TRANSPORTATION RESEARCH RECORD 932

Microcomputers in Transportation

TRANSPORTATION RESEARCH BOARD

NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1983

Transportation Research Record 932
Price $6.00
Edited for TRB by Susan Singer-Bart

modes
1 highway transportation
2 public transit
3 rail transportation
4 air transportation
5 other

subject areas
12 planning
13 forecasting
21 facilities design
24 pavement design and performance
54 operations and traffic control
55 traffic flow, capacity, and measurements

Library of Congress Cataloging in Publication Data
National Research Council. Transportation Research Board.
Microcomputers in transportation.

(Transportation research record; 932)
1. Transportation–Data processing–Addresses, essays, lectures.
2. Microcomputers–Addresses, essays, lectures. I. National Research Council (U.S.). Transportation Research Board. II. Series.
TE7.H5 no. 932 380.5ss [380.5'02854] 84-8352 (TA1230)
ISBN 0-309-03622-4 ISSN 0361-1981

Sponsorship of the Papers in This Transportation Research Record

DIVISION A–REGULAR TECHNICAL ACTIVITIES
Lester A. Hoel, University of Virginia, chairman

Task Force on Microcomputers in Transportation
Howard J. Simkowitz, D.C. Department of Transportation, chairman
Marvin Manheim, Massachusetts Institute of Technology, co-chairman
Richard L. Albright, John J. Dumbleton, Christopher R. Fleet, Kenneth G. Courage, Maximilian M. Etschmaier, Thomas J. Hillegass, Paul R. Los, Carl D. Martland, William R. McShane, James O'Day, Granville Paules, Jack Reilly, Jerry B. Schneider, Bob Jack Sisson, Charles M. Waller

W. Campbell Graeub, Transportation Research Board staff

The organizational units, officers, and members are as of December 31, 1982.

Contents

Authors of the Papers in This Record

Courage, Kenneth, University of Florida, Gainsville, Fla. 32611
Davies, Gary W., Garmen Associates, 57 Whippany Road, Whippany, N.J. 07981
D'Ignazio, Janet, Greater Roanoke Transit Co., P.O. Box 13247, Roanoke, Va. 24032
Manheim, Marvin, 733 Lincoln Street, Evanston, Ill. 60201
Martland, Carl D., Center for Transportation Studies, Massachusetts Institute of Technology, Cambridge, Mass. 02139
Reilly, Jack, Capital District Transportation Authority, 110 Watervliet Avenue, Albany, N.Y. 12206
Ruiter, Earl R., Cambridge Systematics, Inc., 238 Main Street, Cambridge, Mass. 02142
Simkowitz, Howard, U.S. Department of Transportation, 415 12th Street, N.W., Washington, D.C. 20004
Waller, Mike, Metroplan, 105 Main Street, Little Rock, Ark. 72201

An Introduction to Microcomputers in Transportation: Implications for the Future

Marvin Manheim and Howard Simkowitz

In each era of evolution of computer technology, a style of transportation practice has evolved (planning, management, analysis) consistent with the available technology. The microcomputer era is a period of truly personal computational support for the professional--the era of the professional's personal computer. A great explosion of power to support personal styles of use will be seen. Hardware innovation has come first; however, new developments in software will be the stimulus to innovative support of human problem-solving capabilities. These capabilities, provided initially in microcomputer-based environments, will change professional work styles in fundamental ways.

A key feature of the microcomputer revolution is the impact on the capacity, and readiness, of transportation professionals to be more exploratory, more responsive, and less firmly entrenched behind a single set of numbers. The adaptability of microcomputers to transportation problems is a consequence of the types of software used, such as the spread sheets, as well as of the hardware.

Microcomputers will be used in many ways--the office microcomputer will be used by a single user, professional, or staff; the multiuser office microcomputer will be shared; the microcomputer at home will be used at night and during the weekend and for general familiarization and support; and the portable microcomputer will be used in the field and while traveling to support the minicomputer or mainframe computer. All of these are candidate elements of a transportation organization's processing support.

In general, a number of microcomputer units, probably of different types, will be interconnected. These interconnections may be permanent, as when a microcomputer is wired as a terminal to a mainframe computer or minicomputer, or temporary, as when the microcomputer is used sometimes as a stand-alone work station and connected sometimes with a telephone or other link to a multiuser microcomputer, to other microcomputers, to a minicomputer, or to a mainframe computer. In such distributed-processing systems, individual users access the system through microcomputers or terminals, and draw on various levels of computer resources throughout the system when needed. Substantial evolution can be expected toward this kind of multisite, multistation, multiuser system during the next few years. Thus, the microcomputer as hardware is not an issue; the microcomputer will become simply a means for delivering desk-top access to the resources of the networks of services. The microcomputer is, from a hardware perspective, a way-station on the road toward an evolutionary distributed-processing system.

The important issues lie in the domain of software. Traditional computer applications were based on prepackaged programs--programs that were prespecified for particular applications (e.g., UTPS, cost models). A second type of software is typified by spread-sheet programs, graphics packages, word processors, and others, termed prepackaged application-generating environments or bounded environments. Within such software, a user generates a particular program or model of a problem. In that sense the user has great freedom; however, the domain of possible programs or models is actually bounded in that the style of what can be modeled and how it is relatively constrained or bounded. Evolutionary environments are a third type of software. These would provide multiple styles of representation and reasoning. The ideal form of evolutionary-environmental software is not yet available. In such an environment a user should be capable of building up complex processes out of elementary ones, of experimenting with alternative processes and evolving them, and of structuring new procedures after experimenting with many alternatives.

Three major phases of evolution of the use of personal, professional microcomputers in transportation are visualized. In the first phase tasks now being performed through other means are transferred to the microcomputer. These include tasks that were previously done on mainframe computers or minicomputers. These tasks are transferred to the microcomputers largely to increase an individual's accessibility to the capabilities or to reduce costs. (Obviously, many large-scale processing tasks cannot be transferred.) This also includes tasks that were previously performed with manual procedures, such as budget preparation, drafting of memos or reports, hand calculations, and use of tables or nomographs to do complex calculations. The key point is that the tasks were performed before their transfer to the microcomputer environment, but now they may be performed more quickly, more responsively, more elaborately, and with many more iterations and adjustments.

In the second phase, innovative approaches are taken to tasks that existed previously in an organization but were not supported by computer capabilities or even, in many cases, by analyses of any sort. In the third phase innovations occur in the organization--in its selection of tasks to be performed as well as how they are to be accomplished, in how it is organized to accomplish these tasks, and in its definition of its appropriate mission. In this phase the availability of powerful, personal, professional problem-solving tools, through microcomputers and other components of distributed-processing systems, allow, stimulate, and encourage significant changes in how individuals in the organization view what they should do and how they can do it. In this context the hardware and software become means, subordinate means, to much higher ends. Substantial increases are achieved in the efficiency and effectiveness with which the organization performs its missions.

Microcomputer applications in transportation are, and will continue to be, particularly interesting and exciting. The technology is exciting; however, its implications for the practice of transportation as a profession should be even more exciting. Significant evolution can be expected in the hardware and distributed-processing strategies, in the types of software available, and in the definition of the roles and missions of transportation organizations.

On January 16, 1983 the Task Force on Microcomputers in Transportation sponsored a Workshop on

Microcomputers in Transportation in conjunction with the Transportation Research Board 62nd Annual Meeting. The workshop included an introduction to microcomputers for new and potential users of microcomputer hardware and software and a discussion of the adaptability of microcomputers to transportation problems. A variety of microcomputer software programs were demonstrated. The papers presented at this workshop appear in this record and include applications of microcomputers in various areas of transportation--planning, transit, traffic engineering, railroad engineering, and civil engineering.

Microcomputer Software for Transportation Planning

EARL R. RUITER AND MIKE WALLER

A survey was conducted of a number of U.S. metropolitan planning organizations and private-sector software providers. The results indicate that many types of microcomputer software useful to transportation planners are available and are being used by planners, especially in smaller- and medium-sized regions, to plan more effectively and efficiently. The largest group of microcomputer programs implement sketch-planning transportation analysis methods that do not require detailed network coding and processing. Other common areas of application are traditional urban planning methods, aids for providing transportation services such as shared-ride matching, means of predicting transportation-related impacts, and project programming and budgeting aids. A number of programs are also available that broaden the support base for using microcomputers and developing application programs for use in transportation planning. This group of programs includes interfaces with other computing hardware, travel surveying aids, statistical and data processing programs, and system development programming aids. Based on the survey of available transportation planning software, a number of observations and recommendations are made concerning the ideal future development of the area. The broad range of microcomputer systems needs to be recognized—from home-style personal computers to multiuser supermicrocomputers. Also, all program developers should adopt the goal of developing portable software, both among different computers and among different planning agencies. Finally, strong emphasis should be placed on developing ways to use microcomputers effectively as smart terminals that can access the wealth of transportation software available on larger computers.

Many metropolitan planning organizations (MPOs), especially those in smaller- and medium-sized regions, have about 10 years of transportation planning experience. In the typical case the responsibility for a metropolitan area transportation study and planning process was transferred to the newly organized MPO. In general, the MPO staff was immediately charged with the responsibility for updating the land use and traffic forecasts of the latest transportation plan for the area. This assignment involved the review of several thousand numbers that describe land use and transportation system characteristics. In most urban areas this task was difficult to accomplish.

In a typical urban area, with a population of 500,000, the local MPO had no computer-processing capacity, only one or two desk-top-style calculators, and a staff of three or four planners, none of whom had been involved in the completion of the transportation plan under review. Even simple comparisons of alternative data sets involved the summarization, by hand methods, of these thousands of numbers. In the eyes of the average citizen and elected official, the credibility of many MPOs never had a chance to become established.

About 8 years ago many of these MPOs began a major review that was to include a somewhat comprehensive evaluation of alternative transportation plans. This process required the development of at least one 20-year forecast of land use, which would provide the basis for comparison among the alternatives. Again, the size of the data sets involved was substantial and, although the actual synthesis of these numbers into highway and transit assignments was accomplished on large computers, most if not all input data were developed by manual methods.

These were difficult days for most transportation planners. A typical day involved the counting of houses from aerial photographs, the measuring of land use acreages by counting the dots on a sheet of acetate, the summing of several thousand numbers, the converting of the number to ratios, and the coloring of a map to display the results of the day's work. About 5:00 p.m. someone would review this work and suggest that a basic factor should be changed and the entire day's effort should be repeated.

The modern microcomputer has not solved all the data-handling problems of the average transportation planner; however, it provides a significant part of the solution. Two publications stand out as the seeds that ultimately led to the growing use of microcomputers in transportation planning organizations:

1. A two-volume compilation of sketch-planning methods for short-range transportation and air quality planning prepared for the U.S. Environmental Protection Agency (EPA) and UMTA (1) and
2. The quick-response travel estimation techniques prepared for the NCHRP (2).

A number of the air quality sketch-planning procedures compiled in the first report were designed to be used with a small programmable calculator. Microcomputers such as the ones in use today were not readily available in 1978, although a few small ones, such as the early Apples, Ohio Scientifics, and the TRS (Radio Shack) models did exist. These machines generally operated with only 4 to 16K of random access memory (RAM); only infrequently was a disk drive available. A transportation planner with the Association of Central Oklahoma Governments wrote one of the first microcomputer-based transportation planning programs to apply an air quality sketch-planning procedure included in the first report. This program aided in successfully completing the Section 175 of the Clean Air Act of 1964, as amended, planning requirements in several metropolitan areas.

The NCHRP report provides a readily implemented foundation for sketch-planning programs on microcomputers. A number of programs written by using its factors and procedures have been implemented; they are likely to be used by many urban areas to reduce the cost and aggravation of long-range transportation analysis. These procedures also offer techniques that can be used to evaluate the impact of alternative future land use possibilities economically and quickly.

At about the same time as these early efforts were beginning in planning agencies, university research at such places as Cornell and Massachusetts Institute of Technology (MIT), as well as private-sector system development, also began to produce useful microcomputer transportation planning programs. Much progress has been made in just 4 years. The current state of the art of microcomputer programs for transportation planning and, in the light of the existing situation, the major issues that will face program developers and users for the next few years are summarized and discussed in this paper. These issues lead to a recommendation for some of the characteristics of the ideal transportation planning microcomputer program of the future. The conclusion of the paper contains a brief listing of the 55 programs and systems identified in a survey.

MICROCOMPUTERS TODAY

A telephone survey combined with the compilation of existing published information provided background information. Selected MPOs and other microcomputer software developers were contacted. The results of this survey are summarized in Figures 1 to 6. A total of 55 programs were identified, many from previous listings in catalog publications prepared by ITE (3) and UMTA (4). This list is not all-inclusive; however, it does provide a general overview of the range of current capabilities, organized by application area. As Figure 1 indicates, these programs provide a wide span of capabilities. The most common program is one that uses sketch planning, quick response, and innovative analysis methods to predict some aspect of urban transportation patterns. None of these programs is dependent on coded networks. Most are limited to transit or mode-choice analysis, but six--travel budget and quick-response analysis programs--provide procedures designed to address the full range of significant aspects of urban travel in a unified prediction process.

