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ABSTRACT

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This report identifies opportunities to improve transit performance using Advanced Public Transportation System (APTS) Technologies, assesses transit operator viewpoints on and experiences with APTS technologies, and proposes how current adoption and utilization practices might be improved so that these technologies are used in a more efficient and effective manner.

The research consisted of three main phases. First, we identified APTS technologies and developed a framework for assessing their potential value in improving transit system performance. We considered three types of APTS technology, automatic vehicle monitoring (AVM), advanced traveler information systems (ATIS), and advanced fare payment systems (AFP). After describing these technologies, we employ the theory of cybernetics to explain their potential performance benefits. From the standpoint of cybernetics, APTS technologies promise to reduce the cost and improve the effectiveness of a set of regulatory processes by which transit operators and users respond to disturbances in their environment. The categories of APTS benefit thus include (i) cost reduction (ii) improved ability to correctly choose regulatory responses and (iii) a richer set of regulatory responses from which to choose. Examples of these benefits for a wide range of transit regulatory processes are presented.

The second phase of the research consisted of a set of seven case studies of individual transit operators chosen to include properties that have adopted APTS technologies as well as those that have not. Through interviews with management, staff, and line personnel, we investigated the properties' experiences with and attitudes toward APTS technologies. On the basis of these case studies, we generalize about the circumstances leading to active consideration of APTS adoption, the factors influencing the outcome of adoption decisions, and the process of implementing adopted technologies. We also identify opportunities for improving the adoption process, including (i) more explicit identification of the performance goals the technology is expected to further, and consideration of alternative means of achieving these goals; (ii) better information about the organizational resources required to successfully implement APTS technologies, and more balanced assistance programs that combine capital assistance for purchasing hardware with other in-kind and financial assistance to facilitate implementation; (iii) development of methodologies, perhaps based on the cybernetic paradigm, to systematically identify "information bottlenecks" that hamper transit system performance and that APTS technologies can alleviate.

The third phase of the study consisted of a transit operator survey, in which 52 transit operators, 37 of which had adopted at least one APTS technology and 15 had not, were included. The main findings of the survey are: (i) AVM is rated somewhat lower than electronic farebox (EFB) technology (which we use as a "benchmark" for the ratings) with regard to ease of implementation and satisfaction with vendors, while ATIS ratings are not significantly different that those of EFB; (ii) many operators that have not adopted a given APTS technology are actively investigating doing so; (iii) most transit operators have positive attitudes about APTS technologies, but do not expect that they will pay for themselves in a direct monetary sense, and thus will required government financial assistance in order to acquire them.

We conclude with recommendations for a program that we believe will lead to more effective and efficient use of APTS technologies. The proposed program, entitled MOTUS, for MOdel Technology USer, involves intensive assistance and collaboration with a small number of operators identified as promising APTS users. The program would consist of identifying a set of areas in which performance improvements are desired, developing integrated strategies, often involving APTS technologies, designed to improve performance in these areas, implementing the programs, and monitoring the results. Transit operators would receive MOTUS assistance in all aspects of these initiatives. By concentrating assistance in this way, MOTUS is expected to substantially increase the capacity of participating operators, and others who will learn from the participants, to use APTS technologies wisely and aggressively.

Keywords: Advanced Public Transportation Systems, public transit, technology assessment, automatic vehicle monitoring, advanced traveler information systems, automatic fare collection

PREFACE AND ACKNOWLEDGMENTS

This report documents research performed for the State of California, Department of Transportation (Caltrans), under contract #65H998 - MOU 40. The project was conducted through the California Partnership for Advanced Transit and Highways (PATH) at the University of California, Berkeley.

The core research team consisted of Assistant Professor Mark Hansen, and Graduate Student Researchers Mohammad Qureshi and Daniel Rydzewski. Hansen was the principal investigator and is primary author of this report. Qureshi was responsible for the case studies, and served as the resident expert on vehicle monitoring technology. Rydzewski took the lead in researching traveler information technology, and also assisted in developing the transit operator survey.

Three other students, Danielle Cullinane, Dan Thompson, and Ann Fine, provided additional assistance in the transit operator survey. Cullinane developed and pre-tested the questionnaire. All three were engaged the tedious and exacting task of administering the survey via telephone.

The authors would like to acknowledge the assistance of a large number of individuals who participated in this study. We are particularly indebted to the management, staff, and line personnel from the seven transit agencies who granted us extended interviews, and who answered our questions with patience, thoughtfulness, and candor. We also appreciate the assistance of those who responded to our telephone survey.

Earlier versions of this report were reviewed by individuals at both PATH and Caltrans, who we would like to thank for their careful and thorough comments and suggestions. Any remaining errors and omissions are, of course, the sole responsibility of the authors.

EXECUTIVE SUMMARY

ES.1 Introduction

The purpose of this research, funded by the California Department of Transportation (Caltrans) New Technology Program, was to identify and assess opportunities to improve the performance of conventional fixed route transit through the application of a set of technologies that have come to be known as the Advanced Public Transportation System (APTS), and to identify policies and strategies that Caltrans might pursue in order to increase the prospects for realizing these opportunities. The study recognizes that individual transit operators play a pivotal role in decisions about the adoption and utilization of APTS technologies. Therefore, the study focuses on the attitudes and experiences of individual transit agency management, staff, and line personnel that are likely to determine their future choices with regard to APTS adoption and utilization. It is hoped that, by giving Caltrans a realistic idea of how transit operators perceive and use APTS technologies, the study will assist Caltrans in effectively promoting and supporting diffusion of these technologies among California's transit operators. We recognize that Caltrans must consider factors other than those addressed in this study in formulating its APTS program, but view the information contained in this research as an important input.

ES.2 APTS Technologies

The first phase of the study (Chapter 2) overviews APTS technology and develops a theory of how such technology can benefit transit performance. For purposes of this study, three categories of APTS technology are recognized.

Advanced Traveler Information Systems (ATIS) is the first category. The purpose of ATIS is to give transit users or potential users information about transit services, and about the activities motivating their travel. Types of ATIS include automated telephone information systems, computer data retrieval systems, interactive audio/video systems, and display announcement systems. Telephone, computer systems, and teletext are designed mainly for pre-trip planning, and would enhance, supplant, or replace the manual telephone systems that most U.S. transit operators currently employ. By either eliminating the need for a human operator (at least for some types of information requests) or increasing the speed and accuracy with which the operator can respond to information requests, these technologies promise to reduce costs and increase the convenience and availability of present-day manual systems. Interactive audio/video and display announcement systems are designed primarily to inform travelers who are away from their home or workplace, whether en route or at a transportation terminal or other activity center. These technologies facilitate inter- and intra-modal connections, allow travelers to plan activities to conform with the transit schedule, and offer entertainment. They may be of particular value in assisting way finding for travelers with vision of hearing impairments.

The second category of APTS technologies considered in this study is automatic vehicle monitoring (AVM) and control systems. These technologies allow a broad range of information pertaining to the location, physical condition, and patronage of transit vehicles to be collected, recorded, transmitted, and presented in a useful form to vehicle operators, dispatchers or other agency personnel, transit users, or other parties (such as traffic control centers). At the present time, the monitoring technology attracting the greatest interest is automatic vehicle location (AVL). Using proximity beacons, navigation satellites, dead reckoning, or some combination of these, AVL allows the trajectory of transit vehicles to be traced in real time. Benefits include better monitoring of schedule adherence, enhanced emergency response, and more accurate schedule information. Other monitoring technologies include alarms that alert drivers and dispatchers of mechanical troubles and passenger counters that perform automated on-off counts by stop. Finally, we include in this category control technologies that can assist operators in avoiding collisions, and may in the future include fully automated longitudinal and lateral control.

The final APTS technology category considered in this study is advanced fare payment systems (AFP). The technologies are intended to reduce the traveler inconvenience, vehicle delay, and revenue leakage associated with paying cash fares on transit vehicles. Most current advanced fare payment systems employ magnetic farecards, which store information such as the value remaining or time/place restrictions on card validity. Machines located either in stations or on vehicles can read and write card information. Long used in certain rapid transit systems, this technology is gaining increasing acceptance in bus transit, especially as a substitute for conventional paper transfers. In the future, magnetic farecards may be replaced by “smart cards.” These are much like credit cards, except that they include a microprocessor and possibly a very short range transmitter. Smart cards can store much more information than magnetic farecards, and, if a transmitter is included, could communicate with a read/write device without any direct contact. Ultimately, this could lead to highly sophisticated fare structures and completely automated fare payment via electronic fund transfer. However, widespread application of smart cards in transit is unlikely to occur soon, because of the relatively high cost of the cards and the lack of infrastructure for using them.

The value of APTS technologies rests on their ability to improve transit performance. Transit performance is multi-dimensional, but the most important aspects include ridership, revenue, service quality, and cost. In order to understand how APTS may enhance these and other aspects of transit performance, we develop a model, based on the theory of cybernetics, in which the performance of a system depends on its ability to appropriately respond to disturbances in its environment. APTS technologies improve this ability by facilitating the communication of information about disturbances to their associated regulators. For example, AVL provides information concerning schedule deviations to drivers, dispatchers, and others who can respond to this information by taking actions to reduce the deviations. ATIS technologies provide information about transit routes and schedules to the transit user, for whom these constitute a disturbance since they are beyond his/her control. This enables users to “regulate” their activities so that they arrive at the appropriate stop at the appropriate time. Similarly, advanced fare payment technologies facilitate the appropriate transfer of funds from transit users to the transit operator, according to the pre-determined fare structure and the transit services consumed — both of the latter constituting disturbances from the standpoint of our model.

The benefits of improved communication about disturbances provided by APTS technology take different forms. At the broadest level, we categorize the benefits as either cost reducing or regulatory enhancing. An example of the former is automated passenger counters — a form of vehicle monitoring technology — which can eliminate the need to hire temporary personnel to conduct on-board ridership counts. A pure cost reduction benefit implies no improvement in regulatory effectiveness — only a lower expense for attaining the same level of effectiveness. On the other hand, benefits in the second category do derive from improved regulation. We identify two subcategories of regulatory enhancing benefit. First, for a fixed set of alternative regulatory actions, the probability of selecting the best action can be increased. To illustrate, dispatchers respond to on-road emergencies (a disturbance) by sending police or other emergency personnel to the estimated location of the bus. If a transit system has AVL, the response might be similar, except that the dispatcher could give a more accurate location. Second, the APTS technology may increase the range of possible responses. Returning to the emergency road call example, AVL might allow a dispatcher to re-route a bus to pick up stranded passengers.

Certain regulatory enhancement benefits derive from a phenomenon we term regulation-disturbance (R/D) duality, which occurs when the regulation of one process creates disturbance for another. In transit, scheduling and routing decisions constitute regulation from the standpoint of the operator, but the resulting schedule and network are a disturbance from the standpoint of a traveler. In this example, ATIS, by making it easier for the traveler to retrieve updated schedule information, might allow the operator to adjust schedules more often in order to respond to fluctuations in demand or traffic conditions. This is an instance of a regulatory enhancement (more rapid service adjustment) resulting from the enhanced ability of a downstream regulator (a traveler) to respond to the upstream regulatory action (the service adjustment).

The above theory of how APTS can benefit transit performance serves several purposes. First, it allows a systematic search for benefit opportunities. Second, it implies that APTS technologies will often yield multiple forms of benefit. Thus, if a given technology is initially acquired for a narrow purpose, it is likely that the benefits associated with that purpose are less than the total benefit. Third, it shows that many of the benefits of APTS technology depend on adjustments to transit operator procedures so that personnel with access to better information have a wider scope of authority to respond to that information. Since such adjustments may require considerable organizational effort, this implies that organizational resources may be an important complementary input to APTS technology, if the full benefits of the latter are to be realized.

ES.3 APTS Innovation In U.S. Transit Agencies — Case Studies

In the second phase of the research, we explored transit operator experiences with and attitudes toward APTS technologies. We did this through a set of seven case studies of individual transit operators. The operators were selected to cover a wide range of sizes and levels of experience with APTS technology.

We made a 1-2 day visit to each operator, during which we interviewed management, staff, and line personnel. From these interviews, we sought to determine (1) the factors that influence decisions on whether to adopt these technologies, (2) how decisions to adopt, once reached, are implemented, and (3) how the adopted technologies are ultimately utilized. In addition, we considered how the process of APTS innovation might be improved through better adoption decisions, implementation strategies, and utilization practices.

In this summary, we present only our synthesis of the case studies; discussions of the individual operators are found in Chapter 3.

The decision to adopt a APTS technology can be usefully divided into two stages. In the first, a choice is made to give active consideration to adoption. In other words, the adoption decision is placed on the agency's "agenda." One perquisite for this is that the agency knows that the technology exists. We found that this requirement is widely satisfied — virtually all operators had some familiarity with each of the APTS technologies we discussed. In addition, several other factors were found to encourage agencies to actively consider adoption of a technology. These include:

Special Opportunities. A technology may be available as an optional feature of some system the agency has decided to acquire, or an agency may be asked to participate in some joint venture involving the adoption of a technology. These circumstances create windows of opportunity in which a technology may be acquired more inexpensively or cheaply than if the decision is deferred.

Presence of a Champion for the Technology within the Agency. The champion, by strongly and consistently advocating adoption of a technology, can build awareness of and support for the technology throughout the agency. The champion may be motivated either by a generally positive orientation toward new technology, or awareness of particular problems that the technology is expected to alleviate.

Sufficient Managerial Resources. Decision makers at several agencies indicated that they simply had too many other, more pressing, issues to deal with to allow them to give active consideration to adopting APTS technologies.

Problem Awareness. At any given time, an agency is likely to have identified a certain set of recognized "problems" that it is actively attempting to remedy. If an APTS technology is considered a promising solution to such a problem, it is likely to receive active consideration.

General Attitude Toward Technological Innovation. Many agencies exhibit a predisposition either for or against adoption of new technologies. This predisposition clearly affects the likelihood that adoption of a new technology will be actively considered.

Once on the agenda, the adoption decision is influenced by three main factors. These are:

Operating Cost Impact. It is generally assumed that capital costs for acquiring a new technology will be heavily subsidized by the federal government, but operating cost impacts impinge directly on the agency. Adopting a new technology will inevitably result in some operating cost increases (maintenance, for example), but operators are concerned that these be kept to a minimum. Furthermore, operators place a strong premium on any operating cost reductions that may result from the new technology. It is particularly desirable if the savings do not depend on layoffs or any other significant dislocation of agency employees. Past experience has caused many operators to be skeptical that potential labor cost savings from new technologies will actually materialize when such savings entail such dislocations.

Technological Maturity. Operators recognize that a less mature technology is more likely to have unexpected problems and costs, and therefore want a technology to reach a certain level of maturity before they adopt it. This "maturity threshold" varies from system to system. Some operators insist that a technology be adopted by several other operators before they do so. Others are willing to lead adoption, so long as the product is "off-the-shelf" A few operators — generally larger ones with highly trained technical personnel — are willing to participate in system development, at least when they consider the components required by the system to be mature.

Consultant Recommendations. Most operators work closely with external consultants in making APTS adoption decisions. Consultant recommendations are generally given considerable weight in the decision process.

Overall, we found that APTS adoption decisions are made with considerable thought and care. However, we identified two areas in which the decision making process may be deficient:

Limited Alternatives are Considered. In most cases, the "choice set" considered consists of two alternatives: adopt the APTS technology, or do nothing. This approach overlooks the fact that the motivation for considering the technology often includes awareness of some problem, and there are generally many alternative ways of addressing a given problem, not all of which involve APTS technology.

Little Effort to Quantify Benefits. Although some APTS benefits occur in the form of cost reductions that can easily be weighed against the cost of technology acquisition and operation, many benefits take the form of improvements in service quality: ease of obtaining schedule information, improved schedule adherence, and more convenient fare payment. Operators are aware of these benefits, and often cite them as major reasons for acquiring a technology. However, little attempt is made to quantify these benefits, or translate them into monetary terms. This tends to make adoption decisions conservative: operators are more concerned with avoiding high cost penalties than with achieving major service improvements.

Once a decision is made to acquire an APTS technology, implementation begins. This normally involves specifying a system and selecting a vendor to provide it, developing data bases required by the system, training agency personnel, and modifying standard operating procedures. The first step is generally fairly straightforward — or was so at the time of our case studies — because relatively few vendors could offer systems meeting the agency specifications. Data base development often proved unexpectedly difficult, because of the volume and accuracy of data required. An additional problem connected with the data bases was that system malfunctions were sometimes mistakenly attributed to inaccurate data, resulting in major — and unnecessary — revisions. With regard to training, we found that it was generally effective in allowing agency personnel to operate the system on a routine basis. On the other hand, training proved less adequate for preparing personnel to make non-routine use of the system. For example, one operator retained the software developer for its AVL system to make program modifications assumed necessary to generate a report with a new format, only to find that the original system had this capability all along. The final step — adjusting operating procedures — often included certain requirements that were not initially anticipated. For example, some AVL systems require bus operators to use a standard route for turning around their bus at the end of a run.

The benefits of adopting an AVL technology depend on how it is utilized. In terms of the APTS benefit framework outlined in Section ES.2, we found that operators are predisposed toward patterns of utilization that are cost reducing rather than regulatory enhancing. As already noted, operating cost impact is a major consideration in the adoption decision. Other benefits, such as increased convenience of obtaining schedule information, may not directly influence operating costs, but are still cost reducing in the sense that they decrease the effort required to obtain a certain quantity of information. Thus, operators tend to focus on opportunities to make acquiring information cheaper or easier, rather than to obtain more or better information for purposes of enhanced regulation. The main exception to this is advanced fare payments, where several operators emphasized benefits of reducing fraud and thereby increasing revenue. Although technically a form of regulatory enhancement within our schema, it is not surprising that such a direct financial impact would be weighed heavily.

Several recommendations emerge from our case studies. To encourage transit operators to make appropriate choices concerning the adoption of APTS technology we recommend that policies be developed to:

Encourage Operators to Accurately Gauge Internal Resource Requirements. In addition to the fixed cost of purchasing APTS technology and the recurring cost of maintaining it, operators must make a considerable investment of organizational resources if the full benefits are to be realized. Some parts of this effort, such as data base development, are recognized in advance as absolutely essential, but often entail costs greater than originally estimated. Other parts, such as reconsidering job responsibilities in light of increased enhanced regulatory capabilities, are not essential to obtain a functioning system but must be made if the full benefits of the system are to be realized. We therefore recommend that grant proposals involving APTS technologies contain explicit estimates of internal resources required to successfully and fully implement the technology, and a commitment to provide these resources. In some cases, such as data base development, it may also be desirable to shift responsibility from the agency to a vendor.

Encourage Problem-Driven Decisionmaking. As already noted, APTS adoption decisions are often binary in nature, neglecting opportunities to use non-APTS alternatives for dealing with a particular problem. We recommend that agencies requesting grants for APTS be required to conduct an overall study of the main problems the technology is designed to alleviate. Two additional reforms may be necessary if this approach is to succeed. First, it may be necessary to externally fund the initial study. Second, there should be a commitment to fund the preferred alternative identified by the study, so long as it is cost effective, irrespective of whether it involves APTS technology.

We also recommend that action be taken to facilitate the implementation and improve the utilization of APTS technology. With regard to the former, we recommend an acceptance process that requires that a new system be completely operational before the vendor receives final payment. This would mean not only that the hardware is operating properly, but also that training is complete, data bases are validated, and more generally that all parts of the system are in place so that it is performing according to contract specifications. To encourage operators to more fully utilize APTS technologies, we recommend that the theory of APTS benefit outlined in Chapter 2 be used to develop a systematic inventory of information bottlenecks that constrain effective regulation of transit systems. The capabilities of newly acquired or candidate APTS technologies to remove such bottlenecks can then be systematically identified.

ES.4 Transit Operator Viewpoints on APTS Technologies — A Survey

In the final phase of the research, we conducted a telephone survey of transit agency staff concerning their experiences with and attitudes toward APTS technology. The sample of respondents was drawn from two sets of transit operators. One set was identified as having either automatic vehicle monitoring or ATIS technology in a recent Federal Transit Administration publication, while the other set was not so identified. A total of 71 surveys were completed. Of these, 35 indicated that their agency had adopted either AVM, ATIS, or AFP technology, while 36 indicated that their agency had not adopted any of these. Of the 52 transit properties represented in the survey, 37 had at least one respondent report that at least on of the three APTS technologies had been adopted, while the remainder were unanimously reported to be APTS non-adopters.

