MICHIGAN TRANSPORTATION RESEARCH PROGRAM

APPLICABILITY OF DIGITAL DATA COMMUNICATION FEATURES IN PUBLIC TRANSIT SYSTEMS: EXECUTIVE SUMMARY

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16. Abstract

A survey was conducted of the state of the art of automatic vehicle monitoring (AVM) systems and their use in public transit, taxi, and police operations. The survey identified systems applicable to improving operational efficiency and quality of service, and reviewed various of their elements related to AVM systems. These elements included vehicle location, vehicle identification, vehicle monitoring, computer scheduling, computer dispatch, silent alarms, security alarms, mechanical alarms, on-board readout, real time display, passenger counting, management reporting, and digital data hardware.

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Preface

This report stems from a request by Mr. Charles Uray, Jr., Chief Deputy Director, Michigan Department of State Highways and Transportation, to the Michigan Transportation Research Program to carry out a technology assessment on specific transit features of Automatic Vehicle Monitoring Systems (AVM).

In recent years, digital data communication techniques have been combined with mobile radio communication systems to provide an expeditious and expansive information transfer between vehicles and control centers. Numerous systems are currently operative and planned for installation in the United States for operations involving law enforcement, transit operations and to a lesser degree taxi operations.

The emphasis of this paper is on those AVM systems that are applicable to improving the operational efficiency and quality of service of transit operations.

Due to the size and scope of this project, the issue of applicability of digital data communication systems in public transit industry were addressed by using the present state-of-the-art information as available through technical papers, journals, magazines and published reports of the projects that have been implemented across the country. This report is an executive summary of the conclusions and recommendations arrived at by the authors on the basis of the review of the literature.

Executive Summary

A. Introduction

Digital data communication systems provide real time vehicle identification and location which when coupled with passenger counting allows the transit manager to apply more accurate fleet deployment and control strategy. The digital data communication system components have been utilized, either fully or partially, in various systems to date, including emergency response systems and police units with recent applications in public transit systems. Optimal application of control strategies, based on a real time vehicle location data, provides a potential for reducing cost, as well as increasing the level of service, thus providing a potential for increased operating efficiency. While it is widely accepted that the hardware elements necessary for digital data communication systems have been in practical use for quite some time, the application of an AVM (Automated Vehicle Monitoring) system in public transit is fairly new. As such, a careful investigation is required to determine the features that should be included in a comprehensive AVM system for a public transit application. The feasibility of the application of a digital data communication system in the public transit industry, has been addressed in this study with specific emphasis on the following questions:

1. Is this system operationally feasible for public transit operation as it exists today?
2. Is it financially feasible to implement a digital data communication system to improve the management capability of public transit operators as well as the level-of-service of the riders?

3. Is the system and its components, which are generally used for an AVM system, maintainable by the operating agencies? Are system components and spare parts which are necessary to keep such a system in good working condition easily available on a timely basis?
4. Has the "track record" of such system applications, as well as the reliability of the individual hardware components in other areas of digital data communication systems been established?
5. Is an AVM system cost effective and if so under what circumstances?

All of these questions need to be addressed on the basis of the past experience of the operating agencies in the area of public transit and digital data communication systems. While the answer to the above questions can be fully addressed by a controlled experiment (using digital data communication systems and all their components for a public transit application) for the sake of this report, the authors have addressed these questions by utilizing state-of-the-art information as available through technical papers, journals, magazines and published reports of the projects that have been implemented across the country. In addition, the authors participated in dialogue with persons actively engaged in AVM systems.

In order to fulfill the objective of this study, a critical review of the various elements related AVM systems have been made. These elements included vehicle location, vehicle identification, vehicle monitoring, computer scheduling, computer dispatch, silent alarms, security alarms, mechanical alarms, on-board readout, real time diaplsy, passenger counting, management reporting and digital data hardware.

B. Conclusions

A review of the state-of-the-art of the AVM system and its various elements resulted in the following general conclusions.

