NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE **55**

STORAGE AND RETRIEVAL SYSTEMS FOR HIGHWAY AND TRANSPORTATION DATA

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:
TRANSPORTATION ADMINISTRATION
URBAN TRANSPORTATION ADMINISTRATION

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1978

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the National Academy of Sciences, or the program sponsors.

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PREFACE

There exists a vast storehouse of information relating to nearly every subject of concern to highway administrators and engineers. Much of it resulted from research and much from successful application of the engineering ideas of men faced with problems in their day-to-day work. Because there has been a lack of systematic means for bringing such useful information together and making it available to the entire highway fraternity, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize the useful knowledge from all possible sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series attempts to report on the various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which they are utilized in this fashion will quite logically be tempered by the breadth of the user's knowledge in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of special interest and usefulness to transportation administrators and others seeking information on the use of computer systems in highway and transportation agencies. Detailed information is presented on data storage and retrieval systems.

Administrators, engineers, and researchers are faced continually with many highway problems on which much information already exists either in documented form or in terms of undocumented experience and practice. Unfortunately, this information often is fragmented, scattered, and unevaluated. As a consequence, full information on what has been learned about a problem frequently is not assembled in seeking a solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of synthesizing and reporting on common highway problems. Syntheses from this endeavor constitute an NCHRP report series that collects and assembles the various forms of information into single concise documents pertaining to specific highway problems or sets of closely related problems.

The increasing complexity of operating highway and transportation departments has caused many agencies to develop comprehensive computer systems for storage and retrieval of data. This report of the Transportation Research Board reviews and evaluates what has been accomplished to date and includes recommendations for future development.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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James K. Williams, Transportation Safety Coordinator, Transportation Research Board, assisted the Special Projects Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

STORAGE AND RETRIEVAL SYSTEMS FOR HIGHWAY AND TRANSPORTATION DATA

SUMMARY

State highway and transportation agencies use modern computer systems and software as tools to increase the productivity of administrative and engineering personnel. These agencies are now developing automated storage and retrieval systems that provide accurate information within useful response rates. This is especially necessary because transportation agencies are taking on increased responsibilities while inflation, declining revenues, materials shortages, and energy problems are making their tasks more difficult.

A major issue confronting many agencies is the type of operation that will best meet their needs. One choice is an internal operation, in which all data processing equipment and personnel are under the direct jurisdiction of the agency. Another choice is a consolidated operation, in which several agencies share equipment and personnel. In between are many alternatives that involve a combination of these two operations.

With an internal operation, the transportation agency controls priorities in system development and operation and does not have to compete with other agencies for the available resources. In addition, the personnel are familiar with and sensitive to transportation needs, and equipment can be arranged to meet the needs of the agency.

A consolidated operation is necessary where budget allocations do not permit acquisition of enough equipment and personnel to support the agency's needs or where the needs are insufficient to support a full-time staff.

The development of computer system hardware has outpaced the introduction of new software packages that can use the increased capability. New applications and software systems under development are more sophisticated, productive, and versatile. One of these technical developments is distributed data processing (DDP), which is the next logical step after remote terminal processing. Key questions that must be answered by management are:

- Where should responsibility for DDP decisions lie?
- Who should do the programming?
- Who should evaluate the success or failure of a project?
- How far down the line should hardware acquisition decisions be placed?
- How much change can an organization dictate to its operational units?

Since the early 1960s, many state transportation agencies have used time sharing and interactive systems for routine administrative, engineering, right-of-way, planning, and programming work.

Data base integration, especially when supported by a data base management system (DBMS), allows data from various applications to be shared by all applica-

tions. With a DBMS, data need be collected only once and programs need not conform to the structure of the data files.

Based on the analysis of the state of the data processing art in industry and transportation agencies, it is recommended that administrative, financial, and management information systems be designed as integrated systems. The overall consideration for this recommendation is that data should be independent from application processing programs and from functional organization entities. A single person (data base administrator) should be responsible for the integrated system.

Maximum use should be made of user-controlled, interactive systems with on-line terminals, which allow data input at the source, reduce errors, have information available when needed, and allow all data to be available to all users.

Finally, a transportation agency should not attempt to develop its own generalized software package when it can purchase a proven package.

CHAPTER ONE

INTRODUCTION

The primary goal of the study undertaken for this synthesis was to survey the status of computer systems development and the use of modern computer software in state highway and transportation agencies. The focus here is on the use of computer science as a tool to increase productivity of administrative and engineering personnel.

All state highway and transportation agencies have access to some computer resources. All have developed and are developing some computer-assisted support tools. Therefore, a synthesis of applied computer use as it fits the needs of highways and transportation agencies is now appropriate.

The definition of scope provides wide latitude for investigation, particularly as a presentation on all aspects of the information systems development process. However, in view of the present environment in which all highway and transportation agencies find themselves, it is an appropriate charge. The primary thrust in these agencies today is the development of automated storage and retrieval systems that provide accurate and complete information within useful response rates to support administrators and professionals in the performance of their work.

With the creation of departments of transportation at the federal level and now in many states, the environment in which the agencies operate has become immensely more complex. Such increased responsibilities as public transit, air and rail travel, and coastal and interior waterways provide a potentially enlarged scope that is beyond accurate assessment at this time. In the traditional area of highway development, the situation is also becoming more complex because of the additional variables of material shortages, increased difficulty in predicting costs of labor and materials, and above all, energy-related problems.

While pressure on funding resources is increasing, the traditional and dedicated funding resources are actually decreasing relative to the rate of inflation. Also, the public's demand for good highway and transportation services continues to increase. Therefore, the only avenue available to agencies is to get the most out of the resources they have, and this leads to the increased application of automation in all areas of management, operations, planning, and engineering.

More than ever before, management must have at its fingertips dependable information on a vast array of topics. Agencies must compile and distribute a myriad of reports to federal, local, and other state agencies; the general public; and, increasingly, state legislatures. These overwhelming information needs, coupled with the high costs of labor-intensive operations, have led administrators to the conclusion that automated systems must play an ever-increasing role in both the administrative and operational areas of highway and transportation agencies.

CONDUCT OF THE STUDY

In the development of the study undertaken for this synthesis, great care was taken to ascertain the state of the art in the data processing field so that it could be determined whether innovations could be applied to the highway and transportation environment or whether the highway and transportation agencies were already incorporating them. Evaluation of these state-of-the-art developments, when outside the specific applications of transportation, is limited to the technical approach to information-handling. The areas of study and evaluation focused on are the techniques and equipment employed in data collection, data processing, and information-reporting.

An extensive search of the literature centered primarily around the data processing technical periodicals and the publications of professional organizations, such as Data Processing Management Association (DPMA), Association for Computing Machinery (ACM), and Project Management Institute (PMI). Selected information was also obtained from ACM special interest groups, such as Special Interest Group of Automata and Computability Theory (SIGACT), Special Interest Group for Computer Architecture (SIGARCH), Special Interest Group for Data Communications (SIGCOMM), Special Interest Group for Design Automation (SIGDA), Special Interest Group on Computer Graphics (SIGGRAPH), Special Interest Group on Information Retrieval (SIGIR), and Special Interest Group on Management of Data (SIGMOD). Further, several discussions and interviews were held with recognized professionals in the information-processing field at large.

To obtain a representative sample, site visits were made to several highway and transportation agencies to meet data processing management and review operations. To gain perspective, a questionnaire on data processing operations was sent to every highway and transportation agency. Appendix B contains some of the questionnaire results.

In following up a particular state-of-the-art development, distributed data processing, several large banks, insurance companies, and railroad companies were contacted to gain information on the techniques they employed in planning and developing their application and on the problem development and justification they used. This was done to develop a synthesis of the solution and problem statement logic that would be applicable to highways and transportation.

Every effort has been made to examine the trends in the general field of data processing, but it must be understood that in the analysis of these trends the investigative emphasis is on how the application or technology could apply to highways and transportation.

BASES FOR SYNTHESIS

The determination of the value of any informational or operational computing system or of the full spectrum of services provided by a data processing operation must be based on the agency's management philosophy and operating policies. Because of the wide differences in the size and scope of operations among the 50 state highway and transportation agencies, there can be no single set of criteria for comparing one agency with another. This synthesis, then, defines several broad categories under which all the agencies can be grouped and highlights those application systems that are most productive within the environment in which they operate.

The state highway and transportation agencies are grouped, first, into those having centralized operations management and those having decentralized operations management. Agencies are considered centralized if the design and operational administrative functions are controlled directly from the central office. The agencies also are grouped by size: large or small. The size has been determined arbitrarily for this synthesis on the basis of three criteria: the agency's overall budget, the agency's construction budget, and the number of miles of road in the state system.

These four categories (centralized and decentralized, large and small) are defined only as a method of developing the organizational framework to analyze the best applications of information systems within state highway and transportation agencies. With this simple, if arbitrary, organizational concept, the reasoning behind the selection of various systems, hardware use, and service levels can be judged.

The application systems presented in this synthesis are defined as either administrative or engineering. Administrative systems are used primarily as management and financial information tools. Engineering systems provide problem-solving support to an agency's professional and technical operations. An integrated civil engineering system, a road design system, and an interactive graphics and automated drafting system are examples of engineering systems.

DEFINITIONS

Following are definitions of several terms commonly used in describing the elements and technical requirements of modern computer use and application. Because this synthesis is directed toward agency personnel who are not necessarily trained in the use of computers, the definitions are limited to those that will convey the concepts under consideration here.

Hardware

The physical components of the computer are known as the hardware (Fig. 1). Hardware includes such elements as the central processing unit (CPU), which performs the logic and arithmetic computations, and the peripheral devices, which connect to the CPU to provide communication (input and output) and auxiliary functions (additional storage). Peripheral devices can include tape drives, card readers, printers, disk drives, CRTs (cathode ray tubes or video screens) and typewriter consoles.

Software

Software is the element that instructs the computer by coordinating the operation of the hardware (system software) and the processing of the information stored in the computer (applications software). The programs that update personnel files and print payroll checks are applications programs (or applications software). The programs that make the computer run and keep track of the operation of the hardware (generally written by the computer manufacturer) are the system software.

Figure 1. Data collection office of the Puerto Rico Highway Authority.

Storage Media

During the execution of a program and the subsequent processing of data, a number of storage media may be employed. There are two major classifications of storage: primary and secondary. Primary storage (also called mainframe memory and core storage) is resident within the CPU and is that area where the programs and the immediate data records currently being processed are stored. Secondary storage can take many forms, depending on the equipment available, the size of the file, and the access time desired. Magnetic tapes, punched cards, diskettes, and magnetic disks are some widely used secondary storage media.

Magnetic tapes are among the most commonly used secondary storage media. They are convenient and easily transportable, can store a high volume of information, and are adaptable to most computers. The main drawback to their use is that they are strictly sequential (i.e., to obtain the 140th record, one must read 140 records). Punched cards are extremely limited in terms of volume (each card can record a maximum of 80 or 96 characters), access speed is very slow, and they are bulky and difficult to handle. Diskettes look like 45 rpm records with nonremovable jackets. They present an alternative to punched cards in the sense that they are generally used as a means of entering information into the computer, but in smaller computers they are sometimes the principal storage medium for data files. Compared to other storage media, diskettes are low-volume, medium-speed, and easily transportable.

Magnetic disks are among the most versatile high-speed, high-volume storage media available. Because of these and other distinctive capabilities, they are currently the most widely used storage medium. They resemble long-playing record albums stacked one on top of the other. Read/write heads, one per surface, are extended on retractable arms that scan the surface to the areas where records are to be read or written. The information on magnetic disks can be handled sequentially (beginning to end), sequentially by indexes (beginning at the start of a particular group and working forward sequentially), and randomly (direct location and retrieval of the record). The success and versatility of a number of significant state-of-the-art advances relate directly to capabilities offered by magnetic disks.