Respondents reporting adoption of the various technologies were asked to rate the ease of implementation, satisfaction with vendor(s), and system performance. In addition to AVM, ATIS, and AFP, respondents were also asked to rate electronic fareboxes (EFB) on these dimensions, in order to provide a set of “benchmark” ratings based on a widely known technology. We found the principle differences in ratings to be with regard to ease of implementation, on which AVM is rated significantly below EFB and ATIS. On the other hand, there were no significant differences among AVM, ATIS, and EFB with regard to system performance, nor between ATIS and EFB on any dimension. No meaningful ratings were obtained for AFP, because the number of respondents reporting adoption of this technology was so small.

We asked respondents to report on what, if any, steps had been taken to investigate and decide whether to acquire the various APTS technologies that their agencies had not yet adopted. Our general finding is that there has been considerable investigative and decision making activity underway. For each technology, a majority of operators report visits by salespeople. A sizable proportion — between 41 and 75 percent, depending on the technology — also report either the appointment of an individual or committee to investigate, or visits to another agency to see the technology in action. We also found that operators have generally progressed further in their consideration of AVM than in their consideration of ATIS or AFP. Approximately two-thirds report that they have either not researched or are in the process of gathering information about the latter technologies. With regard to AVM, 60 percent report having progressed beyond gathering information, including 31 percent who are about to implement, 15 percent who have decided not to pursue, and 15 percent who are conducting an experiment or demonstration.

The survey concluded with a set of questions concerning respondents' attitudes toward APTS technologies. The results indicated that, irrespective of whether their agency has adopted such technologies, most respondents viewed them favorably. For example, there was strong disagreement with the statement that APTS technologies "are more trouble than they are worth." On the other hand, there was also little agreement with the statement that personnel hours could be reduced by adopting APTS technologies, and the costs of acquiring and operating these technologies were cited as major obstacles to adoption. Thus, although respondents generally believe that APTS technologies offer substantial benefits, they do not expect the benefits to be in the form of direct cost savings. In addition, uncertainty regarding the magnitude of APTS benefits, and a tendency to give other initiatives higher priority, were cited as obstacles to more rapid adoption.

The general conclusion of the survey is that transit operators are showing considerable initiative in responding to the opportunities provided by the development of APTS technologies. Most have general knowledge of these technologies, and many are taking steps to find whether they should proceed with adoption. However, these actions are being taken in a context in which operators require considerable federal or state assistance with acquisition of APTS technologies, and in which operators do not expect the technologies to pay for themselves in a strict accounting sense. This suggests that federal and state funding agencies should consider carefully whether subsidies for APTS technologies represent a cost-effective use of their resources.

ES.5 Recommendations

We conclude that Caltrans has a significant opportunity to promote APTS technologies in the California transit industry. Observing the problems and obstacles transit agencies encounter in adopting APTS, and the shortcomings of current government programs involving APTS, we recommend (in Chapter 5) the creation of a new program of intensive, wide-ranging, assistance to selected transit operators so that "best practices" for effective use of APTS technology can be established in a California (or U.S.) context. The program would require the participation of transit agencies with well-defined performance objectives and an organization-wide commitment to pursuing these objectives. Participating agencies would receive a combination of capital assistance and consulting services designed to define and implement cost-effective performance improvement programs, of which APTS adoption could (but would not necessarily) be a part. In cases when APTS is acquired, assistance in procurement, installation, and utilization would also be provided. The program would thus teach participant agencies how to make appropriate choices concerning the adoption of APTS technologies, and how to use these technologies, once adopted, to maximum advantage. The knowledge would then be transmitted to non-participants through a variety of technology transfer mechanisms. Thus, while directly involving only a small number of agencies, the impacts of the program would be felt throughout the transit industry.

Table of Contents

List of Figures

List of Tables

CHAPTER 1:
INTRODUCTION AND OVERVIEW

1.1 Introduction

Recent years have witnessed a spurt of interest in the application of advanced information technologies in urban transit. The Federal Transit Administration (FTA) has recently established the Advanced Public Transportation Systems (APTS) Program to promote these applications. The Intelligent Vehicle Highway Society of America (IVHS America) has recently established an APTS Committee. Several states, including California, have included transit programs as key components of their overall IVHS efforts (California Department of Transportation, 1991).

The Federal government has also released two studies, by the Transportation Systems Center (Casey et al, 1991) and Castle Rock consultants (Davies et al, 1991), respectively, that discuss the state of the art and future prospects for a wide range of transit APTS applications. The reports reveal a wide range of ongoing efforts by individual operators both in the U.S. and abroad, as well as a number of as yet untried but promising concepts.

The interest in APTS applications for transit has several underlying causes. Tremendous technological advances in communications and information processing technologies, largely the result of the rapid development of microelectronics, have created many new opportunities for transit, just as they have for the automobile-highway system. Further, the national commitment to balanced transportation, reinforced in many areas by the environmental problems caused by the automobile, create pressures for modal balance in efforts to harness new technologies for urban transportation. Finally, urban transit in the United States continues to suffer from poor financial performance, a very low share of the total urban transit market, and a reputation for poor service. Any and all potential remedies for these problems can be expected to spark interest. Indeed, the idea that “the transit problem” in the United States can be solved through technological advance dates back at least to the 1930s, when streetcar operators, battered by financial problems and losing traffic to the automobile, sought to turn the tide by combining their resources to design a new generation rail vehicle, known as the PCC (Electric Railway Presidents’ Conference Committee) car (Saltzman, 1979).

Despite, or perhaps because, of the vast amount of interest and activity surrounding APTS technologies, transit operators face difficult challenges in assessing, procuring, and using these technologies. There are many different systems with differing but overlapping capabilities and benefits. The technologies are rapidly evolving, raising the specter that hardware obtained today will be obsolete tomorrow, and are based on components unfamiliar to many operators. Further the benefits of different technologies may be tightly coupled to one another, or dependent on changes in operations on procedures, making isolated decisions about individual options difficult. In short, in the current environment transit operators have good reason to be concerned about making the “wrong” choices regarding APTS technologies, and thus perhaps a strong motivation to err on the side of caution and do nothing at all.

These circumstances, while difficult, are typical in periods of technological change, and there are different paradigms for managing them (Pitstick, 1991). In an evolutionary approach, the current profusion of technological options would be welcomed, and the strategy would be to encourage a wide range of experimentation from which the most effective technologies would be revealed. There would be many dead ends and false starts, but the end result would be a set of proven transit APTS technologies that could be confidently adopted by operators. Alternatively, in a top down or systems design approach, FTA or some other central authority could develop a set of transit APTS technologies based on the best available expertise. This approach would avoid the mistakes inherent in the evolutionary one, but would be prone to other mistakes stemming from the limitations in the information available to the system designers. Also, such a government-centered approach would be subject to strong political pressures.

The difficulties with the above alternatives suggest an intermediate strategy. As in the evolutionary approach, decisionmaking regarding transit APTS technology would be decentralized and left to individual operators. However, state and federal governments would play an active role in assisting local operators in APTS planning and decisionmaking. Such a program would make available technical assistance to operators throughout the processes of evaluating, adopting, and implementing APTS. In addition, while respecting operator autonomy, it would tie financial assistance for acquiring APTS to requirements designed to encourage "best practices" throughout these processes. With this support and encouragement, many mistakes could be avoided, while at the same time maintaining assurance that the adopted technologies meet the needs of operators.

The intermediate strategy is broadly consistent with FTA's general approach to fostering innovation, which has mixed decentralized and centralized innovation diffusion measures (Rogers and Macgill, 1981). But this mix has evolved in the context of relatively simple, non-technical, innovations (Harrison, 1988). Rogers et al. (1981) has argued that the appropriate mix between centralized and decentralized diffusion strategies depends on the technical complexity of the innovation, with greater complexity calling for greater centralization. He notes that many of the non-technical innovations have been substantially "reinvented" by operators adopting them to suit individual needs. Such reinvention by operators will be difficult if not impossible for technically complex APTS systems.

These circumstances suggest a need to define how state and federal transportation agencies can support local operators in their efforts to take advantage of APTS technologies. In order to better define that support role, it is necessary to understand how transit operators are currently proceeding in this area, and to determine their current views concerning the promise of APTS technologies for their operations. Further, in cases where operators have not given these issues serious consideration, it is desirable to obtain their informed assessment of the technical possibilities. These are the objectives of the Caltrans-sponsored research project "Potential Applications of Advanced Information Technology in Transit."

1.2 Overview

The project has three main parts. First, we identify some of the major opportunities for employing APTS technology to improve the performance of public transit systems. In doing so, we develop a conceptual framework that is intended to assist us in systematically identifying such opportunities, rather than presenting a laundry list of ideas appearing elsewhere in the literature. Chapter 2 covers this phase of the research.

In the second phase of the study, we studied how transit operators are responding to these opportunities. To do so, we conducted a series of seven case studies, each focussing on an individual transit property. Through interviews with a range of management, staff, and line personnel, we investigated how operators decide to adopt APTS innovations, how they implement such innovations, and their assessment of APTS technologies that they have not yet adopted. Chapter 3 details these case studies.

In the third phase of the research, operator experiences with and attitudes toward APTS innovations were further explored by means of a telephone survey. Some 71 respondents representing 41 different transit agencies participated. They were asked a series of questions, mostly closed ended, in which they evaluated the technologies their agencies had adopted, identified the steps taken by their agency to consider adoption of additional technologies, and stated their level of agreement with various attitudes toward APTS that had been expressed in the case studies. By covering a larger number of operators, and yielding results that could be statistically analyzed, the survey provided a useful complement to the richer, more qualitative, and more narrowly based case study results. Chapter 4 discusses the survey.

Finally, in Chapter 5, we offer recommendations for how the process of APTS innovation can be improved. We call for a program involving intensive assistance to a small number of operators who would be designated Model Technology Users (MOTUS). The program would be oriented toward achieving measurable performance improvement in well-defined areas, and would combine APTS technologies (where appropriate) with other actions in integrated programs designed to achieve the desired improvements in the most cost-effective manner. Although directly involoving only a small number of operators, we argue that the MOTUS program will yield industry-wide benefits by developing capacity within the transit industry to use technology both wisely and aggressively.

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CHAPTER 2:
APTS TECHNOLOGIES AND TRANSIT PERFORMANCE

2.1 Introduction

The purpose of this chapter is to describe how APTS technologies can benefit public transit. First, we describe and categorize the specific APTS technologies that appear to have the greatest potential for improving the performance of U.S. transit properties. Next, we discuss the performance of the U.S. transit industry. Third, we develop a general theory of how APTS technologies can benefit transit performance, applying this theory to identify potential benefits of the aforementioned set of technologies. The first two steps are highly derivative, relying on a number of recent studies that have similar objectives. It is in the theoretical development that this chapter makes an original contribution. As will be seen, the major practical value of the theory is to allow a more systematic search for opportunities to improve transit performance through the application of APTS technologies. We demonstate that such a systematic search yields many more opportunities than are likely to be uncovered through the more haphazard, incremental, approach that appears to characterize most current thinking on this subject.

The balance of this chapter proceeds as follows. In section 2, we describe, in purely functional terms, existing and possible future APTS technologies. In section 3, we discuss the performance of the U.S. transit industry. In section 4 we consider how APTS technologies can further transit operator objectives. Section 5 presents a summary and conclusions.

2.2 Overview of the Technologies

Exactly what is encompassed by the term “APTS Technologies” is a somewhat arbitrary matter. For purposes of this research, the term will be used to refer to three broad categories: Advanced Traveler Information Systems, Vehicle Monitoring and Control, and Advanced Payment Systems.

2.2.1 Advanced Traveler Information Systems

Transit users and potential users require information concerning schedules, routes, and fares to plan trips and activities motivating these trips. Such information is of value both prior to making a trip and during the trip. Several APTS technologies facilitate access to such information for the transit user. They include: automated telephone information systems, computer data retrieval systems, teletext systems, interactive audio/video systems, and display announcement systems.

Automated telephone information systems involve accessing the information needed for a trip through the use of a telephone. Instead of receiving information that has been manually retrieved and compiled the caller receives information that has been generated by a computer. The information requested may be quite simple — a bus stop’s next scheduled arrival time — or quite complex — an itinerary of buses and transfers for a trip across town.

One component of automated telephone information systems is computer hardware and software to retrieve or generate the requested information. Simple requests such as arrival and departure times can be handled with relatively simple database software. If itinerary advice is to be offered, more complex route-finding software is required. Inputs to the software include a database of routes and schedules as well as the origin, destination, and time of the needed service. The program outputs the recommended bus route number, transfers, schedule time, and, when appropriate, alternative routes (Philips, 1983). The costs associated with implementing this type of computerized information system include the hardware purchase, software purchase or development, the effort of compiling and coding the database, and training of personnel. The size and complexity of the transit system will influence the amount of these costs (Ross and Soberman, 1987; Diewald, 1983).

The other component of the system is a means of retrieving information via telephone. Several methods are in use. They all utilize state-of-the-art call sequencing technology known as private branch exchange, or PBX, which can answer calls in a first in - first out service priority. The simplest telephone retrieval method is direct dial to an information operator, who can handle both simple and complex information requests. The second method is direct dial to the information system itself with requests input by use of the telephone keypad. This method can also handle both simple and complex information requests, but is less covenient for the more complex requests. The third method involves direct dial to the system itself but only to access a route schedule data base. This method only handles simple, route-specific, requests, and should therefore complement, rather than substitute for, information operators (Diewald, 1983).

Systems with direct dial to an information operator are similar to standard transit telephone information systems except that the operator uses a computer instead of various printed materials. The potential advantages of this include reduced time for processing a call, greater uniformity of response, less difficulty in implementing route scheduling changes, and increased capacity of the operator system due to reduced response time (Philips, 1983), and 24-hour service availability. However, experience has shown that response time is reduced only if the system is used selectively, since many requests are handled so routinely that operators have memorized the information. There was an initial increase in response time when an automated system was introduced in Washington DC, because operators were using it for every request (Philips, 1983).

All automated telephone information systems with direct dial to the system employ computerized voice synthesizer response. Advantages of this method are reduced labor cost, increased call-handling capacity, and 24-hour availability of the service. In one form of this system, the caller may input the information request by way of the touch tone pad on the phone itself. The caller has the ability to vary, by dialing a pre-selected sequence of numbers, different parameters such as waiting time, fare cost, and walking distance, to optimize the trip route (Ross and Soberman, 1987).

The alternative method to direct dial is to assign a telephone number for each and every bus stop in the transit system. The information is then made available by posting the unique telephone number at its bus stop. By calling the assigned number the transit user can then receive the times of arrival for the next two or three buses at his/her desired stop (McKendrick and Hubbell, 1989). Advantages of this method are that it removes the simple schedule or itinerary oriented calls from the caller/operator interactive system, and provides the option for 24-hour access. This type of system does not require the extensive computer system hardware, software, and data bases associated with automated route finding, but neither does it supplant the human operator-based system.

With computer data retrieval, the traveler communicates with the system in much the same way as someone calling the system with the phone and using the touch tone buttons. The difference is that the caller uses a modem, or a terminal provided at a transit station/heavy use area, to link their computer with that of the system. The information generated can then be printed up in the form of hard copy to be referenced in route. The costs associated with this type of information system are much the same as those for an automated telephone information system utilizing touchtone.

A more sophisticated form of computer data retrieval found in some airports and train stations in called interactive audio/video (IAV). These systems have greater graphics capabilities and could offer an extremely flexible yet easy-to-use tool for disseminating information pertaining to both the transportation system and other domains. Because of its graphics orientation and greater flexibility, IAV requires both greater data storage and faster data transmission than a conventional modem-based system (Hunter and Perfader, 1991). Storage is provided by a computer laser disc — a thin sheet of metal in which information is stored in the form of pits burned by a laser beam. IAV programs have different levels of sophistication — from simple sequential programs to ones with branching and multiple forms of interaction, such as keyboard and mouse.

Teletext is a method of making information in the form of written text available to the transit user by way of a television. This information is transmitted using World System Teletext, a communication protocol that uses a portion of the broadcast signal. This portion of the broadcast signal assigns the teletext material to the Vertical Blanking Interval (VBI) — the portion of the television picture that appears as a black line when the television picture rolls vertically. There are 21 transmitted horizontal scan lines in the VBI. Of these 21 there are a few that involve the vertical control for the video-picture, several are reserved for transmission of closed captioned text for the hearing impaired, and the rest are void. It is within these void lines that transit information may be transmitted (McConnell and Blackburn, 1990).

The ability to only transmit textual material limits this type of information access to that of route schedules. Each individual line carries one route in the transit system. The transit user need only access the line corresponding to the route of interest. The user accesses these VBLs through the use of a decoder. Presently, Zenith manufactures two models of TVs with this type of decoder built in, and Sony and Magnavox are scheduled to introduce such models in the near future (McConnell and Blackburn, 1990).

In order to be able to make schedule information available to the public the transit system must compile and encode the route schedules so that they can be transferred to an inserter that formats and inputs this information into the broadcast signal. The costs associated with this system are those for establishing the database, encoding the route schedules to be transferred to the television station's encoder, and the fees required by the station for transmitting the signal.

Advanced technologies are additionally altering more traditional forms of transit data transmission, such as the display signs located in vehicles and terminals. The main progress has been to make the messages programmable, so that they can easily be modified to reflect routing and scheduling changes, even on a real time basis when used in conjunction with an automatic vehicle location system (see Section 2.2.2). Several kinds of electronic formats, including liquid crystal, dot matrix, and video monitors have been employed for this purpose.

2.2.2 Vehicle Monitoring and Control Systems

The category of vehicle monitoring and control encompasses various technologies that monitor the performance of vehicles and routes and can assist the operator in driving the bus.

Automatic vehicle monitoring (AVM) systems monitor the performance of both vehicles and routes. AVM consists of a combination of technologies, including a location subsystem, a monitoring subsystem, a communications subsystem, and a central control facility.

The communications subsystem is radio-based and has for the most part remained unchanged since AVM systems were first tested in the late 1970's. The primary changes have been the miniaturization of components and reduction in equipment costs.

The central control facility is a combination of computer equipment adapted to the needs of the system. This subsystem has benefitted from advances in computer techology resulting in lower costs, increased power, and enhanced capabilities.

The location subsystem relies on automatic vehicle location (AVL) technology. There are several locating strategies that can be utilized. These can be divided into ground-based and satellite-based systems.

There are three types of ground-based locating methods. Dead reckoning relies on elapsed time, changes in direction, and distance travelled to calculate a vehicle's position relative to its starting position (UMTA, 1991). Alternatively, proximity beacons can be used to determine a vehicle's position. In this method, the vehicle initializes its position when it passes a beacon and measures distance travelled relative to this beacon until the next beacon is encountered. Finally, there are radio determination systems. These systems triangulate position based on modulated and coded radio signals (UMTA, 1991; California Department of Transportation, 1991). Loran C, used primarily for maritime navigation, is one such system.

The satellite systems also rely on triangulation. However, the transmitters are in the sky as opposed to on the ground. Currently there is one operational system: the Global Positioning System (GPS) operated by the U.S. Department of Defense. The system became available on a 24-hour basis in 1993 (Perviainen, 1990).

All these systems require on-board equipment to calculate the vehicle's position. Proximity systems, in addition, require a network of beacons. Depending on the number of beacons this can become costly. The other systems require less infrastructure investment but also the purchase of expensive receivers. All these systems also suffer from accuracy problems. However, each can be adapted to improve accuracy. Dead reckoning can be improved by combining it with proximity beacons and/or map-matching software to correct the position at pre-determined intervals. For GPS systems, a stationary receiver at a known position can be used to calculate an error term which can be applied to the area of coverage. One as yet unsolved problem faced by both radio determination and satellite systems is that tall buildings can impede reception of the signal, making it difficult to calculate vehicle position.

The monitoring subsystem monitors both vehicle operating conditions and route operating conditions. The vehicle operating condition is monitored by sensors connected to an on-board computer, or OBC (Davies et al, 1991). Sensors can monitor such items as vehicle speed, engine speed, oil level, coolant level, etc. With the aid of automatic passenger counters (APC), the monitoring subsystem can collect data on passenger boardings and alightings. APC's consist of pressure sensitive pads or light beams across the doorway that once activated measure boardings and alightings. Other technologies discussed in the category of advanced payment can also be used to collect data on route performance. Once the data has been collected it can transmitted in real time or at the end of the day to aid planners and maintenance personnel.