1. Past experience has demonstrated that electronic vehicle monitoring can improve the service and efficiency of transportation systems.
2. The transit operating process includes the following basic tasks.
   a. Planning
   b. Operations and control
   c. Providing data for management decisions
   d. Marketing and promotion.

   All of these tasks can be performed more efficiently if a well designed AVM system is implemented in an area where there is need and scope for improvement in the public transportation system.
3. There have been several generations of innovations of automatic vehicle monitoring and location over the last three decades. The current generation of AVM systems which utilize digital data communication hardware provide the most potential for improving efficiency of the operating agencies, as well as providing direct and indirect benefits to the system users. The use of electronic processing equipment provides an additional benefit in terms of achieving optimality in scheduling and in providing data for management purposes. The vehicle control system is also benefited by the use of information which can be collected and retrieved via electronic processing equipment.
4. The use of two-way digital communication allows a greater degree of driver self regulation and more effective control actions by the

dispatchers. The use of a digital data communication system in public transit with the current control strategies is effective for the following operating functions of public transit operators.

a. Scheduling and dispatching

b. Route supervision

c. Emergency handling

d. Maintenance

5. AVM systems have been applied in police and other para-transit applications, such as taxi cabs, in various communities in this country in addition to public transit applications.

6. Cost Benefit Analysis of application of AVM systems in various functions (police, public transit and taxi) was performed by the Department of Transportation, Urban Mass Transportation Administration. The data indicated that application of digital data communications systems can provide significant cost savings for police operations. This is primarily due to the high cost of the patrolmen's labor. Therefore, even a small reduction in the required number of vehicles can account for large amounts of overall savings.

7. The same study also concluded that the direct cost savings for public transit applications can be considered positive. A significant amount of savings can be achieved by using AVM systems which replace manual schedule checkers. The study also concluded that the savings that could be realized varied widely between the communities due to large differences in operating costs such as insurance, administrative and maintenance costs, number of personnel, paystales, and characteristics of the transit systems.

8. The same study also concluded that often only limited immediate payroll savings can be expected by installing a digital data communication system. This is due to the fact that personnel are often unionized and their positions are relatively secure. Any manpower reductions brought about by an AVM system must occur by not hiring replacements for departing employees.

9. The same study also concluded that overall costs and benefits are highly dependent upon the numerical magnitude of the bus fleet in specific public transit applications.

10. The benefits which can be derived from the installation of silent alarm systems are important but it is difficult to estimate the tangible benefits that can be attributed to such items. The resultant increase in passenger/driver safety and state-of-well-being can be considered an extremely important by-product of AVM systems.

11. The capability of AVM systems to collect data, process this data by use of electronic processing equipment and produce data summaries, can be considered as extremely important. This data collection and retrieving capability provides management with the information vital to increasing operational efficiency.

12. The capability of AVM systems to provide realtime information about bus schedules to passengers has been concluded by various studies as increasing the perceived level of service. While it is difficult to attach any tangible benefit on this capability of AVM, it does provide a potential for increasing transit ridership by allowing riders the opportunity to better plan their trip.

13. Various hardware components of AVM systems have been used in many diverse applications such as computerized traffic control systems, banking systems, inventory control, toll collection, security procedures, parking control, etc. As evidenced by their widespread usage today, these applications have satisfactorily performed their intended purpose. As such, it can also be concluded that there is an adequate supply of hardware components for use in public transit applications that have been tested under actual field conditions and found to be acceptable.

14. The maintenance record of existing AVM systems is not available in a form which would allow an analyst to perform an effective cost benefit analysis. There are private companies that can perform the maintenance activities which are necessary to keep an AVM system in good operating condition, on a continuing basis, at reasonable cost. Such an approach for continuing system maintenance is presently being used in computerized traffic signal systems. It is believed that similar companies would be available to perform the maintenance functions for an AVM system.

15. While the costs of electronic hardware have in the past displayed downward trends, the associated software costs have been escalating. Therefore, any future cost reductions for the central processing equipments or micro-electronic technology would probably be offset by the increased labor cost involved in developing, implementing and maintaining sophisticated software systems, as well as increases in AVM labor costs. Thus, it is believed that future cost reduc-

tions of the central processing equipment and micro-electronic technology may not have any significant cost saving potential on an overall spectrum.