Data Base

A data base is a collection of stored operational data used by the application systems (or programs) of a particular enterprise. Operational data can include information on accounting, planning, equipment, and personnel.

The term *data base* does not include input or output data, because the very nature of such data is temporary and represents merely the means by which (a) data base records are created, modified, or deleted (input) or (b) management and operational information is derived in the form of CRT displays and printed reports (output).

The data base, then, is the "central files" of an organization. It is the organized, recorded mass of detailed data that, taken as a whole, reflects the historical, current, and in some cases planned operations of an organization. From this resource, detailed data are periodically extracted and condensed by the application programs to provide information to management and operations.

In many current systems, each application has its own private files. This often leads to considerable redundancy in stored data and considerable wasted storage space. For example, the accounting application and the maintenance application may each have a file identifying all equipment and giving its value, use, location, and so on. As new equipment is acquired, each application must independently update its file. Using the same data elements to update two or more files independently and perhaps at different times almost always produces contradictory information, but this type of situation, if coordinated properly, can be alleviated. Because both applications require essentially the same data, the two files can be integrated, producing one file that is shared by both applications. The data need to be stored only once, and errors and costs can be reduced significantly. Exercising this concept wherever possible leads to an integrated data base and a much more efficient, economical operation. The value of the data base is that data and processing are managed independently, thus simplifying the changing of either the data or the processes.

Data Base Management System

Most larger operations, once they have realized the significance of integrated data base concepts, consider the application of a data base management system (DBMS). A DBMS is a set of specialized software that situates itself between the application programs and the data base, handling all access to the data.

The decision to apply a DBMS warrants a great deal of consideration. The costs and efforts involved in implementing it are considerable, but the benefits can far outweigh these concerns if the DBMS is properly applied. Below are listed the most noteworthy advantages of a DBMS.

- Data redundancy and inconsistency are reduced. Because the DBMS maintains all the data, it requires only one copy of the data item.
- Data can be integrated and shared. Instead of being restricted by the traditional file concepts, the DBMS allows programs to access data items—those needed to perform the function desired. For example, any authorized program may access equipment cost, but only one program is permitted to update the item.
- Organization, control, and security is improved. Through the required involvement of a data base administrator, the data are structured to best suit the information needs of the agency. Through the data base administrator, security measures (access control, update capabilities, etc.) may be established and enforced. Because of this organization, control, and security, the data are being managed as any valuable resource, and their usefulness increases dramatically.
- Data independence is achieved. In the traditional applications, a program conforms to the structure, content, and accessibility of the data files it uses. If there is one change in a particular file, every program accessing that file must be changed. In addition, if the file is to be accessed differently by different programs, duplicate files often result (possibly in a different sequence), updates or changes must be applied to both files, and so on. In a DBMS, the programs request only the data required to perform their tasks, and the DBMS handles the rest. Data base changes do not affect the application programs. A user could develop a DBMS, but most of those in use (e.g., IMS, TOTAL, ADABAS, System 2000, and IDMS) are commercially marketed, proprietary systems developed by computer manufacturers and independent software firms.

Processing Modes

The difference between on-line processing and batch processing is like the difference between requesting information by telephone and requesting it by memo: the first promotes immediate, one-to-one interaction; the other means lag time between request and results. The difference, however, does not end there. On-line and batch programs are written differently. Batch programs typically process vast amounts of records and produce updated files and associated reports. On-line programs usually involve a single input record (or request) from a terminal, directly access a very limited number of records from the data base, and display the results on the terminal soon afterward. Many on-line uses of computers involve time-sharing, where more than one user has access to a centrally located, large-scale computer through the use of terminals.

The term *interactive* refers to a conversational mode of using a computer in an on-line situation. In this case, responsive reaction of the computer is used to zero in quickly on specific information in a data file. Interactive systems are particularly adaptable for use of the computer by management or technical personnel who are not trained in computer programming, because conversations with the computer can be in abbreviated English. Some of these systems are therefore referred to as user-oriented systems.

Remote job entry (RJE) applies to the use of terminals that are not located at the same place as the computer and that can be used for direct input to the machine. Direct output—readout—is usually a companion feature. This does not necessarily imply on-line use, for batch processing may be initiated through the RJE terminal. To the computer operating system, however, the RJE resource of a computer center is just another job, and often it is time-shared, on-line with many other jobs at the same time. One good example of RJE is in its use on-line for data entry under control of a program; data are entered to the computer system from a remote location over a terminal network. The data are checked for logical errors, and any that are found are immediately indicated to the data entry operator. Then the data are stored in a temporary file, to be processed when time is available or on a fixed schedule. Another use of an RJE terminal is as a work station in the office of the computer programming staff so they can enter changes to their programs, set-up testing, and program completion.

Operating System

The operating system is that part of the system software that provides for the efficient scheduling and execution of application programs. The operating system does this by controlling the flow of input, output, and storage functions: checking for errors, translating program languages, blocking and unblocking groups of records, and so on. The two systems most commonly referred to in connection with third-generation IBM computers are System 360 and 370 Operating System (OS) and Disk Operating System (DOS). There are numerous versions of each of these, and the different versions have special capabilities. At present, the most advanced operating systems are the IBM Virtual Operating Systems (VS, SVS, and MVS).

Programming System

Programs are written using programming languages, such as COBOL, FORTRAN, BAL, and PL/1. Each has predefined key words and standards for use. When a language is applied to a particular processing need, what is produced is a source program that must be prepared (keypunched) for translation by the programming system that applies to that language. The programming system then compiles, or assembles, the program, performing error checks and translating the programming language into the more complex machine language. This translated version is the object program and is the one that is later executed by the computer to accomplish the particular processing need.

- *COBOL*—Common Business-Oriented Language is a high-level computer programming language whose statements most closely approximate English language statements. This Problem-Oriented Language (POL) usually is used for management and administrative information systems application programs and is the most widely used programming language.
- *FORTRAN*—Formula Translation is a high-level computer programming language whose statements very closely approximate mathematical statements. This POL is most widely used for programming mathematical equations.
- *BAL*—Basic Assembler Language is a one-for-one computer language that most closely approximates the computer's internal machine language. Whereas the COBOL and FORTRAN language statements, when compiled for the computer, generate several computer instructions, each BAL statement generates only one computer instruction. BAL generally is used for programming generalized software, such as a computer operating system or a generalized data-sorting package. Each computer has its own BAL.
- *PL/1*—Programming Language 1 is an IBM Corporation computer language development. It is a high-level language that combines the data-handling and output features of COBOL with the strong mathematic computing capabilities of FORTRAN. PL/1 is a very rich POL, and one needs extensive training to use it efficiently.

Distributed Data Processing

The terms *distributed data processing, distribution processing,* and *distributed processing* all have the same meaning, and they represent a significant advance in the area of electronic data processing. The terms refer to the linking of one or more intelligent terminals (which are actually microcomputers and therefore programmable) or minicomputers to a main computer and placing them in remote locations(whether it be across a warehouse or across a state) to allow on-line processing to occur on-site. Processing may be limited to mere edit functions or may involve full application processing at the remote location. The key factor is that the terminal is programmable, thereby allowing it to perform some or all of the processing needs of the remote location without the involvement of the main computer while still retaining the ability to access and use the greater capabilities of the main computer.

The advantages of distributed data processing are significant: Remote programs and equipment can be tailored to the needs and characteristics of the location; response time is almost immediate; and the main computer is free to process other applications. The concept works well and is being employed throughout the nation. It is particularly adaptable to the needs of transportation agencies because of their geographic dispersion and their use of interactive data processing.

CHAPTER TWO

EVALUATION AND ANALYSIS OF SYSTEMS

An objective questionnaire (see Appendix C) was sent to all 50 state highway and transportation agencies so that the current level of automation being employed in connection with transportation could be ascertained. The responses provided information on the following areas:

1. Data processing budget allocations
   a. Equipment
   b. Personnel
2. Data processing staff
   a. Systems analysts/programmers
   b. Applications analysts/programmers
   c. Operations personnel
3. Data processing services
   a. Internal systems
   b. Consolidated systems
   c. Time-sharing
4. Data processing equipment
5. Commercial software support
   a. Data base management systems
   b. Generalized report writers
   c. Communications software
6. Data processing applications (current and planned)
   a. Planning and traffic
   b. Program control
   c. Engineering and operations
   d. Finance and administration

A number of on-site visits permitted contact with key individuals in highway and transportation agencies and in data processing departments. The visits permitted (a) identification and exploration of different applications and management philosophies and (b) further determination of the factors that supported or detracted from the success of these applications and philosophies.

The response to the questionnaire was very good. Table 1 provides a summary. Some state budgets are disproportionately high or low when compared with those of other states because of dissimilar operational environments and conditions. For example, data processing budget allocations are easy to determine for a fully internal operation (where the DOT has its own electronic data processing (EDP) equipment and personnel) but can be very difficult to determine when services are pooled and provided by a consolidated data center or when data processing analysts are also engineers, budgeted as such through their departments.

No attempt is made here to compare sets of responses in an effort to determine "the best" approach to data processing. Rather, the intent is to broadly classify various approaches to data processing and present their advantages and disadvantages along with major factors to be considered in their application.

DATA PROCESSING SERVICE ALTERNATIVES

The very size and scope (and consequent information needs) of state highway and transportation agencies strongly justifies responsive data processing support; in each case, the question is what kind of support. At one end of the scale is the internal operation, in which all data processing equipment and personnel are under the direct jurisdiction of the agency. At the other end is the consolidated operation, in which several agencies share data processing equipment and service personnel. Between these two extremes are many alternatives that involve a combination of these two types of operations.

Internal Operation

The main advantage of an internal operation is in the planning and control that it affords the agency in providing data processing services. With dedicated equipment and personnel, the agency can establish and control priorities in system development and operations without having to compete with other state agencies for the available resources. This is a significant point, because the main function of a computer system is to provide needed information quickly; delays can cause the information to lose its effectiveness (imagine reading a day-old newspaper). Also, requirements for computer system changes occur in all installations, internal and consolidated. If the service personnel are in the agency, maintenance activities can be performed as needed; if service personnel are not in the agency, the maintenance may take a back seat to another agency's development requirements.

An agency that maintains internal data processing personnel can develop service personnel who become specialists in highway and transportation systems without having to be jacks-of-all-trades. Such personnel are knowledgeable and sensitive to highway and transportation needs, thereby preventing misunderstandings of priorities and concepts and reducing costly familiarization time. The results are systems that are specifically tailored (and consequently more responsive) and personnel that can provide prompt and effective attention to maintenance of existing applications. Further, analysts are more effective as advisors and as participants in related decision-making processes. Consequently, management/EDP interface problems can be significantly reduced.

An internal operation also allows the equipment to be arranged to meet the specific needs and requirements of the agency, which results in a much more responsive operation.