An often overlooked component of the monitoring subsystem is software for reducing monitoring data into useful information (Mellor and White, 1987). AVM systems often generate huge volumes of data that would be inefficient or impossible to sift through manually. Vendors of AVM are often hardware oriented, however, and assume that others are responsible for data reduction. Furthermore, while operators want software that is easy to work with, they also have diverse and changing information needs. These conflicting requirements make AVM software difficult to develop.

Vehicle monitoring can serve as a basis for technologies to assist in operation and control of the transit vehicle. Automatic vehicle control systems (AVCS) aid drivers in controlling certain vehicle functions and may ultimately have the potential to replace driver control (Mobility 2000, 1990). In its basic form AVCS will provide warnings and information to the driver. The next stage will include the capability to assist the driver in controlling the vehicle. The highest level of AVCS will completely automate the driving functions.

The first phase consists of information and warnings to assist the driver. Obstacle warning and maneuvering guidance compose one aspect of such a system. These systems detect obstacles and alert the driver with an audio signal when evasive action may be required. The maneuvering action could be a buzzer to alert the driver. Alternatively, there could be an automatic braking system which is enacted if there is not enough time for the driver to react.

Several technologies for automating the driving function are being explored. In automated guideway transit (AGT), vehicles run under automatic longitudinal and lateral control on their own guideway. Additionally, there are dual mode vehicles being explored in which one vehicle could run as an AGT vehicle as well as a conventional vehicle (Davies et al, 1991). Finally, the longitudinal and lateral control technologies under development for private cars could ultimately be applicable to transit vehicles as well.

2.2.3 Advanced Payment Systems

The traditional method of collecting fares is for the passenger to place money or tokens in the farebox upon entering the transit vehicle. While simple, this method is time consuming, inconvenient, and requires labor-intensive, theft-prone, money-handling activities. Advanced payment systems are intended to reduce these transaction costs. At the same time, they typically generate a rich base of ridership and revenue data with a broad range of planning applications.

Advanced payment systems involve a fare medium, a means of reading and altering that medium to reflect payment and system use, and a means of controlling system access based upon whether an individual possesses the proper medium. By far the most widely used medium in these systems is the magnetic farecard. It consists of a paper or plastic card, typically the size of a credit card, with a magnetic coating which can be polarized to store information. The card can be processed by either a read-only or a read-write device. These devices work from the principle that a changing magnetic field produces an electric current, which is then interpreted by the reader. When the user either purchases additional card value or uses the transit system, the write device alters the information on the card to reflect this. Other information, such as the points of entry and exit from the system and the time period during which the media is valid, can also be encoded in order to compute the fare, control access, or for other purposes.

The smart card is a more sophisticated and expensive medium. Similar in size to a magnetic farecard, it contains a microprocessor and may also have a tiny transmitter for remote communication. This technology offers many possibilities for transit fare payment. At the least sophisticated level, it could be used in a manner similar to the farecard, but with the ability to store additional information which, for example, could be used to identify a passenger as belonging to a special user group that qualifies for a reduced fare. In a far more advanced scenario, the smart card could be used to automatically transfer funds from the bank account of the user to that of the transit operator with each use of the system. Smart card capabilities can also be used to identify passengers who have made prepaid reservations, and to bill the appropriate parties for users participating in special purpose subsidy programs.

At the present time, magnetic farecards have attained widespread use in rail transit but little penetration of the urban bus transit market, while smart cards have so far been used only in a few demonstration programs.[*] Bus use of the former is, however, beginning to develop, motivated by needs to integrate with rail transit and to facilitate handling of transfers and monthly passes. The introduction of smart cards is hindered by the relatively high costs of the technology, especially for the cards themselves, and by the lack of infrastructure necessary to capitalize on its more advanced capabilities.

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[*] It should be noted that magnetic farecards are sometimes referred to as smart cards, particularly if the magnetic stripe is used to store information about the card user. Thus, several programs that include “Smart Card” in their title do not employ the smart card technology described here.

2.3 Transit Performance

The value of APTS technologies depends on their ability to improve transit system performance. At the broadest level, transit performance is often conceptualized as having two dimensions, efficiency and effectiveness. Efficiency is an intensive concept based on the ratio of system output to system input. Measures of efficiency include cost per vehicle-mile, labor hours per vehicle-mile, and vehicle-miles per bus, to name a few. Effectiveness is an extensive concept based on the total contribution the system is making to the urban transportation system. Passenger-miles, share of trips versus other modes, and quality of service indicators are examples of effectiveness measures.

Over the past two decades, both efficiency and effectiveness of transit have trended downward. Operating cost per revenue vehicle mile has increased 35 percent in constant dollars since 1975 (UMTA, 1991). Nationwide, the farebox recovery ratio has gone from over 80 percent in 1970 to just over 40 percent in 1988. Transit ridership in 1988 was slightly less than in 1965, but the transit share of commute trips has sunk dramatically, from 12.6 percent in 1960 to 6.2 percent in 1980 (Eno Foundation, 1987).

These trends have been widely observed and analyzed. It is useful to distinguish two types of contributing factors. The basic causes for the decline of transit derive from the increasing dominance of the private automobile. On the one hand, the inherent advantages of the automobile as an urban travel mode, combined with the increasing proportion of the population with access to it, have stimulated its share of the urban travel market. At the same time, the urban landscape has become increasingly shaped by the automobile, with evolving land-use patterns increasingly ill-suited to conventional fixed route transit service.

Several secondary effects have accentuated these trends. First, as transit has become increasingly dependent upon public subsidies, it has been shackled by constraints on managerial prerogatives which have reduced the efficiency (at least as conventionally measured) of transit operations (Wachs, 1985). Second, because transit is characterized by strong service economies of scale (more service means higher service frequencies, shorter waiting times, etc.), declines in service and ridership reinforce one another, creating a “downward spiral” (Jones, 1985, p. 75).

Transit operators everywhere are anxious to reverse the deterioration of past years. Four broad objectives can be identified as furthering this goal. These are (1) improving service quality (2) increasing ridership (3) enhancing revenue and (4) containing costs.

2.3.1 Improving Service Quality

Two forms of payment are exacted from transit users. The first is the fare, while the second consists of a myriad of non-fungible components including time, physical and mental effort, and stress. Service quality is an inverse measure of the second component — the lower the difference between the fare and the full user cost, the higher the quality.

More concretely, service quality can be tied to a variety of observables, including travel time, time spent waiting, time and distance of walking, day-to-day variation in these times, seat availability, crowdedness, crime and accident rates, and cleanliness. Other factors — time and effort to obtain service information, transaction costs (i.e. time and effort spent obtaining correct change and paying the fare) — are observable in principle but not in practice. Other aspects of service quality — productivity or quality of time spent in transit, social status of the service, and perceived safety and security — are inherently subjective but may nonetheless significantly influence the perceived quality of the service.

The need to improve service quality needs little justification. Analysis of mode choice suggests that service quality differences are the major reason for commuters preferring the automobile, despite its sizable disadvantage with respect to out-of-pocket cost. Indeed, experiments have shown that, even when the fare is eliminated, transit ridership gains are modest because of the service quality deficit. Furthermore, unlike fare reductions, service quality enhancement can, at least in principle, benefit users without depriving the operators of revenue (although often at some cost penalty).

2.3.2 Increase Ridership

Increased ridership benefits transit operators in several ways. First, ridership level is a key determinant of the operator's overall contribution to the urban transportation system. High ridership levels justify public subsidies and other forms of support. Second, if the increase is attained without increasing cost or reducing fares, this naturally leads to improved financial performance. Third, higher ridership can allow service improvements, perhaps reversing the "downward spiral" referred to earlier.

The objective of increasing ridership is, of course, furthered by that of improving service quality. Increased ridership can be obtained in other ways, however. These include fare adjustments, such as across-the-board reductions or (following the airlines) adjustments to the fare structure that capitalize on differences in fare elasticities among different types of users. Ridership can also be increased by making alternative modes — particularly the private automobile — less attractive.

2.3.3 Enhance Revenue

With farebox recovery ratios* in transit rarely exceeding 50 percent, revenue enhancement is clearly an important objective for any operator. For some transit operators, increased revenue translates to a larger budget and the resulting ability to increase services and upgrade facilities. For others, such increases are required to absorb reductions in subsidy.

Transit demand is relatively inelastic, creating a tension between the objectives of increasing revenue and maintaining or increasing ridership in the faresetting process. Further, the low-income, transit-dependent population and their advocates frequently offer strong opposition to fare increases. The use of more complex fare structures that effectively discriminate among passengers based on their fare elasticity

* The farebox recovery ratio is the ratio of a transit property's fare revenue to its cost.

(and, also, on equity grounds, their ability to pay) can, however, both enhance revenue and stimulate ridership. Such pricing strategies can be made more effective through the introduction of differentiated service quality — express commuter buses, for example.

2.3.4 Contain Costs

The containment of operating costs is clearly of concern to transit operators as it is to any organization. Dependent on the decisions of government officials and the traveling public for their revenue, operators' ability to manage and when necessary reduce costs is essential to maintaining a financially viable system. Overall, costs in the industry have trended upward for several decades. Lave (1991) reports that for the U.S. industry as a whole, real (inflation-adjusted) cost per bus hour increased 2.1 percent annually from 1964 to 1972 and 3.1 percent annually from 1972 to 1985. There is evidence that this cost escalation is in part the result of increasing government subsity (Lave, 1991; Pucher, 1983).

Since nearly three-quarters of transit operating expenses are for labor (UMTA, 1979), labor cost has been the major focus of cost reduction efforts. However, whereas other transportation firms, such as the airlines, have been able to use wage rates and work rules as safety valves for financial pressures, strong unionization and labor protection requirements imposed by federal and state assistance programs severe limite operators in this area (Kirby, 1992). One avenue that has been pursued is the use of part-time labor, a promising strategy because of the highly peaked pattern of transit demand. Giuliano and Lave (1989) report that, while agencies that employ part-time bus operators require somewhat less labor, in most cases this saving is cancelled out by the wage and benefit concessions demanded by unions as a condition for allowing part-time workers to be used. Another strategy for reducing cost is contracting out services to private operators. Giuliano and Teal (1987) estimate that a large transit agency could save 5-7 percent of total operating cost by contracting out 20 percent of their services, while smaller agencies would achieve smaller percentage savings. The labor protection provisions noted above mean that most opportunties for contracting out occur when agencies are expanding services.

2.4 Transit Performance and APTS Technologies

APTS technologies offer the promise of improved transit performance. Much more research is necessary before the magnitude of this performance gain can be assessed, but it is possible to understand the possible improvements in a qualitative way. Central to such an understanding is the development of a taxonomy of benefits derived from a unified conceptual framework.

The framework we propose is based on the notion that transit performance is the outcome of a set of <u>regulatory</u> processes. In such processes, outcomes depend upon inputs from two sources, a disturbance and a regulator. The objective of the regulator is to choose inputs which, when combined with those from the disturbance, produce desirable outcomes.

The various dimensions of transit performance outlined above can be tied to a plethora of different regulatory processes. Service quality, for example, depends on a combination of routing and scheduling decisions (regulation) and demand-side characteristics such as origin-destination patterns and service preferences (disturbance). Ridership and revenue, in addition to depending on service quality, are influenced by the combination of fare structure (regulation) and riders' willingness and ability to pay (disturbance). Costs are affected by many regulatory processes. For example, maintenance costs depend on decisions concerning whether and when to carry out various maintenance activities (regulation) and the degradation and failure of various vehicle components (disturbance).

In this section, we develop a simple framework for analyzing the potential of APTS technologies to improve the effectiveness of the various regulatory processes that determine performance. The framework is, in fact, a very general one that has been applied to a broad range of technical and biological systems. It is largely based on the work of Ashby (1961) and others who developed the field of cybernetics. The cybernetic paradygm offers a simple yet powerful theory linking the performance of a system to its ability to process information. Specifically, the theory relates system performance to successful regulation, and successful regulation to the ability to accurately transmit information about disturbances through the choice of a regulatory response. In other words, the higher the level of performance of a system, the more one can learn about disturbances in its environment from its regulatory responses to these disturbances. Within the cybernetic lexicon, this is known as the "transmission of variety" (Ashby, 1961, ch 8).

A simple regulatory process is depicted in Table 2-1. There, a system is depicted as a table relating two inputs, D and R, to an outcome, which in this particular example may be either **a**, **b**, or **c**. The input D represents disturbances impinging on the system. The input R represents the input from the regulator of the system. The outcome represents the performance of the system, or some aspect of it — for example, **a** might depict the highest level of performance, **b** the next highest level, and so on. Alternatively, **a** could be an acceptable outcome, while **b** and **c** are unacceptable ones.

The task of the regulator is to choose inputs so that the acceptable or most desirable outcomes are attained. To do this R must have information concerning D. The situation is depicted in Figure 2-1, where the D and R again refer to the disturbance and the regulator, respectively, and T stands for the table shown in Table 2-1, and E stands for the outcome (which as above may be **a**, **b**, or **c**). The bold lines indicate causal relationships, while the dashed line indicates an information link.

In Table 2-1, no column in T has a repeated outcome. Assuming this, one can see that the ability of R to ensure that the most desirable outcome depends on there being a unique one-to-one relationship between the set of possible disturbances and the choice of regulatory inputs. For example, if the desired outcome is **a**, then the correspondence is:

Table 2-1.
A Regulatory Process

		Regulator Input (R)		
		α	β	γ
Disturbance Input (D)	1	b	a	c
	2	a	c	b
	3	c	b	a

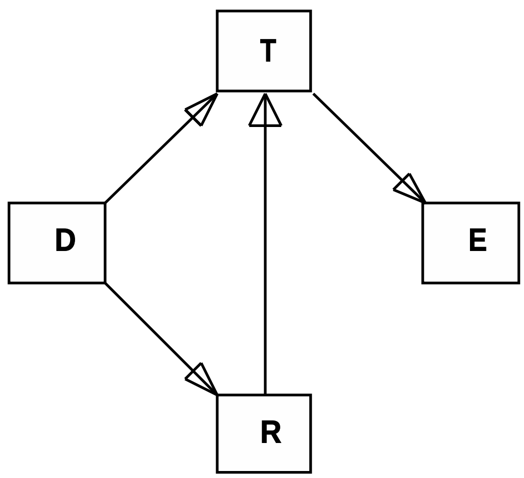

Figure 2-1.
Information Flow in Simple Regulatory Process

$1 \rightarrow \beta$
$2 \rightarrow \alpha$
$3 \rightarrow \gamma$

From this observation, it is clear that for R to be completely effective, it must act as a perfect transmitter of the information from D. On the other hand, it is apparent that R would be a ineffective regulator if its inputs were independent of D. From these extreme examples, we can see that the effectiveness of R depends on its ability to transmit information from D. In most cases, the ability will be neither perfect nor completely lacking.

Before proceeding further on these abstract lines, it is useful to consider how the concepts of distur-

Table 2-2.
Regulatory Processes in Urban Transit

Process	Disturbance Inputs	Regulator Inputs	Outcomes
Strategic Planning	Long term changes in operating environment.	Mission definition, capital improvement.	System performance and survivability.
Short-term Planning	Changes in travel patterns and traffic conditions.	Routing and scheduling decisions.	Ridership, service quality, operating cost.
Vehicle Operations Management	Divergences from schedule due to traffic conditions, driver behavior, traffic levels.	Operating speed, time at stops, routing adjustments.	Schedule adherence.
Emergency Response	Vehicle breakdown, medical emergency, crime, unforseen service need.	Transit vehicle dispatching, calls for emergency services.	Amount of passenger delay, level of injury and property loss, additional costs incurred.
Maintenance	Wear and failure of vehicle components.	Upkeep, maintenance, and repair activities.	Vehicle performance, failures, mainte nance costs.
Pricing	Willingness and ability to pay of users, costs of different forms of use.	Fare structure.	Ridership, revenue, equity.
Fare Collection	Individual transit usage, fare structure.	Transfer of funds from users to transit system	Accuracy, leakage.
Trip Planning	Transit routes and schedules, other scheduling constraints, travel and activity needs.	Choice of service, pre- and post-trip activity scheduling	Service convenience, fulfillment of activity needs.
Vehicle Operation	Roadway characteristics, movements of other vehicles, pedestrians, location of obstacles, condition of vehicle	Ignition, steering, shifting from emission acceleration, braking.	Crash avoidance, ride quality, schedule adherence.

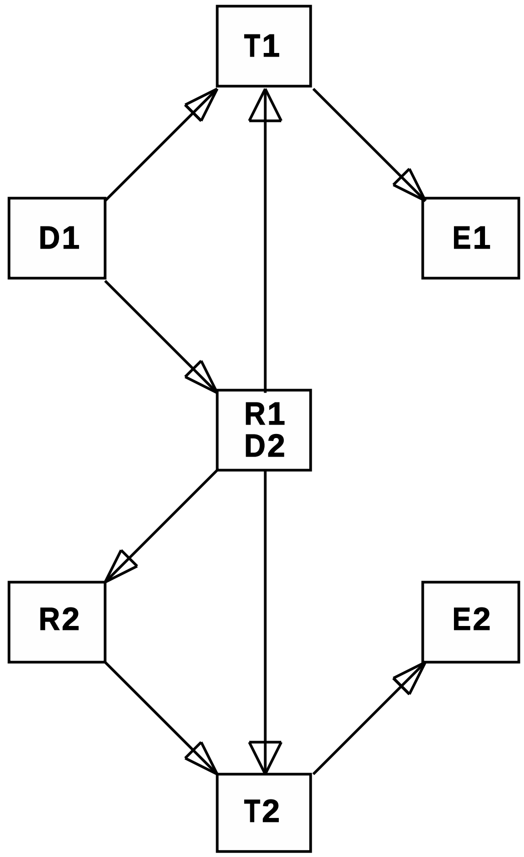

Figure 2-2.
Coupled Regulatory Processes

bance, regulation, and outcome apply to urban transit. Table 2-2 identifies nine major regulatory processes related to urban transit. In each case, as in Table 2-1, the likelihood of a desirable outcome can be increased by the choice of regulatory inputs appropriate for the set of disturbance inputs. Consequently, each of these areas requires information about the disturbance to be transmitted to the regulator.

The regulatory processes in Table 2-2 involve a wide range of time scales. The time scale of a given process depends upon the rate of change of both the disturbance and the regulatory inputs. These rates are generally compatible for the two types of inputs. If the rate of change of the disturbance input is much greater than that on the regulatory input, then effective regulation is generally impossible. On the other hand, the longer the time scale, the greater the set of available regulatory actions. The time scale of regulatory inputs thus tends to expand to match that of the disturbance.

Table 2-2 also reveals that "one man's disturbance is another's regulation." This is particularly true when the perspective of the operator is compared with that of the traveler. Transit planners, for example, adjust the transit schedule in response to changes in travel patterns and traffic conditions. In the trip planning activity of a traveler, however, the schedule becomes a disturbance, to which the traveler must adjust in choosing how (and whether) to use the system. Hereafter, we will refer to this phenomenon as R/D duality.

When regulatory processes are coupled so as to create an instance of R/D duality, it is also useful to distinguish the upstream process, for which the variable is R, and the downstream one, for which it is D. To illustrate, Figure 2-2 depicts coupled regulatory processes in which process 1 is upstream and process 2 is downstream. It is also possible for the duality to be reciprical. In other words, process 1 and process 2 can be both upstream and downstream of each other. This would be the case if transit operators attempted to schedule their vehicles to arrive at periods of high demand, while travelers attempted to schedule their trips according to when the vehicles arrive. In such situations, the situation can also be viewed as a "game" between the two regulators.*

We are now in a position to identify the potential benefits of APTS technologies for public transit, and for open technical systems in general, in terms of the ways in which they enhance processes of regulation. Figure 2-3 depicts various forms of such enhancement. All benefits are connected with changes in the ability of R to transmit information from D. At the broadest level, this ability can be altered in two ways. First, the cost of transmission can be reduced. This cost can be monetary, as when labor required for on-board ridership counts can be saved through an automated counting system. In other cases, the cost represents effort or time expended to attain the information, such as when a traveler can obtain schedule information from an Advanced Traveler Information System (ATIS) more easily than from consulting paper schedules or waiting several minutes on the phone to consult with an information operator.

The other major category of benefit fromAPTS technologies is through increasing the amount of

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* In fact, Ashby uses the example of a game to illustrate the relationship between effective regulation and information transmission. However, the game he considers asymetric, since it assumes that the regulator player responds to the disturbance player but not vice versa.