The second-most-common group of programs apply one or more of the traditional urban transportation planning steps (land use and demographic forecasting, trip generation, trip distribution, mode choice, and assignment) similar to the way in which these steps are usually applied with large computers. The only significant differences are more stringent problem size limits, a higher degree of analyst interaction, and simplified process or job control. Some of these program packages are now being developed for supermicrocomputers, which does much to relax the problem size limits of the smaller personal computers.

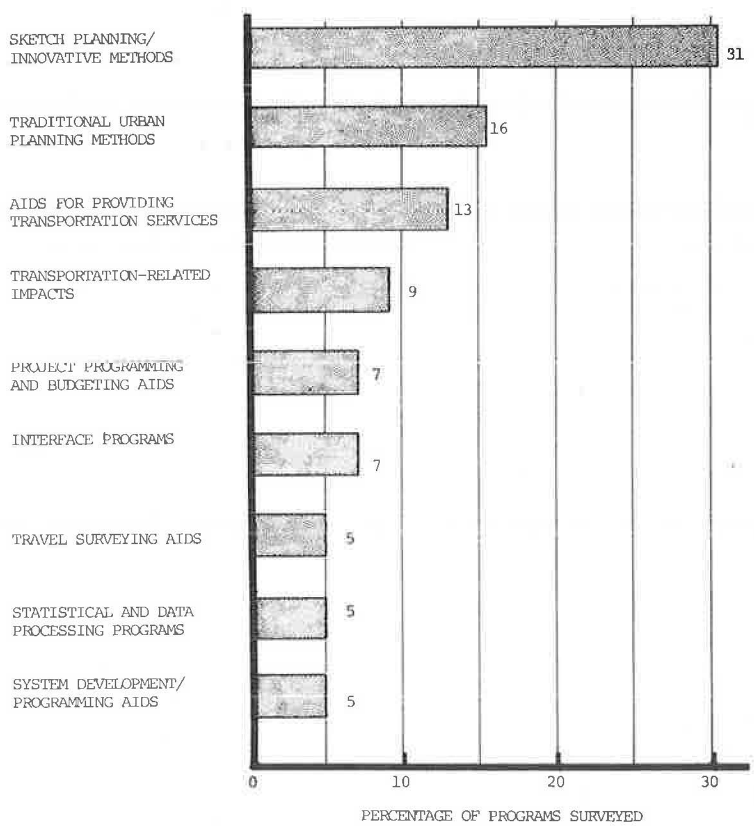
A significant emphasis in microcomputer program development has been the provision of aids for transportation service providers such as ridesharing promoters and paratransit operators, the third-highest grouping shown in Figure 1. The ease of using microcomputers in interactive and real-time environments, plus the increase in the need for carpool-matching and similar programs at the same time that microcomputers are becoming more common are two causes for this emphasis.

The remaining planning application areas, impact forecasting and programming and budgeting, are examples of areas not well addressed by commonly available software for nonmicrocomputer planning. Planners are likely to look for readily developed and easily applied computer tools to aid them in addressing these issues. They now find that microcomputers are available more frequently and are used more easily without the extensive involvement of more-computer-oriented professionals. In some cases generally available software such as spread-sheet programs and data base systems are ideally suited to these new problem areas. In other cases simple programs developed in high-level languages such as Pascal and Basic are appropriate. Applications of these types can be expected to be areas of significant continued growth in microcomputer capabilities in the future.

The four remaining application areas represent a different, but equally important, trend in the development of microcomputer programs. Interface programs, travel surveying aids, statistical and data processing programs, and system development programming aids each represent a broadening of the support base for planning analysis and microcomputer program development. They also represent the involvement of the more-computer-oriented analyst who is able to generalize the needs in a particular application into sets of capabilities that can be used in many applications. These efforts also provide a start toward the development of the more portable planning software advocated in the following sections.

Figure 2 indicates the variety of programming languages that have been used to develop existing programs. Basic is the most common language used;

Figure 1. Application areas.



however, no one language dominates. The entire range of languages, from assembly language to VISICALC, which is not strictly a language but has many of the same characteristics, has been used.

Although 54 percent of the programs surveyed are proprietary, this figure undoubtedly represents a surveying bias. The larger number of potential developers of public domain programs is more difficult to survey completely; this group is less likely to spend the extra effort required to provide fully documented transferable programs that others can implement in their own microcomputing environment. Also, proprietary system developers must advertise in order to sell.

The costs of obtaining microcomputer programs vary widely, which is a reflection of whether or not the programs were developed with public funds, whether or not source material is provided, and the wide range of sizes and scopes represented. The smaller programs tend to be sold for a one-time price in the $150 to $300 range, with no continuing support provided. Licensing arrangements, with an annual fee for maintenance and updates, tend to apply to the larger, more complex packages. These have initial costs in the $5,000 to $12,500 range. In addition, turnkey packages, including both hardware and software, are options available for some of the larger systems.

Apple brand microcomputers remain the predominant computers for which transportation planning software has been developed (see Figure 3). The IBM Personal

Figure 2. Programming languages.

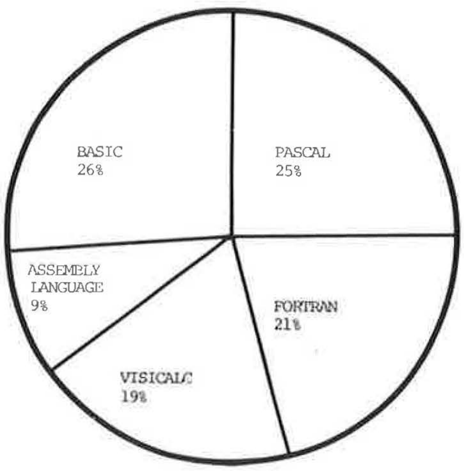


Figure 3. Microprocessors supported.

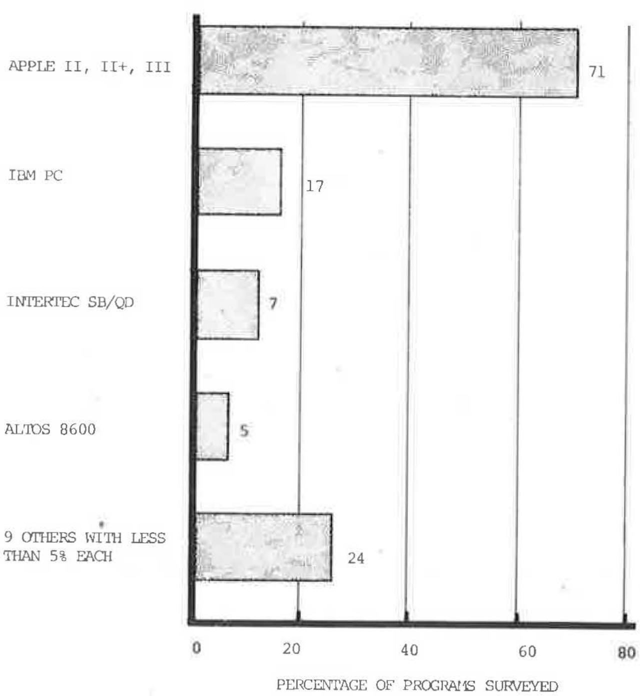


Figure 4. Operating systems.

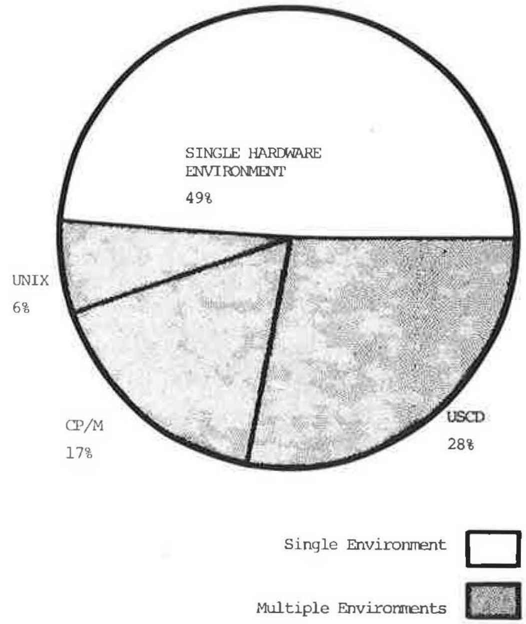
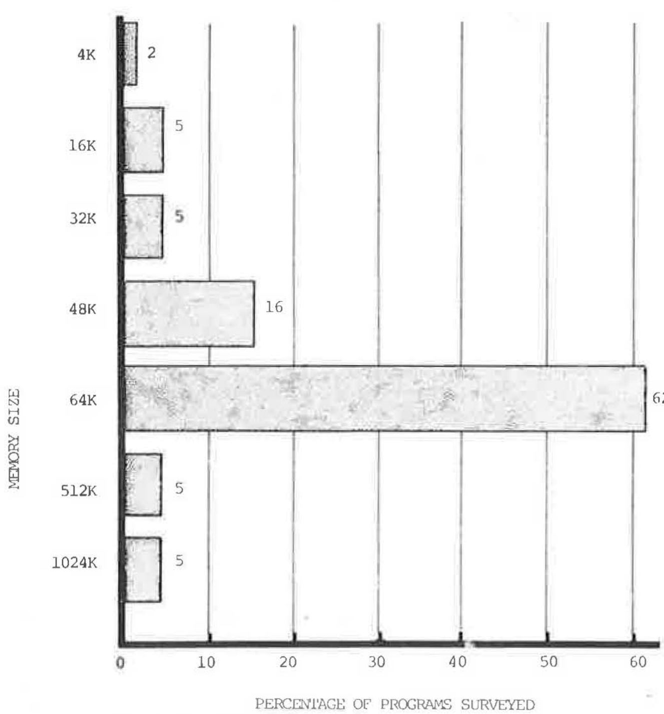
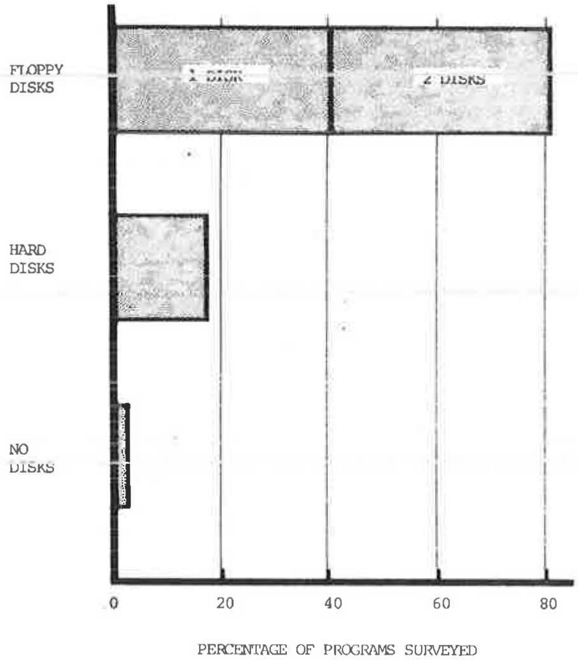


Figure 5. Memory requirements.



(K = 1,024 bytes)

Figure 6. Disks required.



Computer is becoming increasingly popular; it has already overtaken the TRS-80 models for second place. The range of computers represented is very large--from inexpensive TIs and TRS-80s to multiuser supermicrocomputers (Pixel, Momentum, and Altos). This shows how increasingly difficult it is to view microcomputer hardware and software in an undifferentiated way.

Figure 4 shows a commendable trend toward the use of operating systems available in a number of hardware environments. The lack of a predominant multiple-environment system remains a fact of life, however. Only by adapting their programs to two of the multiple-environment operating systems can developers of operating system-dependent software hope to span more than a third of the potential market.

The hardware requirements of the surveyed programs are summarized in Figures 5 and 6. The most common configuration is 64K bytes (K = 1,024) of memory and one or two floppy disks. This configuration, with two disks, can probably be taken as a hardware standard minimum requirement for new transportation planning systems and programs. Increasingly, however, larger machines that have hard disks and much higher data storage capacity are being used as the basis for developing new capabilities oriented to the use and maintenance of large data bases, such as census data processing, carpool-matching programs, and transportation network processing.

MICROCOMPUTERS IN THE FUTURE

The use of microcomputers in transportation planning will undoubtedly be one of the major impacts on the field throughout the 1980s. This new technology has the same potential for revolutionizing the profession as machines like the IBM 704s and 709s did in the late 1950s, when these machines provided the means for origin-destination surveys to evolve rapidly into the computer-assisted urban planning process we now think of as the conventional four-step approach.

Much thought and analysis must go into the process of developing new urban transportation planning strategies for current and future needs. To be more appropriate and effective, strategies must be developed that reflect the changes that continue to occur in energy costs and availability, concern for the environment, and the role of the federal government in urban transport, as well as in computing capabilities such as microprocessors. Although most of these areas are beyond the scope of this paper, comments on how microcomputer software should be developed to support the effective evolution of transportation planning practice throughout the 1980s are in order.

