different kinds of information, the implementation process may require considerable redefinition of data collection forms and procedures.

Modify an Existing System

Like the first alternative presented above, the second approach, modifying an existing system, assumes that a system is modified to satisfy department needs. Tailoring, of course, requires programming additions, deletions, and changes. The extent of these changes determines the cost and risk incurred. A key decision is who will do the programming. Options include using in-house personnel or contracting with a software consultant.

Again, both options present unique problems. In-house personnel may be knowledgeable about the agency but may not be as technically competent as a consultant. In turn, consultants may have considerable data-processing experience but may lack specific knowledge about traffic records. Another potential disadvantage with consultants may be total cost if the project takes longer than expected, a common (almost certain) occurrence in software development.

Tailor a Generic Records System

At the price of losing some flexibility, it is possible to adapt a generic data base management system to the terminology and format required for a traffic record system. This tailoring may not involve as much risk as modifying an existing system because generic record systems are usually designed to be user-tailored when first implemented. A more risky approach is modification of a data base management system originally designed for a different application. Often these systems are promoted by management consulting firms that tend to minimize the actual programming required for the modifications. Effective use of a consulting firm requires that the user agency and the consultant specify in written form what the final system must be able to do, the schedule for completion of the project, and the total cost.

Develop a New System

The most ambitious approach is the development of a new system. This alternative offers the greatest opportunity to obtain a product that is consistent with the needs of the agency. Although this may be an important issue, its value must be weighed against the risks and costs involved. The key issues to be considered are how closely the automated system should emulate the current manual system and who should design and program the new system. On the surface, using an existing manual system as the model for an automated system seems simple. But it must not be assumed that an inadequate manual system will be miraculously corrected when it is automated. The usual result of such an approach is an ill-designed system that makes the same mistakes as the manual system but at a much faster rate. To be successful, this approach requires that an agency objectively assess the strengths and weaknesses of its manual system and aim to retain the strengths and redesign the weak points. The creation of a completely new system represents risks that few agencies should take. The uncertainties involved in the design, cost, and schedule of any software project make this an extremely risky approach. An agency should not consider in-house development unless it has highly capable, experienced personnel who can be committed to the project.

CONCLUSIONS

It is clear that within the next decade most agencies concerned with the use of accident and law-enforcement records will, regardless of their size, have access to computers for the storage and analysis of data. What is also likely is that the process of acquiring and using these automated systems will not be as easy as advertised. The lack of data-processing experience among the personnel of small agencies, coupled with dramatic changes in the marketplace, will make the automation of record systems a risky and difficult process for many agencies. However, if agency administrators are alert to the pitfalls cited in this paper, the task of automation can be accomplished with realistic expectations and maximum payoff to the agency.

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Application of Small Computers to Traffic Records Systems in Small Communities

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The application of small computers to traffic records systems in small communities is investigated. The study is based on an assumption that small computers (micros) are useful for the management and analysis of traffic records in communities of 5000-100 000 population. Factors bearing on the apparent hesitancy of small communities to use small computers for traffic records are examined. It is concluded that the volume of traffic records generated by small communities is within the capacity of present small computer systems and that the systems are adequate in terms of secondary storage, primary memory, speed, and input-output devices. Costs are modest. It is suggested that available generic software has not been exploited for traffic records management and that, with some exceptions, there is a lack of specialized applications software for traffic analysts. Remaining barriers to the use of small computers include data-quality concerns, organizational issues, justification of purchase, acceptance of the equipment by agency personnel, and management problems. Adoption of small computers for traffic records systems will depend on how these issues are resolved.

In the past five years, economically priced small computers have become widely available. There were an estimated 1.3 million small computers in homes in the United States in 1981, an estimated 800 000 of which were bought that year. In addition, it is estimated that there are now 200 000 microcomputers on desktops in large corporations (1).

In 1982, the National Safety Council Traffic Records Committee for Data Analysis conducted a survey that provided responses from 63 users in 29 states (2). When respondents were asked what system or devices were used for various types of analyses, the microcomputer was mentioned 29 times out of a total of 332 responses (8.7 percent). The respondents who mentioned using small computers were almost exclusively from law-enforcement agencies in California and Illinois. The sampling and the questionnaire design do not allow adequate control to make valid conclusions. But the results provide some indication of the limited extent of current use of small computers in traffic records. Although better data are not available on the extent to which the small computer is in use in state and local government, extensive contacts with police and the transportation engineering community indicate that there is a lag in the use of these machines.

It is assumed that the small computer can be useful to police and the transportation engineering community in their common effort to enhance highway safety. This assumption led to the analysis of one application of the small computer to the traffic records system of a small community. The purpose of the analysis was to determine whether technological barriers could be identified and specific applications evaluated.

FORMAT FOR ANALYSIS

The format selected for analyzing small-computer applications to traffic records involved the specification of three basic hypotheses related to the technological issues:

1. The hardware is inadequate.
2. The software is inadequate.
3. The costs are too great.

Although there exists a multitude of other issues, these were selected for immediate focus. Certainly there are a number of human factors and organizational issues involved in applying new technology. Some of these are addressed later in this paper.

