Automation in Public Transit Operation and Management: Update

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The concept of a system of operations, planning, and management tools for transit operators is discussed in light of recent developments in automation. Minicomputers and microcomputers have improved the ways in which computers are perceived, increased their acceptance, and vastly increased their potential uses for transit planning. This paper discusses the elimination of barriers to the use of automation, some events that create an ideal opportunity for development of an operations planning system, and a general concept for use of microcomputers and automated tools. A sample application that involves the analysis of route-level data for the purpose of route-performance evaluation is presented. Design issues for the development of transit operations tools are discussed.

The decade of the 1970s was a period of expansion for the transit industry. As the demand for transit rose, in part due to the rising costs and intermittent shortages of gasoline, coverage was extended to more outlying areas of urban regions and service hours were increased. Ridership and revenues increased but not as fast as operating costs. Deficits were covered by both the federal government, which initiated the Section 5 operating assistance program (Urban Mass Transportation Act of 1964, as amended), and by local and state sources, which appeared willing to increase their support to transit. In general, there was not a strong incentive for most operators to vigorously seek ways to improve productivity and keep costs to a minimum.

Now, a new conservatism, spearheaded by a new administration, has led to changes in transit operating philosophies and the need to review and revamp the service provided. Financially hard-pressed local areas can no longer support rapidly rising operating costs and must accept cutbacks in service and fare increases. The planned phase out of federal operating assistance over the next few years will also hurt, particularly small and medium-sized properties.

Although federal funding support is being reduced, the federal government recognizes the substantial payoff in supplying the transit industry with technical aids and information designed to improve service delivery. Transit operators have never had the appropriate tools to be able to plan and operate service at a high level of efficiency. Further, they have rarely had even the information required to make good decisions consistently. In the current planning and operating environment, the ability to forecast the results of possible service and operations changes may be essential to the survivability of many operators in the coming lean years. As an example, most operators cannot estimate the net revenue impact of an operating change or, even in some cases, whether the impact might be positive or negative.

This paper describes the potential development and use of a system of automated tools that will enable transit operators to plan, maintain, and operate service efficiently (i.e., at a level of efficiency that will be acceptable to those who use it and to those who pay for it).

BACKGROUND

The concept of a system of transit planning, management, and operations aids in the form of handbooks and especially automated tools is not new. An early comprehensive description of what such a system should entail was prepared by the Transportation Systems Center in 1978 (1). That paper discussed the requirements of an operations-planning system (OPS) based on a number of structured conversations with transit operators across the country. The paper presented several examples of applications and a possible system design. In addition, it described in some detail the performance requirements and preferences for computer hardware and software capabilities that were perceived to be appropriate at the time.

Another 1978 paper (2) prepared by the Urban Mass Transportation Administration (UMTA) outlined many of the potential applications and benefits of automated data processing in the transit industry. It also suggested exploitation of emerging low-cost minicomputer and microcomputer technologies and state-of-the-art communications methods. A 1980 paper (3) updated the OPS concept by describing potential uses of the still-evolving microcomputer and minicomputer technologies. It also raised a number of issues relating to how automated processes could be designed and developed.

Since these papers were written, a number of events have taken place that provide increased impetus for the development of an OPS and suggest slightly different frameworks for both its development and use. First, the transit industry is again experiencing severe financial difficulties. The past decade saw expanding service and steadily increasing operating assistance at local, state, and federal levels. Operations and planning needs were often focused in such areas as new route design or schedule improvement. Although these remain important topics for planning-method improvements, a shift in emphasis is necessitated by the new transit operating environment. Reductions in operating subsidies that are forcing higher fares and service contractions will require a redirection of operating policies toward improvements in productivity and efficiency. Thus, tools that will quickly evaluate the effects of alternative fare increases and/or service changes are needed. Capital-planning tools to achieve the proper balance between facilities and operating costs are of extreme importance. Performance evaluation, cost analysis, and management information reporting are areas where help is needed badly, and soon.