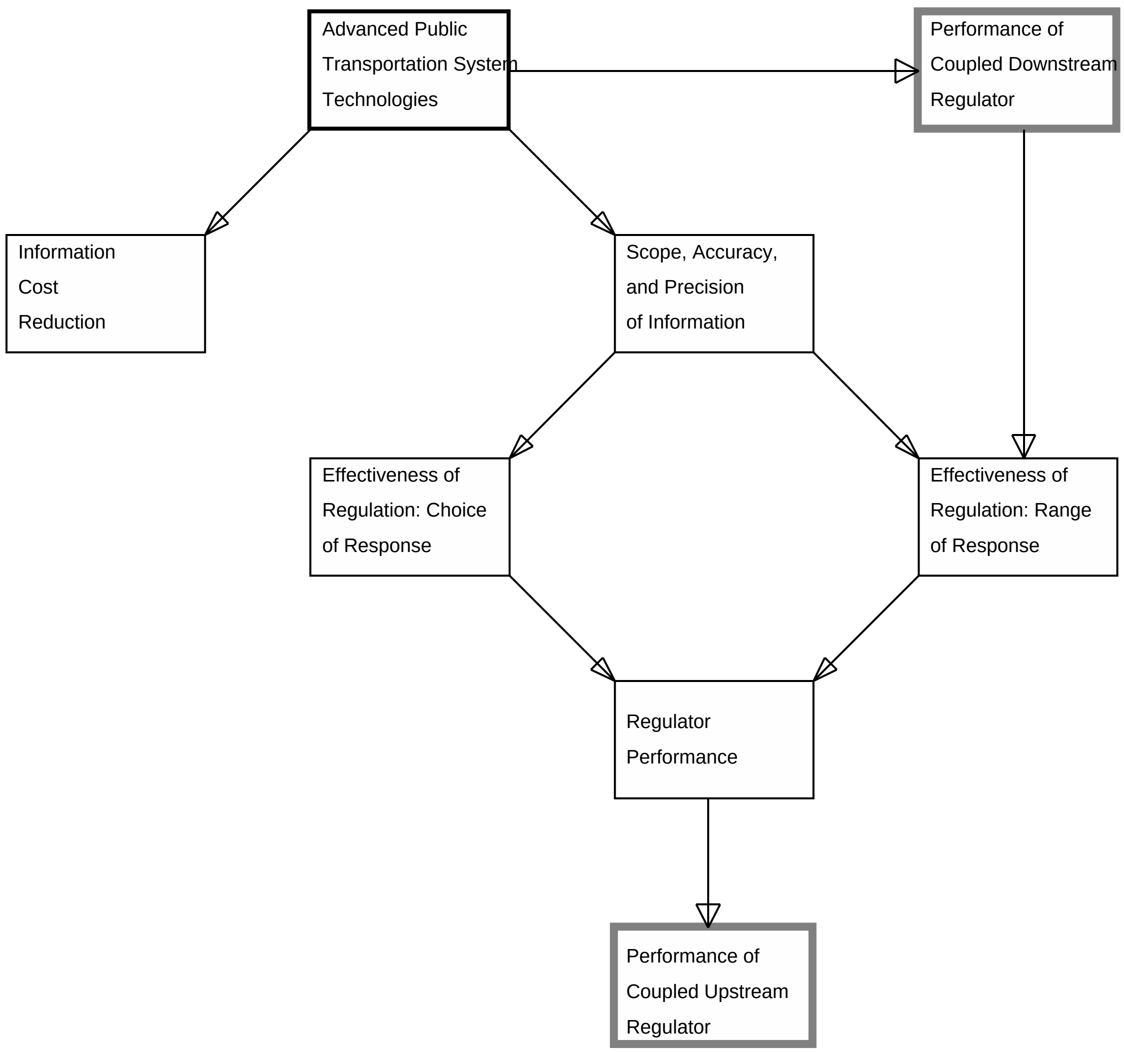

Figure 2-3.
Benefits of Advanced Public Transportation System Technologies

information transmitted by the regulator. The “amount” of information concerning D can increase in several ways. If D is multidimensional (which is almost always the case), the additional information may concern dimensions not originally addressed. Alternatively, the information may pertain to the same dimensions as previously, but be more accurate or precise.

In each of the above possibilities, the effect is to increase the amount of information reaching R. This yields no direct benefit, because it is the information transmitted by R which determines the effectiveness of the regulatory process. Several mechanisms act to convert the additional information reaching R to additional information transmitted by R. This effect may occur until the point is reached where R is a perfect transmitter. In real world systems, however, R is never perfect, so the potential for benefit always exists.

The simplest way in which the increased information reaching R can be translated into additional information transmitted by R is through an increase in the “fidelity” of R — the probability that the correct response will be selected for any given disturbance. As an analogy, consider television. If upgrading a television antenna increases the amount of information reaching the set, the benefit results from the set — unchanged from before the upgrade — transmitting a clearer picture. In the case of transit, increased accuracy in fare collection (measured say, by mean square difference between the appropriate fare and the fare actually tendered) is a benefit deriving from advanced payment systems.

A second way in which more information reaching R can be translated into more information transmitted by R is for the range of possible regulatory responses to increase. In the television analogy, the stronger signal can translate not just into a sharper picture, but can allow a color picture as well. For this to happen, however, the set must be upgraded from black-and-white. Similarly, an automatic vehicle location system can permit real-time control of vehicle operations in order to improve schedule adherence or remove bunching. In order for this to occur, however, the scope of dispatcher’s role in system operation would have to be increased from what it is currently.

In each of the above cases, the benefit from an APTS technology occurs within a particular regulatory process. A final form of benefit involves regulatory processes coupled by a variable with dual R/D status. In these circumstances the regulatory capacity of the downstream process, for which the coupling variable constitutes a disturbance, can constrain the range of regulation possible in the upstream process. Consequently, the effectiveness of upstream regulation can be enhanced by improving the effectiveness of downstream regulation.

To give an example of this effect, consider the dual role of the fare structure in urban transit. As a regulator, it interacts with willingness and ability to pay of different users, and the costs different types of use impose on the system, to influence the financial performance, equity, and patterns of use of the system. From the standpoint of the fare collection system, the fare structure is a disturbance. The fare collection system must provide regulation to assure that the appropriate funds are collected and transferred to the systems accounts with a minimum of cost and theft. If the fare collection system can be improved through

Table 2-3.
Potential Benefits of APTS Technologies for Urban Transit

Process	**Cost Reduction Benefit**	**Choice of Response Benefit**	**Range of Response Benefit, Within Process**	**Range of Response Benefit, Upstream Process**	**Technologies**
Strategic Planning	Traffic monitoring.	Accurate basis for ridership trend analysis.	More frequent updates and monitoring of progress.		Traveler Information Systems. Automatic Vehicle Monitoring.
Short Term Planning	Traffic monitoring.	More accurate and disaggregate ridership data.	Routing and scheduling adjustments.	Service experiments.	Advanced Payment Systems.
Vehicle Operations Management		Vehicle location and traffic conditions.	Operator guidance to minimize divergence from schedule.	Flexible operator assignments; frequent routing and scheduling adjustments	Automatic Vehicle Monitoring.
Emergency Response		Location of vehicle detection of emergency, ensuring appropriate response.			Automatic Vehicle Monitoring.
Maintenance	Time to determine maintenance requirements and diagnose malfunctions.	Correct identification of maintenance and repair needs.	Substitution of real-time for periodic maintenance Structure to even out workload.	Use of more sophisticated vehicular technologies Greater fleet specialization	Automatic Vehicle Monitoring.
Pricing	Traffic monitoring.	More accurate and disaggregate ridership data.	Pricing adjustments.	Pricing experiments	Advanced Payment Systems. Automatic Vehicle Monitoring. Traveler Information Systems.
Fare Collection	Effort to have exact change, money handling, transaction delay.	Accurate identification of fare category.		Complex Fare structures based on service and rider characteristics	
Trip Planning	Time and effort to obtain/ provide schedule information.	Real time, latest schedule changes, reduce errors.	Use of time before departure, complex itineraries.	Schedule and routing adjustments and deviations	
Vehicle Operation	Driver Stress.	Avoid crashes, improve schedule adherence.		Flexible operator assignments frequent routing and scheduling adjustments, routes requiring more difficult maneuvers	Automatic Vehicle Monitoring.

information technology, it might be able to handle a more complex fare structure (for example, one which varies by route and time-of-day). The greater the complexity a fare structure can have, the more effective regulator it can be.

As Figure 2-3 indicates, this “spillover” benefit takes two distinct forms from the standpoint of a given regulatory process. The range of regulatory response in the process itself may be enhanced by improved downstream regulatory effectiveness, and the range of regulatory response for upstream processes may in turn be extended as a result of the increased effectiveness of the regulation in this process.

Table 2-3 summarizes the ways in which APTS technologies can enhance the regulatory processes described in Table 2-2, employing the taxonomy derived above. The regulatory processes involving planning, which have longer time scales, benefit from reductions in data acquisition cost and enhanced data. These allow better assessments of current performance and predictions of future conditions. In addition to permitting more informed planning decisions, these types of information may encourage a shorter planning cycle. In effect, this expands R because, although it contains the same alternatives, choices among them can be made more often.

In contrast, operations management will benefit primarily from extending the set of regulatory actions available. For example, automatic vehicle monitoring will permit guidance to vehicle operators to minimize divergences from the schedule. There may, however, be additional benefits from the reduction in costs associated with modifying routes and schedules. In this case, the effectiveness of the short term planning process is enhanced by the increased capacity of the operations management process to adapt to it — an instance of R/D duality.

The benefits of APTS technologies for the emergency response process are perhaps the most simple to understand. In this case, R is unaffected by the technology — the choice of responses is the same as it was before. What is improved is the ability to correctly determine what emergency services to send and where to send them.

The maintenance process can benefit from APTS technology in several ways. A significant proportion of maintenance time is spent acquiring information in order to diagnose a specific problem or insure that some system is running properly. APTS technologies could provide substantial savings here. Further benefits should accrue from more accurate diagnoses and identifications of maintenance needs. With these gains, real time maintenance can supplant routine preventive maintenance in many instances. If R is the choice of whether or not to carry out a given maintenance activity, the benefit would be to improve the fidelity of R: fewer unnecessary maintenance procedures will be carried out, and fewer necessary procedures will be missed. Finally, the increased capability of the maintenance function may enable it to accommodate more sophisticated vehicles and a more heterogeneous vehicle fleet.

Pricing, like planning, benefits from less costly, better information concerning ridership and revenue. In addition to helping to determine fares for a given set of rider categories, the information may encourage the use of a larger set of such categories, a good example of expanding R. R could also be expanded — in a manner analogous to that discussed in the context of planning — by more frequent fare changes.

The fare collection process is closely coupled with the pricing one. The fare structure is another good example of a variable with dual status — part of R from the standpoint of pricing and part of D from the standpoint of fare collection. Hence the ability to increase the complexity of and frequency of adjustment to the fare structure depends on the regulatory capacity of the fare collection process. APTS technologies enhance this capacity primarily by reducing transaction costs and by increasing the accuracy of the process of determining the correct fare.

Trip planning has among the most interesting set of benefits from APTS technologies. The time and effort to obtain a given set of fare and schedule information would be reduced. Further, the accuracy of the information will be improved by incorporating the latest schedule changes and perhaps real time information. The improved information will allow travelers to make better use of the time before their departure. This could be especially important at stations and transfer points, where travelers would no longer be “chained” to the stop waiting for a bus which “will be here any time now.” Finally, as noted when we introduced the concept of R/D duality, improved traveler information may make it possible for the bus operator to make more routing and scheduling adjustments in response to traffic conditions or other factors.

2.5 Conclusions

This is a turbulent period in the technological development of urban transit. The widespread interest in the application of APTS technologies poses significant and unique challenges to transit managers and policymakers. The wide array of available technologies, their complexity and pace of development, and the range of possible applications pose difficult choices, particularly when the recent history of technical change in transit has focussed on “low-tech” measures. While the search for the most suitable technologies and applications is best carried out in bottom-up fashion, it is also greatly expedited for good technical information and a sound understanding of the potential benefits of APTS technologies.

In this chapter, the various APTS technologies and their potential benefits have been described, with special emphasis on the development of a unified conceptual framework for the benefits. Based on the cybernetic theory of regulation, the framework encompasses a wide range of potential benefits through the identification of key regulatory processes and different modes by which the processes can be enhanced through better information.

Many of the benefits of these technologies hinge on extending the range of regulatory alternatives. Although the technologies allow such extensions, they do not guarantee them. A major challenge to transit managers is to foresee how different regulatory activities — ranging from strategic planning to vehicle operation — must be redefined in order to fully exploit the potential of APTS technologies. In many systems, such an appreciation may be necessary to tilt the assessment of APTS technology costs and benefits in favor of implementation.

This is not to suggest that at the present time, a reliable quantification of benefits to APTS technologies, either in general or for any specific operator, is possible. Decisions to adopt these technologies will, for the foreseeable future, require a significant leap of faith. The experience of those systems that take this risk will provide a much firmer basis for assessing both costs and benefits. One can only hope that those who lead the way use these technologies to their full advantage. A theory of how APTS technologies benefit the performance of systems can improve this prospect, by allowing benefit opportunities to be systematically identified.

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CHAPTER 3:
APTS INNOVATION IN U.S. TRANSIT AGENCIES — CASE STUDIES

3.1 Introduction

Despite the continuing reliance of public transit on federal, state, and local subsidy, transit decision making in the U.S. remains heavily decentralized. Individual operators have primary responsibility for determining what services to supply and how to produce them. While government programs and regulations influence and constrain these decisions, substantial autonomy remains. Efforts to improve the performance of this sector will succeed or fail according to the responses these efforts elicit from individual operators.

This is also true in the adoption of Advanced Public Transportation System (APTS) technologies by transit operators. The rate of diffusion and ultimate level of penetration of APTS innovations depends upon the adoption decisions of individual operators. Equally important, the benefits of adopted technologies will rest on how agency managers and workers elect to use or not to use them. In making such adoption and utilization decisions, these individuals act as gatekeepers. No technical innovation, however revolutionary or worthwhile, can succeed without their consent.

Transit is not unique in the decentralization of innovation decision making, but the limited role of competitive forces, combined with the lack of clear performance criteria, make internal processes particularly important in determining innovation outcomes. In competitive markets, producers have strong incentives to adopt innovations that are cost-effective and avoid those that are not. Bad choices frequently result in harsh punishment: loss of market share, reduced profitability, even bankruptcy. Mistakes are made, but they are usually corrected either by the individual firm, or through its demise. Transit operators make innovation decisions in a different environment. Since their mission is more complex than that of a profit-maximizing private firm, so are the criteria for assessing a new technology. Since they are not exposed to direct competition, inappropriate choices regarding the adoption and utilization of new technologies can go undetected, and uncorrected. There is no invisible hand guiding the transit industry toward cost-effective use of APTS technology.

In light of such circumstances, it is essential to understand how APTS innovation, including the investigation, adoption, implementation, and utilization of APTS technologies, occurs in the transit industry. Such an understanding is essential if technology development efforts are to be appropriately targeted, since the success of these efforts hinges on operators adopting and effectively using the technologies that are developed. Even more important, the study of transit APTS innovation may lead to the identification of biases and imperfections that may be remedied through policy change.

The purpose of this chapter is to describe and critique the process of APTS innovation in U.S. transit operators. We use the term “process” not to imply a structured sequence of events, but a set of choices, whether implicit or explicit, concerning whether to investigate and adopt, how to implement, and how to utilize APTS technologies. We are interested in how transit agencies perceive, make, and implement these choices.

To help focus our inquiry, we developed a series of research questions. The questions fall into two categories. The first concerns how APTS innovation occurs in U.S. transit agencies. More specifically, our questions about this process include:

Under what circumstances do transit operators give active consideration to APTS technologies?

What are the factors that transit agencies consider in deciding whether to adopt APTS innovations?

How deliberate and rational are APTS technology adoption decisions?

How do transit agencies implement APTS innovations?

How are APTS innovations utilized?

The second category contains questions more normative in nature. Generally, they ask how the process of APTS innovation can be improved. The specific questions that fall under this general theme include:

How can transit operators be encouraged to make appropriate choices concerning the implementation of APTS technology?

How can the process of implementation be facilitated?

How can effective utilization of implemented APTS innovations be encouraged?

We should not expect definitive answers to the above questions on the basis of our case studies. First, the number of operators we consider is too small to allow reliable generalizations. Second, it is inherently difficult to predict the impact of actions intended to improve APTS innovation. The findings of this study are, therefore, hypotheses. They require further confirmation, based on evidence from a broader cross section of transit agencies, and on implementation and evaluation of recommended actions.

We restrict the scope of this paper in several ways. First the focus is on transit operators. Other actors — such as equipment vendors, consultants, and the Federal Transit Administration — who also play important roles in the innovation process, but we do not consider their viewpoints here. Second, our study is based on the viewpoints of decision makers rather than objective analysis. Our concern is with what decision makers perceive more than in the accuracy of their perceptions. Finally, we restrict our attention to transit involving road vehicles-primarily bus, and to a lesser extent paratransit.

3.2 Approach

This paper is based on case studies of seven bus transit operators. We use the case study method for a number of reasons. Case studies are required to obtain the detailed information necessary to describe and analyze the process of APTS innovation. Also, since we are studying transit organizations, it is necessary to interview persons from throughout a transit agency in order to obtain a relatively complete picture of its APTS experience and outlook. Finally, case studies are the best means of uncovering the complex phenomena that shape APTS adoption and implementation outcomes at transit agencies.

Several factors influenced the selection of the seven case study operators considered in this report. First and foremost was the willingness of the operator to participate. In addition, we wanted operators with a diversity of APTS innovation experience. Our set of operators includes three with Automatic Vehicle Location systems (AVL), three with some form of advanced fare payment, and four in the process of either replacing or acquiring dispatching software for paratransit operations. In addition, two of the operators were in the process of modernizing their traveler information systems. For reasons of both economy and relevance, four of our case study operators are located in California. We chose the other three based on their having adopted AVL, which no California operator was using at the time of our research. The diversity is also reflected in the size of the agencies, with the smallest operating a vehicle fleet less than a tenth the size of the largest.

For each case study, we made a 1-2 day site visit. The site visit involved interviews with persons from throughout the organization, including upper management, staff and department heads in planning, transportation, marketing, maintenance, and other groups, and line personnel such as drivers, dispatchers, and supervisors. Discussions were open-ended, but revolved around two main areas: the experiences of the operators with APTS technologies that they had already adopted, and the outlook for adoption of additional APTS technologies. Also, we reviewed documentation including short-term plans, system descriptions, brochures, and items of specific relevance to APTS.

In conducting the case studies, we found it necessary to be selective in the ground we covered. We made it a priority to learn of transit agency experiences with APTS technologies, as opposed to agency attitudes toward technologies with which they lack experience. In some cases, we stretched our working definition of APTS technology (covering vehicle monitoring, advanced fare payment, and advanced traveler information systems) in order to learn about other relevant innovation experiences. At the same time, we had some discussion about each of the three main categories of transit APTS technology (as we define them) at each agency.

We used these sources to prepare individual reports for each case study operator. After trying a number of somewhat complicated organizational schemes for these reports, we settled on a very simple one, consisting of an operator description (more or less detailed, depending on the documentation available), a discussion of the operator's general outlook on APTS, discussions of experiences with and attitudes toward each of the three primary APTS technology categories, and a conclusion. These individual reports are presented in the next section. A final section seeks to analyze and synthesize the individual case studies in order to suggest answers to the research questions posed above (page 29).

3.3 Individual Case Studies

3.3.1 Mass Transit Administration (Baltimore MD)

3.3.1.1 Description

Mass Transit Administration (MTA), an agency of the Maryland Department of Transportation, is responsible for serving the Baltimore metropolitan area. The service area is 1795 square miles with a service population of nearly 2.1 million.

MTA operates four types of service, bus, demand responsive paratransit, heavy rail and light rail. The bus and rail services are integrated with the same flat fare and transfer charge. Heavy rail service began in the mid 1980s while light rail service was initiated in 1992.

MTA operates approximately 700 buses in peak periods to provide regular, Express Flyer and Metro Connection routes. Express routes originate from park and ride lots while Metro Connection routes feed selected Metro stations. In addition, MTA contracts for commuter services to Washington, DC and for demand responsive service as well.

3.3.1.2 General Outlook on APTS Technology

MTA is aspiring to become an APTS pioneer in the U.S. transit industry. The agency has acquired a state-of-the-art AVL system that it is testing on a small part of its system. At the time of our visit, the head of the Systems Technology Group, advised by a task force from throughout the agency, was preparing a major grant proposal for the Federal Transit Authority (FTA). The proposal will call for expenditure of $35-$40 million to create the Maryland Advanced Public Transportation System (MAPTS). The proposal includes equipping the entire bus fleet with an upgraded AVL system using Global Positioning System (GPS) technology. Computerized decision support for the dispatchers, automatic passenger counting, information kiosks tied in to the AVL, and a smart card system for the paratransit service are among the additional elements being considered for this system.