First, the broad range of microprocessor capabilities reflected in Figures 5 and 6 must be recognized explicitly. The separation into at least two categories of systems is desirable; for want of better labels these might be termed personal computer systems and supermicrocomputer systems. The former systems are typified by the standard minimum requirement identified previously: a single-user system with 64K bytes of memory and two floppy disk drives, typically also having an impact printer and both an operating system and programming language that are available on a number of other machines. Such systems, in addition to having the capabilities required for many existing transportation programs, also provide much of the computing needs of the transportation planner in the form of widely available packages such as spread-sheet analysis, word processing, and personal data base management.

An example of a supermicrocomputer system would be a multiuser computer that has 512K (or more) of memory and a hard disk. These supermicrocomputer systems can be thought of as much less expensive replacements for minicomputers and (in many applications) mainframes rather than as larger personal computers. Past experience indicates that further price reductions will occur. The supermicrocomputer will soon be just as available and inexpensive as the personal computers.

Until these changes occur steps must be taken to clarify the differences between the two types of computers to prevent the planning community from confusing their distinctive capabilities and current costs. By providing this clarification, the TRB Task Force on Microcomputers in Transportation can continue to assist planners in understanding the innovations that microcomputers make possible in computer use by individuals, professionals, and organizations as well as how the technology is rapidly changing.

A major concern with respect to both types of systems is to minimize redundant software development. Software developed for use in transportation planning should provide the maximum possible level of portability, both to other agencies and to other machines. The potential magnitude of redundancy is great if we consider the number of transportation planners who will face similar planning problems.

Unfortunately, the provision of portability to other agencies will often require significant costs to provide the required level of generality. In most cases individual agencies have no incentives for incurring these costs in connection with the programs its staff have developed. As a result, only federally funded public-domain systems and proprietary systems are likely to provide sufficient levels of interagency portability. The people who support proprietary and federally funded systems, however, are somewhat opposed to the whole idea of the personal ad hoc approach that has made microcomputers so popular. A balance must be struck between these opposing pressures if microcomputers are to be used cost effectively.

Table 1. Summary of surveyed microcomputer programs.

Application	Computer	Memory	Disks	Operating System	Distribution Conditions[a]	Developer
Sketch Planning and Innovative Methods						
EXTRA: Express bus corridors	IBM	64K	1	DOS	Proprietary	W.G. Barker and Associates
Transit systems analysis (DODOTRANS II subsystem)	Apple	64K	_[b]	UCSD	Public	MIT
PVT: Impacts of service changes on transit line	Apple	64K	1	UCSD	Public	MIT
FARE PROG: Transit fare policies	Apple	64K	1	DOS	Public	Berkshire Company Planning
Transit fare policies	Commodore	32K	2	DOS	Public	Old Colony Planning
Transit service analysis	Apple	_[b]	_[b]	USCD	Public	Dartmouth University
UMOT: Travel budget analysis (4 programs)	Apple	64K	1	DOS	Licensed	Mobility Systems, Inc.
AGGREGTN: Pivot-point mode choice	Apple	64K	1	USCD	Public	MIT
Pivot-point mode choice	Ohio Scientific	4K	0	_[b]	Public	Little Rock Metroplan
PIVOT: Pivot-point mode choice	Apple	64K	2	UCSD	Proprietary	Schimpeler-Corradino
Paratransit planning	Apple	_[b]	_[b]	UCSD	Public	Dartmouth University
SAMPLENUM: Sample enumeration mode choice analysis	Apple	48K	2	UCSD	Licensed	Cambridge Systematics, Inc.
Quick-response methods	Apple, IBM	64K	2	UCSD	Public[c]	COMSIS
IMPAX: Quick-response prediction and evaluation	Apple, IBM, Intertec, TRS-80	64K	2	CP/M	Sold	PRC Voorhees
Traditional Urban Planning Methods						
MicroTRIPS	Apple, IBM, Intertec, TRS-80	64K	2	CP/M	Sold	PRC Voorhees
TMODEL	Apple, IBM	_[b]	_[b]	CP/M	Proprietary	Professional Solutions, Inc.
POP ITER, RTZ POP	Apple	64K	1	DOS	Public	Berkshire Company Planning
MINUTP	Molecular, IBM	_[b]	_[b]	CP/M	Sold	COMSIS
TRIPGEN	Apple	64K	2	UCSD	Sold	Garmen Associates
ASSIGN	Apple	48K	1	DOS	Proprietary	CH 2M Hill
EMME	Pixel	_[b]	_[b]	UNIX	Licensed	University of Montreal
TRANPLAN	Momentum	512K	20M	UNIX	Licensed	Vista Systems
Aids for Providing Transportation Services						
Carpool matching	TI99	16K	1	Ext. Basic	Public	Little Rock Metroplan
Carpool matching	Altos	1024K	Hard	Xenix	Proprietary	K. Roberts and Associates
MicroCRIS: Ridesharing support	Molecular	64K	Hard	CP/M	Proprietary	COMSIS
Ridesharing matching	TRS-80	_[b]	Hard	_[b]	Public	University of Tennessee
COMPOOL: Carpool and vanpool matching	Altos	512K	Hard	UNIX	Licensed	Crain and Associates
Dial-a-ride: elderly and handicapped service support	Altos	1024K	Hard	Xenix	Proprietary	K. Roberts and Associates
PSP: Paratransit scheduling	Northstar	64K	2	_[b]	Proprietary	W.G. Barker and Associates
Transportation-Related Impacts						
AQ ROADWAYS and AQ INTERS: Air quality impacts	Apple	64K	1	DOS	Public	Berkshire Company Planning
URBEMIS: Air quality impacts	Apple	_[b]	_[b]	_[b]	Public	California Air Resources Board
PROLEV: Energy requirements	Apple	48K	1	_[b]	Public	New York State Department of Transportation
PROLEV.HICOND: Energy related to highway conditions	Apple	48K	1	_[b]	Public	New York State Department of Transportation
Programming and Budgeting Aids						
MPS: Multimodal Priority System (DODOTRANS II subsystem)	Apple	64K	2	UCSD	Public	MIT
Priority ordering of street segment improvements	Apple	64K	2	DOS	Public	District of Columbia Department of Transportation
Local allocations of federal aid	Apple	64K	2	DOS	Public	District of Columbia Department of Transportation
REKEN: National transit budgeting	Apple	48K	2	CP/M	Licensed	Cambridge Systematics, Inc.
Interface Programs						
TTY: Micro-mainframe communications	Apple, IBM, Intertec, TRS-80	64K	2	CP/M	Sale	PRC Voorhees
ACCESS: Micro-UTPS interface	Apple	_[b]	_[b]	UCSD	Proprietary	Garmen Associates
Digitizer interface	TI99	16K	1	Ext. Basic	Public	Little Rock Metroplan
Graphics system	Apple	48K	2	_[b]	Public	North Central Florida Planning
Travel Surveying Aids						
COMPARK: License plate survey matching	TRS-80	48K	2	DOS	Sold	ADA Computer Services
LMAT: License plate matching	Apple	64K	2	UCSD	Proprietary	Schimpeler–Corradino
VISTA: Data collection via video recorders	Apple	_[b]	_[b]	_[b]	Proprietary	Wootton, Jeffreys and Partners, England
Statistical and Data Processing System						
MicroSURVEY: Editing, tabulating, regression	Apple, IBM, Intertec, TRS-80	64K	2	CP/M	Sold	PRC Voorhees
MDA: Statistics, regression, logit estimation	IBM, Apple, Data General, TRS-80, Northstar, Osborne	64K	2	MP/OS, CP/M, various DOSs	Licensed	Cambridge Systematics, Inc.
OCTAGON: Census data processing	Apple	_[b]	Hard	CP/M	Proprietary	Vistar Enterprises
System Development and Programming Aids						
DODOTRANS II: Analysis environment system	Apple	64K	2	UCSD	Public	MIT
Utility programs	(PASCAL)	_[b]	_[b]	_[b]	Sold	Garmen Associates
Function graphing utilities	Apple	64K	2	UCSD	Public	MIT

[a]Proprietary denotes a program that must be paid for, but the arrangements (license or sale) are either unknown or unspecified. Public denotes a program that is not proprietary but may require a payment to cover transmittal costs.
[b]Information not determined.
[c]UMTA.

Portability among machines can probably be achieved more readily than among agencies, but this objective calls for careful planning and cooperation by both program developers and those who decide on hardware configurations. As multiple-environment operating systems, programming languages, and analysis environment subsystems oriented to transportation planning become available for a wider range of processors, they should be used rather than the single-environment systems now so commonly used.

For maximum portability, however, planners must go even further. Ideally, they should agree on the use of just one operating system. UMTA has taken the lead in specifying its preference for the UCSD p-system and Pascal. Unfortunately, CP/M operating systems are currently more generally available.

The same issue faces all professions and companies that have made substantial investments in data processing. Several approaches to the solution of this dilemma have been suggested, and clearly a consensus is needed. The most likely approaches are

1. Specify a standard operating system and language combination,
2. Establish user groups to promote and support the exchange of whatever software emerges from the use of microcomputers, and
3. Encourage the use of microcomputers as intelligent terminals that communicate with Urban Transportation Planning System (UTPS) and other programs that operate in the mainframe environment.

The most apparent problem with the specification of a standard system is that most agencies now own systems that probably would not meet the standard requirements and therefore can no longer be used as effectively. The selection of this approach also may preclude taking advantage of future developments in microcomputer technology because of a lack of compatability. Simply stated, this approach could result in the same situation in which we already find ourselves, with UTPS-type software running in an environment many agencies cannot or would prefer not to use.

The second approach has appeal, perhaps because of the freedom and creativity it can foster. The previously mentioned problem of redundant effort is still not completely avoided.

Microcomputers have proven to be excellent terminals for use with conventional timesharing computer systems on which a wealth of software for transportation planning exists. Examples include land use models, UTPS, statistical packages such as statistical analysis system (SAS) and statistical packages for the social sciences (SPSS), and travel model estimation tools such as logit programs. In the area of transportation planning, however, this use of microcomputers has been minimal. Although a few success stories can be told, most state and local government mainframe computer installations remain closed to access by microcomputers. Instead planners must place the required data in the proper formats and then submit their desired run to a data processing department for eventual processing. Planners usually consider this process unsatisfactory. This is frequently cited as justification for the purchase of a microcomputer, even when the bulk of the required computer work can be done within the UTPS system. Under these conditions access to mainframes via microcomputers is highly desirable.

This access is particularly difficult to arrange when it is requested from outside the agency that owns the mainframe computer. Many have been faced with established mainframe data processing departments that oppose efforts to incorporate use of the microcomputer into agency work. However, use of the microcomputers as intelligent terminals for access to conventional U.S. Department of Transportation software, as well as for running stand-alone microcomputer programs, can be a feasible compromise that takes maximum advantage of the available equipment and software.

The task force must consider these factors, make its own decisions on the values of each development direction, and then work with the U.S. Department of Transportation to promote the acceptance of a common strategy for using microcomputers with portable software. By helping to resolve the technical details of how to provide software portability, the task force can make a major contribution to the advancement of transportation planning practice in the 1980s. If these issues are not resolved the significant segment of the planning profession represented on this task force will find it harder to address the larger questions of what to plan for and how to plan most effectively.

LISTING OF PROGRAMS

The 55 microcomputer programs that were surveyed are summarized in Table 1. Only limited information is provided. Two catalogs (3,4) provide one- to two-page descriptions of microcomputer software packages. Programs appear under the headings and in the order used in Figure 1. To reduce the chances for errors (at the expense of specificity), computers and operating systems are identified in Table 1 only by their more generic names, not by model names or numbers or release numbers.

REFERENCES

1. Sketch Planning Methods for Short-Range Transportation and Air Quality Planning, Vol. 1 and 2, U.S. Environmental Protection Agency; UMTA, 1979. NTIS: PB80-158702-A13 and PB80-158710-A-15.
2. Quick-Response Urban Travel Estimation Techniques and Transferable Parameters. User's Guide. NCHRP, Rept. 187, 1978, 229 pp.
3. Micrompputer Applications in Transportation Engineering. Institute of Transportation Engineers, Washington, D.C., 1982.
4. UTPS Microcomputers in Transportation: Information Source Book. U.S. Department of Transportation, Nov. 1982.

Microcomputer Applications in Transit Agencies

JACK REILLY AND JANET D'IGNAZIO

To say that microcomputers have and will continue to affect the way that transit systems are operated and managed is to state the obvious. Within the last few years microcomputers have been used by transit systems to perform a variety of tasks, ranging from common business applications such as payroll and parts inventory to more sophisticated algorithmic applications particular to transit management, such as run-cutting and scheduling and transit service performance monitoring. A discussion of what has been learned from the experience of several transit agencies with microcomputers is presented in this paper and some direction for future microcomputer activities in transit agencies is proposed. Topics addressed in this paper are (a) how microcomputers are being used in transit operations, (b) problems and possible solutions in their deployment, and (c) some ideas on how to help ensure that microcomputers are used appropriately within transit agencies in the future.

Several microcomputer projects are ongoing at several transit operating agencies, federal agencies, universities, and consulting firms. Microcomputers in Transportation Information Source Book (1) provides a good synthesis of these activities. In addition, several ad hoc projects in microcomputer introductions are being conducted, usually through the efforts of individuals who have a high level of interest in this technology. As part of the transit industry microcomputer users' group project, a survey of microcomputer users who have some transit interest was undertaken. Results are incomplete at this time; however, some generalizations can be made from this survey. First, most users are employing generalized packaged software for analytic purposes. Few agencies use microcomputers for business functions such as payroll or financial management. This is probably because smaller transit operating organizations tend to be departments within general purpose local government agencies that maintain transit financial records as part of their overall accounting system. In addition, many are using word processing software.