Another significant event is the release of the first year's worth of Section 15 operating data (Urban Mass Transportation Act of 1964, as amended) (4). Now that comparable operating and financial information from most of the country's transit properties is available for all to see, it is certain that operators will become much more aware of areas for improvement and will appreciate help in realizing potential gains.

A third major event of relevance to transit planning is the rapid growth in the availability and use of small computers, which now can be found in common use in schools, libraries, small businesses, hospitals, and homes. Standardized components, peripheral equipment, and a variety of useful and inexpensive software make small computers ideal for an OPS. Their features and advantages have significant benefits for both the development of an OPS and the nature and extent of its use.

This paper describes a development philosophy for the OPS, a concept for its use, and a scenario for a subset of planning modules that would be representative of the system.

ELIMINATION OF BARRIERS TO USE OF AUTOMATION

There are a number of reasons why automated planning tools have not been extensively developed for the transit industry and why those that are available have not been widely used. The most important of these is cost for both development and use. Although the costs of computer hardware and machine time have been decreasing steadily for many years, it is only recently that the price of using automation would not represent a significant item in the budgets of small and medium-sized transit properties.

Today, for example, a microcomputer and associated peripheral equipment with significant capabilities and capacity can be bought for less than $10 000, and this figure will likely fall further. Also, there are no computer use charges.

However, the cost and time required to develop software for larger machines are items that have not decreased substantially, if at all. These costs, combined with other problems discussed below, have inhibited the development of planning tools for the transit industry. The risk of an expensive effort that might only result in limited use was too great, in many cases, to allow development to take place.

It is likely that cost efficiencies associated with microcomputers and minicomputers can change the nature of software development. For example, a large and increasing volume of commercial software that is transferable across a variety of machines is available. These packages, which approach the power of software that costs tens of thousands of dollars and that can be bought for a few hundred dollars or less, can be easily modified and tailored to transit planning and operations needs. If applications software developed on and for small machines can be acquired or built quickly and inexpensively, and if there is confidence that it will receive wide acceptance and use, then the need for a slow, systematic, and totally integrated design approach is vastly reduced. Rather, software modules for a variety of planning and operations applications should proceed in a fast parallel-track effort. Several approaches to addressing the same problem can be developed concurrently. Tools of a more experimental nature can also be built and quickly distributed to a select group of operators for assessment. Software can be tested, modified, and tested again or later upgraded, replaced, or scrapped if appropriate--all of this at a cost much less than that of traditional software development. Ease of maintenance and modification will also allow planning tools to be tailored to the needs of individual properties that have operating and financial processes that are rarely identical.

Until recently, the skills required to use computers and terminals were significant; hardware and software design was not user-friendly. Now, since no special skills or training are necessary to use microcomputers and many minicomputers, no specialized personnel need be hired or regular personnel sent to training courses.

Another general reason for limited use of automation is the psychological barriers involved in using larger facilities, which traditionally were felt to be imposing and intimidating. Many subconscious fears have been identified in conjunction with computer use (5). Terminals connected to a remote site are associated with fear of the unknown. Users of terminals or batch-processing facilities experience a feeling of lack of control. They may worry about the possibility of causing program blow-ups or system failures. They may fear embarrassment at making errors or appearing ignorant. Many of these problems apply particularly to managers and executives.

The new small machines, particularly microcomputers, eliminate most of these difficulties. Judicious design of software and user interface relies on a comfortable dialogue, eliminates jargon and job-control language, and can result in a virtually error-proof system. The instant response, compactness, and proximity of microequipment lead to a user atmosphere of control and privacy.

Finally, the state of the art of computer hardware and software has been advancing so rapidly in recent years that it was difficult to plan and design a software system that would not be obsolete in some aspects when it was finished. Although computer advances are not likely to slow, the basic features of today's small machines (e.g., personal operation, range of purposes, layman skills, etc.) are not likely to change.

The general population is becoming more and more comfortable with the use of computers. Witness the tremendous growth in 24-h cash-dispensing machines. In part this is due to the increased exposure of students at all educational levels to computers and to the increased use of computers in diverse facets of our daily lives. These trends may be even more relevant to the transit industry, which has been experiencing a high rate of management turnover and looks toward a younger group of transit executives and line managers to take over.