MTA staff anticipates a wide array of tangible benefits from MAPTS, as described below. Above and beyond these utilitarian aims, the system is designed to be, in the words of the one staff member, “hot and sexy” and therefore appealing to the congressmen and high level Department of Transportation officials whose support is necessary for such a large expenditure. The new system was first outlined in preparation for a presentation the staff member quoted above made to such individuals. Again quoting him, the question guiding this presentation was “How can we wow them today, and how can we wow them tomorrow?”

3.3.1.3 Vehicle Monitoring

MTA has emerged as an industry leader in transit APTS through its acquisition of a state-of-the-art AVL system. Most of our attention in this case study focused on MTA’s experience with this system.

MTA had given some consideration to AVL as early as 1972. At that time, they were acquiring a new radio system, and considered AVL as a possible feature. They did not proceed, however, because experiences of other operators, particularly Chicago, indicated that the signpost technology of the time was not reliable. In 1985, MTA decided to again replace their radio system because of its age and the resulting difficulty in finding replacement parts. In 1986-87, MTA received funding from the Urban Mass Transit Administration (UMTA, which has since been renamed the Federal Transit Administration) for the upgrade. In preparing the specifications, staff reviewed the specifications for the previous radio system, where they found sections that discussed AVL.

This spurred the staff to begin looking into AVL. Members of the Systems Technology Group quickly "got excited about" this technology. Two individuals in particular, the head of the group and the radio engineer directly responsible for preparing the radio specification, became the "champions" for AVL. Initially, they encountered resistance both from other parts of the organization. According to the radio engineer:

> There wasn't a lot of support from the top of the organization...or the bottom. People were hesitant to go into new technology and try new things. ... At first, everyone was against it. If you look at this thing for the first time and we give a concept paper that says 'We're going to know where everyone is. We're going to be able to listen to them. We're going to be able to watch them. We're going to be able to monitor how they're doing, when they're doing [it], what they're doing. We're going to automate.' It's kind of scary. There was a lot of that Big Brother thing initially.

It is not entirely clear how AVL advocates overcame this opposition, but several things are apparent. First, the AVL supporters within the Systems Technology Group kept the idea alive when it had little support elsewhere. Second, after about one year of AVL advocacy, they were able to develop enough support to form a committee, with representatives from operations, maintenance, and planning, to define the functional requirements of the AVL system. This represented a turning point in terms of the MTA's commitment to AVL.

Two benefits of AVL appear to have been the most critical in winning support for the system. The first was schedule adherence. MTA suffered a 9 percent ridership decline in the early 1980s, and evidence from passenger complaints and surveys suggested that unreliable service was a major reason for this. The second was enhanced security for bus drivers and passengers. Although the problem of security on buses is, in the view of one MTA manager, "more perceived than actual," security enhancement proved an effective counter to the concerns about Big Brother.

Six months after the committee was formed, MTA issued a specification for a new generation AVL. The process of preparing the specification included substantial research, including talks with many vendors and site visits to White Plains, New York and Toronto, Canada. MTA staff considered many technologies, incuding signpost, infrared, video, detector loops, microwave, and others. The research effort convinced the Systems Technology staff that no existing AVL system was sufficient. Rather, MTA sought a system combining a set of features found in existing products that they considered among “the best and most mature.” However, when they discussed customization with AVL vendors, they encountered a reluctance to alter existing products to fit MTA’s requirements:

> They weren’t willing to change. Their products were selling pretty decently, so why change and make their life miserable? They weren’t interested in inventing products just for MTA.

Therefore, if MTA was to acquire a suitable AVL system, a considerable development effort would be required.

Thus, from its beginnings as a possible feature of the new radio system, AVL evolved into “an animal by itself.” After realizing that implementing AVL would be a greater task than just revamping the radio system, MTA requested and received additional funding from FTA. FTA had funded several earlier, and largely unsuccessful, demonstrations involving AVL, but was interested in showing the potential of a next generation system. MTA, with its proximity to Washington, technically competent staff, and obvious interest in AVL, was an ideal test-bed for this experiment. Since FTA’s objective was to prove technology, the project was redefined so that only a small fraction of the MTA fleet would be outfitted with AVL. Full deployment would occur later on, if the technology proved successful.

During the research stage, MTA was able to identify several vendors who could provide individual features that MTA desired. Teleride/Sage was identified as the vendor who could provide transit oriented software. RMSVA Industrial Control could provide the best computer-to-radio interface. Mets could provide the mapping features. Finally, Motorola or GE could provide the radio system hardware.

Only one piece was missing — someone to play the role of system integrator, putting the different components together and making sure they that they communicated with one another. Westinghouse had recently contacted MTA along with other transit operators in an effort to identify market opportunities in the transit industry. During a follow-up contact, MTA proposed that Westinghouse play this integrator role, and Westinghouse expressed its willingness to do so.

MTA then advertised a request for proposals. Several firms responded. They included Motorola, CGA, GRS, Systems Group, and Westinghouse Electric Corporation. From this group, MTA chose Westinghouse as the prime contractor, rating it highest on technical merit as well as cost. Subcontractors included many of the companies MTA had previously identified: Teleride/Sage for the Computer Aided Dispatch (CAD) software; Mets for the location tracking and base maps; RMSVA Industrial Control for the radio controlling hardware; and Synetics for the management reports.

The specification called for a route independent system. The research had indicated that with Loran technology, acceptable accuracy could be obtained from a route independent system. MTA staff considered route independence beneficial because it enhanced the security benefits of the system, since a bus could be located even if it is not following a regular route. Such a situation could occur as the result of a hijacking, use of a test course for driver training, or providing special non-scheduled services. In addition, this technology can locate buses while they are parked in the garage. This is expected to be useful for verifying that parking positions are such that each driver will be able to get their assigned bus out of the garage at the beginning of the day.

The whole AVL project has proved “frustrating right to the end” according to the radio engineer. Initially, MTA had problems with the project team from Westinghouse. Westinghouse was primarily a defense contractor and, despite some experience with transit vehicle technologies, had little familiarity with transit operations. Furthermore, the expertise of Westinghouse in communications was not in radio but rather radar communication. MTA’s unhappiness with the prime contractor resulted in three changes in the Westinghouse project administrator.

Although critical of Westinghouse, MTA staff also faulted the subcontractors responsible for individual system components. The were serious problems getting the various components of the system to communicate properly with one another. Contractors shifted responsibility for these problems onto each other. Difficulties often arose because the subcontractors were unwilling to share information about proprietary technology. Westinghouse had difficulty resolving disputes and conflicts among the subcontractors concerning these matters. In some cases, MTA staff had to step in and resolve problems themselves. It is difficult to determine the extent to which the problems Westinghouse had were of its own making, or were instead the fault of the subcontractors.

For unknown reasons, UMTA desired very quick project completion — within nine months of contract award. Westinghouse strove to meet this tight schedule, but it proved impossible. It took Westinghouse almost four months just to retain the subcontractors. Consequently, the project duration was doubled to about 18 months. In retrospect, the tight deadline had a negative effect on the project. Westinghouse, eager to meet project milestones and avoid liquidated damages, had hardware delivered on-site in a piecemeal fashion, as soon as each component was ready. They rushed to create some semblance of a functioning system, which, not surprisingly, did not operate properly at first. The bugs in the system included a display in which buses would “hop” from one part of the city to another.

Getting dispatchers to use the system also proved difficult. In part this problem stems from the early technical problems such as bus hopping, which harmed the credibility of the system in the eyes of some dispatchers. Simple inertia also played an important role. The manager of supervision recounted a story about the introduction of the new radio system that illustrates this problem. When MTA replaced the radio system, it installed a new control room. For a time, MTA had both the old and new control rooms available, in the hope of gradually easing the transition from one to the other. However, the manager discovered that despite the new facilities the dispatchers continued to use the old radio facility. Eventually, MTA had to “cut the cable” to the old radio control room and force the dispatchers to use the new radio control room. The same situation arose with the AVL system. While some dispatchers were enthusiastic about the system, most did not begin using it voluntarily. The manager of supervision has resorted to assigning each dispatcher a minimum number of hours with the new system.

According to the dispatcher we spoke with, the system is now working properly about 80-90 percent of the time, but problems occur frequently enough to cause dispatchers considerable frustration. Nonetheless, he estimates that roughly 6 of 10 dispatchers — himself included — view the system positively. On a day-to-day level, the primary use is to monitor schedule adherence, particularly to detect buses that are running ahead of schedule:

> I usually look for a bus that is running in the blue, which means it's running ahead of schedule. If I see a bus that's running ahead of schedule, I'll either call the operator and remind him that he's being monitored by the AVL, or I'll send a supervisor there to get him, depending on how much he's up.

Recently, he's noticed that the AVL-equipped buses are not "running in the blue" as much as before, and believes this is because the drivers know they are being monitored. Although schedule adherence was monitored as closely as possible before AVL, on-street supervisors could give only a fragmentary picture since they tend to stay near the central areas of their zones of responsibility, going out "into the far reaches" only infrequently. The "total coverage" provided by the system is therefore considered a major benefit.

Drivers' response to the system appears somewhat negative, although there has been little if any outright resistance. One driver we interviewed estimated that 75 percent of the operators don't like AVL. According to him, many drivers (not including himself) like to run ahead of schedule, since this tends to reduce the number of passengers they have to deal with and give them longer breaks at the end of the line. Drivers also will sometimes cut routes short — head for the bus garage as soon as their bus is empty without completing their run — at the end of their shifts. Since, with AVL,, these dispatchers easily detect these transgressions, it is not surprising that drivers who indulge in them dislike the technology. Yet, drivers have not voiced strong opposition to AVL. Perhaps this is because they recognize the legitimacy of MTA taking steps to curb these abuses. Acceptance may have also been increased by the ease of operating the system from the driver's point of view. Drivers needed less than half an hour for the necessary training, in which they learned how to initialize the system at the beginning of their block with a few simple responses to system prompts. Several interviewees also pointed to the security gain as a factor that increased driver appeal, although the operator we spoke to seemed to downplay this aspect.

MTA management has come to view the current phase of the AVL project in narrow technical terms. The focus is on whether the technology works, as opposed to whether or how it can benefit MTA's performance. MTA has made only one inquiry into the latter question. The purpose of the experiment was to see if dispatcher intervention could improve schedule adherence. In the first two weeks of the experiment, dispatchers monitored the AVL system but did not do anything if they detected a bus behind schedule. In the next period, dispatchers would notify the driver if schedule deviation exceeded 5 minutes. Schedule adherence, as measured by the proportion of buses less than 5 minutes late (or 1 minute early) increased from 62 percent to 77 percent when dispatchers notified late drivers.

Although the benefits of the existing system are largely unexplored, interviewees identified a wide range of anticipated benefits from AVL once the new system is in place. Many consider the ability to respond to breakdowns, accidents, crimes, and security threats as a primary benefit. A second benefit, one emphasized by the head of Systems Technology, is to have better measurements of operational efficiency, particularly on-time performance. This individual also cited the ability to improve efficiency through enhanced dispatcher control, assisted by computer automation. He envisaged a system in which dispatchers would need to make decisions only in exceptional circumstances, so that on a good day the only requirement is that he "know how to relax."

Bus operations staff stressed the elimination of the need for on-street supervisors to make time-checks. Although in theory this could reduce the number of supervisors required, there are no plans to eliminate such positions. Supervisors have many other responsibilities, to which managers expect them to devote extra time. Examples include investigation of passenger complaints, increasing interaction with passengers, and spending more time riding buses in order to monitor and improve service quality.

Planners at MTA have strongly supported including automatic passenger counters (APCs) in the new system. Indeed, planning staff perceive automatic passenger counting as "the biggest benefit MTA gets out of AVL." Part of the benefit is cost savings — MTA has a budget of roughly $100 thousand for part-time passenger counters each year. Since the counters are mostly MTA retirees on pensions, MTA planners see little difficulty in eliminating these positions. Further, planners expect that using APCs will greatly speed the process of collecting data, which is currently slowed by the time required to schedule counters and the frequent occasions when they fail to appear. The primary benefit of this enhanced data gathering capability will be to guide route adjustments made under the Enhanced Service Program (ESP). The ESP process involves systematic review of the performance of all transit routes. Routes not achieving a 50 percent farebox recovery ratio are targeted for cost reduction or ridership enhancement. Planning staff believe these changes can be designed more effectively with better count data. They also expect to make changes in situations where the AVL reveals recurring bunching, since a paired bus is likely to produce greater benefit if it is reassigned elsewhere.

One feature unlikely to be included in MAPTS is real time monitoring of bus mechanical systems. Since "the horses return to the barn every night," the maintenance manager does not think such monitoring is of much benefit. Manufacturer warranty requirements drive scheduling of preventive maintenance and inspection work. Additional information is therefore unlikely to influence it.

3.3.1.4 Fare Payment

MAPTS may include smart cards for the paratransit service. The primary benefit of benefit of this technology will be for developmentally disabled clients who are unreliable in handling money. The paratransit manager related the story of one individual who frequently spent his return fare money on candy, making him unable to pay for his ride home.

Otherwise, there seems to be little interest in advanced fare payment technologies at MTA. Although magnetic farecards are used on the light rail system, there is little interest in extending this technology to buses, where paper transfers are currently used for feeder service. MTA staff stated that advanced fare payment technology might be of some value under the current, zone-based, bus fare structure, but that they are recommending that this structure be replaced by a simple flat fare structure under which such technology would be less useful.

3.3.1.5 Traveler Information and Paratransit

MTA expects information from the new AVL to be forwarded to passengers through kiosks set up in rail stations, major downtown bus stops, and other activity centers. The concept is still under development, but is likely to involve a menu-driven videotext system, including information on local activities as well as transit services. The AVL will also feed into the telephone information system.

Adoption of a computer scheduling system for the paratransit service is being considered at MTA. A top priority in this system will be strong mapping capabilities, so that the system can output maps showing the routing of each vehicle that the driver can then use for navigation. Interest in both the system as a whole and the mapping feature in particular derive from changes brought on by the Americans with Disabilities Act (ADA). The paratransit manager anticipates a “surge in demand” as a result of ADA. Also, it will be necessary to substantially expand the service area in order to conform with ADA regulations requiring that paratransit service be available to all areas within 3/4 mile of a fixed transit route. Since drivers will be less familiar with the new area, the customized route maps are expected to be very helpful.

3.3.1.6 Conclusions

MTA has become a transit industry leader in the Advanced Public Transportation Systems (APTS) movement. The seeds for this were planted and nurtured by its System Technology group, who believed in the benefits of APTS technology, and had the technical sophistication and ambition to aim for a new generation AVL system rather than a more mature, off-the-shelf, one. The FTA also played a major role, both by funding the system, and by setting an ambitious timetable for its completion. MTA is now seeking to parlay its technology leadership position into federal funding for a project of far greater scope and cost.

Several factors contributed to the successful aspects of the MTA experience. The System Technology Group played a crucial role in getting the project started. In addition to reflecting its technical competence and motivation, their success also testifies to their credibility within the organization. On the other hand, it also demonstrates the receptivity of the middle managers concerned with bus operations, and of upper management, to trying new things. At least part of this receptivity can be traced to recognized problems to which the AVL promised some remediation, including poor bus reliability, and seemingly widespread problems with driver discipline. Finally, system proponents mobilized support for the system through a task force cutting across different parts of the organization. The task force was able to define a system that promised widespread benefits.

MTA has been less successful in identifying appropriate uses for AVL technology, or assessing the benefits from these uses. MTA, with FTA encouragement, has focused on proving that route-independent AVL is technically feasible rather than economically worthwhile. Further, the technology itself has been defined in narrow terms — as merely the production, transmission, and communication of information, but not the use of this information to improve performance of the system. The demonstration offered many opportunities for quasi-controlled experiments to explore how to use the information, but with one exception (the test of dispatcher advisories to late buses described above) MTA failed to exploit such opportunities. Thus, while MTA knows much more about AVL hardware as the result of its demonstration, it still knows little about how to use the hardware, or even whether it is worth using.

MTA has avoided such questions by conceiving of their AVL activities as developmental. Project participants consider the value of such activities to be in advancing the state-of-the-art in AVL, not in cost savings to MTA or improved service to MTA passengers. MTA staff clearly believe that benefits of these kinds exist as justifications for the development activity, but have so far shown little interest in quantifying or maximizing them. This makes it difficult to know whether the large investment in APTS technology planned at MTA will yield commensurate benefits.

3.3.2 Tidewater Regional Transit (Tidewater-Norfolk-Virginia Beach, VA)

3.3.2.1 Description

The Tidewater Transportation District Commission, also referred to as Tidewater Regional Transit (TRT), is a regional authority that includes the five cities of Chesapeake, Norfolk, Portsmouth, Suffolk, and Virginia Beach in southeastern Virginia. TRT's service area covers over 1,000 square miles with a population near one million. The District was chartered in 1973 and works in close cooperation with its component cities. The District does not tax and relies on annual contributions from local, state, and Federal governments.

The region has low density housing and employment areas typically found in midsize metropolitan areas. Current development continues to be low density, single family residential. Commercial development continues to favor low density industrial parks and regional shopping centers away from the downtown.

TRT offers a variety of services to meet the needs of its service area. The fixed route service runs on thirty and sixty minute headways, which is comparatively long for local transit. TRT employs a pulse transfer, called Direct Transfer, with 18 transfer centers throughout the network. TRT operates a fleet of 141 vehicles on the fixed route system.

TRT also offers two demand responsive services. The first, termed Handi-Ride is door to door service for the disabled. Clients must request service 24 hours in advance on a space available basis. TRT is also the centralized provider for many social service agencies that serve the elderly and disabled, on a contract basis.

The second type of demand responsive service, termed Maxi-ride, serves low density areas where fixed route service has proved inappropriate or too costly. Service is provided by cellular phone equipped vans within assigned areas. Users must make reservations two hours in advance for curb to curb service within the assigned zone. Transfers can be made to fixed route service or to other Maxi-ride service.

In addition, TRT operates ferry service from Portsmouth to Norfolk downtown across the Elizabeth River. TRT also operates a tourist oriented trolley service to Virginia Beach, and several commuter services including vanpool, carpool and ridesharing. The agency maintains a fleet of vans that it leases to vanpoolers, offers assistance to employers who want to establish ridesharing programs, and provides areawide carpooling matching services.

3.3.2.2 General Outlook on APTS Technology

Innovation — both with and without APTS technology — is a tradition at TRT. In the words of one respondent, “Management here likes to keep up with what’s new. They like to experiment.” Recent years have witnessed several examples. The routes and schedule have been completely reconfigured to create a pulse transfer system, in which buses are scheduled to converge at designated transfer points at the same time in order to minimize layovers. Also, fixed route services in certain areas have been replaced by demand-responsive services, with service requests routed directly to cellular telephone equipped vans. In the area of APTS, TRT was an early adopter of electronic fareboxes, as well as mechanical and silent bus alarms, and has also participated as a test-bed in a university research project on electronic passenger counters. More recently, TRT has acquired an AVL system, and is among the first transit operators to adopt Ticket Reading and Imprinting (TRIM) machines for handling transfers.

3.3.2.3 Vehicle Monitoring

TRT’s experience with AVL began in 1987 when it decided to upgrade its bus radio system. Their system was getting old and replacement parts were becoming hard to find. According to one interviewee, in the initial stage of the procurement process, “You look around to see what [features are] available, so we did.” From this, AVL was identified as a feature worth of consideration, for several reasons. First, top management “had a longstanding desire to reduce resources allocated to street supervision,” and AVL seemed to have promise in this regard. Second, TRT’s survey of customers had shown that service reliability was their foremost concern, and proponents saw AVL as a means of improving reliability, both through real time control and schedule adjustments. Third, TRT was implementing its timed transfer route system, and some advocates believed that AVL would be helpful in maintaining the integrity of the “pulses” in and out of the transfer points. Finally, in the words of one respondent, “It was flashy and high-tech.”

The initial impetus for AVL came from upper management and the Department of Planning and Scheduling. However, since the AVL was a feature of the radio system, the Transportation Department had primary responsibility for the decision whether to acquire this technology. Interestingly, this department initially opposed AVL, since all it really wanted was a radio system: “I was really interested in basic communications at the time and that was all,” according to one member. Members of the Transportation Department, initially viewed AVL as a source of information for planning and scheduling, but without functional value for operations.