The prepackaged software used includes file management system and spread-sheet analysis programs. Microcomputer use has been primarily in financial planning (particularly in budgeting and cash forecasting). Other applications have included analyses of ride-check data and vehicle requirement forecasting.

Little actual development of computer programs was observed in this survey. Some of the more formal projects of general interest to the transit community include the following.

Financial forecasting model--The Tri-County Metropolitan Transit District in Portland, Oregon, (Tri-Met) has contracted with a consulting organization to develop a multiyear financial planning and forecasting model. Once developed, this model will be field tested at three or four transit agencies in the country before public distribution.

Management information system--The transit agency in Isabella County, Michigan, will soon be using a distributed microcomputer system for financial management, vehicle scheduling, maintenance management, inventory, and word processing. This is likely to be a suitable model for other small transit properties to emulate.

Route demand forecasting model--Through a University Research and Training grant, staff from Cornell University have developed a route-level analysis model that assesses the impacts of headway and changes in fare levels on ridership, revenues, and passenger waiting and in-vehicle times. Field testing will be conducted in the future.

Transit data management system--A consulting firm, under contract to UMTA, is developing a data management system for processing transit field data from sources such as ride checks, load checks, and schedule-adherence checks. This work complements some work in statistical sampling for transit performance monitoring recently developed by the consultant.

In addition, considerable ongoing microcomputer work is being conducted in driver pick assignments (Seattle), run cutting and scheduling (San Diego), transit service performance monitoring (Albany), and timetable building (Chapel Hill). A number of transit agencies have used commercial spread-sheet accounting packages for analysis work within their organizations. These have focused on financial planning (particularly budgeting and cash forecasting); however, other applications include analysis of ride-check data and vehicle requirement forecasting.

Significant microcomputer activity relevant to transit operations is ongoing at the Transportation Systems Center. These activities include reviews of commercial data base management systems, financial planning practices, and applicable software. The major program of this organization over the next several years of interest to the transit community will be the development of an Operational Planning System (OPS). Most small- to medium-size transit properties do not currently use computers in their operation. OPS is intended to conduct a number of research and review activities to help foster the use of microcomputers in these agencies. The major elements of OPS include the following:

1. Studies of the transit industry, including the development of syntheses of operating practices and recommendations for solutions to common problems;
2. Research into new methods and development of techniques for analysis and planning in several transit functions, including service design, financial planning and management, and maintenance planning methods;
3. Technology reviews of commercial software and hardware for application to transit agencies;
4. Software development and demonstration, including development of some application and utility software to be tested at transit properties before distribution; and
5. Dissemination of results through regional seminars and workshops, newsletters, and software distribution channels.

Another project of interest to the transit community is the development of a national transit computer software directory being undertaken as part of the National Cooperative Transit Research and Development Program (NCTRP) of TRB. The contractor assigned to this project will develop a software directory on magnetic media for distribution. This directory will be updated periodically and will catalogue programs suitable for mainframe computers, minicomputers, and microcomputers.

ISSUES IN THE DEPLOYMENT OF MICROCOMPUTERS IN TRANSIT AGENCIES

Despite the diversity and complexity of applications to which microcomputers are applied in transit agencies, there are limitations to what they can perform. Further, the press may have inadvertently spawned a number of myths concerning microcomputers. Some think that a system that can perform all business and operations applications can be acquired for only a few thousand dollars. In addition to acquisition cost, however, there are costs of training even for the simplest commercial software, costs of documenting the programs, costs of procedures introduced, and costs of ongoing maintenance and operation. When all of these costs are considered, the cost of a microcomputer installation increases dramatically.

The ease with which individuals not skilled in data processing can use computers has been overstated. Small programs can be developed without considerable difficulty. More complex programs, however, often have to take into account memory and disk storage limitations, problems encountered infrequently in larger computers. Commercial software is available for most common business and analysis applications; therefore, transit agencies should not use their own staffs to develop software.

In the short run, the largest barrier to more widespread use of microcomputers will be transit staff training, particularly in small- to medium-size transit agencies where data processing and analyses are secondary staff skills. Unquestionably, the need exists for training at several levels. Most training, however, need not be transit- or transportation-specific to be useful to transit managers. UMTA staff are currently conducting several one-day workshops across the country on an introduction to microcomputers. These workshops introduce hardware selection concepts, commercial software availability, and some transit applications. By the end of these workshops attendees should be able to decide the place of microcomputers within their operations.

After an introductory session, additional training areas fall into four categories.

1. Business applications--demonstrations of how common business functions such as payroll, accounts payable, accounts receivable, ledger, and inventory can be performed by using microcomputers;
2. Analytic tools--training in general-purpose commercial software such as spread-sheet accounting, file and data base management systems, statistical packages, and graphics;
3. Programming languages--training in specific computer languages and operating systems; and
4. Transit operations applications--a series of demonstrations of software in the public domain useful in transit line and staff functions.

Of these four, the first three should be available through universities, computer stores, adult education programs, or local users' groups. Training in programming languages probably has limited usefulness to transit agencies, given the availability of commercial software for some applications and UMTA focus on software development in several other areas.

The most appropriate public training role is in disseminating information on transit operations applications. Such training could be a logical extension of the Bus Transit Operations Planning training course recently developed by UMTA through a contractor. Such short courses should be targeted to their intended audiences rather than introduce all aspects of microcomputer applications. For example, one course in service design and analysis; another in financial forecasting, budgeting, and analysis; and one in maintenance analysis would be appropriate. Interestingly enough, microcomputer and video technology can play a useful role in training. Either videotape training modules or new interactive video-training products can be used for this type of training.

The second barrier that could impede introduction of microcomputers is information on hardware and software capabilities not only for prospective purchasers but also for those who own particular systems. Information needs include the following:

1. Independent software and hardware reviews,
2. Assessment of suitability of commercial software for proposed applications,
3. Information on software development and use of commercial software at the transit agencies, and
4. Development of sample specifications and guidelines for specification development.

The first function is being performed by popular microcomputing journals. At least 60 product reviews of hardware and software that could be used by transit agencies have appeared in popular journals within the last 2 years (2). In addition, Datapro (3) provides a detailed review service. Local user groups fill the second information need.

The third barrier, namely sparce information on projects in transit agencies, can be overcome by establishing an industry users' group. In June 1982 the Capital District Transportation Authority (CDTA) was awarded a grant to initiate such a user group. A few months later CDTA, in turn, awarded a contract to Rensselaer Polytechnic Institute (RPI) in Troy, New York, to perform the technical support function for the group. The RPI staff has three major functions: publication of a quarterly newsletter on microcomputer use in transit systems, operation of a telephone inquiry service to field questions, and operation of a software exchange. The first newsletter, published in October 1982, was distributed to 1,200 persons and included a questionnaire, the results of which indicate a high degree of interest in the subject. The newsletter focused on some items of general interest to neophyte users and announced the availability of software in the public domain for distribution. The telephone inquiry service has fielded several calls on software suitability and how to obtain more information on microcomputers. Where practical, callers are referred to persons in other transit agencies who are working in similar application areas.

Over time, the most beneficial function of the user support center will be the operation of a software exchange. The support center staff has already distributed programs useful in budget calculations, cash-flow analysis, and service performance monitoring. Transit agency personnel are expected to contribute software so that a pool of programs can be made available. Further, support center staff, in conjunction with the staff of the Transportation Systems Center, are expected to convert software from formats in one computer or operating system to those in another.

Thus far, software contributions have been limited. For the most part claims are made that the software is not sufficiently documented for external distribution. This suggests that it may not be documented sufficiently for internal use either. This can present a problem if staff members who develop software leave the agency at which the programs were developed. Non-data-processing personnel should be trained in at least rudimentary documentation concepts to ensure that the software that is developed is usable by persons other than the original author.

Finally, the lack of good, understandable information concerning specification development is currently causing considerable confusion and delay in the purchase of microcomputer systems by transit operators. This problem has two parts. First, most managers are unclear as to what should be included in a set of specifications. Also, they have difficulty determining the reasonable range of options available for any particular feature. Information on specification preparation is currently being disseminated informally among transit properties. UMTA should consider adding an overview of specification preparation to its training courses.

Although substantial benefits can be achieved by implementing microcomputer systems in a transit agency, policy and personnel issues that surround the integration of the computer into the operation must be considered and addressed. To date, most transit systems that have purchased microcomputers have initially limited the computer's use to a few functions and individuals and have only gradually expanded the use and availability of the machine. The impacts on the organization, therefore, have been less dramatic and more easily dealt with as they occur. Transit properties, however, are beginning to recognize the benefits of a comprehensive approach to computerization. At this level, the implementation of a computer system can affect the transit operation substantially.

Policy questions surrounding the implementation of a computer system are similar to those related to implementation of any major organizational change. Examples of these include allocations of scarce resources among departments or even within a department; assignment of responsibility for equipment and tasks; evaluation of the schedule for implementation; and consideration of issues involving the security of the equipment and information. In evaluating these questions, realize that the computer system represents an unfamiliar technology. As such, people have preconceived ideas and attitudes that can affect the implementation of the system. Therefore, the personnel issues related to the implementation of a microcomputer system should receive greater attention.

A computer system is only as accurate as the people who operate it. Errors caused by poor data collection, handling, or analysis procedures are only compounded by computer processing. The result is inaccurate data that have the appearance of accuracy. At least three personnel-related issues need to be addressed. First, the cost of a computer system is frequently justified by projecting the number of people the machine can replace. From a personnel standpoint this can be a poor approach. It can create serious morale problems and can give rise to a general resistance to the system as a whole. In addition, although computers frequently change the nature and scope of the work required, the complete elimination of a position in the organization is rarely reasonable. Data must be collected, checked, entered, and interpreted. The initial benefit of a computer system is the speed and accuracy with which the information is produced. Improvements in the quality of decision making will take time to achieve. With the introduction of computer systems new information that was too expensive to process by hand could be collected. If over the long run a staff reduction is possible, it is handled better by attrition than by staff reduction.

A second personnel problem resulting from implementation of a microcomputer system is possible resistance based on fear of the computer itself. Microcomputers represent a technology that is unfamiliar to most adults. Many articles and portions of books discuss computer anxiety. These anxieties do exist, and they can affect the success of the implementation. Easing computer anxiety can be as simple as allowing adequate time and money for training. Another approach is to consider innovative or unorthodox methods for easing the initial contact, for example, the use of computer games or educational software. This approach will have the most impact if the employee is allowed to choose the program. A third method for easing computer anxiety is to demonstrate the direct benefit of the system to the employees. Introduction of the system by implementing a program that is easy to use and well documented and that shows direct and immediate benefits to the workers can accomplish this goal. This approach usually involves preprogrammed software applied to some simple but particularly time-consuming or onerous task.

The last common personnel problem is the need to allow time for the employees to learn the system and make the transition from manual to computerized processing. Even with the simplest preprogrammed software people need time to learn the basics of the machine and the software. Also, the computerized system may not replace a manual system immediately. For more critical applications, such as financial records or maintenance inventories, good managerial practice is to run the manual and the computerized systems in parallel. This allows for a check on the computerized system. This approach requires considerably more time on the part of the employees responsible for the tasks. Not only should this time be built into the implementation schedule for the computer system, but it may also be necessary to adjust deadlines for submission of standard reports.

A LOOK FORWARD

The rapid development of new products and services over the past years in information processing makes any prognostication of the future use of microcomputers in transit quite difficult. Some generalizations can be made, however.

An exciting new development is a class of integrated software systems for microcomputers that combines modeling and statistical analysis with graphics and word processing. In addition, these systems are designed to be easier to use than previous single-purpose systems such as the electronic spread-sheet programs. These systems also permit accessing external and internal data bases for analyses. Such systems should greatly increase the ability of microcomputers to be useful analytic tools for conducting special studies such as budget analysis and maintenance work order analysis.

Another area that should benefit transit operators is the development of new peripheral devices, particularly those related to data input and output. Several of the application areas in transit are highly data intensive, for example, passenger counts and vehicle maintenance.

Further, many transit data are collected in a hostile environment, such as on-board buses, in service buildings, and in repair shops. Already, we are seeing some creative uses of nonconventional data collection methods such as bar code readers (used by the Greater Cleveland Regional Transit Authority for parts inventory) and hand-held data recorders and computers (used by several transit systems for passenger load studies). Although the data collected in these two examples are not processed by microcomputers, no technical barriers exist to doing so.

In two application areas improvements in software and hardware can make a significant impact on how transit systems operate. These areas are maintenance management and service design, scheduling, and passenger information.