TABLE 1

DATA STORAGE AND RETRIEVAL SYSTEMS SURVEY RESULTS

	BUDGET ($1,000)			SERVICES			EQUIPMENT			SOFTWARE SUPPORT			APPLICATIONS											
													Planning Traffic			Prog/- Control			Engineer. & Oper.			Finance & Admn.		
STATE	EQUIPMENT	STAFF	TOTAL	INTERNAL	CONSOL	T/S	LRG.	MED.	SMALL MINI	COM'L DBMS	COM'L RPT WTR	COMMUN.	H	R	A *	H	R	A *	H	R	A *	H	R	A *
ALABAMA	540	336	876	x				x		IMS		CICS	4						4			6		
ALASKA	288	450	738		x			x	x	-	ESYTRV	-	5			1			2			2		
ARIZONA	2,208	1,293	3,501	x			x			IMS	MARK IV	ITF/TSO	5	2		2			5			3		
ARKANSAS	765			x				x		-	REACT	-	4						4			4		
CALIFORNIA	4,500	5,000	9,500		x	x	x		x	-	SYNTAX DS/2 MARK IV+	CICS/TSO	5		2	2			7			7		1
COLORADO	814	439	1,253		x			x		-	MARK IV	CDC/- TEXAS I	5			2			6			4		
CONNECTICUT	580	704	1,284	x			x		x	FMS-8	FMS-8	EXEC-8	4	2	2	2		2	5		1	7	2	6
DELAWARE	-0-	-0-	-0-		x			x		-	-	-	4	2	1				3			2		
FLORIDA	1,781	1,898	3,679	x		x	x			IMS	GIS	TP/TSO	6		1	2		2	6		1	3	1	2
GEORGIA	1,025	365	1,390		x	x	x	x		TOTAL	ESYTRV SOCRATES	ENVIRON/ 1	8	3		2			5			9		
HAWAII	60	200	260	x	x	x	x		x	-	-	-	2			2			2			1		1
IDAHO	480	444	924	x				x	x	DATACOM	EASY-TRIEVE	DATACOM	4			2			6			5		2
ILLINOIS	2,600	1,200	3,800		x		x			IMS	EASY-TRIEVE MARK IV	HYPER-FASTER IMS TSO	5			1			7			6	6	6
INDIANA	320	307	627	x				x		-	-	TCAM	4			1			6			5		
IOWA	1,566	1,101	2,667	x	x			x		-	-	TSO	5			2			9			6	6	7
KANSAS	370	164	534		x		x			TOTAL	-	CICS	4			1			3			3		
KENTUCKY	1,712	1,440	3,152		x	x	x			IMS	MARK IV	TSO	7		1	2		1	6			6		
LOUISIANA	1,130	877	2,007	x	x		x			DL1	-	CICS	3	2		2			4			7		1
MAINE	350	400	750	x	x			x	x	-	-	CMS	5	6	3				4			4		
MARYLAND				x			x																	
MASSACHUSETTS	456	-	456					x		-	-	CRJE	9			3			2	1		3		
MICHIGAN	1,800	2,300	4,100	x		x	x	x	x	DMS-II (Burroughs)	DMS-II	CANDE	5			2			8		1	7		
MINNESOTA			1,011		x		x			TOTAL	SOCRATES	TP-EXEC												
MISSISSIPPI	350	328	678	x	x	x	x		x		-	CICS TSO	4			1			6			6		
MISSOURI	100	500	600	x				x		-	-	-	5			2			5			5		
MONTANA	333	589	922	x				x		-	-	CICS	9						3			3		
NEBRASKA	500	650	1,150	x		x		x		-	-	CAM CMS	5			2			5			5		
NEVADA	300	586	886		x		x			ADABAS	EASY-TRIEVE	CICS TSO										1		
NEW HAMPSHIRE	185	257	442	x	x	x		x	x	-	-	COS	5	1		1			5			6		
NEW JERSEY	648	1,405	2,053	x	x	x		x		-	-	CMS CICS	5	2	2	2	1		7	1		7	1	2
NEW MEXICO	632	664	1,296	x		x		x		-	-	CMS	9	1					6			7		
NEW YORK	250	1,125	1,375	x			x			-	-	-	4	1		1	1	1	4			2	2	2
NORTH CAROLINA	1,800	2,002	3,802	x			x			-	-	CICS ROSCOE	5			2			5			4		
NORTH DAKOTA	881	145	1,026		x			x		-	MARK IV	CICS	4			2			6			3		
OHIO	889	758	1,647	x				x	x	-	MARK IV	CICS	5	2		2			6	1	2	5	2	2
OKLAHOMA	1,200	1,000	2,200		x	x	x			IMS	-	IMS TSO	5			2			7			4		
OREGON	1,825	1,628	3,453	x	x	x	x			-	CAP	CICS TSO	5			2			5			7		
PENNSYLVANIA	6,353	3,260	9,613				x			IMS	MARK IV	IMS TSO	5			1			5			5		1
RHODE ISLAND																								
SOUTH CAROLINA	570	400	970	x				x		-	-	CICS	4			1			1			4		
SOUTH DAKOTA	319	200	519		x		x		x	ADABAS	MARK IV	CICS	11	1		1			5			3		
TENNESSEE	530	395	925		x		x			IMS	CULPRIT	IMS TRIMS	5	1	2	2			3			5		
TEXAS	2,601			x			x			ADABAS	MARK IV	INTER-COM	5	1		2			9			10		
UTAH			935		x	x	x				MARK IV	CICS												
VERMONT	120	150	270		x			x		-	-	CMS CICS	4						3	2		5	5	
VIRGINIA	790	1,050	1,840		x			x		-	-	-	5			2			10			8		
WASHINGTON	1,300	1,300	2,600	x			x			ADABAS	MARK IV	TSO INTERCOM	5			2			7			6		
WEST VIRGINIA					x		x			IMS	-	CICS IMS	4						4			5		
WISCONSIN	2,260	2,880	5,140	x			x			IMS	MARK IV	IMS	7		1				6			8		7
WYOMING	1,700	2,600	4,300		x		x			-	MARK IV	CONVERSE	4			1			4			6		

(H) Highway (R) Railroad (A) Airports

Consolidated Operation

The internal operation is an ideal situation for an agency. In some states, however, such an operation is not justifiable when the cost of equipment and personnel is considered. In smaller states, where budget allocations prohibit the acquisition of dedicated EDP personnel and equipment sufficient in size to support the needs of the state DOT, or where the needs are insufficient to support a full-time staff, a consolidated center provides a worthwhile answer.

North Dakota is a good example of this type of situation. On the staff are two systems analysts who coordinate all data processing activities with the state consolidated center. Data processing personnel from the center participate in system development and ongoing maintenance, all of which is coordinated through the DOT analysts. Through terminals linking the agency with the center, the agency has access to IBM 370/145 computer capabilities that could not be acquired otherwise.

The key factors to success in using fully consolidated services are size and control. Where consolidation is required to provide the minimum hardware and services needed by the agency (typically, a medium-sized computer installation), the comparative smallness of the center and of the number of users it supports is sufficiently controlled. This allows the center to be responsive to the needs of the agency and still be cost-effective in terms of equipment and personnel. Through close coordination by the agency analysts, control is maintained by continual promotion of agency priorities and objectives and by rapid response to problems. Under these conditions, services are maximized and costs minimized.

The consolidated operation can take advantage of the availability of commercialized software support that is considered of marginal cost-effectiveness in smaller internal operations. These can include data base management systems, generalized report writers, and communications hardware and software, which lend themselves most effectively to on-line applications, promoting direct, effective interaction with data in both administrative and operations applications.

A saturation point is often reached in a consolidated operation, as more users are acquired, more applications are developed, and more personnel and larger equipment are added to meet increasing demands. It is a point at which the cost of service becomes disproportionately high in relation to the level of expected benefits—a point at which increased services are virtually impossible to obtain.

Although runaway growth is more prevalent in consolidated centers than in internal operations, it is an area of concern that must be addressed in all data processing installations. It requires that EDP management be keenly sensitive to areas experiencing rapid growth and provide viable alternatives that are in keeping with the level and quality of service expected by all users. At times this may require a significant break from the traditions of the past, including a reevaluation of techniques that were once thought to be too expensive or cumbersome but have experienced dramatic refinements in recent years—on-line applications, for example. The use of appropriate, proven, state-of-the-art advances in computer technology and concepts (e.g., DBMS, distributed data processing, structured programming) also may be required.

Many states have found that decentralizing their consolidated data processing services controls the growth of operations. Where several larger agencies have existing equipment and personnel, a limited number of other agencies can use their services.

Combination of Internal and Consolidated Operations

Some states use a combination of internal and consolidated services to make efficient use of computers. No agencies now use distributed data processing, but several that have decentralized management philosophies have placed on-line terminals in the field where decision-making information is needed and where operational data are entered by the originators of the data. The agencies have found this type of application well-suited to their increased management needs. Several of them (e.g., Texas and Georgia) are also using minicomputers to augment their larger, consolidated services by providing the capability to perform engineering computations on-site.

Through the availability and use of a combination of services, state highway and transportation agencies are in a good position to adopt the computer configuration that best addresses their information needs, whether the agencies are centralized or decentralized or whether they are large or small.

STATE OF THE ART

A completely new era of computer system development has been ushered in by modern computing equipment—giant, semiconductor, fast-memory computers; a fantastic variety of very fine miniprocessors and microprocessors; the ultra-high-density disk and mass storage devices—coupled with lower costs per unit. This new capability is only beginning to be used in terms of new applications and software systems design. Indeed, the development of computing system hardware has far outpaced the ability to use it fully. However, as new and more powerful software operating, control, and networking systems are developed, the ability to apply and use this vital resource will quickly catch up with the potential of the hardware.

Even now, new applications and software systems under development are far more sophisticated, productive, and versatile. Distributed data processing, time-sharing, and interactive systems and data base integration appear to hold the greatest promise for application.

Distributed Data Processing

Of all the cutting-edge technical developments in the field of computer science, the distributed data processing (DDP) concept holds the most promise for putting information processing where it is needed and streamlining operations by placing the application systems processing where the work is done. With new, intelligent, computer and terminal products, specialized services, and networking and transmission techniques, computer resource management can now pattern a unique computer/communications network to match an organization's precise needs.

For only the second time in the short history of the computer industry, a single concept has so dominated management planning for future applications that whole advertising campaigns have been built around it. Several computer manufacturers have committed a great measure of their companies' futures to it, including IBM (which has quietly been building and introducing to the market—separately and out of context—a product line that would provide a full DDP system).

The Honeywell Corporation is currently marketing an advanced DDP system called "Level 68/Distributed Processing," a multiprocessor system (68/DPS). The Data Point Company has a complete package of minicomputer, printer, and terminals configured into a distributed network. Several other companies are active in the field of DDP, and many more are planning to enter it.

In the 1960s, time-sharing was the big, new answer to all problems. Unfortunately, it was oversold, and although it was and is a very useful and productive technique, many abuses were perpetrated in the industry's rush to implement time-sharing systems. Poor planning caused inefficient use of the technique and low cost benefits. The rush to implement a technique could also happen with DDP, because it appears to offer so much in the way of freeing users from the grasp of technology. Today's computers are more powerful and cheaper than ever before; there are numerous powerful minicomputers; the cost of computer memory is dropping fast; and terminals are more efficient and cheaper. Because of all this, management can now decide whether to use a giant central computer complex, myriads of minicomputers, or both—whatever does the job.

Today the top management of transportation and highway agencies can use the computer rather than be subject to its discipline. The question of whether centralized or decentralized management is preferable now can be answered by choice rather than by technical necessity; the answer can be reflected in how the agency's central information system is constructed. For the first time, management is in a position to map the structure of its data processing equipment and data communications network to reflect its organization and precise information requirements.

The industry is having problems defining the concept of distributed data processing, and, in a general sense, this may be the case for some time. For the purpose of this synthesis, however, that problem does not exist, for within the context of the data processing and computing needs of transportation and highway agencies, DDP can be defined as the next logical step after remote terminal processing. Because most of the agencies were among the first in state government to adopt the remote data processing terminal in their district operations, it is logical to investigate the possibility of using intelligent terminals or minicomputers in these locations to replace the current remotes. Defined simply, DDP is the distribution of data processing resources to areas where the data is generated and used, with simultaneous transmittal of the data to the central headquarters' main computer center. A more thorough definition of DDP would include these facts: (a) It is a network of processing nodes that are functionally or geographically distributed and are connected by a communications link; (b) data are stored and manipulated at each node so that the data base is spread through the network but is accessible; (c) systems development and hardware and software acquisition are under central control so that all pieces function as a network rather than being simply a series of interconnected nodes.