TRT published a request for proposals (RFP) for a consultant to guide them on the upgrade of their radio system. From the RFP, the firm NIACAD was chosen. They performed a needs assessment based on TRT’s operations. From this assessment, NIACAD recommended an AVL. It also arranged a site visit to Hull, Canada, which had an operational AVL system. This visit was instrumental in changing the view of the Transportation Department. Members from this department were impressed by the technology they saw, and were better able to appreciate the operational value of being able to locate buses. Soon after the visit, TRT management, in conjunction with NIACAD, decided to acquire AVL. NIACAD was assigned to write specifications for a radio system with AVL capabilities.

From these specifications, TRT accepted a bid from F&M Global over GRS, Atkinson Technology and Motorola. The AVL system is of the signpost variety. In addition, silent and mechanical alarms — also features of the previous radio system — were included. Automatic passenger counters were not considered because a previous university demonstration project of this technology conducted at TRT had not been successful. The system has been operational since fall of 1990 and TRT accepted it in October 1991.

The manager with the most direct involvement in implementing the AVL describes this experience as “a nightmare.” Several factors appear to contribute to this characterization. First, the process of setting up the system has required much more organizational effort than was anticipated. Much of this effort revolved around measurement of distances along routes so that the system could accurately track vehicles between signposts. These measurements were performed three times, apparently because TRT personnel attributed failure of the system to track buses accurately to faulty distance measurements. In fact, it is likely that the problem was not with the distance measurements, but with the odometer readings. The sensors in the on-vehicle “data box” which accept input from the odometers and convert it for radio transmission have shown a propensity for spiking, resulting in false odometer readings: “A bus is going along just fine when all of a sudden it registers 10-15 miles in just a few seconds,” according to a technician working on this problem. A replacement interface turned out to be worse. Finally, TRT’s chief radio repairman designed a new sensor that has thus far proven satisfactory on the three buses where it is has been installed, although at the time of our visit testing was not yet complete.

At the time of our visit, a new problem was emerging, this one with the AVL Transmitters (AVLTs). When these transmitters fail (generally as a result of dead batteries), it should be evident from the AVL output. However, technicians had recently discovered that, according to this output, signals were being received from non-transmitting AVLTs. Consequently, there is a large backlog of previously undetected failed AVLTs, as well as an apparent malfunction of the AVL software.

TRT has created a new position for an electronics technician to deal with some of these hardware problems. A maintenance person has also been assigned to deal with the odometer problem. In addition a radio group has been created to handle all problems arising from the AVL system. This group is headed by the schedule analyst and includes the electronics and maintenance personnel, the radio operators, and the computer systems administrator. They meet on a regular basis to discuss and attempt to solve problems with the AVL.

These, apparently unforeseen, labor requirements have negated the manpower savings that sparked interest in AVL on the part of top management. In the words of one manager:

> It's marketed to save you manpower: on-street supervision. I think what they don't tell you is that you in turn have to have others that you didn't have before to take care of the system, more of a technical nature. The system is very technical and you do need electronic technicians and electricians and so forth that have to be familiar with calibrating the odometers and troubleshooting and things of that nature. So I'm not sure that we've saved any manpower.

The situation may be even worse than this individual suggests, since the AVL had yet to yield net savings in operations personnel at the time of our visit. While street supervision had been curtailed, additional labor was being used in the control room. Staffing in the control room has been increased from two to three during daytime hours. Prior to the AVL, a dispatcher and assistant dispatcher were assigned to the control room, with the assistant dispatcher responsible for answering radio calls as well as paperwork. With the AVL, a radio operator job has been added. This individual handles radio calls, and also monitors the AVL. In essence, AVL monitoring has turned radio operation from a duty of the assistant dispatcher into a full-time position. According to a radio operator who served as an assistant dispatcher prior to the AVL:

> I was doing payroll and answering the radio which was just voice communication. You didn't have to sit there and monitor. I'd have to go there when somebody called. I didn't sit at the console. Now I'm stationed at the console. I have to man it now. I didn't used to have to man it. I could do my other work and just go to the radio when I had a call or had to call someone. There was nothing to monitor. Now we have to monitor what's going on, what's happening.

Two full-time employees fill the radio operator position.

On the other hand, on-street supervision has been reduced, with the number of peak period on-street supervisors reduced from five to three, two supervisor positions eliminated, and the on-street positions reclassified from "supervisor" to a lower paying "inspector" category. The immediate cause of the cutbacks in on-street supervision was budgetary pressure, not the AVL. However, the general manager indicated that he considered the AVL acquisition to be a justification for the cuts, while managers in the Transportation Department stated that they opposed the cuts less strongly as a result of the AVL.

On balance, it appeared that AVL was increasing labor costs for TRT, even if managerial time and one-time costs for system setup are neglected. However, top management believed that there was room for further cuts in on-street supervision. The general manager expressed frustration at Transportation Department reluctance to provide analysis to determine just how many street supervisors were actually needed with the AVL in place, an attitude he attributed to their not wanting to eliminate a job: “Eventually ... I’m going to go over there and tell them to cut the ... job off.”

As the prospect for labor savings has receded, focus has turned to capturing the service quality benefits of AVL. Transportation department staff believe that schedule adherence has already improved, primarily as a result of increased driver vigilance and the obvious disincentives to practices such as cutting routes short and running ahead of schedule. According to a supervisor, the number of write-ups for such transgressions has decreased since the AVL was acquired. It is not, however, possible to measure the impact on overall schedule adherence. Although the AVL can generate a report on this, many of the schedule deviations it records are fictitious. For example, when a bus reaches a layover point, the system considers it ahead of schedule until it is time for it to leave. Faulty odometer readings can also result in deviations being falsely recorded. Thus TRT actually has less reliable information on system schedule adherence than it did when the on-street supervisors were making manual time checks.

When radio operators detect a schedule deviation that they think is real (as opposed to a layover or odometer problem), various responses are possible. When the bus is early (a major transgression), the driver is typically instructed to stop the bus. This is a rare event, occurring perhaps once a month. If the bus is a few (five or so) minutes late, the radio operator will contact the driver for an explanation, but can do little else except encourage the driver to make up the time. When the bus is very late, the radio operator may send an on-street supervisor to cover the end of the route so the bus can turn around and thus regain its schedule. (On-street supervisors drive vans that can carry a few passengers so that they can fulfill this function.) When schedule deviations reach the point where pairing is occurring, radio operators may consolidate passengers onto one bus.

TRT management believes that much more can be done to improve schedule adherence with the AVL. There is keen interest in using the system to improve connecting services, by having the radio operator coordinate bus movements around transfer points so that passengers on late buses can make their transfers. This is especially critical at TRT because most of its routes operate at 30-minute headways. At the time of our visit, this transfer point monitoring was not occurring: the system generated an “exception queue” of all off-schedule buses (including many at layovers or with bad odometers), without regard to the “pulse” to which they belonged. Modifications to the system that would facilitate monitoring on a transfer point basis were being considered, however.

There was a difference of opinion within the agency concerning the potential for using AVL information to modify schedules. Since buses must arrive at transfer points at the same time, it is often impossible to make a simple schedule modification in order to reflect the more accurate run-time information that the AVL provides. Generally, adjustments to the schedule must be made in conjunction with adjustments to the route so that arrival times at transfer points can be maintained. In the view of the chief scheduler, this means that there will be few opportunities to use AVL data for schedule adjustment. His supervisor, while aknowledging the difficulties with adjusting the schedule, was more optimistic that improvements could be made.

Several respondents expressed the view that TRT was far from realizing the full potential of the AVL. According to the head of Service Development:

> I think it's worthy of the expense, the time we spent with it, right now, and what I'm telling you is we can do much better and that's our goal in the next year or two: to tweak it to that point of excellence.

The head of Service Development compared the AVL with the personal computer. Initially it was used for a few basic functions such as word processing or spreadsheets, but over time applications have proliferated.

> We have not yet learned how to make full use of it...This machine (pointing to his personal computer) right here has been around over a decade...It's taken a decade for it to get on everybody's desk and people still only use it for...If you're a secretary you use it for one thing. If you're a financial person you use it for one thing...Maybe now, because of other things that are available, you might use it for E-mail, too, or you might use it for a data base, or a spreadsheet...Maybe we communicate over a modem...That's after many years. We've had AVL for a year now and we're starting to learn how to use it...I would consider it a failure if we didn't within a year make better use of it.

As part of the effort to make better use of AVL, TRT has retained the programmer of the AVL as a consultant. He is providing training on the capabilities of the system, and may also make software modifications if these prove necessary. It has already become apparent from meeting with the consultant that many of the enhancements TRT desires are already present in the existing program:

> We had the consultant come in who originally designed the system. Sat down and said, 'We need this,' and 'we need that,' and 'this doesn't work.' And he looked at us, really quite frankly, as if to say 'You dummies. Don't you know what you have? Let me show you what you've got here.'

Further training on the AVL system has thus become a high priority in TRTs efforts to make better use of the system.

There were different views concerning automatic passenger counting at TRT. Respondents all agreed that special counting devices were not sufficiently mature. However, the general manager expressed interest in combining the AVL and electronic farebox data in order to obtain location-specific boarding information. However, members of the Radio Committee, while recognizing this as theoretically possible, considered it well beyond the present capabilities. Also, the head of Planning downplayed the utility of information any more detailed that the trip-level results already available from the electronic farebox:

> It's more than we can handle to plan...There's the idea that if you had how many riders were going on the bus you could make a change but I don't know what change you could possibly make. We can barely make the changes every six months, in terms of finding out what's going on and rescheduling it and writing the new schedules and getting the brochures ready. All that data pouring in ... is a pretty low priority as far as I'm concerned.

As already noted, the TRT radio upgrade included silent and mechanical alarms as well as the AVL. Neither of the features has proved useful so far. When a mechanical alarm triggers, the radio operator contacts the driver, who generally has already noticed the problem because of the in-vehicle warning lights. Sometimes the in-vehicle warnings go on shortly after the alarm in the control room. Since the in-vehicle warnings are considered more reliable, it is on the basis of these that road calls are generated. Perhaps the call from the radio operator will make the driver somewhat more vigilant and thereby ensure that the in-vehicle warning is promptly detected, but there is no evidence that driver failure to detect these warning lights, which are prominently displayed on the dashboard, is a major problem. With regard to the emergency alarm, so far it has been triggered only by mistake or when a driver seeking radio contact with the control room gets impatient. Because of this, the alarm, which is intended to prompt the radio operator to send emergency personnel to the vehicle, was, at the time of our visit, ignored. The general manager had recently learned of this however, and had ordered that a better solution be found. One option being considered is to include a signal to tell the driver when the alarm has been sounded, so that he can deactivate it if it is triggered by mistake. Ironically, the alarm was not activated on the only recent occasion when it should have been. The female driver, who was subsequently assaulted, feared her assailants, standing right over her, would see what she was doing.

3.3.2.4 Fare Payment

TRT was one of the first transit operators to acquire electronic farebox technology. The first models it acquired did not perform well. When it replaced them, TRT decided to take a different approach in the procurement in order to avoid the earlier problems. It used outside consultants to support the process by assessing needs, preparing specifications, evaluating bids, and performing “acceptance testing” to make sure that the delivered product performs to specification before TRT accepts the system.

The new fareboxes have worked very well. Despite the problems with the earlier models, the electronic farebox stands out as TRT's most positive recent experience with adopting a technology. In the words of one respondent:

> They've worked well. We wouldn't be able to handle the paper (money) without it, and my department makes regular use of the data (it generates)...More than AVL, the electronic farebox is a much more immediate, high payoff, success story in the industry. Once you found one that worked it was a immediate success.

(TRT has since adopted the acquisition process used for the fareboxes for acquiring other technologies. In particular, the AVL acquisition described above followed this approach.)

TRT is one of the first two U.S. operators to experiment with Ticket Reading and Imprinting Machines (TRIM) machines for handling transfers. The machines will issue transfers whose expiration time is magnetically encoded, and read the transfers to determine whether they are valid. The machines may be programmed for other uses, such as handling multi-ride tickets, but there are no immediate plans to do this. In the eyes of TRT staff, the TRIM machines offer two main advantages over their current paper transfer system. First, under the current system, TRT must print many more transfers than are actually used. Thus, the TRIM machine will save printing costs. TRT expects these savings alone to justify the acquisition. Second, like electronic fareboxes, TRIM machines will eliminate disputes between passengers and drivers. Under the current system, drivers must decide whether a transfer is valid, and disputes are common, particularly when the expiration is recent. With the TRIM machines, on the other hand, "If (a transfer) comes out of the machine (that is to expire) at 4:04 PM on March 25, 1992...(and) you get on at 4:05 PM and it rejects it, ... you get buzzed." In addition to these advantages, several other factors have probably encouraged TRT to be an early adopter of this technology. First, because of its timed transfer system, the volume of transfers is quite high. Second, as noted above, TRT has had a positive experience with electronic farebox technology, and sees the TRIM machines as a natural extension of this. Last but not least, TRT, has a federal demonstration grant to experiment with the TRIM machines. This makes it a low risk venture: "They're prototypes, but we're not depending on them. If they work, great, we'll buy some more. If they don't work its not any money out of our pocket, either."

TRT has had some exposure to smart card technology. A local firm that was in the smart card business approached them about experimenting with this technology for fare payment. However, the firm has subsequently pulled out of the U.S. market, and this is not presently an area in which TRT is actively interested.

3.3.2.5 Traveler Information and Paratransit Scheduling

The AVL-equipped bus system that TRT staff visited in Canada included a telephone system for providing AVL information to passengers. TRT did not opt for this feature. Its primary objective was upgrading the radio, and it was also "not ready to get that sophisticated yet." An AVL monitor has been installed in the room where the traveler information requests are answered. It is positioned inconveniently, on the other side of the room from where the Customer Service Representatives (CSRs) sit, so the CSRs rarely if ever use it. TRT is considering putting additional monitors in the CSR room and locating them more conveniently. There is also some interest in making the AVL information directly available to the public, perhaps by installing monitors in the 18 transfer centers, or even by allowing modem hook-up with personal computers. Marketing staff believe that the reliability of the information must improve before distributing it to travelers, however.

There is some skepticism at TRT about whether riders would consider real-time schedule information very useful, even if it were reliable. In the words of the head of the Planning Department:

> I don't think that's our high payoff area yet. Most people call in and want to know schedule information-'What time is the next bus? Where can I catch the bus?'...The only way (real-time information) would do the passenger any good is if they were waiting at a bus stop. I don't know if they would call from home a half an hour early to see if it's going to be on time: anything could happen in the next 30 minutes...It's not quite like the airlines where you might call an hour ahead...What would a person do? I don't know how they'd use it...Before we start doing this I'd want to do market research on all that. What do passengers need to know?...We haven't done any research to find out what that is, but before I designed a passenger information system using AVL data I'd would sure find out if people could indeed use it, need it, or even want it. It could be a big ... waste of time.

This individual was even more skeptical about the possibility of using AVL to obtain information of road traffic conditions for use by drivers and highway agencies:

> Bus service is scheduled, so whether there is a lot of traffic or no traffic it's supposed to take the same amount of time. The schedule is designed for those kind of conditions. A bus should never tell you anything other than it's going along just as it is supposed to be doing. If they have to drag, they drag. If they have to speed up, they try to speed up. So I don't know how that would work.

3.3.2.6 Conclusions

TRT exemplifies a technologically progressive transit agency, an industry leader in innovations ranging from electronic fareboxes, to time transfer routing and scheduling, to cellular-telephone equipped dial-a-ride services, to AVL, to TRIM machines. Although we cannot pretend to fully explain why TRT has taken this approach, three factors emerged in the course of our interviews. First, TRT operates in a service area that is highly auto oriented, particularly in its lack of a significant radial commuting. Since this environment is one with which traditional fixed route transit service is fundamentally incompatible, TRT has sought to "reinvent" such service in order to achieve even a modicum of success. Second, the Service Development manager, who also serves as deputy executive director, has championed innovation throughout his tenure. This, in turn, appears to derive from his strong educational background, which includes a masters in transportation from Carnegie Mellon. Finally, TRT appears to be willing to accept the disappointments and failures that seem inevitable when transit operators implement technologies before they are fully mature. Although the Service Development Manager stressed that TRT would never spend its own money on "prototypes," there is a willingness to acquire "Version 1.0" of a system, even with the "bugs" and lack of established operating procedures that this entails. For whatever reason, TRT has not developed a "fear of failure" as strong as that observed in many other agencies, or at least balances against it a stronger appreciation for the fruits of success.

TRT's considerable experience with cutting-edge technologies has led to the development of mechanisms to increase the probability of success. These include the use of consultants to advise, prepare specifications, and determine whether a delivered product actually meets them, as well as the use of committees cutting across different departments to work out problems. Although its experience with AVL shows that these procedures are not foolproof, their development suggests how adoption of new technologies can, like other transit agency activities, be routinized.

Although TRT staff remain at least guardedly optimistic about the value of AVL technology, it was clear that the experience to date has been negative in many respects. There are several underlying reasons for this. First, the system has proven unexpectedly difficult to implement and operate. Second, a variety of problems with hardware and software have compromised the reliability of the system. Third, the labor savings in on-street supervision that initially sparked interest in AVL have been more than offset by the additional workers employed to monitor and maintain the system. Although such outcomes may in some respects typify the downside risks of any venture involving adoption of new technology, they also illustrate problems to which APTS technologies may be especially subject. For example, these technologies frequently require a considerable data base, the creation of which is both resource-intensive and prone to performance compromising errors. Also, APTS technologies frequently make new forms of data and information available, and therefore require complementary labor resources to monitor this information. Thus the adoption of an APTS technology may occasion additional labor needs in order to both produce and consume information, and these can easily offset labor savings deriving from automating manual functions, streamlined operations, or other putative APTS benefits.

These problems with AVL notwithstanding, there remains a consensus that the technology will ultimately prove beneficial. In part, this reflects anticipated improvements in system reliability that will substantially increase its utility. However, TRT has also shifted the primary objectives of its AVL program from labor cost reduction to service quality improvement. While the latter is undoubtedly a worthy goal, it is also extremely difficult to quantify, precluding a reliable assessment of the cost-effectiveness of the technology. The faith in AVL technology expressed at TRT is just that, not an objective judgment based on its experience to date.

3.3.3 Kansas City Area Transportation Authority (Kansas City, MO-KS)

3.3.3.1 Description

The Kansas City Area Transportation Authority (ATA), also known as The Metro, was created when a bi-state compact created by the Missouri and Kansas state legislatures was signed in December 1965. Service began in February 1969. ATA provides contracted service to Kansas City, Kansas, Missouri, along with Independence, North Kansas City, Gladstone and Johnstone County, Kansas. These contracts account for approximately 60% of their operating expenses.

The Kansas City Urbanized Area, 25th largest in the U.S., comprises 762 square miles with a population of approximately 1.2 million. ATA services an area of 173 square miles and a population of approximately 500 thousand.

In 1991, ATA operated a fleet of 279 vehicles over 43 routes. ATA vehicles traveled nearly 30 thousand miles each weekday while providing an average of 61 thousand passenger trips. ATA employed 343 full time and 111 part time operators.

ATA also administers the provision of paratransit services throughout the area. It coordinates service from various contractors to provide approximately 200 thousand annual trips from a database of approximately 4,000 eligible riders.

3.3.3.2 General Outlook on APTS Technology

Two contradictory attitudes shape ATA's general approach to new technology. On the one hand, there is suspicion, particularly among upper management, that much of the new technology developed for the transit industry is not cost-effective. According to the general manager, "I tend to think that we're an industry that occasionally tends to get overly enamored with technological change and expects to get results that may be oversold." He recalls a speech given by a general manager at the Chicago Transit Authority some years ago that made an impression on him. The speech argued that since investment levels in bus transit are low, private industry does comparatively little research and development. Furthermore, it tends to introduce new technologies into the market prematurely, "when they are still in the process of making the thing work." For example, when the advanced design bus (Transbus) was being developed, "it took three years to produce an acceptable vehicle, and all of those who wanted to be out front and bought those advanced design buses paid the price with buses that were just falling apart." Thus, "my experience has been consistent in this industry: be a follower, don't be a leader."