In dealing with the technological issues, it is necessary to examine the current trends in small computers in sufficient detail to determine the status of key attributes in relation to traffic records systems requirements. First, however, some of the key parameters involved are defined.

Small Community

The small community represents the greatest pool of potential users of the small computer. In Illinois, for instance, whereas the state has accident data for 258 communities in the 5000-100 000 population range, it has data for only 3 cities with populations greater than 100 000 (see Table 1). Among the possible safety applications, the traffic records system probably represents the greatest data-handling test of the small computer.

Traffic Records System

System Elements

A traffic records system is generally considered to include the following elements or files: accident, vehicle, driver, citation, roadway, and control device. These can represent substantial quantities of data and, where automated, are generally considered feasible for operation only on mainframes.

Although the files listed above are considered desirable for a comprehensive system, many small communities currently maintain only an accident file (if any) on an automated basis. Even in cities with populations greater than 100 000, citation, roadway, and other files may not be automated. Therefore, for the purposes of this paper, the core system needed for a small community to conduct effective safety analyses is considered to include the accident and citation files.

Volume of Data

As previously noted, Table 1 gives the most recently available accident frequencies for Illinois communities in the 5000 to 100 000 population range. Accidents are related to community size. The table indicates that all cities with less than 10 000 population had fewer than 1000 accidents/year and that all cities with more than 40 000 people had more than 1000 accidents/year (the maximum was about 5000 accidents).

Data-storage requirements for these accidents are determined not only by the number of records in the system but also by the length of each record. Record length, in turn, depends on the number of data elements in each record and the coding conventions that are used for data entry. The digitizing of locations, dates, times, etc., can substantially reduce the size of fields. The judicious limitation of data elements can be even more important. Because few communities are likely to use identical record formats, how are the length parameters for a typical traffic record to be determined?

To obtain information on the length of a record, two systems are used to represent upper and lower bounds. Washington State has an elaborate coding scheme for accident records processed by its mainframe computer (3). The coding is so detailed that, in the event of a "collision with a pedal-cyclist," the system can provide separate tabulations for "unicycles," "bicycles," and "tricycles." Each accident record takes 212 bytes of storage. (A byte

Table 1. Motor vehicle accidents reported during 1981 by Illinois communities.

	No. of Communities by Population[b]							
	5000-9999		10 000-39 999		40 000-100 000		Total	
No. of Accidents[a]	No.	Percent	No.	Percent	No.	Percent	No.	Percent
0-399	77	91.7	39	26.5	0	0	116	45.0
400-999	7	8.3	83	56.5	0	0	90	34.9
1000-2999	0	0	25	17.0	20	74.1	45	17.4
3000-4999	0	0	0	0	7	25.9	7	2.7
Total	84		147		27		258	

[a]Accident data are from the Illinois Department of Transportation.
[b]Population data are from the 1980 U.S. Census.

can be considered as the amount of computer storage necessary to hold one character of information.) The Washington State coding scheme was used as an indicator of the upper limit for record size.

A lower boundary for accident record size was derived from a report that proposed a record format for the city of Newport News, Virginia (4). The coding scheme captured the essentials of an accident record in 24 data elements coded into a total of 50 characters. As a consequence, 50 bytes/record was taken as a reasonable lower boundary for the size of a collision record.

A desirable system would contain three years of historical accident files and a current year-to-date file. This would result in a maximum of four years of accident data on file at any time.

The discussion to this point has assumed a single basic file type, although a hierarchical file design may be desired. In such a case, the record is segmented into a master file, a vehicle file, and occupant-pedestrian files. In addition, a location index file is required for locational analyses.

Figure 1 translates the basic file type defined above into data storage requirements. Hierarchical file structures and a location index file will add some storage requirements (say, 50K, where K = 1024 bytes), but the range shown is considered sufficient as an estimate of system requirements for accident data. The range of annual accidents shown in the graph is likely to be representative of cities with populations of up to 200 000 to 250 000.

Accident records have been noted above as only one part of a comprehensive traffic records system. The citation record has been identified above as the other element of a core safety analysis subsystem. Citation files are to be distinguished from the driver file, which is a history of individuals usually maintained by the state motor vehicle department for licensing and other purposes. The citation file contains records of traffic offense actions taken by the police officer. Typical data elements for a local citation file would include the location, type, time, and date of the offense. Individual driver and disposition data are of interest administratively but are not essential for safety analyses in general.

Estimating the number of citations in a community, especially in relation to the population, is not a simple task due to lack of data. Experience has shown, however, that the number of citations can be related to the number of accidents as a crude indication of the level of enforcement activity. A general rule of thumb used in the law-enforcement community is that a ratio of 20 citations/injury accident represents a point of diminishing returns. On the other hand, 8-10 citations/injury accident represents a reasonable level of effective enforcement action. If one takes into account property-damage-only accidents, it is reasonable to expect ratios of 10:1 and 3:1 as bounds. Although these are not well-documented values, they do make it possible to estimate a reasonable range for data storage requirements.