WORK-STATION CONCEPT

The flexibility, convenience, and economy of microcomputers permit a variety of uses widely ranging in functional complexity, some of which would not be appropriate with larger machines. Simple although time-consuming tasks of a clerical or computational nature are not usually feasible to perform with mainframe computers even on an interactive basis, or with minicomputers of the desk-size variety, for several reasons. First, machines that have processing-time costs are perceived to be too expensive to use for simple tasks, even if it could be shown that the net costs of labor and machine are lower than that of a labor-only process. Machine costs are often considered out-of-pocket costs and allocated to different budgets than labor costs, which are usually considered to be sunk and to have little or no marginal value for a small task.

Second, start-up chores for minicomputers and larger machines in each and every application usually make it highly inefficient for simple needs. These chores often involve telephoning, log-on procedures, use of job-control language, etc. The time required to accomplish just the start-up procedures in many instances would exceed that for performing the work by hand. Third, prior to the advent of compact typewriter-size terminals, the inconvenient locations of access to large machines made their spontaneous use infeasible.

Aside from the more obvious applications of microcomputers for transit operations planning and policy needs [e.g., routing and scheduling aids, forecasting and cost-estimating tools, training aids, management information reports, etc. (which are discussed later in this paper)], it is other applications, perhaps considered somewhat mundane, that make the work-station concept so appealing. For example, microcomputers can be used as scratch pads and simple calculators, either in conjunction with more complex processing or in separate computations. Or they could be used to recall and review frequently needed documents, tables, or data such as work assignments or daily cash flows that would otherwise have to be stored and retrieved from hard-copy files. Notes from telephone calls can be typed in real-time or stored after the fact along with supplementary ideas. Draft memos and letters can be input to the machine and transmitted to a secretary's terminal for editing and final preparation on a word-processing package. Most of these applications can be initiated with the touch of a few buttons and completed even more simply.

The work-station concept involves the placement of a microcomputer or a microcomputer terminal on an employee's desk or proximate work table for routine use--sometimes continuous, sometimes intermittent--similar to the use pattern of a desk calculator. In many circumstances it will be appropriate for several staff members to have readily accessible terminals. For example, a junior clerk may be responsible for receiving, processing, and reporting ridership data by using a microcomputer data-base package. One of a service planner's major duties may be the design and evaluation of route-service changes by using stored information on schedules and patronage combined with a service-cost model. And a department head could access the latest budget projections from several divisions (e.g., maintenance, supplies, utilities), display the data in tabular or graphic form, and perform a variety of analyses including, for example, a comparison of the property's cost trends with those of other operations (by using stored Section 15 data) or perhaps forecasting future Section 15 cost and performance measures for planning purposes.

In fact, it can be seen that maximum benefits will accrue when several types of staff have access to and use microcomputers, thus enabling information and data at many levels of detail to be passed back and forth with little effort. Effects of changes in one area on another (e.g., revenue service on maintenance operations) can be observed--an important control capability for management. Data can be transferred either by linking the microcomputers to a larger central computer (which might be required to maintain a centralized data base) or by linking them directly to each other by using a communications network.

Further, the use of microcomputers expands, rather than precludes, the possibilities of using larger machines, data bases, and software applications. Microcomputers can be used as terminals to connect to a variety of computers that have features and capabilities far beyond those of the small machines. In particular, present users of the Urban Transportation Planning System and other existing automated planning tools will find that they can access and exercise these tools more easily with microcomputer terminals.

In summary, the benefits of a microcomputer work station are the ease of information organization and storage; the facility to communicate ideas, text, and data in a structured, yet effortless, manner; and, of course, the capabilities of an on-line computer always at one's fingertips.

OPS CONCEPT

The OPS concept is that of evolving systems of compatible automated tools for use directly by transit property staffs. Ideally, every staff member who would make substantial use of these tools would have a dedicated terminal, although this is not essential. The OPS will contain both management information functions (such as monitoring, data organizing, and reporting) and analytical techniques for accounting, planning, forecasting, and evaluation.