These are the key questions management must answer to plan for a DDP system:

- Where should responsibility for DDP decisions lie?
- Who should do the programming?
- Who should evaluate the success or failure of a project?
- How far down the line should hardware acquisition decisions be placed?
- How much change can an organization dictate to its operations units?

These questions regarding control are critical to the type of DDP operation desired. Distributing the organization's data processing workload does not mean merely subdividing it and parceling it out to several convenient locations. The operation must be centrally controlled, coordinated, and directed if optimal efficiencies and management's desires are to be gained. The answers to the above questions, then, clearly lie with the organization's central data processing authority, although the remote users of the service should be consulted regarding the operation of the DDP system.

At the present there are very few distributed data processing networks operating, because it takes several years to develop a comprehensive DDP plan. Some of the pioneering systems described below bear this out.

Missouri Pacific Railroad—From start to finish, it has taken Missouri Pacific's Distributed Processing System 10 years to get rolling. Four years of study preceded the decision in 1970 to automate the company's freight-tracking and scheduling by using DDP instead of terminals and a large host main frame. In phases, the railroad moved its yards from punched cards and remote batch terminals (very much like many of today's highway and transportation agencies) to a minicomputer-controlled, work-scheduling, car-tracking system (intelligent terminals perform the job at low-volume yards). Future applications will include computer control of freight-car distribution and car-scheduling at point of origin.

Citibank—One of the earliest pioneers in the development of systems was Citibank of New York, which converted one massive computer center into six processing centers and used about 100 minicomputers, including some of the first new series/1 minicomputers from IBM. The use of a DDP minicomputer system split a three-billion character data base into manageable portions broken along industry subgroupings. The conversion was not an immediate success; there were many initial problems. Some problems are unavoidable in an operation that big, but there is no doubt that many of the most serious problems would have been eliminated if more time had been spent on planning and training the system users.

Bank of America—The world's largest bank, with more than a thousand branches and seven million checking accounts, Bank of America had an untenable information control situation that was unsolvable by traditional data processing techniques. The bank decided to divide and conquer; it designed and implemented a DDP system that has these characteristics:

- Branch terminals connect to a programmable controller that, in turn, connects to a processing module of four minicomputers at one of the bank's two data centers.
- The data base of customer accounts is broken into smaller bases and assigned to the modules.
- Each module supports a number of branch banks, supplying on-line account status to branches that interrogate the data base.

The major benefit of the system is its modularity. Processing modules can query one another's accounts, and their tandem minis provide redundancy in case of system failure. Thus a nonfunctioning computer does not bring the whole system to a halt.

Development in Highway and Transportation Agencies

Although no DDP systems are in operation today in a state highway or transportation agency, two large agencies (Texas and Illinois) are currently planning the development of distributed systems that use minicomputers. The DDP system of the Texas Department of Highways and Public Transportation is to involve all of its 26 district offices (Fig. 2). The plan centers around the placement of minicomputer subprocessing centers in several districts. The equipment configuration will be determined by the needs of each district. This plan envisions the distribution of local processing to each district for administration information processing as well as on-line, real-time support for engineering design problems. Some of the system's components, such as interactive graphics and automated drafting, are already in the design and implementation phases.

The Illinois Department of Transportation is currently using the services of the state's large centralized computer, but the department is actively developing plans to implement a network of minicomputers throughout the department to provide computing service at the work source. The department expects to realize greater processing and work support efficiencies while at the same time reducing processing costs. In addition, the department is planning pilot installations of interactive graphics technology in the district offices, which are expected to vastly improve design capabilities.

It should not be very long before others follow the pioneering example of Texas and Illinois. DDP's potential is tremendous, and it appears to fit the needs of state transportation agencies very well. However, it takes quite a while to implement a DDP network—sometimes five to six years. Why so long? First of all, development costs are high. Other contributing factors are the long lead time for implementation, organizational environment, software shortcomings (particularly networking software), and personnel availability.

Distributed data processing is simply one more phase in the evolution of data processing—from the early standalone systems of the 1960s, through the strong centralization phase of the early 1970s with order entry/inventory control applications over telecommunications networks, to the transaction-driven and parameter-reactive applications suitable to the distributed data processing of today. The state of the art in data processing is that the resource can be deployed to match management's policies and control philosophy. Once this is accepted, the concept of distributed data processing will have fully arrived.

Time-Sharing and Interactive Systems

Time-sharing, the major development of the 1960s, occurs when many users make use of the computer simultaneously and thus share its processing time. Time-sharing is not of itself a state-of-the-art application; however, a combination of time-sharing and on-line integrated interactive systems is a true state-of-the-art development.

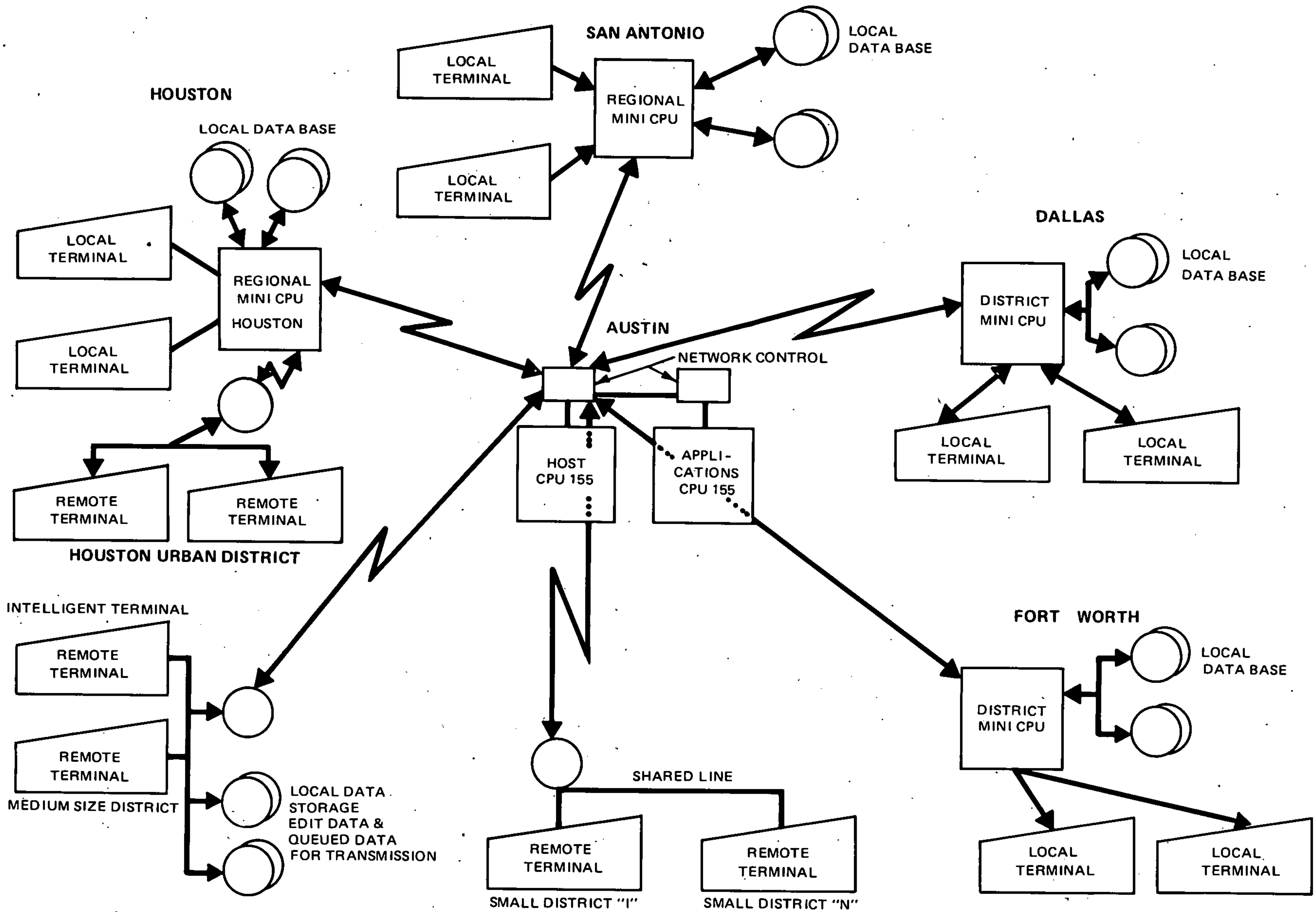
The real-time interactive system first came into performance in the early 1960s and was promoted by the Department of Defense. In the transportation environment, many applications of the system are currently in operation. The common denominator for interactive systems is that (a) they use either video tube (CRT) or typewriter terminals, (b) they are reactive to data input on a real-time basis, and (c) the data base is updated on-line in a real-time mode.

Examples of interactive systems are the right-of-way management systems in Utah, Washington, Georgia, Louisiana, Mississippi, and Illinois. These systems use video terminals in both remote and local environments for data retrieval and collection. Data enter the system from either district office or central right-of-way office work stations and update the data base as soon as they enter the system. Because of this direct data entry to the system, it is necessary to edit the data immediately. This on-line edit allows the user to correct errors that occur and validate data while the source of information is at hand.

The system provides visual information on the project status of property bought for highway construction—what parcels have been purchased, how many parcels are needed, and how much they cost. It also provides manpower status, projection of manpower availability, completion target dates, and dates released to advertising. Each district office has a video display terminal, enabling personnel to enter data and inquire into the data base to find out, for instance, if needed parcels have been purchased for a particular project. For some of these systems, the agency's legal staff has access to a terminal to match attorneys to condemnation cases quickly and tie in appraisers (as witnesses) to the appropriate court dates.

These systems begin with initial project data from roadway design personnel. That information, as well as all identifying parcel data, is entered into the system, and

Figure 2. Conceptual example of distributed data processing network system (Texas).



thereafter, review, appraisal, relocation, and acquisition data are added as those events occur.

These applications are time-shared with other applications that are operating simultaneously; the right-of-way system is also time-sharing with itself, inasmuch as different users in different locations can use the system at the same time. And the system is interactive, in that data are collected on-line, edited, and used to update the data base immediately. Additional information is generated automatically but indirectly, based on data input (i.e., new manpower projections based on work assignments input and cash forecasts based on current levels of spending for a particular project).

Typical inquiries are: right-of-way requirements for projects in preliminary engineering, status of utility adjustments, outstanding parcels, projected cash requirements summary by project compared with initial estimate, and parcel status display.

Much of the data required for this type of system is collected over the terminal, input by the users of the system, and the rest of the data is extracted from the existing accounting and payroll systems.

Data Base Integration

The development of integrated systems is not a new concept, but it is only recently that applications that utilize it fully are beginning to be implemented among the state highway and transportation agencies.

The integrated system makes use of a data base concept in which data collected for each application function are available and are used by all of the integrated system. This vastly reduces data collection costs, because each data element is collected only one time and from the best source. It also reduces maintenance and storage costs, because there is less data volume to store and problems involving unmatched redundancy errors are eliminated. A further advantage of the integrated information system, particularly when supported by DBMS software, is a very powerful cross-referencing capability in developing and finding information elements. This capability is of special interest to managers who do not always know a key word or code that identifies an information element. With this system, they can use category parameters to describe what they want and quickly find the needed item.