It is believed that only a single year's citation history needs to be on file for most analyses. The greater number of citations per year, compared with

Figure 1. Data storage required for accident records.

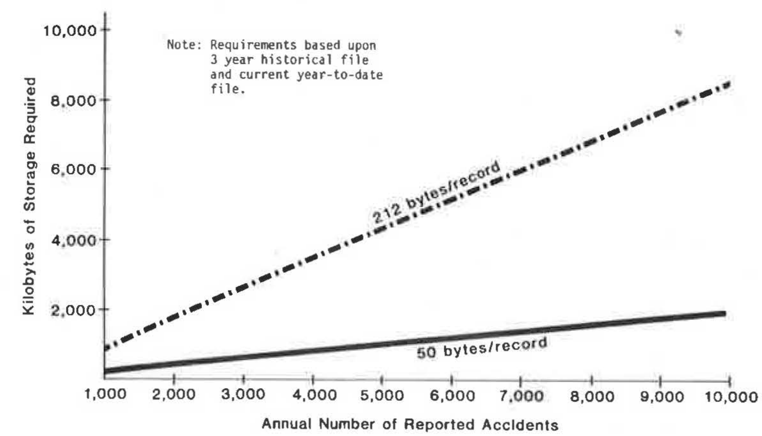
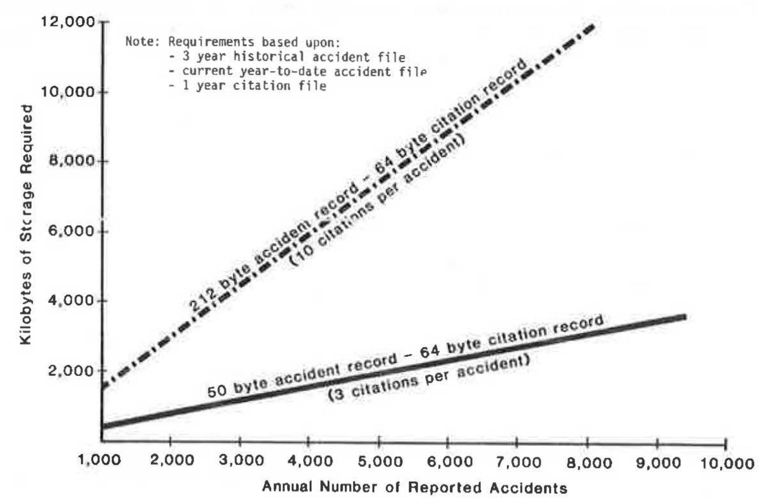


Figure 2. Data storage required for accident and citation records.



accident frequencies, provides an adequate statistical base if maintained on an annual basis. Current enforcement activity can be compared with accident histories to determine whether enforcement actions are appropriate and how they may be planned for the future. In addition, comparisons between enforcement and current accident patterns can be made to evaluate effectiveness. Figure 2 shows a graphic summary of the data storage requirements necessary to add a citation file to the previously defined accident file.

Small Computers

It is necessary to have some understanding of what is being referred to under the classification of small computer. In general, in this paper a small computer is one that costs between $2500 and $20 000, including peripheral devices. This is a general definition because distinctions at this time are fuzzy and the technology is changing rapidly.

The remainder of this paper examines each of the hypotheses in the light of available information.

HYPOTHESES TO BE TESTED

The background given above allows an analysis of the technological issues around which the hypotheses have been formulated.

Adequacy of Hardware

Primary Memory

Primary memory is one of the principal characteristics that distinguish small and large computers. In large measure, primary memory is determined by chip technology. Eight-bit chips simply do not have the direct addressing capability of 16-bit chips, which, in turn, lack the addressing capability of 32-bit chips, and so on. The vast majority of small computers in use today are based on 8-bit technology, but 16-bit machines such as the IBM PC and the TRS 16 have been enthusiastically received. Recently, National Semi-Conductor and other chip designers have developed 32-bit microprocessors. This will permit not only greater memory capacity but also more versatility.

There is a general disposition among computer enthusiasts that memory is good and the more the better. In the early days of computers, primary memory was extremely expensive and memory, beyond the essential requirements, represented a considerable cost burden for a computer system. Widely used small-computer business systems typically have 48K or 64K memory for 8-bit equipment. The newer machines offer 128K to 256K, and some go higher.

The impact of memory size will vary according to the principal use made of the equipment. Large data bases, involving matrices of substantial dimensions, will rapidly eat up memory. Compared with 48K or 614K machines, systems with 256K and 512K memory are more desirable for data base management because they permit reasonably large files to be manipulated entirely within internal memory. The payoff is greater processing speed and more convenience in file maintenance. When a file does not fit into the machine--as frequently happens with machines with limited primary memory--then the file must be segmented. Portions of the file must be moved back and forth between the computer and secondary storage devices.