For several years many transit systems have computerized their run cutting and scheduling, the task of assigning buses to scheduled service, and the task of assigning bus operators to scheduled buses. In some instances the data base for internal (personnel and vehicle) scheduling has been used to produce printed public timetables. Many other opportunities are available to use these data to improve passenger information. Among these are visual displays of transit schedules at major generators, printed custom-tailored timetables to be posted at bus stops, video terminals for persons who answer public inquiries on scheduled, voice synthesized automated schedule information, and, in the long run, the ability of persons who have home computers to access the transit system schedule data base. Such improvements in the distribution of schedule information are likely to increase the level of transit use, particularly by nonpeak riders, a market that transit systems should attempt to penetrate better.

Service monitoring, service design, and passenger information can be viewed as a continuous process of using common data bases rather than as a set of disjointed tasks. The data that transit operators collect, including boarding counts and schedule adherence checks, are necessary to make decisions about service design. A useful analytic tool would be a system that reduces the raw data to information useful to make decisions on service headway and scheduled time between terminals. A transit analyst could then design the service and perform the run cutting and scheduling. This could be done as an iterative process in which the scheduled service reflects both passenger demands and operating constraints on schedule making.

With automation of the mechanical tasks of scheduling, transit staff can devote more time to the policy analysis functions of transit operations that, to a large degree, are currently underfunded.

The other area in which substantial innovation can be anticipated is in-fleet maintenance and servicing management, a function that typically accounts for nearly a third of transit system costs. For several transit systems microcomputers can perform the housekeeping tasks of vehicle repair records. The real benefit of maintenance management information systems may not be in their ability to display the service history of individual buses or components in order to make instantaneous decisions on individual vehicle repairs but in the more strategic planning areas of personnel planning and deployment, fleet replacement, servicing policies, life-cycle costing, and fleet specifications. A number of first generation maintenance management information systems exist, some of which operate on microcomputers. Once data on individual bus work orders are assembled into sizable data bases, a maintenance decision support system would be a useful enhancement. Some elements of such a system could include programs to design and monitor controlled experiments on inspection and service intervals and to perform assignment models for scheduling mechanics and service bays to anticipated work loads.

In conclusion, the use of microcomputers by transit agencies is a natural complement to other activities intended to improve the productivity of transit systems. The major benefit of microcomputers is to allow transit managers and analysts to devote more time to the tasks of data interpretation and policy development rather than to data assembly and tabulation. This should enable transit agencies to be better prepared to face the challenges of the next few years.

REFERENCES

1. U.S. Department of Transportation. Microcomputers in Transportation: Software and Source Book. 1983.
2. TIME Capsule, Vol. 1, No. 2, Rensselaer Polytechnic Institute, Troy, N.Y., 1983.
3. Datapro Research Corporation. All About Personal Computers. McGraw Hill, New York, 1982.

Microcomputer Applications in Traffic Engineering

KENNETH COURAGE

Microcomputers have proven to be an effective tool for the solution of traffic engineering problems. Even in the early stages of its development, the microcomputer was recognized for its utility in a wide range of traffic engineering tasks. The current use of microcomputers by traffic engineering agencies is reviewed. An overview is presented of the general categories in which microcomputers are applied. Specific examples of available programs are mentioned in each category. The applications include general desk-top computing for signal system design and analysis, data base management of accident records and inventories, and special graphics. Communication with other data processing devices is also discussed, including traffic data collection, intelligent terminals, and real-time signal system control.

Engineers in all fields are making use of the computer technology bonanza. The possibilities for microcomputer application in the traffic engineering field are endless, and many of these possibilities have already become realities.

The hardware systems within the scope of this discussion include general purpose microprocessor-based central processing units (CPUs) that have at least 64K of memory, at least one floppy disk drive, and a printer. A variety of peripheral and interface equipment might also be involved. The cost of this type of system is generally well within the budget of a traffic engineering agency. Equipment that is beyond the scope of this paper includes dedicated process control hardware (such as signal controllers) and larger-scale minicomputer and mainframe systems.

The purpose of this paper is to review the state of the art in the application of microcomputers to traffic engineering problems. Several available programs will be mentioned as examples of the current technology. Further detailed information on the capabilities and availability of the programs can be found in the references. Microcomputer Applications in Transportation Engineering (1) and Microcomputers in Transportation: Information Source Book (2) are valuable sources of information on traffic engineering. Microcomputer Applications in Traffic Engineering Agencies (3) offers guidelines for getting started in the microcomputer field. Together, these three references should provide the prospective user with a complete picture of the application of microcomputers in traffic engineering.

NUMBER CRUNCHER

Most of the available traffic engineering design programs involve traffic signal operation in some way. The following sections contain examples.

Capacity Calculations

Capacity calculation programs generally apply the TRB Circular 212 (4) methodology to determining critical lane volumes, intersection capacity, and level of service. Examples include CAPCALC (1), SIGCAP (1), and CMA (1).

Single Intersection Design and Evaluation

Several programs deal in some way with computing optimal cycle lengths and splits and evaluating the effect of a specified signal operation on such measures of effectiveness as stops, delay, fuel consumption, and air pollution. Examples include SOAP/M (1), SPLIT II (1), CYCLE-SPLIT-I (1), CYCLE (1), INTERANALY (1), POSIT (2), CAPSSI (2), and SIGNAL (2).

Arterial System Design and Evaluation

Several programs are available for the design and evaluation of arterial signal progression. Programs are available to achieve optimum coordination of cycle length, phasing, splits, and offsets, although not all programs seek optimum coordination of all of these variables. Examples include SPAN (1), PASSER II (1), SIGART (1), AAP/M (1), FORCAST (1), and NOSTOP (2).

Network System Design and Evaluation

The microcomputer has somewhat limited capability for network system design and evaluation because of constraints in memory size and execution time. The network program achieves optimum coordination of the same list of variables as the arterial programs, except that explicit optimization of phase sequence does not appear to be offered by any of these programs. Examples of network programs include EVALUATE (1), SIGRID (1), and TRANSYT (1).

The microcomputer system is used in three ways in these applications:

1. Traditional mainframe computer programs such as TRANSYT and PASSER II have been converted to use small microcomputers;
2. Special microcomputer programs have been written for capacity analysis, signal timing, and progression design; and
3. Other engineering calculations are performed routinely by small, often specially written, programs.

In all of these applications the microcomputer is simply used as a desk-top calculator. Numbers are fed in and results are generated. The advantages include accessibility and interactive data entry. The main disadvantage is the speed of computation, which is usually significantly (and sometimes painfully) slower than that of the larger systems.

DATA BASE MANAGER

Applications for data base management differ from simple number crunching applications in the permanent storage of data for nearly instant retrieval. Traffic engineering data bases fall generally into two categories.

1. General applications involving a commercial data base management system (DBMS) to store data and generate reports. Among the most popular are dBASE II (CP/M) and DBMASTER (APPLE); their data base management capabilities (search, sort, and merge) and their report generation capabilities are impressive.
2. Specialized applications with a DBMS written specifically for the purpose.

The popular trend among software developers is toward the first alternative (i.e., commercial DBMS). Some of the commercial systems such as dBASE II have attracted peripheral development in the form of utilities and statistical packages.

Although a signal system inventory for a medium-sized city can be stored onto a couple of floppy disks, serious data base applications will probably require a hard disk. The advantages of the hard disk include an increase in storage capacity (a 10-megabyte hard disk is equivalent to about 75 floppy disks) plus a significant increase in the data transfer rate.

Inventory Applications

The simplest data base application is the inventory or filing cabinet system. Data are stored, usually by intersection or location, for easy retrieval in response to interrogation commands. Limited capabilities for report generation are provided and only one data base may be used at a time. Several cities are using file management systems such as DBMASTER for physical inventories of signals, signs, and streets.

Accident Record Systems

The microcomputer, combined with a 10-megabyte hard disk, can provide an effective accident records system for a small- to medium-sized county. The disk can store 100,000 accidents with no difficulty, but with state-of-the-art DBMSs such as dBASE II files larger than 20,000 records, for example, may require excessive time to manipulate.

The main differences between simple inventory systems and state-of-the-art accident records systems include

1. The use of relational data base management systems (such as dBASE II) that work simultaneously with more than one data base; this permits cross reference between geographical information, traffic volumes, and roadway characteristics and the actual accident data;
2. Data analysis capabilities that extend beyond simple report generation to computation of accident rates based on exposure or hazard ratings; and
3. Collision diagram plotting capability included in the more comprehensive systems.

Examples of functional accident records systems on microcomputers include the ATEMS Traffic Accident Record System (1) and SCARS (5). Pfefer and Reischl (6), Kelsh (7), and Brown and Colson (8) discuss microcomputer-based accident records systems.

Network Data Bases

Most network data bases are used for transportation planning purposes and are therefore beyond the scope of this paper. A couple of applications are worth noting. An integrated traffic data base system (2) is available that includes physical inventory, traffic characteristics, and accident history. Another system is under development (2) that will provide automatic coding of input data for common traffic engineering models such as PASSER and TRANSYT from an areawide data base.

INTELLIGENT TERMINAL

The microcomputer has vastly expanded the capabilities for remote terminals that communicate with larger computers. Intelligent terminals, unlike their predecessors, offer the ability to transfer and store large blocks of data, to perform computations on these data, and to display the results in numerical or graphic form.

The most important applications of intelligent terminals to traffic signal systems include the following:

1. Monitoring the operation of a computerized system and generating status reports interactively (9);
2. Transmitting signal operating parameters to local or submaster controllers in the field (10);
3. Interactive data entry for mainframe signal optimization programs such as PASSER II and TRANSYT (11); and
4. Graphic displays of the results of these programs to enhance the traffic engineer's understanding of the system operation (12).

Graphic Displays

Graphic outputs are likely to become more common in the future because of the capabilities of microcomputer systems. Of particular interest is the compatibility of many systems with standard color television monitors. This creates the potential for public displays of areawide traffic conditions through commercial cable television channels. The large-screen projection television monitor is an excellent central signal system control room display because of this compatibility.

Two advanced developments in microcomputer graphics of particular interest to traffic engineers involve variations of the familiar time-space diagram for arterial signal progression. The first, part of the SPAN (1) program, displays a time-space representation that is corrected for travel time on the route to eliminate the need for proportional spacing of intersections. A 20-intersection system can be presented on a single video screen by using this technique, which is referred to as the time-location diagram (see Figure 1).

A second graphics development extends the concept of the time-space diagram beyond simple progression bandwidth to include a representation of the traffic density at all points in time and distance. This technique, which produces the platoon progression diagram (see Figure 2), uses a dot-matrix printer common to microcomputer systems. The platoon progression diagram combines the advantages of the time-space diagram produced by bandwidth optimization programs such as PASSER and the flow profile plots produced by TRANSYT. Two versions of TRANSYT have been modified to generate flow profile tables that are transferred to the microcomputer. The BITE (13) microcomputer program can then produce the graphics shown in Figure 2.

Real-Time Process Control

Can a small general purpose microcomputer system actually be used as the master controller for real-time control of a group of intersections? These systems have already been introduced into the market (14). If they are successful, substantial competition can be expected in this area, and a large variety of systems will be available.

Another process control area is in the signal maintenance shop. A system is currently under development that will perform a standardized series of tests in real time on a signal controller to determine how well the controller meets specified functional requirements (15). A separate system, in operation for 4 years, provides vehicle detection inputs to a controller and monitors the outputs. Displays of simulated traffic are displayed on a video screen (16).

TRAFFIC STUDY MACHINE

The microcomputer offers some relief from the tedious task of collecting, reducing, analyzing, and interpreting the vaious data used to support traffic

Figure 1. Time-space diagram compensated for travel time on each link to condense display onto video screen.

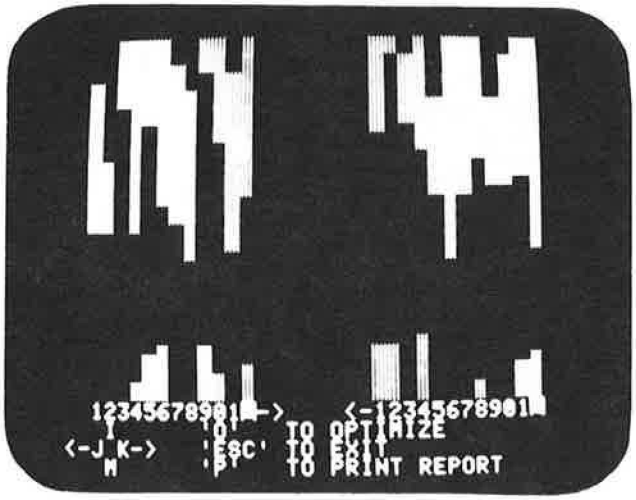
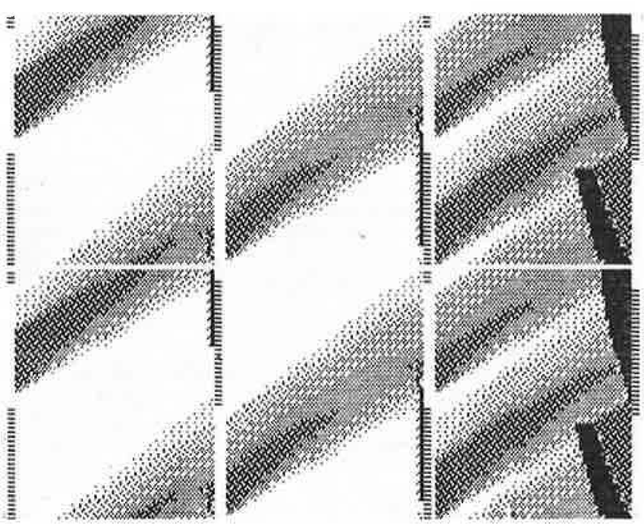


Figure 2. Time-space diagram with traffic densities superimposed to show propagation of platoons.



engineering decision making. Major areas of assistance are

1. Reading data automatically from field data collection devices to reduce labor costs and improve accuracy,
2. Processing the data to generate summaries that were previously developed manually,
3. Storing the data on disks instead of sheets of paper to facilitate future analysis by specialized programs, and
4. Transmitting the data automatically to other computer programs that perform design computations (e.g., signal timing).