16. Most researchers and system operators agree that careful planning and management is necessary to exploit and expeditiously utilize the vast amounts of data which the digital data communication capabilities can offer to public transit systems.

16. Most researchers and system operators agree that careful planning and management is necessary to exploit the potential benefits which digital data communication capabilities can offer to public transit systems.

17. A review of the available literature does not indicate any specific criteria pertaining to when a comprehensive digital communication system becomes cost effective. It can be concluded therefore, that a set of feasibility criteria need to be established in order to determine when a digital communication system will be desirable. This criteria would be beneficial in determining the appropriate size and characteristics of a public transit system that would warrant digital communication facilities.

18. While mechanical alarms are an effective means of reducing road service calls and major repairs, it is not practical to install all of the necessary sensors on existing transit fleets. Experience in

Chicago, for example, has demonstrated that the cost of installing certain fuel level sensors on existing fleet vehicles was prohibitive. As such, they ensured that the necessary on-board and central control equipment had the add-on capability for monitoring fuel levels and to install mechanical senors only on new vehicle purchases. This strategy allowed the eventual placement of fuel sensors on all vehicles without excessive initial cost.

19. The wealth of information received from an AVM system may not improve the level of service if adequate planning and personnel training is not conducted prior to system implementation. For example, a system that was installed in Paris developed problems because the controllers did not know, how to use real time information to control the schedule performance of the buses on the route. They had traditionally been accustomed to only controlling the route through departure regulation at the route terminal. With the new information, the controllers were unable to visualize well enough in advance, the corrective strategy that would be required to maintain a high level of operating performance.

20. Due to labor restrictions, employee unions and policy procedures, there are often no immediate savings to be realized due to reduced manpower requirements of AVM systems. In fact, the converse may be true. If the existing personnel are not able to adapt to the new job requirements then personnel, shifts and additional training might be in order.

21. More experimental work is needed to demonstrate, quantify and/or measure the degree of improvements that can be expected from an AVM system.

22. There are quite a few systems under implementation and/or operation, which may provide additional evaluative data to perform a comprehensive study to establish parametric criteria of feasibility of AVM systems.

The above conclusions made for AVM systems have in general been based on the experience reported in project research papers and technical documents. More specific conclusions relative to each individual subelement of the AVM system have been made and are presented in the following section.

Silent Alarm Security

1. The silent alarm function of the AVM system is generally considered to be a very significant benefit to any transit property.
2. The drivers find the silent alarm as an added security measure for the security of themselves and the passengers, especially during the times of darkness and off-peak passenger loadings.
3. The indirect benefits which can be derived out of a silent alarm system include reduction in crime rate, reduction in property loss, increased passenger confidence and an increase in operating revenues. The increase in operating revenues can be attributed to the increased passenger confidence in the public transit systems. The past experience of researchers gives no indication as to the magnitude of ridership increases that can be expected due to the installation of a silent alarm system. All researchers and transit authorities generally agree however, that this feature is an extremely important element in AVM technology which has an indirect impact on the increase of transit ridership.
4. The silent alarm system can also act as a crime deterrent for subversive activities occuring outside the buses. By the use of mobil communication equipment to report subversive activities, the vehicle driver can be an immense aid to law enforcement agencies in the quick apprehension of criminals.
5. The Philadelphia Transit Authority believed that silent alarms were one of the most important features of their test system. Although no dollar value was assigned, they believed that the benefits provided sufficient reason to proceed with an AVM implementation which might otherwise be marginal in terms of cost effectiveness.

Mechanical Alarms

1. Sensors placed on the vehicle to monitor parameters vital to the mechanical performance of the vehicle are effective in reducing the number of road calls and major repairs.
2. An indirect benefit of these sensors is that vehicle failures can often be detected in time to allow the dispatcher extra time to make remedial strategies. This can result in a replacement vehicle or similar maneuver being ready to reduce passenger lost time and inconvenience.
3. The cost for purchasing and installing the sensors is more than offset by the monies saved in repair and road calls.