The available data base management system (DBMS) software has aided greatly in the development of integrated systems and has simplified programming and data base design problems immeasurably. Before DBMS software was available, the user was obligated to plan a data base that could easily be modified and expanded to support new applications as needed. This requirement usually limited the functional integration, without a redesign of the data base, to only those applications currently identified and defined as to general process requirements. Generally, under this concept, integration of major functional systems never exceeded three. However, with the adoption of DBMS software by many agencies, the integrated system is now coming of age in state highway and transportation agencies (Table 2).

APPLICATIONS

In this section are described a number of functional areas in which state highway and transportation agencies have applied computer technology to address their administrative and operational information needs. The examples illustrate uses of state-of-the-art concepts and resources that effectively meet the demands currently facing all state highway and transportation agencies.

Administrative and Control Systems

These systems are management-oriented systems. Most have the capability of providing some detailed operational data, but their main function is to support management analysis.

Maintenance Management and Cost Reporting System

Systems currently being developed in Texas and Kansas mark a significant departure from the traditional systems approach to maintenance management. The key features of the systems have resulted from an initial clear and comprehensive definition of the management process. The high degree of management orientation in the automated process leads to more simplified and maintainable data coding conventions. Other benefits include:

- Straightforward and understandable field reporting.
- Simplified budgeting.
- Timely reporting.
- Interfaces to accounting, equipment, materials, and roadway inventory systems.
- Interrelated routine and major maintenance programs.

The systems emphasize pavement work activities, inasmuch as the current trend is toward rehabilitation of aging and heavily traveled roadways rather than new construction. In addition, routine maintenance activities are budgeted and scheduled according to the characteristics of the roadway inventory, whereas major maintenance, rehabilitation, and safety activities are determined according to the roadway conditions.

Sophistication ranges from relatively simple activity reporting to automated budgeting and work scheduling, but certain common characteristics are critical to the effectiveness of the systems:

- *Consolidated input reporting* interrelates personnel, equipment, and materials data, satisfying accounting and maintenance requirements while improving timeliness and data accuracy.
- *Simplified activity coding* allows management planning and budgeting to occur at the level it was intended, as opposed to the extensive detail level that attempts to encompass all data needs.
- *Structured output reporting* emphasizes 24-hour access to budget status for programs and projects by highlighting exceptions as they occur and providing a means for analyzing detailed data on request.

TABLE 2

STATES REPORTING INTEGRATED DATA BASE SYSTEMS *

State	Application	Terminal & DBMS Software
Alabama	Project Management System with Financial Management**	IMS-DC/DB
Arizona	Fleet Management with Accounting System	CICS (planned Data Base)
Colorado	Administrative and Financial Systems (in process of conversion)	ADABAS
Florida	Project Scheduling & Management Financial Management and Administrative Systems, Traffic Data and Traffic Analysis, Accidents	IMS(DC/DB)
Georgia	Right of Way Management and Accounting System	TOTAL/ENVIRON 1
Idaho	All Financial Management Systems**	DATACOM
Illinois	Accounting Systems and Right of Way Management System	Hyperfaster Planned Data Base Integration
	Materials Information System for Test Information and Communication (MISTIC)	IMS(DC/DB)
Kentucky	Total Management Information System (Right of Way, Financial Management Project Management and Maintenance)	IMS(DC/DB)
Louisiana	Project Management and Accounting Right of Way Management, Financial Management and Materials Management System**	CICS Planned Data Base Integration
Michigan	Financial Management and Accounting Interactive Graphics, Urban Systems Model Right of Way Management System	CANDE
Nebraska	Accident Reporting, Project Scheduling and Right of Way Engineering Computing Integrated Management System	CMS GAM Planned Data Base
New Jersey	Engineering Computations Financial Management and Accounting Systems, Accident Systems	
Ohio	Fleet Management and Inventory System Maintenance System and Accounting System**	CICS (Planned Data Base)
Oklahoma	Accident Systems; Financial Management Systems	IMS(DC/DB)
Oregon	Project Management and Scheduling System; Inventory	CICS Planned Data Base
Pennsylvania	Accent System Vehicle Registration	IMS(DC/DB)
Tennessee	Roadway Information Management System (TRIMS)	IMS(DC/DB)

State	Application	Terminal & DBMS Software
Texas	Management Information System (Design and Construction Management System, Maintenance Management System, Equipment Management, Inventory Management System and Financial Management System) Automatic Drafting and Interactive Graphic System**	INTERCOM ADABAS
	Project History and Status System Materials Test Information System and Contract Information System	TCAM MIDUS
Utah	Right of Way Management System and Project Management System with Accounting and Payroll System	CICS - Planned Data Base
Washington	Right of Way Management and Property Management with Accounting and Payroll System	INTERCOM Planned Data Base

*All systems are on-line interactive.
**currently under development

Both systems are intended for batch processing yet will maintain integrated data bases using commercialized data base management systems (ADABAS and TOTAL). The systems are updated nightly, or as input is received, and exceptions are reported as they occur; however, regular structured reporting occurs at month-end.

Through use of DBMS, the system can interface easily with adjacent systems—the equipment and materials inventory systems, the accounting system, and the project management system, for example—allowing on-line access to pertinent maintenance information.

Project Management System

In today's environment, where transportation projects are typically small and of short duration, where funds are limited and greater accountability is required, and where new construction is on the decline, state highway and transportation agencies are finding it necessary to increase management control over projects and expenditures and to respond more effectively to conflicts and changes in priorities and schedules. In response to this situation, a number of states have developed or are in the process of developing a project management system (PMS).

The primary goal of PMS is to provide a tool that enables all levels of management to monitor project progress, resource consumption, and priority conflicts within a highway program. Three basic subsystems interact to achieve this goal:

- *Project scheduling*—Monitors the planned schedule and progress of the phases of each project.
- *Project financing*—Tracks estimated and actual costs as a basis for reporting project financial commitments and fund status and for forecasting cash requirements.
- *Estimates/contracts*—Provides historical unit costs for preparing estimates, evaluating proposals, and assessing contractor performance.

The effectiveness of PMS is realized through the use of on-line terminals, which allow users to enter, update, and access data on a timely basis. Through use of advanced data base management concepts, simple and understandable on-line displays allow users to interact with a common data base, though they may be separated organizationally and geographically.

The PMS data base contains the project schedule and resource data pertinent to the project phases and management functions. Projects are initiated by entering the desired construction and interim milestone dates. Critical path methods can be used, if necessary, to estimate target dates for complex projects. PMS provides standard resource estimates, which the project engineer can accept or override. Once satisfied with the estimates, the engineer places an individual project in the overall program to simulate the impact. Excessive resource demands are identified by a system comparison of estimates with forecasted availability. The engineer using the terminal realigns estimates to resolve conflicts. PMS users have found that planning around conflicts often releases significant contingency funds for other purposes.

As project work begins, the PMS automatically collects accounting and payroll data from other automated systems. The project engineer tracks progress through inquiries from on-line terminals or through a selection of periodic, special request, or exception reports produced by

PMS. Exception reports for such conditions as lack of activity, overexpenditures, or missed milestone dates reduce hard copy reporting and highlight situations requiring special attention.

Fiscal Management System

Historically, automated fiscal information systems have been developed primarily for accounting purposes. Present-day managers often find that accounting system reports cannot satisfy the needs for timely information interrelating operating and fiscal data. Several states, however, are developing fiscal management systems that support both operating management and accounting functions (see Fig. 3). The design of the central data base management system must allow access for the variety of needs supported by a fiscal management system.

The on-line data entry, edit, and file update processes are primary contributors to the system's effectiveness. Through the use of on-line terminals, data are captured at their source and error correction is performed on entry. The result is a data base that is maintained by those responsible for the data and is updated on a timely basis. Many of the time-consuming clerical and error-correction procedures are eliminated, as are paper-flow transit-time delays.

The central data base is the basis for comprehensive reporting, on request, via terminals or by exception and periodic reports. The key reporting features of the fiscal management system are as follows:

- It provides responsive budgeting, budget/expenditure status, and budget/performance evaluation capabilities.
- It serves to enhance capabilities of other, nonfiscal management systems requiring feedback information from accounting.
- It fulfills complete financial accounting requirements.
- It provides the necessary accounting and fiscal controls.
- It promotes auditability.
- It provides variance analysis capabilities.

Traffic Safety System

An effective traffic safety system is of utmost importance to traffic engineering and planning organizations. The primary objective of the system is to identify the profile of high-accident locations and provide information regarding accident causes so that the organizations can determine traffic and safety trends and identify locations that require safety improvements. In order to fulfill this objective, a traffic safety system incorporates the following features:

- A centralized data base for accident surveillance and analysis of related data.
- Correlation of average daily traffic to the associated traffic location.
- Multiple access methods that allow the system user to analyze a specific location or locations along a route.
- The means for easy and fast access to this informa-

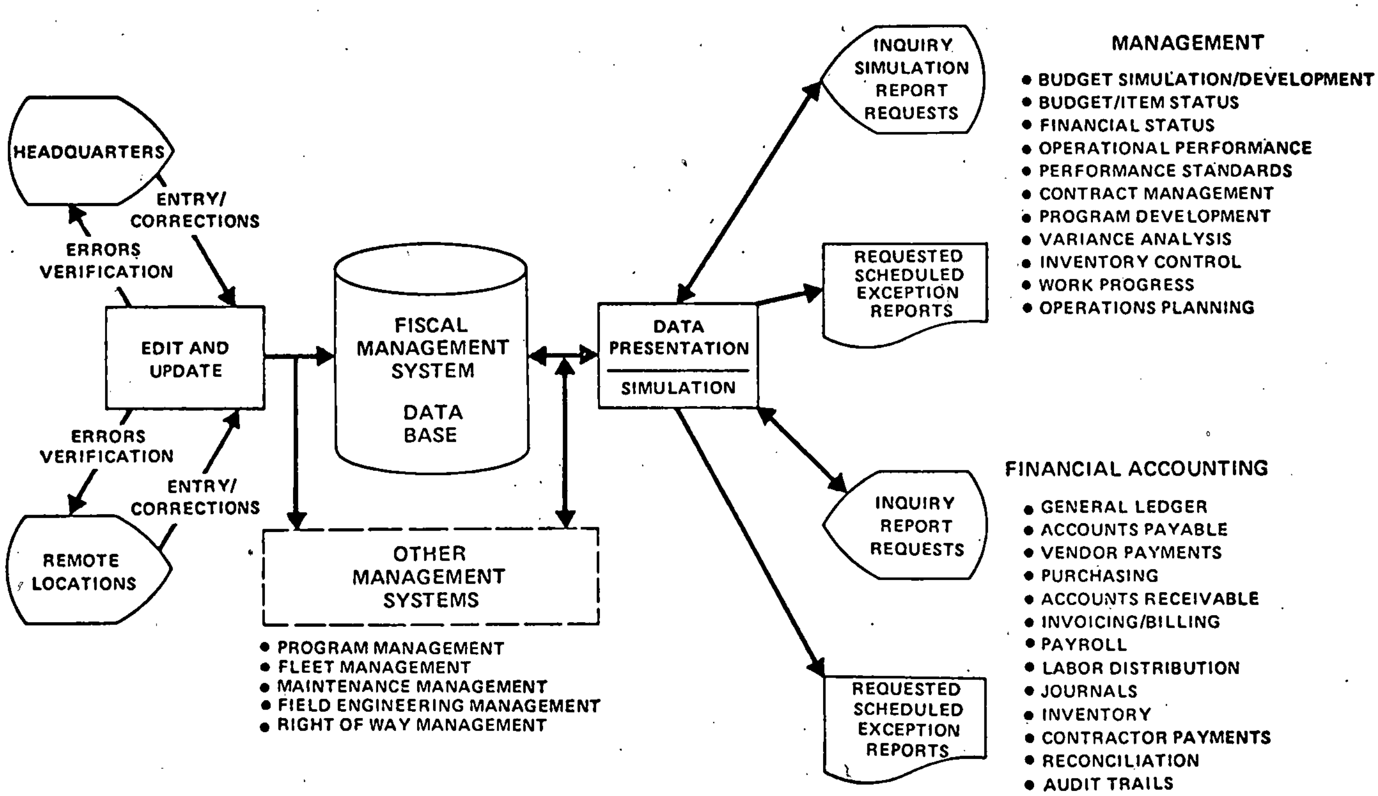


Figure 3. Fiscal management system.

tion, presenting it in an orderly fashion to meet the needs of individual interests.