Although it is intended that the products be useful to properties of all sizes, the target user groups will be the small and medium-sized operators who perhaps have greater needs. Initially, some of these products may be automated versions of existing manual procedures, many of which are inefficient only because they are manual. Later research will result in new techniques that are designed to take maximum advantage of the computer and the integrated systems. As much as possible, OPS tools will be compatible with management information systems already in place. They will also take advantage of commercially available software.

Importantly, the OPS is also seen as a framework for the development of automated systems. Because the federal government does not want or intend to be the sole developers of transit operations tools, it will be highly supportive of private organizations that wish to invest their own capital to develop and sell their own related products and services. In order to encourage these efforts and to increase their overall usefulness, the OPS project will include the development of standards for creating automated tools (e.g., protocols, software languages, interface formats, data structures, recommendations for hardware and software configurations, and other guidance). These standards will improve the chances that independently developed products will be compatible with others and thus promote a wider market for their use.

SAMPLE APPLICATION

As discussed above, the work-station concept encompasses so many useful functions that it is hard to imagine a process or task that could not be carried out more efficiently with a microcomputer OPS. Here, however, we shall briefly describe an application that represents one of several prime uses of the system and would be performed on a fairly regular basis: Analysis of transit route data for purposes of route-performance evaluation and performance forecasting. The primary components of this application include (a) capture of route-level data, (b) data synthesis and route-performance reporting, and (c) forecasting of route performance under assumed conditions.

Data Capture

Data required for route analysis include those that describe both the demand for and supply of service on a route. Primary demand data include route ridership and revenue and rider characteristics. Major supply data include route operating cost and level of service (i.e., service frequency, accessibility, speed, and reliability). The focus in this example is on capture and use of route-level demand data.

Procedures for gathering and processing route ridership and revenue data vary across operators. Some record total farebox receipts on a daily basis and later allocate them to routes and derive passenger totals. At the other end of the spectrum, a few properties with automatic vehicle monitoring (AVM) can gather passenger and revenue data by location and time of day. Flexible data-entry capabilities can be provided at the work station to accommodate these variations in data-gathering procedures and data levels of detail.

For example, clerical or other staff will be permitted to enter via the work-station keyboard daily fare receipts on an hourly, per run, or other basis depending on typical practices or whether the data were to be used for a special study. Data-entry software can be structured to automatically accumulate receipts to a desired time period (e.g., weekly or monthly) to simplify routine updating and provide period-to-date information. Electronic worksheet methods are particularly well suited to this type of application. Additional features can be provided for entering other types of data (e.g., rider characteristics from surveys) that support related applications (e.g., revenue-to-ridership derivation).

Performance Evaluation

In this example, route revenue and ridership data sets that correspond to a particular time period would likely be stored in a microcomputer's secondary memory (i.e., on magnetic disc) or perhaps in the memory of a larger centralized computer that could be accessed by a microcomputer or a terminal. These data could usefully be synthesized with supply data (e.g., operating cost, vehicle miles) to produce route-performance indicators and reports. Capabilities could be available to the work-station user for defining or modifying performance indicators and report formats. In addition, various evaluation aids (e.g., flags for substandard performance) can be used to simplify information assimilation. Data-base management methods can be used for performing the data retrieval, manipulation, and storage operations concomitant to these applications.

For example, existing route ridership, revenue, and operating cost data sets can be synthesized to create the performance indicators revenue per dollar of operating cost and operating cost per passenger. Figure 1 shows a possible performance report as it would be displayed at a work station. The asterisks adjacent to certain numbers are flags for substandard performance (as defined by the user).

In addition to tabular reports, graphical-display capabilities will be provided as an integral part of the performance-evaluation subsystem. Standard bar chart, histogram, and data-plot displays can be used in performance comparison and statistical analysis (e.g., for market research purposes). Graphical displays can also be tailored to specific service-planning applications as, for example, the route passenger-loading profile shown in Figure 2. In addition, interactive graphics methods can be used to assist in more complex, spatially oriented design applications. Relevant service-planning applications include specification of zone fare structures and geographic placement of transit stops and routes.