Farebox Alarms

1. Perhaps the largest advantage that is gained from this alarm is the reduction in violence and intimidation usually accompanying farebox robberies.
2. The farebox alarm can be an effective means of protecting the vehicle equipment during storage.

Vehicle Locating, Monitoring and Identification

1. There are two basic applications of AVM systems: fixed route and random route coverage. Although the main concept of both of these applications is the same (locate and trace a single or group of vehicles), the technological requirements of these systems vary.
2. Sharing costs among a mix of users does not provide significant savings because only a portion of AVM costs are eligible for sharing between users. In addition, a particular location subsystem which is very economical for a fixed route operation may not be very economical for a random route operation. The benefits of shared cost are diluted when participants comprise otherwise lower individualized

technology costs.

3. There are three basic AVM location technologies:

   a. Signpost (both broad and sharp)

   b. Radio frequency

   c. Dead reckoning

   All three location subsystems have certain advantages depending on the type of coverage and the requirements of the user.

4. The following location accuracy requirements were specified by UMTA in Philadelphia (1975) for tests in 1976/77:

   a. Performance specification of 300 ft. accuracy (with 95th percentile certainty) on both fixed and random routes.

   b. Performance specification of 15 seconds time-of-day passage accuracy (with 95th percentile accuracy) on fixed routes.

5. A number of tests of AVM systems have been conducted both in the United States and foreign countries. A conclusion of these AVM tests illustrated that the accuracy requirements could be met with the technhologies available at that time.

6. The Cost/Benefit analysis of AVM systems tested in Philadelphia had the following conclusions:

   a. AVM systems tested or installed previously, have not assigned importance to formalized cost-benefit related data gathering or analysis.

   b. Police cost savings are the most significant due to the high cost of staffing patrol cars.

c. Bus savings are considered positive - However, approximately half of the total savings are made possible by linking automatic passenger counters with AVM in order to replace manual schedule checkers. AVM bus savings vary widely between cities due to extreme differences in operation cost factors such as insurance, O&M, number of checkers and service operating characteristics of transit properties.

d. Costs and benefits are highly dependent upon site and fleet characteristics. Implementation planning must consider the changes in location system costs associated with changes in fleet size, mix or utilization, and operating areas.

e. Usually careful planning and management are required to exploit AVM's potential benefits. The extend of savings can vary greatly with slight changes in AVM utilization.

7. Results of the Huntington beach AVM tests include:

a. Failure of a few signposts had no major effect on the system operation.

b. Theft and vandalism of signposts posed only a minor problem.

c. Location accuracy of $\pm$ 300 feet on major streets and $\pm$ 600 ft. on minor streets was achieved.

d. The measured location accuracy of $\pm$ 300 feet at 70th percentile was achieved against a design specification of $\pm$ 350 feet at 50th percentile.

8. Results of the Hazeltine AVM system test in Dallas (for police operations) indicated that an average location accuracy of 270 feet (with 95% certainty) was achieved.

9. Foreign experience in AVM systems have shown that it is imperative that drivers and operators be trained in the use of AVM systems to achieve the full range of possible benefits.

Passenger Counting/Management Reporting

1. Passenger counters can be installed on every vehicle or on a limited number of vehicles for selective studies. When incorporated with the appropriate software packages they can provide important information. This information can be used to obtain a history of seasonal, daily and hourly fluctuations of passenger demand for use in modifying and/or changing routes and headways to maintain the desired level of service.
2. A computerized management information system offers significant benefits in the form of increased fiscal efficiency and customer satisfaction.
3. The computerized information system can inexpensively perform system analysis that are costly in manual systems because of the manpower requirements. The use of electronic processing equipment can result in beneficial analyses being performed that were not done in the past. Examples of some possible analyses to be utilized for increasing system efficiency can be described in the following categories.

   - Driver Performance - When used in conjunction with schedule performance analysis, these records can be used to detect and evaluate service inefficiencies that are driver related.