The first three areas of assistance are well developed. The fourth area (the automatic link to the design process) offers excellent potential for advancing the state of the art.

Road Tube Counts

Most pneumatic tube counters generate some form of machine-readable output such as paper or magnetic tape. A variety of programs are available to read data into microcomputers. Examples of such programs include GATR (1), ATR COUNT (1), SCAN (1), and COUNTS PLUS][(1). Most of these programs have built-in processing capability. Another class of programs has the processing capability without the automatic reading capability. Examples include SPEED PLOT (1), SPEED (2), and TUBES (2).

Turning Movement Counts

Turning movement count data are still collected manually; however, a number of vendors now offer a turning movement counter that stores data for direct transfer onto a microcomputer. Several programs are also available to accept and analyze turning movement count data. Examples include TURNPLOT (1), TMC (1), and TURNING MOVEMENT COUNT (1). Another program, DELAY (1), uses a standard device for counting turning movements together with a study technique that redefines the meaning of the inputs to measure delay to traffic entering a major street from a minor street.

Travel Time Studies

Travel time is usually estimated by moving vehicle studies, either by stopwatch reading or by automatic recording equipment. Examples of programs that read or analyze these data include CRIT (1) and TRAVEL TIME (1).

Signal Warrants

One example of the direct use of road tube data is the numerical warrants for the installation of traffic signals. The COUNTS PLUS][(1) program generates a written report that compares traffic data with signal warrant criteria. The input data may be entered from the keyboard or read automatically from road tube counters.

MISCELLANEOUS APPLICATIONS

A few other traffic engineering applications that fall outside any of the previous categories are also worth mentioning. Many agencies are using spreadsheet programs such as VISICALC for a wide variety of administrative and technical applications. License plate techniques are also being used for special studies. For example, LMAT (1) performs license plate matching for traffic movement studies, and PKSUR2 (1) computes standard parking lot operational measures from license plate data. Accident reconstruction is another application. The program REC (1) performs a kinematic analysis of a two-vehicle accident by using conservation of momentum principles.

CONCLUSIONS

Microcomputers in traffic engineering are here to stay. As the technology advances so will the applications. The software base is now sufficient to justify the acquisition of a microcomputer system for traffic engineering purposes.

REFERENCES

1. Microcomputers in Transportation Engineering. Institute of Transportation Engineers, Washing-

ton, D.C., Seminar Notebook and Software Directory, 1982.
2. Microcomputers in Transportation: Information Source Book. U.S. Department of Transportation, Nov. 1982.
3. Microcomputer Applications in Traffic Engineering Agencies. FHWA, 1983.
4. Interim Materials on Highway Capacity. TRB, Transportation Research Circular 212, Jan. 1981, 272 pp.
5. Seminole County Accident Records System: User's Manual. Univ. of Florida, Gainsville, 1982.
6. R.C. Pfefer and B.E. Reischl. Application of Small Computers to Traffic Records Systems in Small Communities. TRB, Transportation Research Record 910, 1983, pp. 48-56.
7. W.E. Kelsh. Microcomputer-Based Traffic Records System for Small Police Agencies. TRB, Transportation Research Record 910, 1983, pp. 29-36.
8. D.B. Brown and C.W. Colson. Application of Microcomputer Technology to Local Accident Problem Identification. TRB, Transportation Research Record 910, 1983, pp. 14-18.
9. J.M. Thomas. Closed Loop Systems. City of Atlanta, 1981.
10. System Specification-Model 3800 Closed Loop System. Transyt Corporation, Tallahassee, Fla., 1982.
11. Arterial Analysis Package--Users Manual. Univ. of Florida, Gainsville, 1981.
12. G. Spanos. Platoon Propagation Graphics Model. Masters thesis, Univ. of Florida, Gainsville, 1981.
13. Bandwidth Isn't the End (BITE): Program Documentation. Microtrans Associates, Inc., Gainsville, Fla., 1983.
14. Micro Control System Description. PRC Voorhees, McLean, Va., 1982.
15. Signal Controller Operational Performance Evaluation (SCOPE) Project Description. Univ. of Florida, Gainsville, 1982.
16. Signalized Intersection Monitor Users Manual. Univ. of Florida, Gainsville, 1978.

Microcomputer Applications in Railroad Operations

CARL D. MARTLAND

Railroad officials in North America are using microcomputers more frequently to complement the capabilities of their more formal computer systems. Applications range from simple word processing to complex modeling and real-time control. Within many railroads, however, serious debates address the need for microcomputers, the types of applications that are appropriate, the integrity of their data bases, and other important issues. Nevertheless, the rapid evolution of computer technology will provide a powerful impetus for railroads to install microcomputers or computer networks that give employees access to the kinds of flexible, powerful software that are now available for microcomputers.

Microcomputers and microcomputer applications are becoming more common within the U.S. rail industry. Applications range from simple word processing and filing to complex operations planning models. The power of the widely available software is a great attraction to managers and planners at all levels of the organizations. The impetus for acquiring microcomputers has generally come from mid-level managers and planners who see the microcomputer as a welcome alternative to the difficulties and frustrations of working with their railroad's management information systems (MIS) department. In a number of cases individuals acquired their own microcomputers, used them for company business, and eventually convinced the railroad to acquire additional microcomputers.

No consensus exists, however, concerning the value or appropriateness of microcomputers within the rail industry. Railroads, which have long been leading industrial users of computers, do not view microcomputers as providing an increase in computing power. Some MIS departments view microcomputers as a threat to the integrity of their company's information systems or a costly means of providing distributed computing capabilities.

In this paper various ways that railroads have used microcomputers are summarized and a number of issues that will determine the extent to which the use of microcomputers is likely to spread throughout the industry are identified. Because of the rapid rate of change in this field, the published literature alone cannot be used for a review of the state of the art. The information in this paper, therefore, is drawn from numerous informal conversations with railroad officials, most of whom shall remain anonymous. Although the debate over the role of microcomputers is still raging, identification of the issues is more important than identification of the protagonists.

Much of the information concerning applications has been obtained as a result of participation in various research projects sponsored by the freight car management program (FCMP) of the Association of American Railroads (AAR) (1,2). In particular, the Massachusetts Institute of Technology (MIT) rail group designed the MIT service planning model (SPM) to illustrate techniques of operations and service planning in cooperation with the Boston and Maine Corporation (3) and the Santa Fe System (4). To promote the use of this model by other railroads, FCMP provided support for MIT to (a) reprogram it for a microcomputer, (b) promote its transfer to individual railroads, and (c) provide support services to an SPM users' group. By the end of 1982 SPM had been acquired by six U.S. railroads [Boston and Maine; Burlington Northern; Consolidated Rail Corporation (Conrail); Illinois Central Gulf Railroad Corporation; Chicago, Milwaukee, St. Paul, and Pacific Railroad Company (Milwaukee Road); and Southern Pacific Transportation Company] plus the Spanish National Railroads (5). In addition many other railroads [including Delaware and Hudson Railway Company, Maine Central Railroad Company, Chessie System, Seaboard System Railroad (Family Lines), Chicago and Northwestern Transportation Company, Missouri Pacific Railroad Company, Santa Fe, Union Pacific Railroad, Soo Line Railroad Company, Grand Trunk Western Railroad Company, Elgin Joliet and Eastern Railway Company, and Canadian National Railways plus several foreign railroads] made inquiries concerning SPM, which inevitably led to discussions of microcomputers. As a result of this experience an intimate perspective was obtained on the rail industry's use of and attitudes concerning microcomputers, as reflected in the remaining sections of this paper.

APPLICATIONS

Railroads use microcomputers for a wide variety of applications, ranging from the simple to the complex. These applications can be grouped into the categories listed in the following paragraphs:

1. Word processing,
2. Budgeting,
3. Filing and data base management,
4. Report preparation,
5. Analysis by using commercially available software,
6. Modeling, and
7. Real-time control.

Word Processing

Anyone who has access to a microcomputer eventually uses it for some kind of word processing, either for the preparation of simple memos or the preparation of complex reports. For an example specifically related to transportation, Boston and Maine's transportation department produces its weekly bulletins of train schedules and crew assignments on an Apple 2. In some specialized cases people have used microcomputers for all their word processing, thereby eliminating the need for secretarial services. For example, to provide support service for the SPM users' group MIT has relied on an Apple 2 to produce the SPM Users' Guide, a Teaching Guide, periodic newsletters, minutes of meetings, and technical memos. Unlike railroads' word-processing facilities, which improved the productivity of secretarial staff, microcomputers obtained for other purposes are often also used for typing of the first draft of memos or reports, bypassing secretaries altogether.

Budgeting

Almost all railroads have well-established budgeting systems; therefore, a railroad is unlikely to obtain its first microcomputers specifically to assist in budgeting. Nevertheless, any manager who has access to a microcomputer quickly learns about the wonders of Visicalc, Plan 80, and similar packages. Boston and Maine's transportation department used Visicalc for preparing the 1982 budgets for the department, for its two regional divisions, and the East Deerfield yard. Because of the success in using Visicalc for budgeting at headquarters, Boston and Maine obtained microcomputers for budgeting at the divisional offices (6). Others have used Visicalc for developing budgets for special projects or for estimating budgetary expenses for small groups.

Filing and Data Base Management

Like other businesses that use microcomputers, railroads have used the various commercially available routines for creating and accessing files. In addition to the typical applications for mailing lists and personnel records, railroads have used programs such as DBMaster to create files of train delays, collective bargaining issues, and inventories of spare parts or stores. Chessie uses a data base program to provide information to salespeople and assistant managers in forecasting sales. As with word processing and budgeting, the data base capabilities of microcomputers are unlikely to cause senior management of a railroad to buy a microcomputer, but managers who have access to the microcomputer quickly find ways to use such capabilities.

Report Preparation

Managers can assemble information from various sources easily, edit this information, and produce reports that can be photocopied and distributed like any other computer report. The great advantage of using a microcomputer for report preparation is that the manager can create and modify a report without conferring with or waiting for the MIS department. The disadvantage is that the user, rather than the MIS department, must produce and distribute the reports. The Boston and Maine, as a result of a cooperative research program with FCMP (1) has used the microcomputer to produce a number of weekly reports, including

1. An operating and service plan report that summarizes car use performance, the variances from the car cost budget, trip times, and other key indicators of operating performance and service levels; and
2. A summary of weekly train performance and transportation expense that is used to structure the weekly conference call among senior transportation officers.

The railroads in the SPM users' group stated that the microcomputer was used more often for generating reports than for analysis. Managers frequently use graphics packages in preparing these reports and in making presentations to senior management.

Analysis Using Commerically Available Software

As with budgeting, railroad managers first turn to Visicalc, whose structure is perfect for the kinds of spread-sheet analysis commonly demanded of railroad and other business managers. Applications have been numerous, varied, and creative. In many cases, managers who have little or no computer background have, for the first time, used a computer to assist them in the analysis that is a routine part of their jobs. Access to a user-friendly environment eliminated the barriers to using the more powerful, but more imposing, computers that have been available for many years.

Modeling

The transfer of the MIT SPM to seven railroads and the establishment of an SPM users' group provide the best example of the railroad industry's use of microcomputers for modeling. SPM, which originally required 800K core storage in a Fortran version that ran on a mainframe computer, was revised and reprogrammed to run on an Apple 2. The Apple version of the model, although slower, was actually more powerful and much more flexible than the Fortran version--in large part because the limited storage capacity and the slower processing time of the microcomputer forced programmers to be more creative and to use modular design.

The ease of transferring the program was a key factor in the successful transfer of the model. The Association of American Railroads (AAR) and five of seven railroads acquired an Apple 2 system in order to obtain the SPM. Because all of these users had the same computer, support services could be provided efficiently. The model runs on a microcomputer; therefore, the planners and managers who acquire the model are able, on their own, to devote resources to running the model and avoid the inevitable delays that would ensue if the model were transferred to the MIS departments for modifications to enable it to run on the railroads' mainframe computers.

Other models have also been developed for microcomputers. For example, the Soo Line developed a simulation model for estimating fuel consumption of freight trains (7) and Missouri Pacific developed a model for unit train costing (8). In many cases analysts or managers have bought microcomputers with their own money, then used their spare time to develop programs. The impetus for microcomputer models seems to come from younger managers and analysts; individual railroads do not seem to have made any special commitment to the development of models for use on microcomputers.