Currently, small computers have many times the memory of the second-generation mainframes that were used by large corporations in the early 1960s. Those corporations processed files that exceeded the primary memory available then. The current 64K- to 512K-capacity range is adequate for the file sizes shown in Figures 1 and 2.

Secondary Storage

The secondary storage capabilities of the small computer represent a key potential constraint, given the above discussion on data storage requirements. As indicated in Figure 1, maintaining an automated accident records system in most communities in Illinois requires secondary storage of 1000 to 4500 kilobytes (1 to 4.5 megabytes), depending on the level of detail maintained. The lower limit is within the current floppy disk technology, and the upper limit is well within the current hard disk technology. Figure 2 shows that the impact of adding a citation file results in 3.5 to 11 megabytes of secondary storage. Once again, this is well within current hard disk technologies.

Large (8-in) floppy disks can now hold more than 1 megabyte of data (double sided, double density). Increases in floppy storage capacity are announced monthly. Hard disk drives are commonly available in 5-, 10-, and 20-megabyte capacities. Moreover, systems can be configured with several drives so that 80 megabytes are commonly advertised. The cost of the drive is also becoming less and less of a factor. At present there is extreme competition among drive manufacturers. Apple Computer, for example, which originally listed its 5-megabyte drive at $4000, has reduced the price to $2900, and knowledgeable commentators predict even further reduction. Furthermore, hard disk technology is developing at a fast pace: a 100-megabyte drive is currently in the experimental stage. Secondary storage is definitely adequate for the needs identified here.

Speed

Machine Aspects

Small computers can sometimes seem aggravatingly slow. Sorting of large files may take an unreasonably long time on a microcomputer. This can be the case even when the computer has sufficient primary memory to accommodate the entire file internally. Are small computers too slow to be used for the analysis of local traffic records?

Careful examination of the speed issue suggests that small computers are slow only in a relative sense--i.e., compared with their mainframe counterparts. Moreover, the apparent lack of speed is often traceable to factors other than the computer itself. For example, the 6502 chip is a popular 8-bit microprocessor used in Apple, Atari, Commodore, and a variety of other microcomputers. The slowest 6502 instruction executes in 7 μs with a 1-MHz clock (5, pp. 30, 31, and 87). By mainframe standards, this is not fast, but it permits the computer to perform an enormous amount of processing in the time that would normally be required for a mechanically based peripheral device to perform a task. Computer execution times are infinitesimal compared with disk drive access times and the time it takes printers to generate output. Because the computer must wait for the peripherals, programs that frequently access secondary devices indeed run slowly, but the fault is not with the computer.

Other speed considerations relate to the software. Small-computer programming technique frequently leaves much to be desired. In-house software development often results in routines that are not optimized. The programs work, but not efficiently.

Recursive routines such as sorts can result in long processing delays if the routines are not carefully selected. For example, a bubble sort is often used in software that is developed in-house. The bubble sort is notoriously slow in comparison with other sort techniques, such as a shell sort.

For comparison purposes, 200 random numbers were generated and subjected to a bubble sort and a shell sort. These were run by using an interpreted BASIC language on an Apple microcomputer. By the crude measurement of a stopwatch, the bubble sort executed more than eight times slower than the shell sort. Programming technique, rather than the machine itself, is often a major factor in the apparent lack of speed associated with small computers.

The selection of a programming language is another software area that contributes to the apparent lack of speed of small computers. BASIC is probably the most widely used language in the micro field, but it is an interpreted language that requires the machine to translate each instruction at every step of the program. In a loop, some incredible inefficiencies are encountered. Every instruction in the loop must be retranslated at every loop cycle. The time consumed in interpreting program instructions can be enormous in terms of both relative and real time. A routine that uses nested loops to count from 255 down to zero 255 times will execute in machine language in 329 ms (5). The same logic written in Applesoft BASIC takes approximately 2 min, 32.3 s to execute based on stopwatch timing.

The bottom line is that lack of speed is usually not so much a limitation of the computer as a limitation imposed by peripherals and by the software typically associated with small computers. On both fronts, much is being done to resolve the problems. Several software houses now market compilers for BASIC. Compiled BASIC runs 3 to 10 times faster than interpreted BASIC if the claims of software vendors are taken at face value. In addition, popular brands of microcomputers are often supported by various applications programs and utilities that make use of efficient machine language routines.

The problem of peripheral performance time has been approached in several ways. Printer speeds have increased, and logic-seeking print heads are more widely available. Print buffers now permit computers to pass relatively large quantities of output to the printer and then get on with their computational tasks without having to wait for the printer to do its job. There has been even more progress with secondary storage access. Winchester-type hard disk drives, now commonly available at affordable prices, operate much faster than drives for floppies. Data transfer speed has been substantially increased. Bubble memory in the form of cards, called semi-disks, disk emulators, or a variety of other names, has become available. Because bubble memory is nonvolatile, these cards store data in much the same way as a disk, but they have eliminated the mechanical aspects of storage access. Access is done at electronic speeds.