- Fare Type Analysis - For those transit authorities that use a weighted fare system, this information can provide an important marketing impact for experimenting with different fare structures.
- Incident Analysis - This will improve the accuracy, extend analysis capability and reduce the hand over time as well as the cost of manual incident record systems.

4. Good measures of ridership statistics insure that some routes are not over served nor others inadequately served. This information is useful in increasing the level of service and system efficiency.
5. The appropriate use of available software programs can be instrumental in increasing management capability and reducing current manpower requirements of field supervisors, checkers and central control personnel.

Computer Scheduling and Dispatch

1. The use of electronic processing equipment to establish time tables results in a drastic reduction in the lead time required for manual systems. This makes possible not only savings in manpower but the establishment of various time tables to more closely reflect the seasonal, daily and hourly fluctuation in passenger demand.
2. The system can establish a closed loop information flow that permits a dispatcher to know the disposition of his vehicles and enables him to control their deployment. This information can be used to ensure that schedules are realistic and only the nearest vehicle is used in response to system demands.
3. Realistic timetables result in reduced layover time due to stricter schedule adherence and reduced uncertainty of total travel time.
4. A more even distribution of passengers between vehciles is also a benefit derived from realistic timetables. This results in greater

passenger comfort and a reduction in equipment needs.

5. Computer scheduling results in fewer personnel required to establish, check and control timetables and schedule adherence.
6. Knowledge of the disposition of vehicles and drivers allows the dispatcher to reduce the average response time to service and emergency calls.

Schedule Adherence

1. The real time information available from AVM systems coupled with electronic processing equipment makes possible a dynamic vehicle schedule. Changes can be made in the transit schedules, based on this information, that will be responsive to the changing transit demand, traffic characteristics and unusual incidents.
2. Computer assistance is available through software programs that are designed to handle the necessary information flow and calculate the trade off effects of the remedial actions taken to remedy service disruptions. The system is an invaluable management aid by not only taking into consideration the reason for the disruption but passenger considerations, environmental conditions, time of day, relationship between the delay and recovery time and the possible effects on other routes by the remedial action taken.
3. The improved service regularity possible by stricter schedule and headway adherence can result in increased patronage and operating revenues.
4. Improvements in schedule adherence and reliability often allows the transit authority to increase headways without lengthening the perceived passenger waiting time. The increased headway reduces the equipment and driver assets invested in the route and can increase

the average passenger load factor on each vehicle.

Onboard Readout, Dispatch Systems

1. For fixed route transit systems, it is sufficient to have two way voice communication supplemented by precoded function keys on the vehicle control head. The function keys serve to expedite requests and commands that are frequently used while reducing the required actions of the vehicle operator.
2. Ease of operation and lack of complexity are required of any on-board equipment to reduce driver confusion and to obtain their cooperation.
3. For variable route transit systems, an alphanumeric display is often advantageous in addition to voice communication and precoded function keys. These displays can be used to show the vehicle operator the queue of passengers and the most expeditious routes to meet passenger demand. Besides reducing passenger wait time the displays can be instrumental in reducing the total vehicle miles.
4. The on board communication equipment makes it possible for the dispatcher to contact all the vehicles on a particular route or individual vehicles as needed. This makes it possible for the disptacher to implement real time control strategies to maintain schedule adherence and headway.
5. Control heads are currently available from a number of manufacturers. In accordance with the specifications and needs of the purchaser, this equipment can be bought from production models or constructed to meet the requirements.

Real Time Data Display

1. Real time data displays can be useful to the vehicle operators, transit dispatcher, and system users.

2. Data that is of immediate importance and use can be displayed directly while information that has no immediate use such as transit productivity, can be displayed as off line printouts to operations management, planning and analysis personnel of the transit authority.
3. Large wall displays have been found to be effective in helping transit personnel study the fleet status as well as being an effective public relations tool.
4. The real time displays can increase the level of service by providing the decision makers with timely and accurate data.
5. Tests in Toronto have indicated that employees were more attentive to individual CRT displays that employed the use of color. In addition, color displays were more effective in dramatically displaying unusual incidents and emergencies.
6. Passenger message signs at terminal areas are a highly effective and relatively low cost means of substantially improving the perceived level of service offered by bus transit authorities.
7. The effectiveness of passenger signs is, however, heavily dependent upon the amount of pedestrian activity present. For example, the signs placed on shopping malls or foyers of large office complexes were cost justifiable while those signs placed at wayside transit stops were not.
8. Experience gained form a bus information system initiated by the Mississauga Transit Authority in Canada demonstrates that considerable operating economics can be made by keeping the passenger better informed. This is accomplished by changing the traditional image of transit by making the user and potential user an active participant in the service rather than a passive victim of it.