Performance Forecasting

Computer-aided entry and analysis of data on existing service operations can help greatly in diagnosing problems and suggesting possible service improvements. However, to evaluate proposed service changes or answer "what if" questions requires forecasting of performance under various assumed conditions regarding level of service, service definition, and environmental factors.

Applications programs that use supply-and-demand models to forecast ridership, revenue, and cost performance are being developed for use on microcomputers (see paper by Turnquist, Meyburg, and Ritchie elsewhere in this Record; also see BUSMODEL from Colin Buchanan and Partners, 47 Prince Gate, London SW7 2QE, England). Such programs enable a transit analyst to specify (at the work station) changes in route or systemwide headways, fares, speeds, stop spacing, and alignment and to receive within seconds forecasts of resultant impacts on performance. Performance measures and reports used for evaluating existing service can be used for evaluating proposed new services or service alterations.

For example, service changes on a route with a substandard operating ratio can be tested with forecasted operating ratios reported for each attempted change to compare with the existing operating ratio. Other measures can also be reported to examine trade-offs in service performance along several dimensions (e.g., operating ratio versus ridership).

Numerous tests of alternative service or route

Figure 1. Performance report display.

SYSTEM PERFORMANCE - REPORT 1

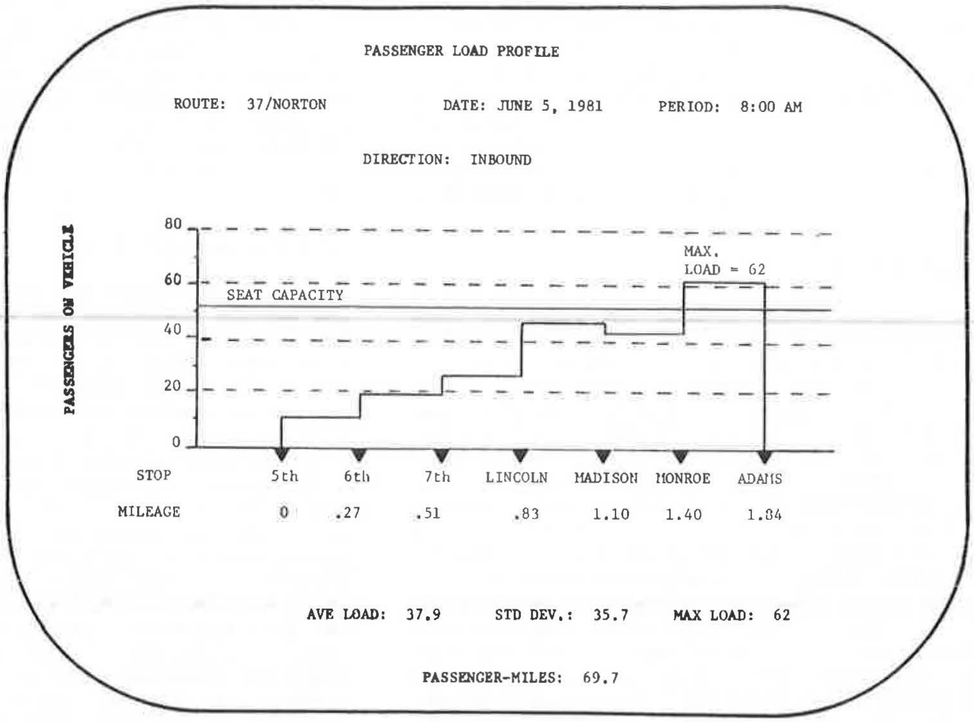
MONTH: JULY 1981

#	NAME	REVENUE	OPCOST	RIDERS	REV/OPCOST	OPCOST/RID
XXX	SYSTEM TOTAL	164000	390000	365090	.42	**1.06
17	BLANCHARD	30000	60000	59642	.50	**1.01
21	ELIOT	16000	80000	35320	**.20	**2.27
37	STOCK	34000	70000	75055	.49	.93
37	NORTON	45000	100000	99338	.45	**1.01
38	LOBO	39000	80000	86093	.49	.93

