970's a complete microcomputer system had become desk size. These computer systems include a CRT terminal, a medium speed line printer, and a dual drive, floppy disk system. Further refinements to this technology allowed hard disks to be attached, thereby allowing a full range of computing power to field offices. This development offers opportunities to the Corps of Engineers, a widely dispersed construction agency.

Construction field office major roles include administering, monitoring, and managing the construction process. These offices are small, widely dispersed and transient in nature. Large-scale, automated procedures are not appropriate for use in these environments as is evidenced by the lack of such tools. Considerable attention has focused on network analysis as the ideal tool for use in managing construction projects. It provides the ability to immediately evaluate large projects using automated tools.

Objective

The RDT&E work unit "Microprocessor Applications to the Military Construction Process" is a research effort conducted at the U.S. Army Construction Engineering Research Laboratory (CERL).

CERL's purpose is to research and test the feasibility of microprocessor applications to the military construction process. The MICRO project will identify, evaluate, and implement tools on micro-based equipment to support construction field office operations. The major effort is to develop applications having high benefits to construction management and to prepare specifications and guidance for implementing these applications.

DESCRIPTION OF RESEARCH PROJECT

Initial steps included an analysis of potential field applications. An economic analysis of each application was prepared and the application ranked according to the potential high cost benefits.

A microcomputer system was procured and a critical path method (CPM) program was implemented on the microcomputer system. This CPM software package was designed to aid Corps of Engineers field officers in the administration of construction contracts for military facilities. The development of this system, which was reported at the October 1978 ASCE Convention in Chicago, proved the feasibility of

comprehensive software packages for the Corps of Engineers on microcomputer equipment.

Concurrent research was conducted in the area of modification analysis. Techniques for impact analysis require network analysis and thus require the availability of this microcomputer tool. Network analysis identifies the impacts of modifications both in terms of project timing and individual activity changes. This work has become a Corps of Engineers manual on impact analysis.

Field Tests

After development of the CPM-based software, field tests were conducted to provide an analysis of our concepts. Basic concepts included (1) a non-ADP oriented user system, (2) a microcomputer system capable of handling a comprehensive project management software package, (3) hardware capable of operating in an uncontrolled environment.

The first field test answered several concept questions as follows:

1. It is feasible to do comprehensive programming on microprocessor-based equipment. Specifically, it is feasible to implement a network analysis program handling up to 1200 activities in core, although it taxes the resources of the printer and floppy disk.

2. It is feasible for non-computer trained personnel to operate micro-based equipment if it is based on "user-friendly design" concepts.

3. A special environment for computer equipment is not necessary.

4. The staff involved with construction management must be committed to analytical practices for a computer tool offering analysis to be of benefit.

CERL is currently conducting another field test with commercial equipment and software. This will enable CERL to develop hardware and software specifications and ADP documentation required to implement microcomputers in field offices.

Both of these tests involve managing large construction projects. The users of the system are not professional ADP staff. The training for both tests was performed in less than one week with the user manually loading the initial networks.

The field test is as follows: A permanent copy of all official changes is made. The network is regularly updated to reflect progress and changes. These modifications must be evaluated quickly and the updated network provides a tool for modification analysis.

Trends in Network Analysis Usage

Based on analysis of the information gathered from Corps CPM usage, those who use network analysis tend to rely more and more on it for project control and analysis. However, only a small percentage of area offices use this technique.

Tables 1 through 4 provide a profile of CPM usage.

The data in these tables indicate use of network analysis for project management is limited. This sample of corps offices may not reflect the total Corps picture nor construction in general. However, in reviewing those offices using network analysis, it is clear that:

1. Project size (number of activities) is not a factor.

2. Project cost is not a factor.

3. Office size is not a factor.

Further, it appears that offices using network analysis must have the capacity to analyze projects as large as 2000 activities. What this suggests is the need for micro-based network analysis to handle large networks.