Cost and Turnaround Aspects

If one were to ask why speed is important, the reply would probably involve two major concerns: (a) computer time costs money and (b) the results are needed as soon as possible. Each of these is important when one considers using small computers in lieu of, or as a supplement to, mainframes.

The cost of computing (as opposed to the cost of computers) is low with the small computer. The machine costs are relatively minimal for the small computer in comparison with the mainframe (cost is discussed further later in this paper). As a result, small-computer use generally does not involve an amortization and maintenance fee. The mainframe represents a major capital investment and maintenance cost, which is often passed on to the user on a time-in-use basis. Thus, whereas speed is often cost to the mainframe user, it is not to the user of the small computer. However, it should be recognized that, in some government accounting systems, an agency may not bear any cost of computing on a central mainframe system. In such cases, not only is speed not an issue but the capital cost of a small computer in that agency's budget would become an extra burden.

Another side of the speed-is-cost issue is the personnel time that may be required. The small computer, if significantly slower than the mainframe, is also usually much closer at hand. Thus, although a technician or professional may be running a program that takes a significant amount of time, the machine can usually crank along on its own while the user does other tasks nearby.

Another issue is the speed that the user experiences. This is often termed turnaround time--that is, the time required from the moment a question is formally asked to the moment of delivery of the data needed to answer the question. Although this does not apply to regularly scheduled computer reports, it does have application to frequent, unscheduled needs. This has been a problem in government environments where central data processing groups are understaffed and computing facilities are used by many different agencies, and levels, of the local government. In that context, the safety analyses desired are often of low priority and thus response is not quickly forthcoming. Time-share systems have helped overcome this to a certain extent. However, in comparing the small computer with the mainframe, although central processing speeds may not be comparable, turnaround times may be; in fact, the small computer may be superior in some cases.

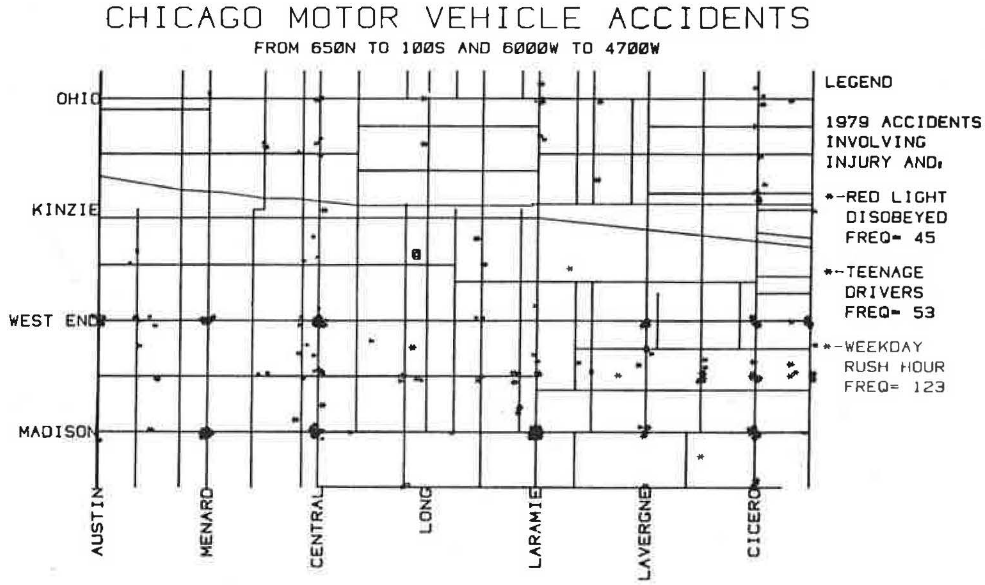
Output Devices

The mainframe computer can generate reports on a cathode ray tube (CRT or television screen) and on paper. It can produce graphs of all sorts, including bar charts and pie charts. It can even create a collision diagram for an intersection, and all at a level of sophistication that is camera-ready for report reproduction. Is it possible that these report generative features discourage the use of small computers? In general, the answer must be no. Small computers designed for general business and scientific use have the ability to drive the same output devices as the mainframes. Although the prices of such peripheral devices are high relative to the cost of the central processing unit, they are well within the reach of the budgets of small communities.

Output devices for small computers include CRTs (with or without color), printers (of varying quality), plotters (with or without multicolor output), modems (for data transmission), synthesized speech, and other audio formats.

The key output devices applicable to traffic records systems are CRTs, printers, and plotters. CRT units are especially important in running programs where user interaction is involved. It is often desirable to go through report design interactively for a particular problem. This can be done on the machine by using the CRT as the user prompter. Monitors with a 10- or 12-in screen and white-on-green or white-on-black image can be purchased for less than $125 and are quite adequate for most applications. Most small computers can be connected to standard television sets with an inexpensive device.

Figure 3. Example of small-computer and plotter output.