Indeed, in some respects ATA is a technological reactionary. The director of maintenance, who has substantial input to any system change that has maintenance implications, prides himself on resisting certain technological changes that are already in wide use. For example, the system continues to order buses with roller curtain destination signs, rather than the newer electronic signs. The meeting at which the maintenance director persuades the general manager to retain the older sign technology has become something of a ritual whenever the specification for a new bus order is being prepared. ATA has also been late in acquiring engines with electronic diagnostic features. In the most recent new bus purchase, ATA ordered half with this feature and half without. The experience with the electronic diagnostics proved so successful that the engines without this feature are being replaced. The maintenance director now regrets not having adopted these electronic diagnostics earlier. "Some technology is stupid to ignore," he concedes.

On the other hand, ATA faces strong pressures to keep operating costs low, and at the same time to do as much as possible to enhance its service. With the federal government covering 80 percent of capital costs, ATA seeks opportunities to use capital investments to either cut operating cost, or to enhance service without increasing operating cost. Says the general manager, "Because we are poor (in a budgetary sense) as a operating system, we're always looking for the opportunity to have a capital intensive improvement that will allow you to improve without increasing your operating cost." To the extent that investments in new technologies offer such possibilities, they are attractive. Indeed, so long as ATA considers the operating cost consequences acceptable, and federal grants along with the 20 percent matching funds are available, it is willing to undertake projects whose value is marginal, or at least uncertain. According to one respondent,

> We've had grant availabilities that frequently no one in our region applied for the money, so almost in a way you go out and look for reasons to spend the capital. That ought to give you a clue about the carefulness of ... you know, it's kind of like if I can get the money to just put a pool in the back of the house: why not? It wouldn't be a bad thing to have, (even though) I otherwise may not do it.

3.3.3.3 Vehicle Monitoring

ATA's main experience with APTS technology is its adoption of an AVL system. The genesis of the AVL dates to the mid-1980s, when the superintendent of transportation made a visit to San Antonio and saw its AVL system. On the basis of this, he became a proponent of AVL, and "put the bug in the ear" of his boss, the director of transportation, that an AVL ought to be considered in the context of a radio system replacement planned to take place a few years later. "When an article would come down either in Passenger Transport or Mass Transit I would be sure to make copies and talk to John (the director) about it. He was getting hit by me all the time about this."

The superintendent's interest derived from his concerns about ATA's schedule reliability. He felt that a major shortcoming in this area was the inability to adequately supervise drivers:

> We would have supervisors run a line that they hadn't been on in a couple of days and find some buses parked over to the side. We'd have buses that would start at downtown in the morning and maybe go up a street that we didn't service at all, go to the end of a line, sleep, and come back down that same street. Some drivers would run a charter sign or a special sign. We had vehicles that were goofing off out there. We've had buses that have gone back to the yard early, and we had no way of detecting them because we didn't have a supervisor down at the gate watching.

Although he did not think these problems were widespread,

> people were doing it and it exposed what little control we had. A lot of the workings of a bus company involve trust, and some people were trustworthy and others weren't to be trusted at all. The AVL addresses that lowest common denominator: those people who aren't going to go along with the system. It helps us identify those people with problems and to let them know that we're watching them, and to remedy those that won't come around.

By 1987, the time for a new radio had come, as replacement parts for the current system were becoming hard to find. ATA published a request for proposals (RFP) for a consultant to guide them on the upgrade of their radio system. From the RFP, ATA chose the firm NIACAD. NIACAD's principal, David Kane, has had considerable experience with AVL systems, and was a strong advocate for them. Kane argued that AVL could be "an important management tool" for ATA, that it "could help with system control," that it could reduce labor costs by reducing the number of supervisors needed, and that it could help in locating buses in emergencies. Finally Kane suggested that AVL was a fairly inexpensive feature, with an estimated incremental cost of about $600 thousand, when acquired as part of a new radio system.

At Kane's urging, ATA staff made a site visit to Hull, Canada which had an operational AVL system. Satisfied that the system worked, and persuaded by Kane's arguments, ATA middle management decided to request that AVL be included as part of the new radio system. According to the Director of Transportation, "the ability to monitor and control schedule adherence" proved to be the most important factor in this decision. The other factors were downplayed. Labor savings were not considered likely because ATA has so few supervisors to begin with, while the emergency response benefit was discounted because emergencies occur so infrequently. The latter argument, however, appears to have been instrumental in selling the system to drivers, or at least dissuading them from strongly opposing it.

Approval from the general manager and Board proved to be "no problem," since there was wide agreement that the radio needed replacement, and they viewed AVL as a minor addition from a cost standpoint. The AVL was thus included as part of a $23 million discretionary grant request from UMTA. According to the general manager, the possibility of acquiring AVL was still remote at this time, since ATA expected the grant to be only partially funded, and AVL "was at the bottom of our priorities." Indeed, when UMTA's decision to fully fund the grant was announced,

> We were kind of shocked. All of a sudden I turned around to John Dobies (the director of transportation) and said 'We've got a vehicle locator system.' This was the first time I found out what the thing was. Literally I had very little knowledge of it. I don't think we thought we had a remote chance of getting it until the day the grant was approved. Then we had to take it real seriously, make sure that we did want it and did think it was a good investment.

Two factors contributed to UMTA's surprising decision. First, it is UMTA policy to distribute Section 3 funds equitably among geographic regions, and ATA's application was the first ever non-rail one submitted from the four-state Federal region in which Kansas City is located. Second, the general manager is a skillful grantsman, with good political connections. He succeeded and in getting participation in the grant from both Missouri and Kansas, and arranged for Congressional representatives from the area to meet with the UMTA administrator. Also, since privatization was a major programmatic priority for UMTA at this time, the grant application stressed — indeed "exaggerated" according to the general manager — ATA's modest efforts to increase use of private contractors.

The specifications prepared by NIACAD led to a contract with F&M Global. Their system used signpost technology, which NIACAD considered the only practical alternative at the time of the procurement. ATA chose to acquire a fairly basic system, without passenger information, passenger counting, or mechanical alarm features. ATA urgently needed the new radio system, and NIACAD advised that additional features could be added later with little difficulty. ATA therefore chose to defer consideration of these options to a later time. With regard to automatic passenger counters, there was also opposition from the Director of Maintenance, who is acutely aware that each additional hardware device added to a bus is subject to breakdown and will thus require additional maintenance resources. Also, ATA is able to get relatively detailed ridership data through its farebox. The decision to exclude mechanical alarms was based on ATA's experience with such devices in the previous radio system, where they gave many false alarms.

Implementing, maintaining, and using the AVL have all been difficult challenges for ATA. According to the director of transportation, "Getting the AVL to work is a big task." First, the time points had to be redefined so that they were at feasible signpost locations. Second, distances between signposts had to be measured. Finally, ATA had to develop a computer data base containing the distance and schedule information required as inputs to the system. In the words of the director, "Once done, it's done and changes are relatively easy, but there's a lot of advance work." In this respect "supporting the AVL is more work and therefore more costly than I anticipated. If it is true that the initial purchase price of the system was relatively low, it is also true that the costs we had were pretty high in terms of staffing and setting everything up."

Maintenance staff concurred with this assessment. According to the maintenance director, "the AVL is the most monumental pain." AVL equipment had to be installed on every bus, and when it failed to operate properly on certain models, the installation procedure had to be modified. The AVL uses a special odometer, and those on the old buses require frequent repairs. Also, the new radio system as a whole requires a substantial maintenance. This is done by a contractor, at a cost roughly double what it was for the previous radio. However, the "incredible disruption" from the initial installing and testing of the AVL has lessened. The maintenance department has gotten used to the new system, and the maintenance effort required, while still tangible, is no longer inordinate.

Technicians had found a new problem with the AVL at the time of our visit. They discovered that some 30 percent of the AVL transmitters (AVLTs) were not working. Although the AVL could still operate with this number of failed AVLTs, it could not do so if there were many more failures. Since F&M Global has withdrawn from the AVL business, repairing or replacing the transmitters was proving to be difficult. ATA was working with other transit operators with similar problems in an effort to identify a solution.

The odometer and AVLT malfunctions, combined with the inability of the system to distinguish buses waiting to begin a new run at the end of the line from off-schedule buses, have reduced the utility of the system. The system generates a list of buses that are out of schedule tolerance, but because of these problems this list is very long, and composed mainly of buses that are not really off-schedule. Thus dispatchers must mentally cull buses requiring some action from this list. Since there is rarely time for this in the peak period, dispatchers largely ignore AVL information at this time. During the less busy time, dispatchers do make an effort to identify and contact buses that appear to be truly off-schedule. They do this tactfully, since there is still a good possibility that the AVL is wrong. Sometimes they ask a driver for his location, while on other occasions they will send an on-street supervisor to verify the schedule violation and, if appropriate, cite the driver. (Union work rules specify in great detail the procedure for handling a schedule violation, and this procedure would need to be followed no matter what the reliability of the AVL.)

The large number of false deviations from schedule reported from the AVL precludes use of the system to monitor trends in schedule adherence. The system produces a monthly report of schedule deviations, but most of these are not actual deviations for the reasons noted above. Prior to the AVL, a monthly report summarized schedule adherence based on manual observations of on-street supervisors, but this practice ended on the expectation that the AVL would supplant it. Thus, ironically, ATA has less information about its systemwide schedule adherence performance now than it did prior to the acquisition of AVL.

Nonetheless, ATA staff believe that AVL is already generating benefits, and that these will increase in the near future. At the present time, the main perceived benefit is increased schedule adherence. ATA staff attribute the improvement to three sources. First, and probably most important, is the direct impact of the monitoring on the drivers. Despite all the problems described above, the AVL system still vastly increases the probability of detecting a schedule deviation, and ATA staff believe that this substantially increases incentives to drivers — at least those belonging to the "lowest common denominator" — to adhere to schedule. Second, the system serves as a universal time clock, thereby eliminating schedule deviations resulting from operators' watches being incorrectly set. Third, the data from the system enables better estimates of running times, which can then be used to modify the printed schedule so that adherence to it is easier. A committee to carry out this process has recently formed. It meets biweekly and goes over data for a specific route.

Not all benefits are directly related to improving schedule adherence. For example, the AVL is used to investigate customer complaints. The AVL provides objective data on whether a bus was early or not and consequently can provide a more concrete resolution to a complaint than was possible before. An additional, largely unanticipated, benefit, has been the enhanced ability of drivers to give passengers schedule information. When passengers request this, drivers contact the dispatcher, who can easily access the information from the AVL data base.

ATA management hopes to make better use of the AVL system in the future. Although the system had been in place for over a year at the time of our visit, it had been providing information considered reasonably credible for a much shorter period. Thus experimentation with use of the system was still in the beginning stages. One avenue being explored was increasing the ability of the dispatchers to act "pro-actively" to improve schedule adherence. Aside from contacting buses out of schedule tolerance, staff could not identify specific pro-active measures, but believed that they would be found. A second type of benefit that ATA hopes to realize from AVL is enhanced on-street supervision, as a result of on-street supervisors being relieved of time check responsibilities. This will give these personnel more time to provide direct assistance to riders and interact with drivers. Furthermore, management hopes that the driver-supervisor relationship can become less adversarial and more supportive. In order to encourage this, the "team supervisor" concept is being promoted. Supervisors are assigned to specific drivers, with whom they are encouraged to make regular contact to identify problems and opportunities for improving services and working conditions. Supervisors are also required to keep a log of their contacts with drivers. This is used as one basis for their performance evaluation. AVL is probably not essential in these efforts to improve relations between operators and supervisors, but it has evidently served as a catalyst for initiating the process.

3.3.3.4 Fare Payment

ATA does not have any experience with or active interest in advanced fare payment technology.

3.3.3.5 Traveler Information and Paratransit Scheduling

ATA is embarking a program of technological enhancements in the passenger information area. It has hired a consultant to, in the words of the RFP "assist in a needs analysis, selection, and installation of a Voice Response System (VRS), a computerized bus schedule and route data system for the ATA Information Center, and an automated paratransit routing and scheduling system for the Authority's paratransit program." According to the director of marketing, the consultant is to:

> come in and assess all of these applications that we have...and then to also determine what it is that we want ... and help us prepare specs so that then we can go out and get the equipment and the software and everything else that we need to be able to implement a more coordinated system for all these different things.

The passenger information project has been in ATA's capital budget since 1986, but has been delayed since many other projects have been given higher priority. The marketing director, recognizing the information center as a problem area, conceived of the project soon after his arrival. The main deficiency is the limited hours of operation: 6 AM to 6 PM, Monday through Friday. The director believes that there is a considerable ridership loss stemming from the inability to get schedule information via telephone at other hours. Other problems include insufficient capacity, resulting in queuing delays and a considerable number of lost calls, and the difficulty of the information operator's task:

> The job is very difficult...it's highly stressful. Most people would think 'You're sitting there. You're talking to people on the telephone all day. What could be easier?' Well that ain't true. It's stressful because people make it stressful. People are very rude, and they are very angry. Its incredible the things that happen to information center operators. They're cussed out. They're called names. They're totally at the mercy of folks who call in who are often not totally rational.

As a result of this difficult working environment, the operators are:

> prone to error...There may be several options available to a person who's calling in... There may be two or three different routes that they can use...You have to rely on the ability of the information operator to just have massive amounts of information. Frankly, they do a hell of a job. They're very, very good at absorbing this information. But again, the stress of all that data that they have be able to draw upon, dealing with the public, all of those things, I felt we could help them be more effective if a computer was providing it. Then they can provide the thing that's most important in this — that human contact, and maybe they can do that a little bit more effectively.

To approve this project, upper management and the board had to be convinced that it would not have a negative impact on operating costs. A major selling point in this regard is that the paratransit reservation system currently operates on a computer owned by the City of Kansas City, and ATA pays $50 thousand per year for this computer usage. According to the assistant general manager, the savings from running the reservation system in-house on the new information system are enough to enable the new system to pay for itself in just a few years. Although she recalled that the new system will also produce "lots of other benefits," the computer cost saving was the only one she could remember specifically at the time of our interview (in which she emphasized at the outset that she had little direct involvement with technical matters).

3.3.3.6 Conclusions

ATA exemplifies many of the forces shaping adoption of APTS technologies in the transit industry. ATA management is wary of new technologies, concerned that they will not perform as advertised and will entail unanticipated costs that will increase the operating budget. At the same time, federal capital subsidies encourage adoption of these technologies, along with other capital projects. ATA attempts to resolve this conflict by choosing capital projects when it does not expect them to entail complementary operating expenditures, or, even better, when it anticipates a reduction in operating costs from adoption.

ATA's experiences with AVL along with its recently initiated passenger information project illustrate these general principles, but also show the challenges of implementing them. In assessing the AVL, ATA underestimated the in-kind staff and management effort that adopting this technology would require. The "sticker price" of the system is well below the true price, with the difference taking the form of organizational resources. It is hard, perhaps impossible, to know the extent to which these resource expenditures ultimately appear in ATA's operating budget, but clearly they were unanticipated, and were not covered by federal grant money.

At first, much of ATA's organizational effort went to activities that were technically necessary to make the AVL operational, such as creating a computer data base of schedule information. Now that the system operates, the effort goes toward using the information it provides, such as the bi-weekly task force that is using AVL data to modify bus schedules. But while failure to undertake efforts of the former type would result in a conspicuous failure — an AVL that does not operate — the latter type of efforts, although essential if benefits from the system are to be realized, are less obligatory. It is thus reasonable to ask whether pressures to cut operating costs in the short term will dissuade ATA from expending the resources necessary to use AVL to its full potential in the long-term.

ATA's experience also shows the obstacles to using advanced technology to directly cut operating costs. The operator responds strongly to savings in non-labor expenditures. For example, it attaches strong importance to the saving the computer lease cost as a justification for the passenger information system. When it comes to labor savings, ATA is more skeptical and less aggressive. Despite the claims of NIACAD that AVL would reduce the costs of on-street supervision, ATA did not take this argument very seriously, nor did it attempt to realize such savings once the AVL was in place. Transportation Department managers prefer to use the AVL to "enhance" on-street supervision rather than cut its costs. One must wonder, however, whether this is a considered judgment about how best to improve the performance of the transit agency, or a reflexive move to avoid dislocating supervisory personnel.

3.3.4 Contra Costa County Transit Agency (Contra Costa County, CA)

3.3.4.1 System Description

The Central Contra Costa Transit Authority (CCCTA) was established in 1980 to coordinate, integrate, and expand transit service within Central Contra Costa County. CCCTA is a Joint Powers Agency of 11 jurisdictions including the cities of; Clayton, Concord, Lafayette, Martinez, Orinda, Pleasant Hill, San Ramon, Walnut Creek; the towns of Danville and Moraga; and the unincorporated areas of Central Contra Costa County. This Authority operates daily and Saturday fixed-route services and administers the delivery of paratransit services within the CCCTA 200 square-mile service area.

CCCTA provides service on 26 routes. Of these, four are express routes and two are contracted with Chevron and Pacific Bell for their employers, although they are open to the general public as well. The city of Walnut Creek partially subsidizes one route for use as a downtown shuttle. All CCCTA routes serve a Contra Costa County Bay Area Rapid Transit (BART) station. The BART stations serve as major transfer points between BART and CCCTA, and between routes within the CCCTA system. CCCTA maintains a fleet of 112 vehicles of which 95 to 98 are in service during peak periods. Generally, service is available 5 AM to 10 PM on weekdays, and 6 AM to 7 PM on Saturdays. Headways are between 30 and 60 minutes on Saturdays and 10 to 30 minutes during peak periods. Total boardings in fiscal year 1990 numbered 4 million.

As of 1990, the total population of this service area was 420 thousand based on projections by the Association of Bay Area Governments (ABAG). This represents a growth of 9.5 percent from 1985. Rapid growth is expected to continue over the next decade. CCCTA's service area is also experiencing high rates of employment growth. From 1985 to 1990, there was a 31 percent growth in the number of jobs available. In the next ten years, a 21 percent growth in the number of jobs is expected. Most of the job growth results from extensive development of industrial parks and other major employment centers.

As job growth outpaces population growth, the demand for labor living outside the service area will increase, resulting in additional commute traffic on an already congested road system. A plurality of Contra Costa County residents cite transportation as the most important problem facing them. Voters passed Measure C in 1988 and Proposition 111 in 1990 to generate additional funds for transportation improvement. CCCTA hopes to play a part in alleviating the county's transportation problems.

As part of this effort, CCCTA has been involved in a number of initiatives. It participated in the Contra Costa County Congestion Management Plan (CMP), mitigation projects for the I-680/SR-24 interchange reconstruction project, the coordination of project planning for Measure C funds, and in the effort to coordinate and improve paratransit services in Central County.

In September of 1991, CCCTA in coordination with the City of Walnut Creek and TriDelta Transit began to operate enhanced bus service between East and Central Contra Costa County. Also in coordination with Alameda-Contra Costa (AC) Transit, CCCTA has extended service into El Sobrante. These initiatives are the beginning of a long-term effort to improve transit services with a particular emphasis in inter-system transfers.

Additionally, CCCTA is a member of the Coordinating Area Transit Systems (CATS). This consortium includes TriDelta Transit, West Contra Costa Transit and Livermore Amador Valley Transit (LAVTA). The purpose of CATS is to study ways these four transit systems can coordinate services to benefit patrons. Current efforts largely focus on the development and implementation of a coordinated fare structure. This program will occur in two phases and began in the Fall of 1990.

In January 1990, CCCTA assumed complete responsibility for paratransit service in Central Contra Costa County, which it contracts to a private operator. CCCTA has plans for building a facility to house these services in order to make them more reliable, effective and efficient. Groundbreaking is scheduled for October, 1994. In addition, CCCTA is considering plans to expand its general public demand responsive service, called Flex-Van.

3.3.4.2 General Outlook on APTS Technology

There is conflicting evidence concerning CCCTA's attitudes toward APTS technology. Many of our discussions suggest that these technologies have low priority on the agency's agenda. Several respondents suggested that other types of improvements have more potential to improve the convenience of the system. The general manager, for example, stated that reducing headways by adding more buses was more important than installing a sophisticated passenger information system. Other respondents articulated a negative view of APTS, as when the manager of Service Development stated that he was "very skeptical of technology. For the most part, promises are not kept. Systems do not deliver. Additionally, costs are high."

On the other hand, as the subsequent discussion indicates, CCCTA has been active in the APTS area, and is the only case study operator that has adopted APTS innovations in all three of our major categories. This disparity between stated attitudes and observed behavior was unique among the agencies we studied.