DO YOU WANT A PRINTED COPY OF THIS REPORT? (Y/N) 'N'

DO YOU WANT TO DISPLAY ANOTHER REPORT? (Y/N) ▶

Figure 2. Load profile display.



specifications can be made quickly at the computer work station by using automated performance-forecasting methods, especially if the man-computer dialogues are well designed and simple. More thorough examination of potential service improvements by the transit planner or manager will be encouraged. Higher quality management decisions and greater service delivery efficiency will result.

OPS DESIGN ISSUES

The OPS will be, in essence, a set (or, more likely, sets) of tools that provides information to transit management. Like any tool, it must be used to be effective. Because its use will not be mandated, the OPS will be used only if the value of the information it provides exceeds the cost of obtaining it. The basic goal of the OPS design and development effort, then, is to produce tools that provide the best possible ratio of information quality to price, subject to the constraints of the development effort. This section investigates certain OPS design issues that will influence its ratio of quality to price.

Maximizing Information Quality

The quality of the information produced by an OPS is related to its usefulness to management and to its reliability. It must be recognized that different transit properties operate in different ways and information useful to one may be of little interest to another. For this reason it will be vital to design the OPS so as to permit customization. For example, while certain basic reports may be available to all transit properties (e.g., reports that support Section 15 reporting requirements), an OPS should permit each property to design its own ancillary reports. Similarly, different properties collect different operations data; thus, while certain data items may be required of all properties, an OPS should permit each property to add supplemental items as it sees fit. Each operator will have the opportunity to incorporate local innovations and tailor the system to his or her own capabilities. In general, an OPS should be designed to permit each property to mold the OPS information output to fit its particular information needs.

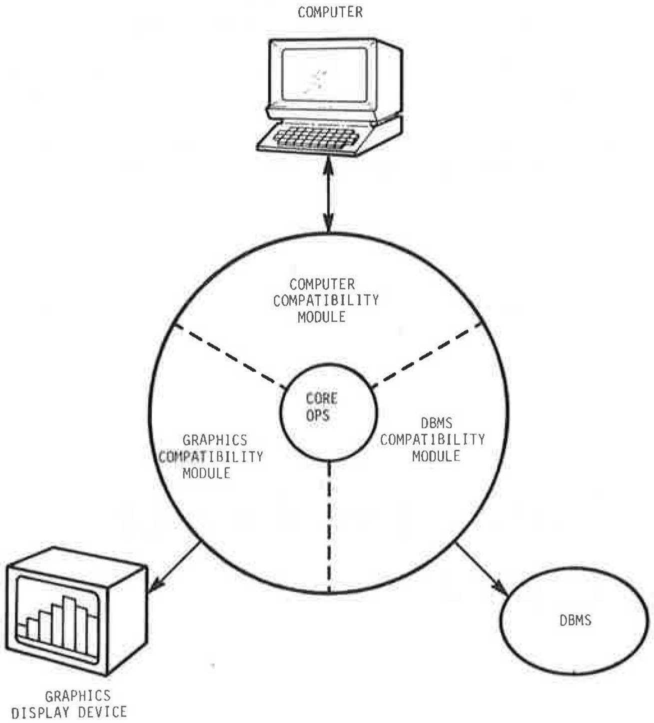
The other component of information quality--the reliability of the information produced--is related to both the quality of the methods that produce the information (e.g., the goodness of a particular forecasting technique) and the frequency of errors in the OPS. Although the OPS will be designed to minimize errors, not all errors will be found during development; thus, some mechanism must be developed to enable the OPS to be upgraded as necessary. In addition, since better forecasting techniques and new analytical capabilities will also be developed later, the OPS should be designed to incorporate such modifications gracefully by using procedures that require minimal specialized knowledge, and it should permit a typical user to accomplish any upgrade with no more than, say, an hour of labor.