Printers represent a more substantial investment but are essential to obtain information in a form that can be easily disseminated. Small computers can drive a wide variety of printers. The most economical are the dot-matrix type. Some dot-matrix printers can be used to create graphics outputs as well as letters. The more sophisticated of these approach letter quality. True letter quality is achieved, however, by driving an electric typewriter, which is slow, or a daisy-wheel printer, which can provide speed and selection of type fonts. Excellent dot-matrix printers are available for less than $1000; a good letter-quality printer will range in price from $3000 to $6000, and more expensive printers are also available.

Plotters are also available for small computers. They provide better resolution and flexibility than printers with graphics capabilities and can be useful if a significant volume of output is desired in the form of maps, diagrams, and graphs. An example of a plotter-generated spot map is shown in Figure 3. Plotters can produce report-quality graphics and can do it in multiple colors. They can be purchased for prices starting at $1500.

Input Devices

Input devices for small computers include keyboard, magnetic disks and tape cassettes, analog devices, modem (data transfer), paper tape, light pen (CRT), digitizer (graphics tablet), capacitance-sensitive screen, punched cardreader, speech recognition devices, and mark-sense devices.

The key input devices applicable to the traffic records systems include the keyboard and magnetic disks. Modem (telecommunication) units, analog devices, paper tape, digitizers, and light pens also have potential application. It is important to note that accident and citation records must be keyed in for the mainframe (whether through a card keypunch or direct entry) as well as for the small computer. The large computer appears to offer no particular advantage with regard to input and output capabilities.

Adequacy of Software

Most mainframe traffic records systems software has been developed by state and large-city data-processing units and their contractors. Some commercially developed systems have been applied in more than one context, but these systems are generally custom built. One major exception is the Accident Data and Analysis System (ADAAS) developed for NHTSA by the University of Michigan to be a general-service system for traffic accident records users (6). The ADAAS system is accessed via remote terminal on an interactive, time-share basis. Several state, city, county, federal, and research accident data bases are currently on the system. Agencies are charged for the system on an as-used basis.

The mainframe traffic records systems vary in accessibility and user friendliness. Some, such as ADAAS, are end-user operated and oriented. Others are batch process only, using predefined and inflexible report formats. Some have exceptional graphics capabilities whereas others have none.

Programming Languages

Small computers are supported by most major programming languages, including FORTRAN, PASCAL, COBOL, and BASIC. There are perhaps more dialects of these languages than one finds in the mainframe arena. The unfortunate result of the proliferation of dialects is that present software is not readily transferable from one machine to another. However, language standardization in the small-computer field has not been so out of control that the situation is hopeless. In addition, both hardware and software manufacturers are creating new means to achieve interchangeability of all types of software.

Generic Software

There are two general software areas that are of interest to local police and engineering safety planners: generic programs and special-application software. In the first category are included generalized data-base management routines and common statistical tests. These may be termed generic software in the sense that they have been developed to meet a variety of user needs. A generic data-base management program, for instance, can be used in a retail or manufacturing environment for inventory control. It can also be used in a mail-order business for customer records. It could be used by an engineering or police agency for maintaining traffic records. Generic statistical packages do much the same thing with commonly used statistical tests: They permit the statistical analysis of a wide range of data that could reflect sales and marketing figures, survey responses, or traffic accident experience.

One of the valuable aspects of generic software is that most of the packages presume little technical knowledge of computers on the part of the user. This is not to say that the programs are always simple to run. (There are books written by third parties to help users learn some of the more popular generic packages.) Generic software packages such as VISICALC and DB Master commonly sell from about $50 through $500. Although the application of some of these packages seems appropriate in the traffic records area, little has been done to test them. Furthermore, it should be remembered that, although these are general-applications packages, once they are acquired they can be used for other purposes, such as administrative records.

Special-Applications Software

Special-applications software would be that designed specifically for traffic records use. Although some of this can be developed by an agency's own data-processing people (in-house), others--both commercial and government--have developed special applications software that can be applied in more than one agency context. The development of programs in-house is an option that, except for unusual circumstances, is usually not cost effective. Nevertheless, some in-house program development is probably inevitable once a small computer is installed on-site. The few agencies that have made use of small computers have already developed some home-grown applications software. In some cases, local university students and faculty have provided able assistance. For the most part, however, these programs are developed for a specific use by an amateur programmer. Although they may be quite adequate for that user, in that context, the program design usually does not contain the error trapping, adaptability, and user friendliness desired for general use, nor is it normally documented adequately so that others may independently operate the package.

Software specifically developed for small computers, to conduct traffic records analyses, is just beginning to become available commercially. These programs are limited primarily to accident records and street and control-device inventories. Little has been developed in the public domain. One exception is the City Accidents Rapid Evaluation (CARE) system developed by Auburn University for the state of Alabama (7, p. 43). This system downloads a city's accident records from the state tape to a hard disk, after special reformatting to reduce file size. The user is then presented with a choice of 11 actions, including identification of high-accident-rate locations, frequency distributions, and cross tabulations. The system has certain limitations, but it demonstrates the potential for application of a small computer in an interactive mode.