Projected Hardware Usage

User-friendly software has drawn favorable comment from the field tests. Basic input to the program can be accomplished by non-technical personnel as the program is menu-driven and data input is inserted to a formattable screen with a movable screen cursor.

The size of the equipment is adequate to handle 90 percent of networking projects. Removable memory storage allows flexibility in user requirements so that the user does not see size limitations.

The user sees a considerable printing time with large sized networks. Consequently, it is necessary to provide a medium to high speed printer or have selective print capability with the software program.

The equipment and software has been used to evaluate modification and project impacts before the fact. It has proven to be a powerful tool in negotiating for two reasons. First, the client can be informed of the cost and time impacts. Based on this information, the client may decline to issue a requested modification. Second, the contractor's proposal for incorporating the modification can be evaluated against several alternatives.

Table 1

Field Office Placement (FY79)

District	No. Field Offices per District	Total Military Placement per District (millions $)	Avg. Military Placement per Field Office (millions $)	Total No. Staff per District	Avg. No. Staff per Field Office	Avg. $ per Staff (millions $ per Staff)
Fort Worth	6	182.3	30.4	218.0	36.3	.84
Kansas City	3	36.7	12.2	27.0	9.0	1.36
Mobile	17	185.5	10.9	177.0	10.4	1.05
New York	4	50.2	12.6	46.0	11.5	1.09
Norfolk	3	45.0	15.0	46.0	15.3	.98
Omaha	7	87.4	12.5	94.0	13.4	.93
Sacramento	4	74.3	18.6	80.0	20.0	.93
Savannah	9	83.3	9.3	95.0	10.6	.88
Total	53	744.7		783		
Avg.		14.1		14.8	.95	

Table 2

Representative Projects Having CPM's
(Summer 1980)

District	Field* Office	Total Number Projects in Office	CPM Projects Number	Average per CPM Project Acts	$ Val (1,000,000)	Duration (days)
5	A	11	9	515	$3.1	665
	B	12	1	495	$2.6	734
2	C	7	4	3300	$14.0	
6	D	17	3	715	$10.0	952
	E	37	2	1016	$13.0	720
3	F	12	4	3779	$14.5	
	G	10	4	1000	$4.7	
	H	7	2	650	$15.	
1	I	13	3	1500	$20.	
	J	30	9	570	$14.	
8	K	11	6	787	$5.3	
	L	16	11	1290	$3.25	
	M	9	7	511	$2.7	
	N	23	11	583	$5.7	
Totals	14 offices	214	76	81455	$584.0	
Averages (weighted)				1072	$7.7	734

Average of $7200/Activity

*Asked for the largest field offices in the District.

Table 3

Profile of Project

CPM/Man CPM

avg. # acts/project	1072
avg. $ value/project	$7.7 million
avg. duration/project	734 days
avg. $ value/activity	$7200
avg. duration/activity	1 month
avg. $ value/modification	$19,250*
avg. frequency of modifications	once/month

*Based on 6% contingency: 734 days 24 months

$$\text{mod} = \frac{\text{cost}}{\frac{.06 \times \$7{,}700{,}000}{24 \text{ mo.}}} = \$19{,}250$$

Table 4

Individual CPM Projects*
(Summer 1980)

District	Field Office	No. Activities	Total $ Val (1,000,000)
5	A	495	2.6
2	C	2750	13.0
		5014	16.6
6	D	600	12.0
		800	12.0
		750	8.2
	E	1279	20.1
		754	7.6
3	F	9426	36.0
		706	6.0
		1205	1.5
	H	300	3.6
		1000	27.0
1	I	1000	3.3
		2000	36.0
	J	200	27.0
		2000	35.0
		250	.65
		200	4.7
		200	2.4
8	K	969	5.6
		418	2.6
		877	1.8
		887	3.0
	L	1764	4.9
		445	6.0
		4990	18.4
		450	3.1
		469	1.9
		679	6.7
		2644	2.5
		782	4.8
		106	.79
		574	1.6
	M	879	8.1
		202	2.0
		236	1.2
		1248	4.0
		647	1.8
		215	1.7
		156	.97
	N	1655	1.4
		984	7.2
		213	.73
		489	2.6
		292	.96
		480	7.6
		284	2.1
		283	.64

Projects with < 2000 activities: 44; % of total = $\frac{44}{49}$ = .90

Projects with > 2000 activities: 5; % of total = $\frac{5}{49}$ = .10

* Only listed those projects having data available on Number of Activities per individual project.