- The means for relating accidents to the characteristics of the location, including the consideration of traffic volumes and roadway characteristics.

The system's ability to effectively edit and validate the input data provides a base of information that supports analysis, planning, and engineering. For example, the incidence of accidents above certain norms can indicate the need for safety improvements and their associated budget expenditures.

It is important that the system be responsive to the user. Also, it is vital that the system monitor accident profiles to identify locations that otherwise might not be disclosed. To support accident analysis, system reports should be produced on user demand, at fixed time intervals, or on the detection of exceptional conditions.

Transportation Resource Management System

The operation of state and local transportation agencies has increased in complexity because of growing social and environmental concerns, increasing population, shortage of energy, and tighter financial constraints. There has been an attendant concern for closer management of time, manpower, and money to provide acceptable service and protect the huge capital investment.

The transportation resource management system (TRMS) provides support for managing the formulation of long-range plans and for tracking the accomplishments or progress against those plans. The system does this by defining directed work programs and reporting the completion of key work activities.

Understanding the management environment is paramount to establishing TRMS requirements. Figure 4 shows such an environment. The contrast of needs and resource capacity is the key interaction to formulating long-range plans.

The TRMS supports a multiproject, multifunding, multimodal transportation management environment. Figure 4 represents the overall system structure for TRMS. This system provides the following functional capabilities in support of effective resource management:

- The ability to define a long-range plan based on an evaluation of needs and capacity and to model the probable impact of the plan on the transportation system.
- Support for all levels of management involved with decisions affecting resource consumption, such as cash, manpower, and equipment forecasts.
- The ability to define work programs as well as to define fund programs, which identify the source of funds applied to the work efforts.
- Feedback on work accomplishment through the reporting of event occurrence, activity completion, and resource expenditures.
- Useful projection of trends and requirements for resources.

Engineering Systems

The major systems available today for direct support of highway designers are few in number. There are many computational engineering programs, particularly for structures, earthwork, traverse coordinates, bearings and distance calculations, and hydraulics, but there are only two modern integrated engineering support systems in general use among state highway and transportation agencies: the roadway design system (RDS) and the integrated civil engineering system (ICES). Both use a planned integrated data base concept, and both are designed in such a way that, with a little training, engineers can use them directly by preparing their own input with special forms provided for this purpose. The next step in developing these design tools is to use computer terminals as work stations in the design office.

These systems are suitable for management policies of either centralized or decentralized control. The only difference is in the use of remote or local terminals; no terminals are necessary in a centralized control environment, because the data can enter the computer through normal centralized data input methods.

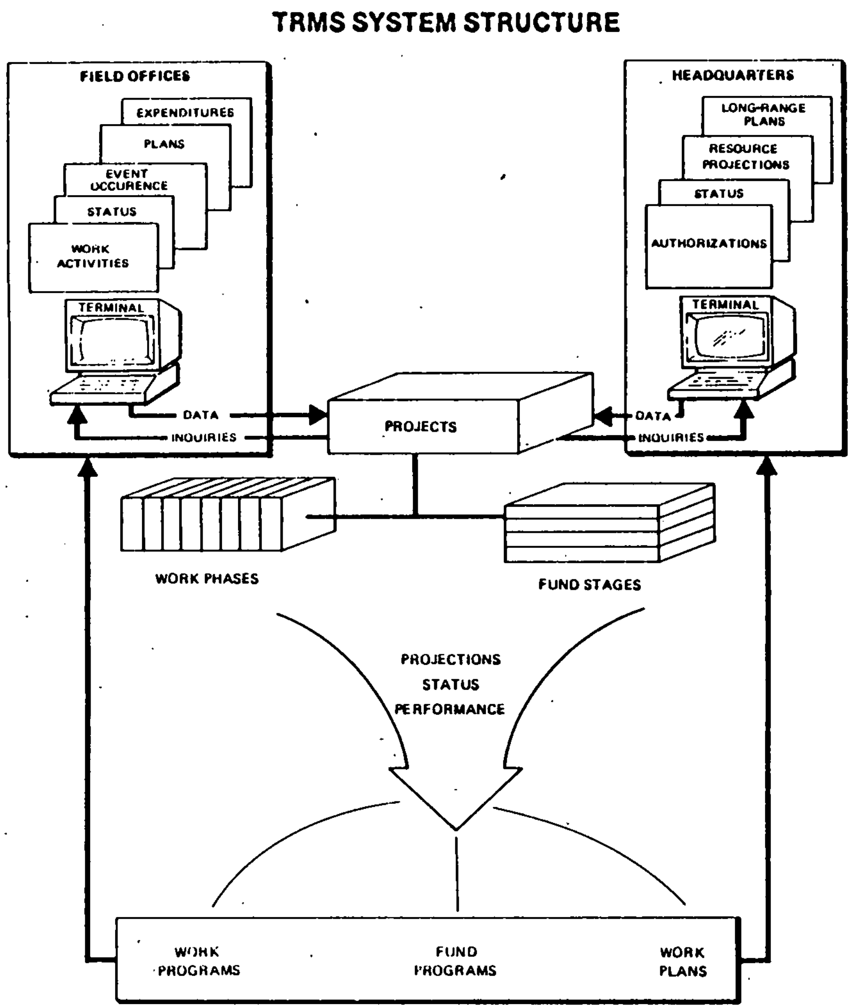
The use of interactive graphics as an engineering design and analysis tool is currently under development in several highway and transportation agencies. Among the leaders in this state-of-the-art development are Florida, Michigan, and Texas. Such a system would be extremely useful when integrated with the two design systems and would greatly expand their utility.

Roadway Design System

RDS is a design and analysis tool that provides direct computer support to the engineer through the use of remote computer terminals. It was developed by the Texas Highway Department in cooperation with the Federal Highway Administration. The system's primary objective is to increase the designer's work output through the use of modern computer and automation technology that reduces the repetitive clerical and computational overhead in the design process.

The RDS is composed of more than 250 computer processes, but they appear as one program to the user. The system is built around a comprehensive integrated design project data base that is served by the computational modules. Thus, when designers are working with these data, their previous computations and information (input from previous work) are available automatically to interact with the new data. This is achieved by the linkage of all processes to a dynamic master file. The RDS capabilities can be used in any sequence chosen.

The system has a powerful command geometry resource, enabling the designer to locate points and curves; intersect curves and intersect with alignments; compute bearings, distances, and angles; establish parallels and perpendiculars; locate circle tangents; compute station offsets; compute roadway evaluations; and compute the relationship of pairs of alignments. The system also has a comprehensive



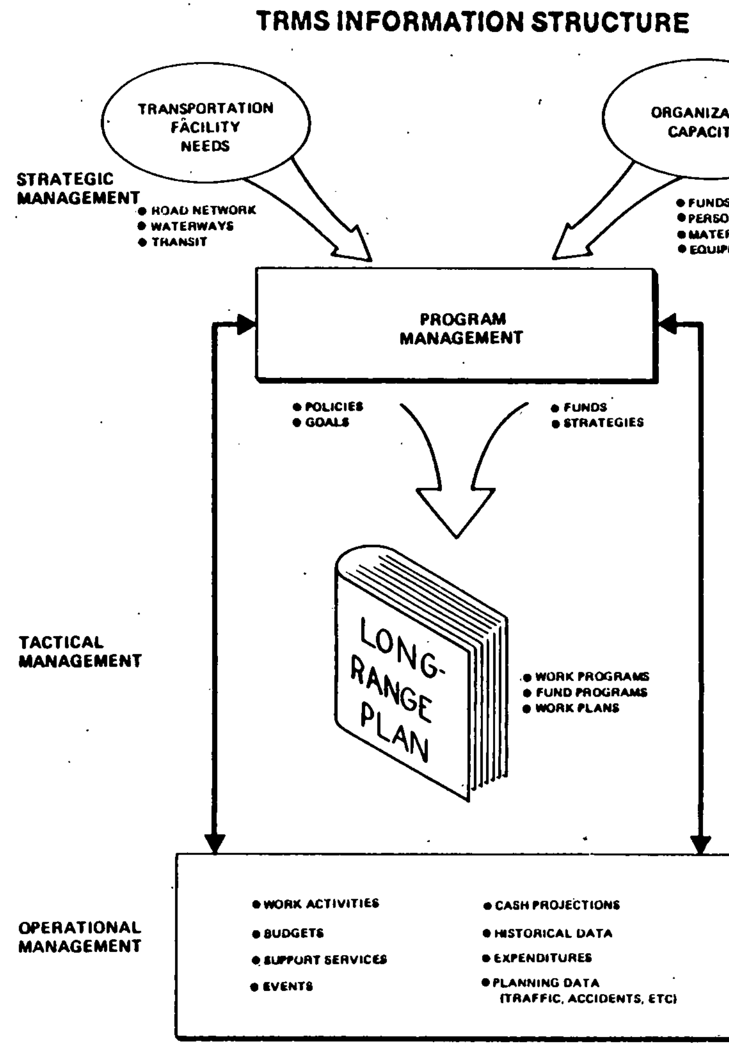


Figure 4. Transportation resource management system.

plotting resource and can plot any geometric features that have been stored or even superimposed on other RDS plots.

RDS is a complete road design system that provides the engineer support in all engineering aspects of the road design process, from earthwork computation to annotated alignment plots that can be requested from the computer at any time. The system has been available for several years, yet it still represents the state-of-the-art development for civil engineering design systems. Even now, the Texas Department of Highways and Public Transportation is in the process of developing an interactive graphics resource for the RDS. This resource will enable the road designer to interact with stored data and see it represented graphically on the video tube.

Integrated Civil Engineering System

ICES was developed at MIT under the direction of the civil engineering department. The development of this system involved input from many highway agencies and received financial support from the IBM Corporation. It is designed around a control root subsystem that controls the major operational subsystems. The basic system as normally configured is as follows: ICES control segment, ICES-COGO, ICES-ROADS, ICES-STRUDL, and ICETRAN.

As part of the overall ICES, all problem data input and computations are stored in the system's integrated data base for subsequent use. The ICES has graphic plotter system resources in another subsystem called SURMAP (survey mapping); this subsystem digitizes data from the data base on command and produces a plotter tape.

ICES Control Segment—The ICES control root segment controls all transaction traffic for the system. All data entering the system are processed through this control segment and then turned over to the appropriate operational subsystem for computational resolution. The modules of this segment of the system perform system editing and housekeeping, whereas the operating subsystem performs the actual engineering computations.

ICES-COGO—COGO, the coordinate geometry subsystem, is the workhorse of the system. It provides a computational resource for general design requirements (traverse closure calculations, vertical and horizontal curves, etc.). This high-level command language is used to express specific problems in a manner that is readable by the computer program. The COGO subsystem allows computations to be expressed in simple geometric objects, such as points, lines, curves, distances, directions, and angles.