Although the CARE system was developed for use by cities in a particular state, it is being marketed commercially for general use. Other accident and citation analysis programs exist for small computers developed in-house. Those of which we are aware generally exhibit the limitations of in-house-developed software noted above. There is some promise of more generally usable packages, as exhibited by a recent report of a small-agency system now being tested (8, p. 102). The system consists of accident records, citation records, street index, and officer badge files created in a hierarchical structure. The program allows the user to select among a number of predesigned reports involving general and location-specific accident and citation summaries as well as identification of high-accident-rate locations and officer activity summaries. The system is designed to accommodate approximately 1000 accidents and 3000 citations. Developed as part of university student course work, the system is being tested in a city with a population of 20 000.

It is interesting to note that, while this relative paucity of development has occurred on the traffic records side, police crime records applications and traffic engineering applications have been developing at a rapid rate. The POSSE system is a crime records analysis system developed by the U.S. Department of Justice for use by small departments on minicomputers and microcomputers. It was developed to meet the growing demand by a variety of local police agencies around the country. An even greater flurry of activity has occurred in the transportation planning and traffic engineering areas of application for small computers. A brief analysis of an UMTA status document (9) shows the extent of the development effort:

Topic Area	No. of Items Developed or in Process
Transportation planning	
Data management	7
Travel demand	10
Design and evaluation	8
Public transportation	
Planning and design	11
Operations	12
Transportation design and operations	
Data management	7
Signal analyses	8
Design	1
Accident analyses	2
Total	66

In summary, it may be said that software availability and design may represent past barriers to the use of the small computer in the traffic records area. Generic packages have not been tested in this context. Applications software developed in-house is generally costly, and what is done is usually limited. Commercially developed, or public domain, packages exist but are of recent vintage and not widely tested. Although these may represent past barriers, the trend of the art is such that henceforth there should be no hesitancy by an agency to venture into such an application. Key attributes that must, however, be built into the new software developments are end-user orientation and friendliness so that the package can be readily adapted for individual agency use and used by personnel for whom the computer is an unknown that is feared.

Cost

The issue of cost is the one that initially attracts attention to the small computer. In view of the fact that the small systems currently available can deliver sufficient computing capability to allow basic safety analyses to be conducted in a small community, the relatively low initial investment required makes them attractive to agencies with no other readily available automation option. Table 2 gives examples of two levels of systems that might be appropriate for this application. It demonstrates that such systems are well within the budgets of small agencies.

Of course, there are costs other than those for the basic system. Space, materials, maintenance, and personnel costs are all involved. In general,

Table 2. Attributes of small computer systems for traffic records applications.

Element	Lower Bound	Upper Bound
Primary storage	8 bit, 64K	16 bit, 512K
Secondary storage	Two floppy disk drives	Hard disk, 20 megabytes
Printer	Dot-matrix	Daisy wheel
Plotter		Multicolor
Monitor	No color	Color
Software[a]	Utilities, data base, electronic worksheet	Utilities, data base, electronic worksheet, word processor, statistical analysis, graphics generator
Cost[b]	$2500	$20 000

[a]Assumes engineering applications software available in public domain.
[b]Approximate.

these costs are also considerably less than those for mainframe systems. The space required is no more than that needed for a normal enclosed workstation. The price of the materials required is comparable to that of many other types of electronic office equipment. Maintenance can be obtained on a contract basis, as with other office equipment, and at comparable fees. Personnel requirements are not nearly so demanding as for mainframe systems. Small computers and the related software are generally designed for an untrained end user. The personnel who maintain the system need not be data-processing professionals, but they do require some special training, which is often available through dealers, local community colleges, or other adult education programs.

CONCLUSIONS

The preceding discussion has demonstrated that hardware is not the issue in considering the use of small computers for operating a basic traffic records system in a small community. Certainly, there is a need for improved software that can be operated by personnel with no special training and can be adapted to meet a variety of needs. The costs associated with the acquisition and operation of the small computer are well within the budget levels of small agencies, especially when the small system is to replace a mainframe service for which the agency is bearing the costs.

Data Quality

There are, however, a number of other organizational and human-factors issues that, although a subject for another paper, one must consider. One of the key factors in achieving a useful system is the provision of accurate data in the form, and at a time, that is appropriate to aid in making the decision for which it is needed. Consideration of this factor points to the recurring problem of technology outpacing human capabilities in such areas as data input and decisionmaking. The quality and accuracy of accident data are below the quality and accuracy obtainable from the reporting systems. This is exacerbated by the declining resources available to police agencies for data collection. Reduced reporting levels, reduced traffic-law enforcement, training, and general deemphasis on traffic-law enforcement due to community emphasis on crime control are a result.