9. Increases in ridership were experienced in Mississauga, due to the passenger signs, especially during inclement weather when the passengers are often exposed to the environment not knowing when the next transit vehicle will arrive.

Digital Data Hardware

1. Today there are numerous manufacturers of digital data systems who have constructed and tested their equipment in various applications. They can modify their production models to handle the particular engineering requirements of their purchaser.
2. The use of color for controller display is a particularly effective means of differentiating system conditions. Different color schemes can be used to indicate the vehicle status and alarm messages to aid in the rapid recognition of emergencies and unusual incidents.
3. Digital communications is a relatively new concept in the transit industry. The dispatcher, a computer, and the data package work hand-in-hand. Digital communications provides fast, accurate control and dispatch of vehicles for status reporting and for pickup and delivery of passengers.
4. With digital data communications and precoded function keys, the radio channels are less crowded so emergency communication will not be delayed or obstructed. Digital data communications also allows the dispatcher to handle traffic more effectively and determine the status of any vehicle at any time.

5. Proper analysis and processing of the incoming data requires a computer of sufficient size, sometimes with magnetic tape storage capability.
6. The magnetic tape is not useful in all installations. Its primary purpose is to provide an accurate record of day-to-day data for use in long term studies.

C. Recommendation

The review of the literature related to the application of Digital Data Communiction Systems in the Public Transit industry revealed several interesting conclusions as outlined in the previous section. While the study was limited in scope, still several very critical issues were covered which resulted in some specific conclusions. In order to deal with questions relative to AVM Systems and its applicability in public transit industry a set of recommendations can be made:

1. An in depth study to develop a set of guide lines and/or criteria which can be followed by Public Transit Administrators/Operators to determine the need of Digital Data Communication systems under varying level of transit demand (ridership), supply (fleet size, etc.) and system characteristics (network configuration, service area, type of service fixed-route variable-route, etc). The current literature does not provide sufficient empirical data to establish specific threshold values of various factors which can determine the appropriateness of digital data communication system for a specific transit system. It is therefore recommended that an in depth study be performed which will include visits to various existing installations of AVM systems and critical analysis of data available through existing AVM systems operations. This study should come up with detailed specifications for various factors which need to be evaluated to determine the appropriateness of an AVM systems applicability for a specific community.

2. The results of this study should be analyzed to establish the ranges of various parameters which may prove the use of AVM system cost effective. The existing systems' (UMTA demonstration programs, and other on going programs) data will form the basis for establishing parametric criteria for evaluating the appropriateness of AVM system in general and its various element's application in specific system environment.

3. A procedure should be developed to estimate the magnitude of benefits attributable to an AVM system based on the current level of a specific transit system characteristics and its environment. Such a procedure is essential to objectively perform a benefit-cost analysis of a potential AVM system under specific environment.

4. A demonstration program which covers all possible ranges of factors should also be conducted to establish the threshold values for various demand, supply and system factors. This demonstration program should be conducted following the specifications developed as a part of an in depth study as outlined earlier. Site selection will be a major activity in successfully achieving the project goals. As such, it is recommended that a careful review of candidate sites be made before committing the resources in a demonstration program. This demonstration program should be oriented towards gathering quantitative data of determinant factors and not as much data on the efficiency of the hardware aspects; since, the current study indicated that the technology is proven and

sound.

5. The experiences of the proposed demonstration project should be analyzed to establish a comprehensive set of criteria which will help the Transit Administrator/Operator objectively decide whether or not implementation of such a system is cost effective for a given set of system parameters.