ICES-ROADS—The ROADS subsystem allows the engineer to investigate alternative alignments and profiles as well as various templates during location studies. In the design phase, preliminary slope-stake data, material volumes, and vehicle performance characteristics can be considered with far greater ease and precision in order to arrive at the optimum route possible relative to the variable constraints of right-of-way, land use, and the environmental impact of the proposed roadway. Like RDS, this system makes use of an integrated data base; thus the data from each computation are stored and available to subsequent design work. In effect, each use of the system becomes another building block in the development of the road design.

ICES-STRUDL—STRUDL, the structural design language, has been used primarily as a bridge design analysis tool, although it is intended as a structure design tool. The addition of special bridge design algorithms (McDonald Douglas Automation ICES System) makes the original goal of this subsystem more tenable. The system performs linear analysis of elastic, statically-loaded, two- or three-dimensional framed structures and continuous bridge girder analysis.

ICETRAN—This subsystem is a computer programming language very similar to FORTRAN. It enables users to add their own computational subroutines to the system. Using this resource, however, involves a very complex procedure that usually requires a trained FORTRAN programmer; and unless the user is very careful, the subroutines could cause problems with the project data base.

THYSYS

THYSYS, the Texas hydraulics system, is a complete system for design and analysis of hydraulics problems encountered in road design. This system is made up of five subsystems, described below.

HYDRO—This subsystem provides four methods of calculating peak discharge rates for surface water runoff. Each method addresses a different type of general problem, depending on the area. The four methods are as follows: (a) gaged analysis—for drainage areas having gage stations; (b) rational method—for areas of less than 5 square miles (13 km^2); (c) commons method—for areas of 5 to 19 square miles (13 to 49 km^2); and (d) 6311 method—for areas of more than 100 square miles (260 km^2). The latter two methods also may be used for areas of 20 to 99 square miles (52 to 256 km^2).

HYDRA—This is the channel hydraulic subsystem of THYSYS. Its main functions are to determine tailwater elevations and store cross-section data for use in the CULBRG subsystem. HYDRA provides three methods of determining tailwater elevations: the one-section method, which uses only one cross section; the two-section method, which uses two cross sections and usually is more accurate than the one-section method; and the many-section method, which is more reliable than the other two but requires much more data—three or more cross sections.

CULBRG—This is the culvert and bridge subsystem of THYSYS. It is designed to perform two separate functions for hydraulic problems: designing required culverts and bridges and analyzing existing culverts and bridges. This subsystem operates on data stored through the HYDRO and HYDRA subsystems.

SEWER—This subsystem is used to design a storm sewer or analyze an existing one. The design and analysis are based on three major functions: runoff, inlet, and the sewer. Unlike the other THYSYS subsystems, this one does not exchange information but is independent.

PUMP—This subsystem is used to aid in designing or analyzing pump stations to lift storm drainage runoff water. The system provides station design based on storage volumes (capacity), average pump capacity, and peak flow.

All these subsystems provide for plotter graphics output on demand and in all cases produce a printed list of the input data as well as the output problem solution data.

THYSYS is currently operational in the Texas Department of Highways and Public Transportation. The engineer has a set of coding forms available on which to describe a problem. These coding forms are keypunch documents from which cards are punched and entered into the computer. This system operates much like ICES and RDS.

CHAPTER THREE

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The development of data storage and retrieval systems is embarking on a new era. There is widespread use of traditional individual applications, such as engineering, accounting, maintenance, and contract administration. The expanded use of automated systems has contributed to the understanding of the management process and has led to the realization that a data storage and retrieval system is a vital tool in organizing data for management decisions.

The full appreciation of the close tie between the management decision processes and the supporting data systems has led to system integration. Such systems are frequently called resource management systems, because they aid managers in making decisions and optimizing the use of available resources.

System integration requires managers to be keenly introspective in defining the management process. Integrated systems are effective only if they are based on specification of management goals and objectives, definition of the management decision processes, identification of interdepartmental dependencies, and definition of management control philosophy (centralization vs. decentralization).

RECOMMENDATIONS

Integrated Systems

Based on the analysis of the state of the art of data processing in general and the highway and transportation agencies in particular, it is recommended that future administrative, financial, and management information systems be designed as integrated systems. In many cases data collection is the most expensive component of an information system, and when systems are not integrated at the data base level, there is much data redundancy (the same data are not only stored in multiple locations but also collected many times). The cost of redundancy that results from nonintegrated systems can be the difference between a positive or a negative cost-benefit analysis for a particular system.

The overall consideration for this recommendation is that data should be independent from application processing programs and from functional organizational entities. In short, the data base belongs to the agency as a whole, and every cataloged element is available for support of any application on the system. Implementing this recommendation may cause an organizational change within the agency's data processing unit. Someone must be given the responsibility of assuring the integrity of the integrated data base. This resource must become the heart of all information-processing within the agency; therefore, standards must be set and maintained for use, updating, editing, and adding data elements to it. Further, the design of the data base's physical and logical structure must be closely controlled and monitored if it is to serve all users.

The person responsible for the DBMS is usually called the data base administrator. Because an integrated data base serves many applications, divisions, and districts, it must be coordinated centrally. The data base administrator has the job of setting up the management process and controlling the evolution of the data base within an organization. This is an extremely important responsibility, inasmuch as it could be the key to an organization's success or failure in the use of data processing.

A typical state highway or transportation agency has many thousands of types of data items, all of which must be organized into suitable records, segments, sets, or relations. A specific data item could be used by several functional areas of an agency and for many applications. The data items must be standardized in name, representation, and definition. The data must be grouped into patterns that best serve the greatest number of users, and the patterns must be structured into an overall physical pattern for storage on computer-accessible devices. Careful attention must be paid to accuracy, security, and data integrity. The data must be protected from accidents, crooks, incompetents, and idiots.

All these responsibilities require central control and coordination. They should not be left to the diverse interests of application programmers, systems analysts, and even user-managers. Only by centralization of data base policies can data base use be optimized for all users. This, then, is the job of the data base administrator.

Interactive Systems

All new development of information systems should strongly consider the use of user-controlled interactive systems with on-line terminals. The use of the on-line terminal as a work station right at the source where the data are created is by far the most efficient and error-free way to provide computer system support to an operation.

This design approach has four main advantages. First, having data input at the source removes the need for transmittal documents, thus eliminating transfer from forms to cards and reducing staff costs and errors in data transfer. Second, a user-controlled system, especially one that uses CRTs for input/output, reduces errors, because the user who knows the meaning of the data is entering the data into the system under program edit control; thus errors are detected at input time, while the operator still has the original document at hand. Third, the user has information available whenever it is needed and thus saves valuable management time. Fourth, data elements are entered once from the primary source but are available instantly thereafter to all users, thus allowing for immediate availability of up-to-date totals.

Commercial Software

In the data processing field today are a great many proprietary utility software packages that greatly aid an installation's ability to perform its responsibilities. Among them are data base management systems, telecommunication monitors, generalized report generators, and system network architecture.

Some agencies have developed these packages in-house, and sometimes the packages are provided by the hardware vendor. The decision to develop this type of generalized software in-house is usually a bad one, for the following reasons:

- If there is a generalized package that fits an agency's needs, it is generally cheaper to buy this package than to develop one.
- The purchased package has been tested by many users, and most of the problems have been solved.
- A generalized package must serve as great a number of users as possible; therefore, the scope of its design is broad enough to service future needs for several years to come.
- A generalized package is designed and maintained by professionals who specialize in that application.
- The purchase guarantees a product; the decision to develop the software in-house guarantees nothing but costs.
- A utility software designed in-house must be maintained in-house.

APPENDIX A

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APPENDIX B

COMPUTER EQUIPMENT AND USES IN HIGHWAY AND TRANSPORTATION AGENCIES

TABLE B-1

COMPUTER EQUIPMENT OF EACH DEPARMENT

STATE	EQUIPMENT CONTROL INTERNAL	EXTERNAL	TYPE EQUIPMENT	MEMORY SIZE (M)
ALABAMA		X	IBM 370-158	2.0
			IBM 370-145	1.5
ALASKA		X	IBM 370-145	0.5
		X	IBM 360-40	0.2
ARIZONA	X		2 IBM 370-158	2.0 ea.
ARKANSAS	X		IBM 370-145	0.5
CALIFORNIA		X	2 IBM 370-168	2.0 ea.
			Tenet 210	0.05
COLORADO		X	2 CDC 6400	0.1 ea.
		X	IBM 370-145	1.0
CONNECTICUT	X		UNIVAC 1106	0.25
	X		UNIVAC 9300	0.01
DELAWARE		X	IBM 370-158	1.0
FLORIDA	X		IBM 370-168	4.0
GEORGIA		X	2 IBM 370-158	3.0 ea.
		X	UNIVAC 1110	0.06
	X		DEC PDP 11/40	0.1
HAWAII		X	IBM 370-155	2.0
	X		DEC PDP 11/40	0.1
IDAHO	X		IBM 370-145	1.0
	X		DATA POINT 5500	0.06
ILLINOIS		X	3 IBM 370-168	4.0 ea.
		X	IBM 370-158	4.0
INDIANA	X		IBM 360-50	0.5
IOWA	X	X	IBM 370-145	1.0
KANSAS		X	IBM 370-155	2.0
KENTUCKY		X	2 IBM 370-168	4.5 ea.
LOUISIANA		X	IBM 370-158	1.5
MAINE		X	IBM 370-135	0.5
	X		IBM 1130	0.02
MARYLAND	X		IBM 360-40	0.25
MASSACHUSETTS	X		IBM 370-145	0.5
MICHIGAN	X		BURROUGHS 7760	0.5
	X		DEC PDP 11/70	0.13
	X		CMC 1800	0.06
MINNESOTA		X	3 IBM 370-158	2.0
MISSISSIPPI		X	2 IBM 370-155	3.5
	X		HARRIS 1620	0.02
MISSOURI	X		IBM 360-50	0.5
MONTANA	X		IBM 370-145	0.76
NEBRASKA	X		IBM 370-148	0.5
NEVADA		X	IBM 370-158	3.0
NEW HAMPSHIRE		X	UNIVAC 70/6	0.26
	X		UNIVAC CADE 1900	0.08
	X		NOVA	0.02
NEW JERSEY		X	IBM 370-145	0.76
NEW MEXICO	X		IBM 370-145	1.0
NEW YORK	X		2 BURROUGHS 5500/5700	0.032 ea.
NORTH CAROLINA	X		IBM 370-158	2.0
			IBM 370-145	0.5
NORTH DAKOTA		X	IBM 370-145	1.0
OHIO	X		IBM 370-145	1.0
	X		DEC PDP 11/34	0.03
OKLAHOMA		X	3 IBM 370-158	4.0
OREGON		X	IBM 370-158	2.0
PENNSYLVANIA	X		IBM 370-168	8.0
			BURROUGHS 6700	0.393
RHODE ISLAND				
SOUTH CAROLINA	X		IBM 370-145	0.25
SOUTH DAKOTA		X	IBM 370-158	2.0
			DEC PDP 8/E	0.01
TENNESSEE		X	IBM 370-155	1.5
TEXAS	X		2 IBM 370-155	2.0
			DEC PDP 11/35	
			NOVA	
UTAH		X	2 ITELAS 5 (IBM-370-158 Comp.)	2.0
VERMONT		X	IBM 370-145	0.5
VIRGINIA		X	IBM 370-145	1.0
WASHINGTON	X		IBM 360-65	3.0
WEST VIRGINIA		X	IBM 370-158	2.0
		X	IBM 370-158	3.0
WISCONSIN	X		2 IBM 360-65	2.0 ea.
WYOMING		X	2 IBM 370-155	3.0