Minimizing OPS Costs

The cost of creating and maintaining an OPS data base will be a major component of OPS costs. Many of the advances in data-processing technology in the past decade have been aimed at eliminating data redundancy (i.e., separate storage of the same data for different purposes). The OPS will of necessity use much information that has other uses. Revenue data and timetables are two simple examples. Entire software subsystems called data-base management systems (DBMS) have been developed to reduce data redundancy. The use of a DBMS can dramatically reduce total system data costs. It is likely that the OPS must use a DBMS if it is to be economically viable. The OPS will also require the use of a graphic-display device to produce visual displays of operational data.

The OPS is thus a system that will require the support of two pieces of specialized hardware (a computer and a graphic-display device) and one piece of specialized software (a DBMS). (Other pieces of

Figure 3. OPS compatibility modules.



hardware such as a printer, disk drives, and user terminals will be required as well. However, these items have achieved a degree of standardization that makes it likely that the OPS will be able to use whatever brands the operator selects. In short, compatibility with these items is not a major design issue.) All three items are available in numerous forms from numerous manufacturers, and the diversity is likely to increase in the future. Moreover, many transit properties already own some of these items and use them to perform tasks that complement the OPS functions (e.g., maintaining payroll and inventory records). The initial cost of an OPS can be minimized if it can use the support items already possessed. To permit this, however, the OPS will have to be designed to permit it to interface with a wide variety of computers, display devices, and DBMSs.

The OPS could best respond to this diversity if it were designed to employ compatibility modules. All of the analytical functions of the OPS would reside in a core module that would interact with the computer, the graphic-display device, and the DBMS only through the compatibility modules. This arrangement, depicted in Figure 3, would isolate the analytical capabilities of the OPS from the diversity of the environments in which it will operate. Every transit property would use the same core module, but each would use different compatibility modules to link the OPS to the particular computer-display device and DBMS in use on its particular computer system. Sets of modules could be merged together to form turnkey packages. The compatibility modules will also increase the ease of integrating software developed by private organizations and the transit properties themselves. This concept has been applied successfully to many other systems.

The operating cost of the OPS will be of little consequence to properties that can use the cheaper minicomputers and microcomputers. But even for those that choose to use OPS on large mainframe computers, careful design will minimize operating costs.

One cost factor that is normally a major concern for transit properties is personnel costs. These costs can be minimized by designing the OPS to be very easy to use. The design should strive to ensure that every minute of human interaction with the OPS will be spent productively. All clerical chores, such as keeping track of data, should be automated. Also, the OPS system must be easy to learn so as to minimize staff training time. Again, use of the compatibility-module concept will help reduce these costs by minimizing the new equipment with which the staff must become familiar.

One final cost is the hassle factor--the intangible cost of frustration. A system that frustrates its users, perhaps by surprising them with unexplained bugs or by requiring convoluted machinations to accomplish an essentially simple task, would not be worth using any more than would an expensive system. The hassle factor can be reduced only by emphasizing the human engineering aspects of the OPS design.

AN OPERATOR'S PLANNING SYSTEM

The U.S. Department of Transportation, through UMTA, is supportive of programs to supply the transit industry with technical aids and information to allow self-improvements in performance and efficiency. UMTA, in conjunction with the Transportation Systems Center, is generally following the concepts described in this paper. The development strategy includes a number of steps designed to provide and maintain consistency between operator requirements and capabilities and the technical design of an OPS. A primary element of the development strategy is transit operator involvement. This includes discussions at the outset with operators concerning their immediate needs, testing and experimentation by operators as each module is prepared, and continuous feedback from operators as the system begins to take shape. An advisory group of representatives from the industry has been formed to advise, review, and test through the development process. System-design standards related to technical design approach and system structure, coding conventions, formats, documentation, and hardware will be researched, including a study of where standards and design guidelines make sense. A clearinghouse for information on ongoing projects, experiments, and up-to-date planning methods and ideas will be set up.