Processing

Table 5 shows the projected processing requirements for network analysis systems based on the field test usage. Requirements for processing are determined by computations for: (a) performing the network analysis, (b) updating onto the disk, and (c) presenting the network results. Current equipment timing is used in deriving the processing times. A microsystem based on floppy disks is clearly unacceptable for expected usages.

Table 5

Monthly Progress Update

		1,000 Nodes	10,000 Nodes	10 Projects @ 5,000 Nodes
CPM	HARD DISK	4m	48m	4h
	Floppy Disk	75m	16h	77h
SAVE	HARD DISK	1m	10m	50m
	Floppy disk	10m	100m	8h
	BYTES storage	84k	840k	4M
PRINT	Time	10m	100m	8h
	Pages	40	400	2000
Total	HARD DISK			13h
	Floppy Disk			93h

m = minutes, h = hours, k = kilo, M = mega.

Hardware

The final system specifications have not been field determined. Based on provisional specifications, the following criteria have been developed.

a. The equipment should be desk size with a main processor having 16-bit registers with a direct memory access channel. It should include four serial and two parallel I/O ports and have a memory management controller and floating point processor. Basic core memory should be at least 64 K bytes. There should be an option to install a mass storage controller.

b. At a minimum, there should be a two-disk drive with a minimum of five megabytes high speed capacity.

c. All field equipment should include a power supply of 115-volts, 4-amp switching supply with a line filter and monitor for orderly shutdown.

d. Peripherals should include an interactive CRT terminal of 80 characters; a medium to high speed line printer (150 lines per minute) capable of printing 132 characters with form feed and bottom feed should have at least a 96-character ASCII set. The system should have a communications port capable of accepting an RS-232 modem for usage as an intelligent terminal.

Software

Software should include a project management package. It should be user-oriented and menu-driven. Input should be to either a fixed format or to a line input of specific information. The system should include an operating system to support higher level languages such as standard FORTRAN or PASCAL.

Utilities should include a text processing subsystem which is line-oriented and a Data Based management system with user defined files. In addition a sort/merge package and a MATH package should be made available.

The project management system should be configured to handle the features as shown in Table 6, CPM/Networking Features Matrix. The table shows the Networking attributes for Micro Based Systems and Large-Scale Time Sharing Systems. The essential characteristics for a microbased network analysis system include summary reporting and medium to large network handling, ideally 2000 activities or more. These features are not found on all systems.

Maintenance

Based on our field tests, the vendor of the hardware and software should provide a maintenance service. The following criteria are necessary.

a. Telephonic consultation for all problems available on a daily basis with a specifically designated project individual.

b. A three-day response time in repair of hardware and software items.

Table 6

CPM/Networking Features Matrix

Features	A Micro Based Requirement	B Time-Sharing
General		
Projects	1	Projects linked
Activities/project	2000	10,000
Relationships/Activity	20	100
Relationships/Network	6000	30,000
Network Scheduling Techrique		
i,j/precedence	Both	both
Activity Identification	5	9 characters
Activity Description	20	45 characters
Calendar	5, 6, 7	5, 6, 7 day multiple within project
Time Segments	Hours, days, weeks	Hours, days, weeks
Error Override	No	Yes
Input Format	Menu, fixed format	Fixed & Free
Input Edit	Yes, selective listing of data	Verification of data
Input Feasibility	Code and logical checks	Code and Logical checks
Open Ends Detection	No	Yes
Loop detection	Yes	Yes
Automatic File Maintenance	Yes	Yes
Resourcing		
Resource edit	Yes	Yes
Availability Profile	Summary lists	Graphical and summary
Resource requirements	Linear, lump	Linear, lump, complex
Utilization/Resource type	Summary list	Graphical and summary
Resources/Activity	6	10
Resources/Network	30	30
Activity		
Resource Summary Reporting	Yes	Yes
Resource Scheduling Options	No	Time and resource constraints
Resource Constraints	No	Priority and ranking rules