At the industry level the story is considerably different. AAR has considered preparing microcomputer versions of various models of track and train dynamics that have been developed during the course of a multiyear research program. As was the case with SPM, the microcomputer offers smoother transfer and greater use of models developed for the industry with support from AAR.

Real-Time Control

Canadian National has used microcomputers in real-time control in some of its maintenance shops, in some cases building its own microcomputers to serve the exact requirements of a particular situation.

Unresolved Issues

Despite the rapid growth in the number of microcomputers in use and the wide variety of applications, the extent of use, how soon, and under what conditions the microcomputer will be accepted by the rail industry are still unclear. At least two railroads (the Boston and Maine and the Canadian National) have welcomed the use of microcomputers and have people in many departments who use them for most of the applications described. Other railroads, such as the Southern Pacific and the Burlington Northern, have approved the acquisition of microcomputers for specific applications, such as being able to run the SPM, but have not encouraged their proliferation. Still others actively discourage or even prohibit the acquisition and use of microcomputers.

Concerns about microcomputers fall into several categories. Senior officials in MIS departments initially seem ill-disposed to consider the acquisition and use of computers that are viewed as small, slow, expensive, and unnecessary additions to their computing capacity. They also raise the issues of the integrity of the company's data base (different people will create different and conflicting data bases that are no longer accessible through the company) and the confidentiality of data that reside on floppy disks scattered across desks in dozens of open offices. People outside the MIS departments, however, look behind these rational reasons and perceive a reluctance to reduce the MIS department's power over information and computation. From this perspective, microcomputers offer the individual an opportunity to bypass the delays and inefficiency of dealing with a bureaucracy in order to produce a new report or to do some analysis.

Many senior officials regard microcomputers as toys that cannot possibly have any benefits to a serious organization. The majority of people who inquired about SPM said that their chances of acquiring it would be better if it ran on a mainframe rather than on a microcomputer. For example, to the senior management of the Spanish National Railroad the status and credibility of the model were lowered greatly because it ran on a microcomputer. In a similar vein, a number of professors working on transportation problems at MIT, Princeton, and elsewhere perceive microcomputers as too small or too slow to provide a serious alternative to larger computers.

Despite the negative reactions to microcomputers, whether based on rational reasons or simply on a fear of losing power, microcomputers will inevitably be used more widely in the rail industry. Two inexorable trends will overcome any resistance that can be offered by either senior managers or the MIS departments. First of all, the price of microcomputers is well within the means of college graduates who take entry-level positions in management and planning. These college graduates will increasingly have experience in using computers of all kinds and will be willing to purchase their own machines even if their employers are not. Management will be unable to prevent people from purchasing and using their own computers, and managers who are illiterate in the use of computers will be bypassed by those who are literate. The second trend concerns the technological improvements in microcomputers, especially in their speed, storage capabilities, and ability to communicate with other computers (of all sizes) in a network. Microcomputers clearly will not be toys, but important components of a larger system. The distinction between a microcomputer and a computer terminal will become increasingly fuzzy. For major corporations such as railroads the logic for linking managers in some kind of computer network will become overwhelming.

If distributed processing is inevitable, and most managers acquire something that can function like an independent microcomputer or tie into a computer network, how such distributed processing will be achieved is still unclear. On some railroads individuals acquired microcomputers to demonstrate the benefits of particular types of programs (usually in budgeting or planning by using something like Visicalc). The response of some railroads to these successful microcomputer demonstrations was not to expand the use of microcomputers but to acquire programs for the mainframe that have similar flexibility but more speed and capacity. This suggests that the use of microcomputers may be a temporary strategy that forces MIS departments to become more responsive, more flexible, and less centralized.

Canadian National has taken a different approach. It established a separate group that has the responsibility for coordinating the acquisition of microcomputers and software, thereby providing individuals with some guidance in setting up their systems and giving the company the ability to deal with vendors on a centralized basis. A third approach may be that taken by the Boston and Maine, which has acquired Apple 2 computers for its major departments and is coordinating them closely with Delaware and Hudson and Maine Central, both of which also have Apple computers. By linking these existing microcomputers with modems, a group of mid-level managers are evolving a microcomputer network suited to their specific requirements.

The evolution of technology may render some of these issues moot. For example, Burlington Northern hosted the SPM users' group in January 1983 to demonstrate how they have linked three Apple 2 computers to their mainframe in order to reduce the time and effort of creating input files for running SPM. At the same time the users' group will be discussing how to modify the SPM so that it will be compatible with the future, more powerful microcomputers (by shifting from Apple Pascal to UCSD Pascal, the users' group expects the SPM to be able to run much faster without having to further modify the program so that it could run on a mainframe computer system). In short, the distinction between the microcomputer and the mainframe, both in terms of technical capabilities and in terms of use, is declining.

CONCLUSIONS

The impetus to use microcomputers in the rail industry has largely come from individual managers and analysts who have either been frustrated by their MIS departments or intrigued by the capabilities of microcomputerss. Most major railroads now have at least one microcomputer and some have dozens, most of which are being used in a wide variety of applications. AAR has encouraged the use of microcomputers to facilitate the transfer of research techniques and models and has supported a users' group for a large, complex microcomputer model (SPM) that was transferred to six U.S. and one foreign railroad.

People have sought microcomputers because of their ease of use, the availability of software, and the ability to control the microcomputer for their own purposes. People who have never before used computers have learned to use programs for budgeting, data base management, and word processing. In many cases, after being exposed to microcomputers, people are anxious to use the more powerful computers available to all large railroads; i.e., the microcomputer seems to entice people into using computers.

Despite the widespread use of microcomputers, how railroads will make the transition from the centrally controlled mainframe computer to a flexible network of computers, jointly controlled by MIS departments and individual users, is still unclear. Current concerns about the proliferation of microcomputers are not likely to withstand the dual impact of continuing technological improvements and declining prices of microcomputers. People who want to use microcomputers will simply buy them, whatever the attitude of senior management.

The rail industry is unlikely to use a great number of stand-alone microcomputers. Instead, railroads will acquire networks, either of microcomputers or of intelligent computer terminals. As microcomputers become more and more powerful, the distinction will become less important. Microcomputers will continue to provide an impetus to railroads to improve their computing capabilities and to make flexible, powerful software available to those who need it.

REFERENCES

1. C.D. Martland, H.S. Marcus, G.B. Raymond. Improving Railroad Terminal Control System: Budgeting Techniques, Probabilistic Train Connection Analysis, and Microcomputer Applications. Massachusetts Institute of Technology, Cambridge, Studies in Railroad Operations and Economics, Vol. 37, July 1983.
2. C.D. Martland and C.D. Van Dyke. Transferring the MIT Service Planning Model. Massachusetts Institute of Technology, Studies in Railroad Operations and Economics, Vol. 38, 1983.
3. C.D. Martland, M.G. Messner, and V. Nowicki. Implementating an Operating/Service Plan: A Case Study of the Boston and Maine. Massachusetts Institute of Technology, Cambridge, Studies in Railroad Operations and Economics, Vol. 29, 1979.
4. C.D. Martland, P.A. Clappison, C.D. Van Dyke, and R.J. Tykulsker. Rail Service Planning: A Case Study of the Santa Fe. Massachusetts Institute of Technology, Cambridge, Studies in Railroad Operations and Economics, Vol. 35, 1981.
5. C.D. Martland and C.D. Van Dyke. Transferencia del Modelo de Planificacion de Servicios del MIT a Renfe. Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Oct. 31, 1982.
6. G.B. Raymond. Performance Standards for Rail Terminals: Case Studies from the U.S. and France. Center for Transportation Studies, Massachusetts Institute of Technology, Cambridge, S.M. thesis, 1982.
7. T.M. Fletcher. Train Fuel Use Simulations. Soo Line Railroad Company Industrial Engineering Department, Minneapolis, Feb. 26, 1981.
8. G. A. Grimes. Terminal Facility Operations and Unit Train Planning. Proc., 23rd Annual Meeting, Transportation Research Forum, Richard B. Cross Company, Oxford, Ind., 1982.

Microcomputers in Civil Engineering

GARY W. DAVIES

The speed and capacity of microcomputers, coupled with their portability and inexpensiveness, make microcomputers attractive to the engineer. Microcomputers have the greatest potential for civil engineering projects being undertaken by individuals and small firms and for projects of a more modest size. In these situations mainframe computer processing has not been feasible because of costs and inconvenient access methods. Microcomputers can be useful even for large engineering firms and large projects because they can support cheaper and more efficient communications, and they can provide graphics, spread sheets, and other utilities that are not available in the mainframe environment. Virtually every area of civil engineering can profit from the use of a microcomputer. Standard utility programs alone can provide extensive and useful capabilities. In addition, a number of applications packages are becoming available to support specific civil engineering activities. Computer-aided design (CAD) and critical path method (CPM) systems are useful in most engineering operations, irrespective of the specific application. Some examples of application-specific software include various coordinate geometry systems for roadway and site layout, earthwork programs that calculate cut, fill, and slope stability, and structural design programs that handle simple beam design and member selection, plane frame and grillage analysis, and two-dimensional stress and truss analyses. In addition, hydraulics analysis and pavement design programs are available, as well as systems for evaluating existing pavement conditions and for assisting in establishing the priority order of maintenance measures.

The conventional wisdom of the 1980s is that microcomputers are revolutionizing business and professional practice. The civil engineer who designs roads, bridges, buildings, and other elements of the infrastructure has probably used computers for years, and so the question, "What is the big deal?" is probably well founded. In this paper an answer to that question is attempted by juxtaposing the concerns and capabilities of mainframe computer processing against those of microcomputing, and some typical civil engineering design applications are discussed that can use the microcomputer most effectively.

MAINFRAME COMPUTER VERSUS MICROCOMPUTER TRADE-OFFS

Since its earliest days civil engineering design has been a numerically oriented discipline, so civil engineers are continuously searching for better ways of performing their computations, for both better accuracy and greater speed. The development of the slide rule was a revolutionary event because this device provided the engineer with a tool that would accurately yet quickly perform computations and was also conveniently sized and easy to use. The development of mainframe computer processing in the 1950s and 1960s also revolutionized engineering, but by contrast the mainframe computer was tremendously inconvenient and expensive. Yet it enabled the engineer to tap tremendous computational powers and data base facilities that eased the work. The blending of these two technologies was begun with the desk-top and pocket calculators, but this was actually only an evolutionary step from slide rules, because even the more advanced programmable calculators were primitive in their capacity to store data and their ability to communicate with the user. The development of microcomputers, however, is a revolutionary event that has transformed the computational environment, and has even begun to change the engineer's approach to problem solving in general. The friendliness, speed, and capacity of microcomputers have been amply discussed. When coupled with these factors, the portability and inexpensiveness of microcomputers make them attractive to the engineer.

This is not to say that mainframe computing is on the wane. On the contrary, no realistic substitute has been found for the massive shared data bases, the multiuser environments, and the computational speed and memory capacity of these large machines. Particularly in a large design organization and for large projects, these features of the mainframe computer are of vital importance. But, much of civil engineering is being accomplished by individuals and small firms and for projects of a more modest size. For these groups, which have been effectively locked out of mainframe computer processing because of costs and inconvenient access methods, microcomputers have great potential. Even for committed users of mainframe computers, microcomputers can be useful because they can support cheaper and more effective communications and can provide graphics, spread sheets, and other utilities that are not available in the mainframe computer environment.

The microcomputer can operate in the design process in three modes.

1. In stand-alone operation the computer operates independently and self-sufficiently. This is probably the most common use of microcomputers.
2. The microcomputer can serve as a distributed extension of a central mainframe computer, with fully integrated operations and data bases both locally (in the microcomputer) and centralized (in the mainframe). Because of the strenuous software and system demands of this mode it is probably the least common operating mode.
3. The microcomputer can be an intelligent terminal, which provides the convenience of a local data base, the user-friendliness of full-screen data preparation tools, and consequent cost reductions in communicating with the applications on the mainframe computer.

The advantages of using the microcomputer as an intelligent terminal over a conventional terminal for accessing a remote mainframe computer derive from a relatively new trend in computing costs. Considering both personnel and operating costs, the costs of communicating between terminals and the computer have become a relatively larger portion of the total cost package. This is because the costs of computation are decreasing at a faster rate than those of communications, and the cost of personnel continues to increase. Thus, applications that use the microcomputer to assist in the preparation of data and speed its communication to the mainframe computer are of great potential and, in this sense, microcomputers greatly complement mainframe computer applications.

Microcomputers also can compete directly with mainframe computers in a number of areas, primarily because of the extremely high screen transfer rates that are possible without interposing telephone lines between the microprocessor central processing unit (CPU) and the user. Although the graphics and text displays of a microcomputer might be somewhat less elegant than those of a Tektronics or IBM-3270 screen, the complete microcomputer probably costs less than the terminal alone, and the costs of mainframe computer processing to drive the terminal are added each time it is used. Thus economical graphics, electronic spread sheets, and full-screen editors are possible in the microcomputer environment but may only be dreamed about in the mainframe computer environment because of their extreme cost.

The comparatively small memory capacity of a microcomputer generally forces larger application programs to be broken down into menu-driven modules. This, in a sense, is an advantage for the problem-solving process, which is then also broken down into manageable segments. Programs can then be written in a way that minor amendments can be made without having to run large sections of the program again, and an iterative or stepwise approach to the solution of the whole problem is more common. In this mode of operation the slower computation of the microcomputer is less noticeable and is more than compensated for by the more direct control of the problem-solving process.