Another aspect of the data-quality issue is the manner in which the data are reported to end users. As in many other fields subject to the control of data-processing professionals, data are often reported in forms not readily understood, or used, by the decisionmakers and their technical advisors. Reports from such systems have been highly inflexible. Systems are needed that produce reports designed to answer the questions at hand. Some of these may be recurring questions, justifying regularly generated, standardized output. But the unique request must be provided for in order to encourage creativity among safety analysts by removing barriers to the accessing of information. Some of this is being achieved on mainframes, but apparently not enough. Consider the case of a large brokerage firm (large data files needed), as reported recently (10, p. 15):

> Three hundred employees at Merrill Lynch, Pierce, Fenner & Smith ... have bought personal computers to help them in research work, analysis, administration and customer support. The company does not buy the personal computers for its employees, but when many of them started investing in their own equipment, it decided to help the process. One reason ... why micros are so popular at Merrill Lynch as well as other companies is that centralized data-processing departments cannot satisfy all the needs of individual employees. When an executive devises a new, computerized way to manage a portfolio, he or she can try it out on a personal computer without running into delays that are often associated with centralized data-processing departments.

Multiple Applications

It may sometimes be difficult to justify the purchase of a unit with a price tag in the $5000 to $20 000 range for a single dedicated purpose. The small computer, however, offers the option of multiple uses within an agency. The generic software, noted above, offers the agency the potential of a sophisticated word processor and a data-base manager for personnel and other applications, plus any special applications for which programs may be developed. This flexibility may be an important factor in considering this type of investment.

Management Barriers

Even if the feasibility question is not an issue, there may remain barriers within management to the use of the small computer. This may arise for several reasons, such as lack of willingness to deal with something not well understood, seeing the small computer as a toy (confusing the $300 Atari with the $5000 TRS 80), concern over the loss of control with decentralized computing, and resistance from the centralized computing facility, which may see this as a threat to its existence rather than a new opportunity for service.

Personal Barriers

Although the programs for small computers are designed for the end user and attempt to be friendly, there exists the fact that a computer is involved. This is enough to discourage many people because the machine is associated with the mysterious black boxes of the past. The potential user often associates use of such a machine with highly mathematical, technical competence. Thus, even when such a person can be convinced to try the computer, it is approached with a fear of failure. When the small computer is applied to the traffic records function, the system should be developed to allow clerical operators to be employed and to allow for technical analysts within the agency to use the system. Thus, the ultimate acceptance of such a system may depend on overcoming these personal barriers.

Need for Management

A recent article by one of the most respected members of the data-processing community (11) contained the following observations:

> The language and software for creating commercial DP [data processing] applications are really improving and will continue to do so. Nonprocedural languages and facilities now permit many applications to be created without conventional programming and in some cases permit them to be created by end users. The image of a computerized corporation of the near future which the reader should keep in mind is one in which many people are creating and adjusting the electronic procedures. They have user-friendly software that enables them to do this rapidly. Inexpensive computers are spreading and there is a terminal on most desks. The challenge for both DP and corporate management is: How do you control this environment? The most important aspect of control is coordinating the data used. If this is not done, there will be a Tower of Babel effect.

As the small computer becomes widely used, its use, even more than the introduction of other electronic office devices, can have a marked impact on personnel activities and office layout and organization. The effective implementation of these systems requires sound management. There are many pitfalls in implementing a small computer system (12). The age of application of this new technology has just begun but it will soon be in full bloom. If the potential is not recognized and planned for, by innovative management within an agency, later pressures for its installation will make the transition much more difficult. The process should be begun now.

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Evaluating and Planning HOV Lane Enforcement

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The different high-occupancy-vehicle (HOV) strategies introduced on California freeways in recent years have included reserved ramps, preferential lanes, and bypass lanes at metered ramps. Several factors have frustrated efforts to enforce the traffic laws that accompany these strategies; these include personnel limitations, enforcement priorities, public hostility, confusion, and physical constraints imposed by the geometry and engineering features of specific projects. As a consequence, violations have increased on certain types of HOV lanes. A summary is presented of the results of a two-year study designed to measure and evaluate the effect of different enforcement options, engineering features, and educational programs on violation rates for various transportation system management freeway strategies and trace the resulting impact of these violation rates on safety, freeway performance, and public attitudes. During the study, statistics were assembled on violation rates, enforcement levels, and operating performance on California HOV lanes; drivers were surveyed; special design features were investigated; and different levels and combinations of routine and special enforcement activities were tested on a variety of HOV lanes. Violation rates were measured before, during, and after the assignment of Highway Patrol officers to enforce specific HOV lanes and metered freeway ramps, accident levels were recorded before and after the installation of HOV lanes, the benefits and costs of HOV lane enforcement were analyzed, and the results of the analysis were used in recommending a program of future enforcement for California HOV lanes.

Adequate control of violation rates on preferential high-occupancy-vehicle (HOV) facilities requires an effective mixture of enforcement, engineering design changes, and public education. Although past operating experience has given the California Department of Transportation (Caltrans) and the California Highway Patrol (CHP) a number of insights regarding the potential effectiveness of different enforcement strategies, engineering changes, and education programs, this experience has not been documented with the quantitative precision necessary to identify the appropriate levels and mixture of these factors needed to obtain adequate motorist compliance.