Table 6 (cont'd)

Target Schedules		
Target Network	Backup	Backup copies
Comparative Reportign	Barcharts, exceptions, and summary listing	Barchart, summary and exception listing
Multiproject Scheduling	No	Yes
Network Interfaces	No	Interrelated and stand-alone
Output		
Report Writer	Yes, flexible	Yes, flexible
Sorting	6 characters	12 characters
Selecting	Chronological on most fields	Chronological all fields
Windowing	Listed and graphical reports	Listed and graphical reports
Summary	Barcharts, listings	Barcharts, continuous and non-continous listings
Hammock	Yes	Yes
Network generator	No	Generates network from frag-nets
Float calculations	Total, scheduled, free	Specified float
Graphical Output (plotter)	No	Yes
Required Personnel	Clerk/typist input	Experienced personnel

Training

Before installation pretraining is required. Pretraining should include, at a minimum, one week of concepts and one week of hands-on experience before installation of the hardware and software.

Other Applications

Given the opportunity to process data, other applications besides network analysis can easily be supported on the same equipment. Table 7 shows the highest potential functions for computerized field office management.

Development of applications such as cost-accounting and personnel should be based on current Data Base Management Systems (DBMS). These systems allow the user to develop in-house data files for specific purposes. Data Base Management Systems allow the users to develop their specific needs and negate the need for a series of specialized software programs in the areas such as shop drawing registers, modification registers, and files for cost estimating purposes.

Additionally, a field computer enables a word processing system to be available for office administration purposes. Both the Data Base Management system and Word Processing system are low-cost and user-oriented. They require minimal training and address the functions of contract administration and office management.

Conclusions

Low-cost microcomputer equipment can be used for network analysis in the following areas:

1. Project control
2. Modification analysis before the fact.
3. Impact analysis before the fact.
4. As a tool to provide information for negotiating.

The ability to generate hard copy data provides a significant tool for the field office. User comments indicate that a significant advance has been made in providing field office support based on this capability. Network analysis techniques have been used to evaluate project logic concepts.

Effective implementation of microcomputers in field offices depends upon existing management philosophy. The basis for project management revolves around the concept of networking. If the manager uses a non-analytic approach, implementation of micro-based computer systems will not be completely successful. However, if the manager

Table 7

Potentials for Computerized Field Office Management

Construction Management

- Project CPM (IJ or Precedence)
- Construction Schedule Monitoring
- Progress Reporting
- Change Order Management
- Cost Estimating Database
- Workload Forecasting

Contract Administration

- Partial Payments
- Fiscal Status & Reports
- Submittal Management
  - Submittal Register
  - Submittal Status
- Technical Reference material
- Installed Real Property

Office Administration

- Word Processing
- Personnel files and listings
- Equipment schedule and utilization
- Time and attendance
- Office Management Systems
- Files Management

is data-oriented and uses data in the decision-making process, it will be feasible to introduce micro-based computing systems.

Current commercial costs for acceptable hardware configurations vary between $6,000 and $20,000 for microcomputer equipment based on Table 5. Software costs vary between $8,000 and $20,000. The total range including Data Based Management system and a Word Processing system is between $10,000 and $45,000. Presently, there are two successful project management large-scale mini-computer systems in the $125,000 to $150,000 range. However, this is a very volatile area and the potential user can anticipate significant changes in hardware and software costs on a yearly basis.

By implementing microcomputer equipment our field tests have shown that:

1. Extra personnel are not required in field offices.

2. Non-technical personnel can be utilized if the software is "user-friendly" and menu-driven.

3. Considerable before-the-fact information can be provided to the decision-maker.

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