In summary, microcomputers can have a very real and effective place in even a highly mainframe-oriented organization. Care must be taken, however, to thoroughly integrate their use into the organizationwide computational scheme so that data structures, algorithms, and techniques are controlled, and the most useful features of both the mainframe and the microcomputer are used.

TYPICAL CIVIL ENGINEERING DESIGN APPLICATIONS

An attempt at defining the uses for a microcomputer in civil engineering design practice is somewhat akin to defining the potential applications for a slide rule or a typewriter. With a reasonable amount of imagination virtually every area of practice can profit from its use. Some applications are generic and common to all the various disciplines of engineering; others are more specifically tailored to particular disciplines and require specialized software. In discussing these applications, the following is not intended to be a comprehensive listing of potential uses, but rather it is intended to demonstrate the breadth and power of microcomputer hardware and software systems and to pique the imagination. Some guidelines for selecting a system are also given.

Generic Applications Using General Utilities

Quite likely the most significant aspect of microcomputers is not the technical sophistication of the hardware but rather the profusion of useful, well-designed software. Each discipline has its own elegant software; nowhere are these advances more obvious than in the general utility programs now being offered. They fall into five general areas, and a practice that taps the fullest potential of a microcomputer would use each:

1. Word processing,
2. Electronic spread sheets,
3. Data base management,
4. Graphics, and
5. Communications.

Until only recently each of these applications stood virtually by itself, which limited the usefulness of that software package. The latest trend (as exemplified by the Apple III SOS Operating System) is to integrate the operation of these utilities through common file structures and disk operating systems, and even (as the Apple LISA will do) through the same overall program environment. Thus, computations developed by the electronic spread sheet can be fed directly into graphics, for example, and the results of both can, in turn, be incorporated directly into the word processor for reporting.

Word Processing

Word processing has been used effectively by engineers since its inception. Reports are an obvious application for word processing; however, probably the greatest usefulness in the design shop relates to the preparation of construction specifications. A complete set of standard specifications can be kept on-line, and minor modifications, additions, and deletions can be made to tailor them to a particular project. The time savings for both professional and clerical staff can pay for a microcomputer system quickly in this application alone.

Electronic Spread Sheets

Electronic spread sheets are an entirely new medium of computation that has been made possible by the microcomputer and should be made a mainstay of the software repertoire of every engineering office. These programs (of which VISICALC, SUPERCALC, LOGICALC, and MULTIPLAN are notable examples) give the user complete flexibility to define a computational spread sheet on the order of 50 columns wide and 250 rows long. In each cell of this spread sheet can be inserted text, values, or mathematical relationships among cells, and a large number of intrinsic functions are provided to support those mathematical relationships.

Each spread sheet tableau can be saved on diskette and recalled, tableaus can be overlayed and merged, and computational results can be transferred among tableaus, to other applications programs, and to word processing and graphics packages. As an example of a spread sheet's use, a construction cost estimate can be developed that contains all likely cost items and their unit cost. For a particular construction project this template is then recalled and the quantity of each item is entered. The spread sheet calculates the total cost for each item automatically and the overall construction cost is stratified in whatever way the user sets up the model. The resultant estimate can be printed directly or incorporated into the word processor, and the entire tableau can be saved (with quantities intact) and recalled for later updating. Other applications could include unit hydrograph computations, earthwork quantitites, pavement design models--in short, virtually any mathematical model that can be expressed in row and column format and does not require extensive iteration.

Data Base Management

Data base management is probably less well developed in the microcomputer environment, principally because of the extensive amount of disk storage and memory space required to support effective data base management. With larger CPUs and Winchester hard disks, which are becoming available at reasonable prices, fully relational data base management systems are now also becoming available. In an engineering practice data base management is probably less useful directly, but it is an absolute necessity to support some facilities such as computer-aided design (CAD) systems and project management systems.

Graphics

Graphics is a key capability of the microcomputer. General utility graphics packages are readily available commercially and can be integrated with electronic spread-sheet programs to assist in the display of results. These graphics packages are typically business oriented, however, and provide bar charts, line graphs, and pie charts. To the extent that these formats can be used to summarize technical findings they are of use to the practicing engineer. For many engineering applications, however, specifically tailored engineering graphics packages must be used.

Communications

Communications is an important feature of microcomputers to the engineer because it permits communication with mainframe computing systems. As discussed previously, communication enables the engineer both to complement mainframe operations with the microcomputer capabilities and also to use mainframe resources to expand microcomputer power. A number of communications programs are available that, with little or no modification, will allow the engineer to communicate with virtually any mainframe system. These packages essentially turn the microcomputer into an intelligent terminal, enabling conventional manual communication and control with a time-sharing system, complemented by the ability to transmit and retrieve entire files of data. These files can then be input to other utilities such as spread sheets, grahics packages, and the word processor, or to specific application programs on the microcomputer.

Summary

Even if only these general utility packages are used, the microcomputer can be made into a powerful tool for engineering design. The programs are generally inexpensive to purchase, readily available commercially, and need virtually no software development to support their use. The key ingredient on the engineer's part is creativity--the ability to envision and develop ways of using these tools.

Generic Engineering Applications Programs

In addition to the more readily available and less expensive utilities, a number of applications packages are becoming available to support engineering specifically. Because of the more limited marketplace and often more rigorous software and hardware demands, these packages are considerably more expensive than the general utility packages; however, they too can be of great use in an engineering practice.

CAD Systems

CAD systems are beginning to appear in the marketplace. For obvious reasons of disk storage space and CPU size, they do not match the power of mainframe CAD systems. Yet, high-quality, two-dimensional drawings and design capabilities are provided. CAD techniques have been heavily incorporated into other engineering disciplines such as mechanical and chemical (both dealing with industrial design); however, CAD has not yet been used extensively by civil engineers. Relatively inexpensive CAD systems that use the microcomputer (with costs on the order of $10,000 to $20,000, including hardware) may begin to encourage civil engineers to use them also. Examples of CAD systems include CASCADE II by CGD Systems in Anaheim, California; CADAPPLE II by T&W Systems in Fountain Valley, California; AUTOCAD by AutoDesk, Inc., of Mill Valley, California; and the PALETTE system developed by Structural Programming, Inc. of Sudbury, Massachusetts, for the DEC VAX system, which has now been modified to operate on the DEC 300-series microcomputer.

Project Management

Project management, both of in-house operations and of construction projects, is an application that is well suited to the microcomputer environment. A number of critical path method (CPM)-type network scheduling systems have been developed and are available commerically. One of the most notable construction project management systems is the management and project planning system (MAPPS), which was originally developed by Structural Programming, Inc., for the VAX system. This management system, which integrates both costing and scheduling, will soon be available for the DEC microcomputer. A number of utilities are available for in-house control of design projects, including Project Control/Micro, a system of software tools that allows a manager to model a project or resource environment and to track, analyze, and simulate it. Both tabular and graphic outputs are provided.

DISCIPLINE-SPECIFIC APPLICATIONS

Software packages that support specific engineering design problems are less common, more expensive, and of inconsistent quality. Undoubtedly, many organizations have been developing systems to support their own practice but, because of the efforts needed to finalize, document, market, and support software systems, few of these packages reach the marketplace. Presumably, time will remedy this situation, and this is evidenced by the ever-increasing number of software advertisements in professional journals.

One trend that seems to be helping the distribution of engineering systems is that larger software suppliers are assembling and mass-marketing civil engineering programs developed by practicing engineers. As part of this process they throughly test and document each program, thereby giving better assurance of its quality. Examples of these packages include the CIVILSOFT line marketed by Advent Products, Orange, California; the systems developed by Advanced Engineering Software for hydrology and hydraulics, by Advanced Engineering Software, Irvine, California; and the DISCO-TECH products by Morton Technologies, Santa Rosa, California.

In addition, computer manufacturers that have a traditional engineering orientation, such as Digital Equipment Corporation (DEC) and Hewlett-Packard (HP), have well-developed engineering packages available for their microcomputers that are thoroughly integrated with their hardware.

Some examples of application-specific software systems for the microcomputer include the following.

1. To support roadway and site layout, various coordinate geometry (COGO) systems are available. They are designed to run on virtually any CPM machine (including a suitably equipped Apple II). Notable examples include the COGO System in CIVILSOFT, a COGO developed by Weltech, Dayton, Ohio, the Coordinate Geometry Program by DISCO-TECH, and systems by HP and DEC. These systems are typically menu-based and provide many capabilities to compute curve, line, and traverse data. Other location-related systems include vertical curve design programs, survey packages, and field note reduction systems.

2. Further support of the highway design process is available through earthwork programs such as the EARTHWK program available from CIVILSOFT. This program calculates cut and fill by various methods and allows input from a digitizer. The SLOPE program is available from CIVILSOFT to deal with slope stability of an earthen embankment. Its solution

consists of a factor of safety for a given slope condition.

3. Structural design has many applications that use microcomputer processing. More obvious applications include simple beam design and member selection, where loads are computed and appropriately sized members are selected from a data base automatically. Other applications include beam, plane frame, and grillage analysis. Various programs are also available for two-dimensional stress and truss analyses. A useful program to the highway designer is a cantilever retaining wall design program. Programs are available from DISCO-TECH, CIVILSOFT, HP, and DEC.

4. A number of hydraulics analysis and design systems are also available. A comprehensive storm water detention design program is available from Garmen Associates, Whippany, New Jersey, and other available programs include pipe network analysis programs, open channel hydraulics programs, and backwater analysis programs such as those available from DISCO-TECH and CIVILSOFT.

5. In the area of pavement design, a number of concrete and bituminous-mix design programs are available from CIVILSOFT and other sources to assist the engineer in designing a pavement. Another useful program is COMPAVE, developed by Allan Davis Associates, Stamford, Connecticut. This is a comprehensive system for evaluating existing pavement conditions and for assisting in establishing the priority order of maintenance measures.

These analysis and design packages do not have the power of mainframe packages to deal with complex and large-scale design problems. ICES COGO/ROADS is an extremely powerful tool for coordinate geometry, roadway design, and earthwork computations as are the U.S. Army Corps of Engineers' HEC-II system for hydraulic modeling, and various STRUDL systems for structural analysis. Often the resources of these mainframe programs are unused in a typical design problem; however, the ease, economy, and utility of microcomputer applications makes this environment a practical alternative.

ISSUES AFFECTING SYSTEM SELECTION

The potential purchaser of an engineering system is faced with a dilemma--the costs of time spent in identifying and evaluating systems may far exceed the actual costs of the systems. The systems will most likely become a major element of his or her practice; therefore, this is reasonable up to a point. This aspect of the acquisition process should be controlled though, and the engineer should be willing to take some chances because even the purchase of a totally wrong system would waste only a few hundred dollars and, in reality, virtually any system will have some usefulness. Technical validity is obviously of paramount concern in evaluating the candidate programs. Also important, however, is that the programs be easy to use and that they have the flexibility to be driven by the user rather than driving the user. Therefore, a well-defined system should have the following features.

1. Technical merit--Clearly, if invalid algorithms are used, the system will be worthless, no matter how elegant. Products of the candidate system should be checked carefully against the results of known procedures to check their accuracy.

2. Open design--Piracy is a real and valid concern of software suppliers, but provision still should be made for the user to have access to the program code, particularly for those portions that relate to the model algorithms. This will enable the user both to further validate the algorithms and to modify them if so desired.

3. User expandability--Related to the open design feature is the ability to accommodate user expansion of the system. This should be supported by documentation of the file structures and any utility modules in the system that assist in file access and other tasks. This feature would permit a user to modify the system to suit particular needs.

4. Menu drivers--To ease the selection of program options and the chaining of program modules, the entire system ought to be menu-driven. This considerably eases the user's learning process and also makes the system considerably easier to operate.

5. Full-screen data edits--Many user interfaces are holdovers from the original punched card input modes of mainframe computers, with line-by-line viewing of data. The high-speed screen capabilities of microcomputers offer a much more effective and easy-to-use means of entering and updating data via full-screen edits. Any system ought to use full-screen displays wherever possible.

6. Interfaces with other programs--For maximum usefulness, a system ought to provide easy-to-use interfaces with other utility and application programs. This can be through standard file structures such as the Data Interchange Format (DIF) file structure associated with VISICALC. These special format files can then be incorporated in the spread sheets and graphics.

The key objective in all of these features is to maximize the usefulness of a system to the user by giving flexibility in use, and by easing the learning experience as well as day-to-day operation of the system. In general, engineering systems have the technical algorithms well worked out and are dependable from a technical perspective. Often, however, their shortcomings occur in communication with the user and inability to communicate with other packages or to be expanded or modified by the user.

SUMMARY

The development of the microcomputer signals a new era of computer use. The user-friendliness and usefulness of general utilities such as word processors, spread sheets, and graphics when complemented by effective engineering applications programs make these computers significant additions to any engineering practice. Their usefulness is bound only by the imagination of the engineer and his or her ability to modify problem-solving techniques and office procedures to harness the computer's power more effectively.