It is hoped that these steps will result in a smooth and effective development process for a highly useful set of planning tools for the transit industry. These tools will include some developed by the federal government, but also those developed by private organizations and the transit properties themselves. When the system is complete (to the extent that most of the functional objectives have been met), it may exist in several variations that correspond to the idiosyncrasies of different transit operations. But each one will be the operator's system. It will need to be modified or upgraded only when the operator's future requirements change.

Today the transit industry is attempting to withstand severe shocks to its financial structure and its base of support. We hope that speculation that these changes will eventually bring the industry to a strengthened position prove to be true, and we trust that the OPS will greatly increase its chances.

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Automatic Vehicle Monitoring: Effective Technique for Transit System Management and Control

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In the context of searching for new approaches for efficient transportation system management and utilization, the Urban Mass Transportation Administration (UMTA) has funded a comprehensive demonstration of an automatic vehicle monitoring (AVM) system in Los Angeles. AVM coverage includes approximately 10 percent of the Southern California Rapid Transit District's (SCRTD) route miles and buses. The system is now operational, the AVM capabilities having been phased in over a year's time. Although the evaluation program on the part of UMTA and SCRTD continues, analysis of the impacts to date shows that benefits have accrued in several areas of transit system operations, including route scheduling and information management, improvement of day-to-day system reliability, rendezvous of scheduled and nonscheduled vehicles, and response to emergency situations.

The cost of providing public transportation service continues to increase due to the high price of energy, other increasing operation and maintenance costs, and the rising costs of building new system elements and/or replacing rolling stock. Thus, operators of public transportation systems, as well as federal, state, and local officials, are looking in earnest at techniques that enable better use of existing systems, and especially the use of buses that have the flexibility to accommodate geographically shifting passenger demand. Questions arise as to how the nation's bus fleets can be used more efficiently and effectively. One approach that is receiving increasing attention is the use of automatic vehicle monitoring (AVM).

In the above context, the Urban Mass Transportation Administration (UMTA) funded an AVM demonstration project in Los Angeles with the cooperation and participation of the Southern California Rapid Transit District (SCRTD). The basic purpose of the demonstration was to enable the evaluation of the effectiveness and efficiency achieved in bus system operation through use of the real-time monitoring and control capabilities of a fully operational AVM system. The project represents the first such comprehensive AVM implementation in the United States. The system was developed and installed by AVM Systems, Inc. (formerly a division of Gould, Inc.) and was operational in spring 1980. The Transportation Systems Center, UMTA, served as system manager for the project.

HISTORICAL DEVELOPMENT OF AVM

AVM is not a completely new concept (1), having been used in one form or another as early as 1935 in Chicago to check on streetcars and for buses in the 1940s. Information on headways was being collected automatically by 1955 in Pittsburgh, St. Louis, and Philadelphia, and optical scanning was being used in London in 1958 (2). However, in these early attempts, vehicles were not necessarily explicitly identified nor was there any attempt at real-time control by using the information that was obtained.

Currently, AVM is considered to be directed to real-time monitoring of vehicles (e.g., location) with the potential for exercising control as opposed to only identification. The basic components of the modern AVM system include the following (3, p. 202):

1. Vehicle locating and status monitoring devices,
2. Communications system, and
3. Central control facility.

Although AVM has demonstrated application in any operation that involves the coordination of fleets of vehicles (e.g., taxis, police cars), several recent experiments with transit operations are of immediate interest. Lukes and Shea (2) and Miller and Basham (4) describe an experiment in the early 1970s that focused on citywide AVM coverage for a small percentage of the Chicago Transit Authority's (CTA) rolling stock. The AVM-equipped buses were those providing "owl" service. Although problems with equipment and an apparent lack of execution of the control potential by CTA dispatchers hindered the experiment, conclusions were that use of AVM resulted in schedule and headway adherence that was at least as good as that achieved with manual control that, according to the authors, would have resulted in sufficient manpower savings to economically justify the system.

Bevilacqua and others (5) describe a more recent demonstration--the General Motors' transit information system (TIS) in cooperation with Cincinnati's Queen City Metro transit system. That system, while