TABLE B-2

COMMERCIAL SOFTWARE IN USE

	Central State Center	Internal Center	Totals
Data Base Management Systems			
IMS(DB/DC)	3	2	5
IMS (DB)	2	3	5
TOTAL	3	-	3
SYSTEM 2000	1	-	1
DMS II	-	1	1
ADABAS	4	2	6
DATACOM (DC/DB)	-	1	1
Total	13	9	22
Telecommunications Monitors			
CICS	13	7	20
INTERCOM	-	2	2
CONVERSE	1	-	1
ENVIRON II	2	-	2
CMS	3	2	5
HYPERFASTER	1	-	1
EXEC-8	-	1	1
Total	20	12	32
Time-sharing System (TSO)	8	5	13
Report Writers			
EASYTRIEV	4	2	6
MARK IV	8	6	14
REACT	-	1	1
SYNTAX	1	-	1
FMS-8	-	1	1
GIS/VS	-	1	1
SOCRATES	1	-	1
DYL-260	2	1	3
CULPRIT	1	-	1
DMS II	-	1	1
RPG	1	2	3
CAP	-	1	1
Total	18	16	34

TABLE B-3

NUMBER OF AGENCIES USING DIRECT AND NONDIRECT ACCESS FILES BY PURPOSE AND TYPE OF APPLICATION

		Direct Access		Nondirect Access	
Functional Area	File Category	Data Storage & Retrieval Only	Automatic Analyses	Data Storage & Retrieval Only	Automatic Analyses
Planning, Traffic	Inventory	6	10	8	18
	Costs	1	10	6	9
	Traffic	5	15	5	20
	Accidents	-	18 1/	6	20
	Urban models	-	11	-	31
Program Control	Project files	2	19 2/	2	10 3/
Engineering, Operations	Right of way	2	12	2	11
	Materials	3	10	3	10
	Maintenance	2	18	3	18
	Bid letting	-	18	1	14
	Progress estimate	-	16	1	15
	Design	-	17	3	17
	As completed files	4	-	10	-
Finance, Administration	Accounting	-	29	-	15
	Integrated financial mgmt.	-	14 4/	-	3
	Budget	2	18	4	10
	Personnel	5	13	8	9
	Payroll	7	17	5	10
	Procurement	3	2	1	10
	Fleet management	-	12	-	14

1/ One state indicates analysis only

2/ One state indicates system limited to automatic project control

3/ Two states indicate monitoring systems only

4/ One state did not consider its system fully integrated

TABLE B-4

NUMBER OF AGENCIES REPORTING OTHER ADP FILES OR MANAGEMENT SYSTEMS *

Functional Area	ADP Files or Mgm't System	Agencies
Planning	Social and economic statistics	1
	Revenues	1
	Travel data 1/	1
	Environmental analysis	2
	Resource base analysis	1
	Population forecasting	1
Programming	Program priority array	1
Engineering & Operations	Construction mgm't system	1
	Signs inventory	1
	Automated mapping	1
Finance & Administration	Cash forecasting	3
	Vehicle credit card system	1
	Supplies and equipment inv. 1/	6
	Materials inv. control & forecast 1/	1
	EEOS affirmative action	1
	Employee safety	1
	Billboard inventory 2/	2
Highway Safety Admin.	Driver licensing	5
	Highway patrol management	1
	Traffic records	1
	Citations	1
Motor Vehicle Admin.	M. V. registration	4
	M. V. inspection	1
Toll Road Administration	Toll road operations	1
	Financial mgm't & audit	1

1/ Many agencies probably construed other headings as covering these applications.

2/ This possibly could be listed under Planning.

*Systems not distinguished or covered in questionnaire.

TABLE B-5

NUMBER OF AGENCIES USING SELECTIVE AND EXCEPTION REPORTS

Applications	Selective Reports	Exception Reports
0	4	9
1-5	4	7
6-10	11	10
>10	26	18

TABLE B-6

USE OF DATA BASES *

File Applications of General DBMS	File Applications of Locally Developed Data Base			
	0	1-4	5-9	10 and over
0	18	7	2	6
1-4	4	2	2	1
5-9	1	0	0	1
10 and over	1	0	0	0

*As defined by individual agencies.

TABLE B-7

USE OF DATA SYSTEMS FOR RAILROADS *

TRANSPORTATION DEPARTMENT	DATA PROCESSING APPLICATIONS																				
	Planning					Program.		Engineering & Operations						Finance & Administration							
	Inventory	Costs	Traffic	Accidents	Models	Proj. Files	Prog. Control	R of W	Materials	Maint.	Bid Letting	Prog. Est.	Design	Accounting	Int.Fin.Mgt.	Budget	Personnel	Payroll	Procurement	Fleet Mgmt.	Cash Forecast
Arizona	X		X																		
Connecticut	X				X												X	X			
Delaware	X		X																		
Florida																					X
Georgia	X		X	X																	
Illinois														X	X	X	X	X			X
Iowa														X	X	X		X	X	X	
Louisiana	X			X																	
Massachusetts	X		1/		X																
New Hampshire	X																				
New Jersey	X	X				X				X					X						
New Mexico	X																				
New York	X						X							X	X						
Ohio	X					X						X					X	X			
Tennessee	X																				
Texas	X																				
Vermont										X				X	X		X	X		X	

1/ Travel data

* Tabulations probably not complete because railroad modal units are not always fully integrated with highway units and may have independent data processing facilities.

TABLE B-8

USE OF DATA SYSTEMS FOR AIRPORTS *

TRANSPORTATION DEPARTMENT	DATA PROCESSING APPLICATIONS																							
	Planning					Program		Engineering & Operations						Finance & Administration										
	Inventory	Costs	Traffic	Accidents	Models	Proj. Files	Prog. Control	R of W	Materials	Maint.	Bid Letting	Prog. Est.	Design	Accounting	Int. Fin. Mgt.	Budget	Personnel	Payroll	Procurement	Fleet Mgmt.	Cash Forecast	Airman Reg.	Aircraft Reg.
California	X				X																		
Connecticut			X		X	X	X				X			X	X	X	X	X		X			
Delaware	X																						
Florida	X					X	X				X			X							X		
Hawaii														X									
Idaho																						X	X
Illinois														X	X	X	X	X			X		
Iowa														X	X	X		X	X	X			X
Kentucky	X					X																	
Massachusetts			1/		X																		
Michigan																							X
New Jersey	X			X										X		X							
New York							X							X	X								
Ohio												X					X	X					X
Pennsylvania															X								
Tennessee	X			X																			
Wisconsin	X													X	X	X	X	X	X	X			

1/ Travel Data

* Tabulations probably not complete because airport modal units are not always fully integrated with highway units and may have independent data processing facilities.

APPENDIX C

QUESTIONNAIRE SENT TO STATE HIGHWAY AGENCIES

I. CONTACTS			
Prepared by:	Title:		Phone:
Computer Systems Manager:	Title:		State:
II. GENERAL INFORMATION			
1. Computer Systems Budget ($)	Equipment:	Personnel:	
2. Staffing Levels (Man yrs)	System Programmers	Application Programmers	Operations
3. Source of Services (yes/no)	Internal System	Consolidated Center	Time Sharing
III. EQUIPMENT			
4. Processing Equipment (Indicate Planned with *)	Make (Vendor)	Model	Memory Size
	Make (Vendor)	Model	Memory Size
	Make (Vendor)	Model	Memory Size
	Make (Vendor)	Model	Memory Size
5. Direct Access Storage (Indicate Planned with *)	Make	Model	Quantity
	Make	Model	Quantity
	Make	Model	Quantity
	Make	Model	Quantity
IV. SOFTWARE			
6. System Software (Type)	Primary Operating System	Primary Program Language	
7. Data Storage Software (yes/no)	Sequential Files	Direct Access Files	Locally Developed Data Base
(System Name)	Commercial Generalized DBMS System		
8. Retrieval Software (yes/no)	Batch Reports	Exception Reports	Selective Reports
(System Name)	Commercial Generalized Report Writing System		
9. Communications (System Name)	Inquiry Terminal Control	Interactive On-Line System	
10. Batch Job Submission (yes/no)	Local Job Entry	Courier Service	Remote Job Entry

V. APPLICATIONS

11. FUNCTIONAL AREA	12. A. D. P. FILES AND ANALYTICAL OR MANAGEMENT[1/] SYSTEMS (Put stroke through inapplicable words)[2/]	13. TRANSPORT APPLICATION			14. DATA STORAGE				15. DATA RETRIEVAL			
		Highway	Railroad	Airport	Sequential Files	Direct Access Files	Locally Dev. Data Base	Generalized DBMS	Batch Reports	Exception Reports	Selective Reports	Generalized Report Writer
Planning and Traffic	Inventories, Inventory Analysis											
	Cost Data, Cost Analysis											
	Traffic Data, Traffic Analysis											
	Accident Data, Accident Analysis											
	Urban Systems Models											
	Other (Describe on Page 3)											
Program Control	Current Project Files											
	Scheduling - Monitoring and Program Management Systems											
Engineering and Operations	R of W Files & Mgmt. Systems											
	Materials Files & Mgmt. Systems											
	Maint. Files & Mgmt. Systems											
	Bid Letting Systems											
	Monthly Progress Estimate System											
	Design Data and Design Analysis System(s)											
	As Completed Proj. Files											
	Other (Describe on Page 3)											
Finance and Administration	Accounting & Cost Acct. System											
	Integrated Financial Mgmt. System											
	Budget Data & Analysis System											
	Personnel Data and Manpower Inv. System											
	Payroll Data & Analysis System											
	Procurement Data and Analysis System											
	Fleet Management System											
	Other (Describe on Page 3)											

V. APPLICATIONS

11. FUNCTIONAL AREA	12. A. D. P. FILES AND ANALYTICAL OR MANAGEMENT[1/] SYSTEMS (Put stroke through inapplicable words)[2/]	13. TRANSPORT APPLICATION			14. DATA STORAGE				15. DATA RETRIEVAL			
		Highway	Railroad	Airport	Sequential Files	Direct Access Files	Locally Dev. Data Base	Generalized DBMS	Batch Reports	Exception Reports	Selective Reports	Generalized Report Writer

1/ Management system refers to complete process information system.

2/ It is important to distinguish between systems which catalogue and maintain input data and make summaries but which do not perform data analyses. It also is important to distinguish between systems which provide complete management information for an entire process, and those which store or analyze only part of the needed information. Distinguish by striking inapplicable words. For example: if systems provide inventory data maintenance only -- no analyses of these data. Strike the words "Inv. Analysis."

THE TRANSPORTATION RESEARCH BOARD is an agency of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 150 committees and task forces composed of more than 1,800 administrators, engineers, social scientists, and educators who serve without compensation. The program is supported by state transportation and highway departments, the U.S. Department of Transportation, and other organizations interested in the development of transportation.

The Transportation Research Board operates within the Commission on Sociotechnical Systems of the National Research Council. The Council was organized in 1916 at the request of President Woodrow Wilson as an agency of the National Academy of Sciences to enable the broad community of scientists and engineers to associate their efforts with those of the Academy membership. Members of the Council are appointed by the president of the Academy and are drawn from academic, industrial, and governmental organizations throughout the United States.

The National Academy of Sciences was established by a congressional act of incorporation signed by President Abraham Lincoln on March 3, 1863, to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance. It is a private, honorary organization of more than 1,000 scientists elected on the basis of outstanding contributions to knowledge and is supported by private and public funds. Under the terms of its congressional charter, the Academy is called upon to act as an official—yet independent—advisor to the federal government in any matter of science and technology, although it is not a government agency and its activities are not limited to those on behalf of the government.

To share in the tasks of furthering science and engineering and of advising the federal government, the National Academy of Engineering was established on December 5, 1964, under the authority of the act of incorporation of the National Academy of Sciences. Its advisory activities are closely coordinated with those of the National Academy of Sciences, but it is independent and autonomous in its organization and election of members.

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