3.3.4.3 Vehicle Monitoring

CCCTA does not have AVL, but has shown some interest in the technology. AVL was on a list of proposed capital improvements submitted to the Regional Transit District, although the Board of Directors, rather than staff, seems to have been the strongest proponents. Several years ago, CCCTA was approached about a system that uses vehicle detector loops already in the roadway. The system was attractive because it would not depend on their radio system, which is not adequate for AVL applications. However, the firm marketing the system didn't have software to enable them to manage the data from the system so that schedule deviations could be easily identified. They told the vendor to come back when they had the desired software, and so far it hasn't.

In the view of CCCTA management, the main advantage of AVL is that it would free up supervisors to do things other than check schedule adherence, while at the same time increasing the amount of schedule adherence information available. Supervisors at CCCTA have many responsibilities, including on-board monitoring, discipline, time-keeping, and accident investigations. Consequently, they don't have much time to do on-time checks, and the time they allocate to that activity has many other valuable uses. With more schedule adherence information, it will be possible to make the schedule adjustments, or talk to individual drivers, or do whatever else is appropriate to improve schedule adherence. Also, drivers are supposed to radio the dispatcher when they are more than five minutes behind schedule. Such messages, which generate a large volume of radio traffic, could be eliminated with an automatic tracking system.

There is a relatively simple computer system for tracking maintenance, based on miles driven. The maintenance manager has done investigations to get more appropriate mileage increments for different types of preventive maintenance. The effort to make better use of existing information have proven successful, resulting in new mileage norms that generally exceed the prior ones and thereby save maintenance expenditures. On the other hand, although the radio system "has the capability to monitor all kinds of things about the coach," CCCTA does not use this capability "every sensor creates a need for maintenance," compromising the functionality of the system.

CCCTA has recently installed devices on its buses that count the number of times bus accelerations exceed acceptable levels. The system is "closed-loop" — drivers record exceedance counts at the end of their shift, but it is not used for formal performance evaluation. The system appears to be working well. The number of exceedances has gone down, and better driving can also be seen visually.

3.3.4.4 Fare Payment

CCCTA is currently engaged in a program called Translink, the purpose of which is to create a common fare medium for BART and the bus systems feeding it. Bus ticket validators (BTVs) are being installed on CCCTA buses. These will process the same magnetic farecards used on BART.

The Translink program is an outgrowth of a joint effort by AC Transit, BART and the Bay Area Metropolitan Transportation Commission (MTC) to establish a common fare medium. This initial effort began in the mid-1980s and resulted in the formation of the AC/BART Plus ticket in 1987. The original committee grew to become the Multioperator Steering Committee. The committee consists transit general managers and representatives of MTC.

Because of pricing conflicts with AC/BART Plus ticket, this group decided to pursue a more direct form of payment. It was in this committee that a consensus arose that CCCTA was the best equipped for demonstrating such a fare payment device. CCCTA had connections to BART and was small enough to perform a demonstration. Consequently, CCCTA in cooperation with BART and MTC submitted a proposal for a Federal grant for demonstrating the Translink BTV.

When CCCTA obtained funding, it was expected that an existing device, already tested in Hong Kong, would be used. However, the size of the existing device was incompatible with CCCTA vehicles and had to be redesigned. A one-route test with the system was started in the first quarter of 1992. Some adjustments, such as the addition of an audio signal to the counting function of the device, have been identified. Once these modifications have been made another test will be performed. CCCTA expects to equip all their vehicles with the devices by the end of 1992.*

CCCTA is optimistic that the Translink program will increase service convenience, as well as generate subsidiary benefits such as facilitating the collection of patronage data and reducing driver tedium in handling transfers and counting passengers. (The system has aroused some concerns from drivers, however, because it will keep a log that could be used to determine when drivers are not doing what they are supposed to.) They hope to keep the program going past the demonstration period, and might be willing to absorb some of the costs if necessary. On the other hand, it was clear that CCCTA would not have undertaken the program if demonstration funds had not been available.

3.3.4.5 Traveler Information and Paratransit Scheduling

CCCTA has gone further than many other agencies in providing information at bus stops. This “low-tech” program involves placing a panel at each stop with “information on every bus that comes by there. It tells you where it goes and comes from, and displays a route map.” This program is designed “to make the service more user-friendly for the occasional rider.” Although the marketing manager expects that the system will be difficult to keep up to date, he is confident that this can be done. CCCTA did not consider more advanced technologies, which might make the updating task easier, due to their higher cost.

CCCTA’s efforts to improve passenger information systems will continue. In the same spirit as the Translink project, there is interest in developing a “more universal” telephone information system so that passengers can get schedule information for different operators by dialing a single number. Phone system

* This was actually completed during 1993.

automation is not considered attractive, both because the “personal touch” would be lost with these technologies, and because “the persons who use [the telephone information system] more are those that would like [automation] less —seniors, students, etc.” The costs of these technologies are also considered too high. The emphasis on low-tech, economical approaches to “get information out without bankrupting the system,” already apparent in the bus stop signage program, is also evident in CCCTA’s plans to place information kiosks in central locations, such as BART stations.

Another reason, in addition to cost, that may cause CCCTA to downplay the need for sophisticated information systems is that its market is primarily commuters. According to the marketing manager, “By and large repeat users are the majority. You can get information to repeat users very quickly regardless of mode. You could use news media, announcements on buses, direct mail, newspaper ads.”

In paratransit operations, there is some interest in vehicle routing and scheduling software, since “computers are more efficient than humans and less prone to errors.” The accessible services manager would also like to see technology for tracking vehicles in order to allow real time dispatching, which “is an efficient way to dispatch. If you are using taxis and vans then you know where they are — it’s much more efficient.” The highest priority item, however, is the phone system — “Our worst nightmare. The demand is so great. We have one of the highest number of phone clerks per vehicle and we still can’t satisfy everyone. They’re on hold, they are waiting, can’t get through.” Since many paratransit clients have Alzheimer’s or other limitations, automation is not an option, but there is interest in finding a better way for managing the queues in the current system.

3.3.4.6 Conclusions

CCCTA’s thinking concerning APTS technology is shaped by two main themes. First, there is interest in APTS technology as a means for increasing compatibility among different transit operators in the East Bay’s balkanized transit industry. This interest derives in part from a perception that compatibility is important and that APTS technology can contribute to it. It may also derive from the fact that efforts in this area, since they are inherently collective in nature, involve less risk to CCCTA management.

Second, CCCTA managers perceive most APTS technologies to be less cost-effective than alternative capital investments, such as acquiring more buses for example. This judgment is not based on detailed study. To the contrary, CCCTA has not carefully investigated most APTS technologies because of the belief that scarce managerial resources are better devoted to other matters. However, one specific concern voiced by several interviewees was that the software to extract useful information from the data gathered from APTS technologies is lacking, raising the prospect that, in the words of the maintenance manager, “more information won’t do more than put paper on the shelves.”

An important lesson from CCCTA is that a commitment to information technology need not imply a commitment to advanced information technology. CCCTA’s bus stop signage and kiosk programs underscore the importance the operator attaches to getting information to customers. The efforts by the maintenance manager to increase mileage between maintenance functions through experimentation and data analysis demonstrates a belief in using information to increase efficiency. It is possible that efforts such as these could yield more gains if they were coupled with the enhanced data APTS technologies could provide, but this is not the view of CCCTA management.

3.3.5 Golden Empire Transit District (Bakersfield, CA)

3.3.5.1 Description

In 1973, the Golden Empire Transit District (GET) was created to provide service for the greater metropolitan Bakersfield area. During the 1970's, GET added dial-a-ride service for the disabled. During the 1980's GET improved service levels by decreasing headways, initiating wheelchair-accessible service on all routes, extending the District boundaries to include service to high growth areas and eliminating unproductive route segments. In September 1986, the District switched from a radial system, focusing on the downtown, to a cross town system.

GET services the city of Bakersfield and the communities of Oildale, Rosedale, Greenacres, and Greenfield. The service area includes approximately 315 thousand people, 85 percent of whom live within one-quarter mile of a bus route. The District has a fleet of 61 vehicles. Peak service utilizes 53 buses while the base period utilizes 38 buses. Service hours are from 6 AM to 7:30 PM. GET operates at headways ranging from 15 minutes in the peak to 60 minutes in the base period. GET has a flat fare of $.50, unchanged since 1982.

3.3.5.2 General Outlook on APTS Technology

While not completely uninterested in APTS technologies, GET is unlikely to lead innovation in this area. The general manager summarizes the attitude:

> When people come in and want to give us a new system I want to say 'What eight transit systems have you used it on?' and 'How many years has it been in existence?' and 'What's the parts availability?' and so on.

This attitude derives in part from experiences with APTS technologies, described below. GET's general manager also cites organization's experience with computers in explaining his cautionary view of new technology. They purchased a Quantel computer system that:

> was able to combine all the functions of the organization into a cohesive whole. [But]if I had it to do again I'd go with PC networks. Most people simply need the word processing function... You used to hear people say that if you put computers in you'd save a lot of time and that there would really be an economic benefit. Every time I look around we need to buy another computer or one of them is breaking down or we need an electronic technician to take care of them. I haven't really seen any people savings — I see greater demand for information from the Federal government. They want us to supply information because we have the capability of assembling it.

Somewhat surprisingly, GET is playing a leadership role in one area — the use of compressed national gas as an alternative fuel. The general manager attributes this seeming anomaly to several factors. First, he has great faith in his maintenance manager, and his maintenance manager is confident that they can make the technology work. Second, with Bakersfield located in one of the most polluted air basins in the country, and with GET marketing itself as the "pollution solution," "our biggest political problem is that puff of smoke that comes out of the back end." Finally, GET management takes a dim view of the more commonly used alternative fuel, methanol, because it is hard on the engine and poisonous. Thus, in this instance, the combination of the general manager's confidence in his maintenance manager, the urgency of the problem the technology addresses, and the limited relevance of earlier experiences with APTS technologies to this particular innovation, have overcome GET's distaste for technological leadership.

3.3.5.3 Vehicle Monitoring

GET has a radio system with mechanical alarms that alerts the dispatcher when the engine is overheating or the oil pressure is rising. According to the maintenance manager, the system gave at least as many "phantom" as true alarms. "It's a pain ... Most alarms are false. We go out there and there is nothing wrong." GET is presently acquiring a new radio system that will not include mechanical alarms.

On the other hand, the maintenance department has had good experience with Transpack maintenance software, which keeps track of bus mileage and indicates when there is overdue maintenance, and the DDEC computer diagnostic system, which reports mechanical problems based on readings from electronic sensors located in different parts of the bus engine. The latter originally generated "phantom codes" — reports of non-existent problems, but this has been eliminated by adding spike suppressers to filter the signal reaching the diagnostic device.

GET does not have AVL, and the prospect for acquiring this technology is remote. A salesman recently showed the general manager a Loran-C system "that sounded fairly attractive to me." However, others in the organization, particularly the operations manager, were less impressed. According to the latter, GET

> is looking for proven technology in widespread use. With a small agency, we have to make sure that it's easy to use and you don't have to create a new department to sit there and monitor vehicle location. I'd want something the dispatchers could use in their normal duties.

Similarly, the maintenance manager, while lacking specific information on the subject, stated that he expected there would be "considerable expense" to maintain AVL.

While concerns over costs are clearly evident in GET's attitude toward AVL, there is also doubt about its benefits. The operations manager considers schedule adherence to be "the very heart of transit," but he believes that while the AVL equipment “would tell us how we’re performing, but would not necessarily make it any better.” Likewise, the maintenance manager, perhaps recalling the problems with the mechanical alarm features of the radio system, stated that an AVL system would be of no value for maintenance.

Others, generally those in less senior positions, had a more optimistic view of AVL benefits. Among the benefits cited were emergency response, schedule adjustment, passenger information, and coordination of bus-to-bus transfers.

3.3.5.4 Fare Payment

GET purchased Cubic Western fareboxes several years ago. The agency acquired these fareboxes in part because they are a potentially rich source of transit patronage data, with capabilities to provide information for individual route segments and for different times of day. Unfortunately, the fareboxes required drivers to make complicated keyboard entries in order to gather this information, and the software often failed when an incorrect entry was made. Thus, it has proved impractical to use the fareboxes to gather anything other than gross route data, and even in this case there are recurring problems with drivers entering the wrong codes and triggering a software shutdown. Further, parts prices for the fareboxes increased steeply a few years after purchase. Consequently, GET is replacing the Cubic Western equipment with less sophisticated GFI models. These problems notwithstanding, drivers appreciate the ability of electronic fareboxes to reduce fare disputes by displaying the amount that has been deposited in the farebox.

GET is currently looking at TRIM machines. The perceived benefits of the TRIM machine include reduced boarding times, avoiding disputes over whether transfers are valid, and the possibility of preselling tickets as BART and Washington Metro do. Still, GET managers view this technology cautiously. The operation manager emphasizes the importance of having a card reader that “can deal with the way customers will use them.” For example, they will expect the reader to read tickets that are “dirty and sticky” since passengers will put them in their pockets. Moreover, in the words of the operations manager, “We don’t want to test it. We want someone else to test it and use it for a year, and then we buy it.” Adds the marketing manager, speaking of advanced fare payment technologies in general:

> It is difficult for a small system to implement new technology. Often new technology has bugs in it. We haven’t the ability to maintain it and get the bugs out, and be able to implement each new generation that comes along...

3.3.5.5 Traveler Information and Paratransit

GET is actively considering electronic dispatching software for GET-A-LIFT, the system’s paratransit service. They hope that the software will allow the system to handle more people without additional vehicles. The system they favor is that it suggests several alternative routings, allowing the dispatcher “to take the human element into account — for example, if there is a new driver who is slower.”

GET’s approach to this system typifies its cautious attitude toward new technology. A GET manager originally saw the program at a technology conference, and considered it promising. Later, the vendors gave an on-site demonstration, and again GET staff were favorably impressed. They have now budgeted money for the system, but are spending this year evaluating it. A neighboring city, Glendale, has adopted the system, and the operations manager "wants to make sure they have a lot of experience with it under their belt and then I'll go and spend a day with them" to make sure that the system is a wise investment.

The marketing manager has investigated passenger information systems, particularly the Telerider system. She considers the technology to be "an outstanding idea" and envisions a system enabling communication from dispatchers and buses so that passengers have up-to-date information. When it comes to adopting such a system at GET, however, she sees little potential in the near future. First, there is a lack of funding. Moreover "we and the community are not geared to be able to accept this type of technology." She doubts that the public will accept that information given by a machine is correct. One reason for this is a phenomenon she has observed on their current, manual telephone information system. That system is busiest on working holidays, with most people who call simply wanting to know if there is service (the system shuts down for the major holidays). However, she has found that most customers are not satisfied with a recorded message stating there is service — they insist on receiving this information from a human operator. The general manager is also skeptical about the role of automated information, noting that "there are a lot of times, when people are not familiar with a transit system and don't know how it operates, that they don't know what question to ask."

3.3.5.6 Conclusions

A series of unsuccessful experiences with APTS technologies, combined with the inherent limitations of a small transit operator serving an auto-dominated area, have made GET what Rogers (1983, p. 246) terms a "late majority" adopter of APTS. While not a slave to tradition, GET has at least a healthy, and perhaps an excessive, skepticism about new technologies. On the other hand, GET's approach to the automated paratransit scheduling system shows that a cautious attitude toward new technology need not preclude the active exploration and consideration of promising new products. Also, GET's pioneering efforts with compressed national gas demonstrate that innovativeness is context specific, so that operators who are conservative with respect to APTS may assume the innovator role for other technologies.

3.3.6 Orange County Transportation Authority (Orange County, CA)

3.3.6.1 Description

The Orange County Transportation Authority (OCTA), which now includes the former Orange County Transit District, provides a variety of services for Orange County. OCTA operates fixed route service, along with paratransit and rideshare services. The new OCTA is also responsible for future rail operations.

OCTA's fixed route service accounts for approximately 84 percent of services provided. OCTA operates 500 buses on 50 routes arranged in a one-mile grid network. Weekday service operates from 5 AM to 9 PM with some selected lines remaining in service until 11 PM. Headways range from 7 to 70 minutes with 40 percent of the service operating on 30 minute headways. OCTA also operates two express routes to Downtown Los Angeles. Greyhound provides this service under contract.

OCTA has a Market Development program that provides service to lower density markets not yet capable of supporting large buses. Part of this program also includes service offered in cooperation with the California Department of Transportation as part of the I-5 widening project. Service is operated at 30 minute headways with some exceptions. When sufficient ridership has developed OCTA converts Market Development routes to fixed routes served by large vehicles.

The paratransit operation, Neighborhood Dial-A-Ride, is provided by various private firms under contract to OCTA, using District-owned small buses and vans. The system operates a zone demand-responsive service. There are five zones of approximately 10-12 square miles. OCTA limits service to seniors and the disabled except during peak hours when a subscription service is available to the general public.

3.3.6.2 General Outlook

OCTA is well suited to be an APTS innovator in several respects. It has a young, well educated, management team, including several individuals with experience in high technology industries. Its assistant director is a leader in the APTS movement, actively involved in IVHS America, the Transportation Research Board (TRB), and the American Public Transit Association (APTA). Its past experience with APTS technologies has been considerable, and for the most part favorable. Also the salary structure of the district is evolving to make it easier to recruit and retain individuals with high levels of technical expertise.

On the other hand, the District's service area is both heavily auto-dominated and economically distressed, making district management extremely cautious about investing in APTS technology with its own funds. Instead OCTA hopes to participate in a multi-modal Intelligent Vehicle and Highway System (IVHS) program, under which it can be subsidized to acquire certain technologies, particularly AVL, in exchange for sharing the data generated by these technologies with state and local agencies responsible for traffic management.

3.3.6.3 Vehicle Monitoring

OCTA uses a computer-based Maintenance Accounting and Purchasing System, or MAPS, which keeps detailed records on the maintenance history of each bus. These are used diagnostically, and also to determine when bus maintenance costs have reached the level where replacement of the vehicle is warranted. There is also a system in place for automatically monitoring the consumption of fuel and oil and flag situations where excessive consumption indicates the need for mechanical servicing. Finally, OCTA uses Detroit Diesel electronic engines, which collect engine performance data and generate failure codes when appropriate.

OCTA has automated various functions related to driver assignment. A special computer system tracks driver attendance, traffic tickets, accidents, and other relevant data. The system is used both to discipline drivers and for management functions such as determining the appropriate number of extraboard drivers. The assignment of extraboard drivers has also been automated. Prior to this, six employees, two at each base, made these assignments, and transfer of extraboard drivers from one base to another was not possible. The automated assignment eliminates the need for the six employees, while allowing for interbase transfer of drivers, greater accuracy, and reducing driver overtime. Despite some initial complaints from drivers who were accustomed to receiving their assignments from a human being, the system has worked well.

OCTA hopes to obtain financial assistance to acquire an AVL system, in exchange for sharing the data collected from the system with state and local traffic operations centers. This idea appears to have been originally suggested by the City of Anaheim. One of the pioneers in IVHS, with demonstration projects dating back to 1986, the City approached OCTA in 1990 with the idea of using selected buses to help collect traffic information, and accessing the District's information on street closures and service detours. Although the idea has yet to reach fruition, OCTA management appears strongly committed to it as a way of pursuing APTS technology while sharing the risks and costs with others.

This is not the first time OCTA has considered AVL. It explored such a system several years ago, primarily in order to reduce needs for on-street supervision and more effectively monitor dial-a-ride operations. OCTA did not adopt AVL because staff believed the technology was not "very polished" and that "not many people have used it effectively." While there is still doubt as to whether AVL could be justified in terms of the benefit for the transit system, OCTA staff believe that using AVL-equipped buses as traffic probes would substantially alter the balance of costs and benefits.

OCTA would benefit under this arrangement in several ways. First, it could use more sophisticated control strategies. For example, dispatchers would be able to identify situations in which buses are pairing and instruct drivers to use a leap frog strategy to make up time. Dispatchers do this now, but only when a driver calls in to say he/she is overloaded. Second, OCTA could use the information in conjunction with automatic passenger counters to rework the schedules, identifying intersections to avoid and stops that are unproductive. Third, the information could be transmitted to bus stops and disseminated either orally or visually to passengers. Fourth, more effective response to a bus breakdown would be possible, for example, by diverting a nearby bus to pick up the stranded passengers. Finally, there is the possibility of reducing personnel needs, although several respondents were skeptical of this. In the word of one: "There's always the promise of reduced personnel. It never seems to work." Indeed, OCTA managers anticipate that additional costs — particularly maintenance — associated with AVL will more than offset the cost saving it generates.

There is some interest in adding real time engine monitoring to the system. Maintenance staff envision a system that collects data on the bus and alerts the dispatcher when something is wrong. This could prevent catastrophic failures by identifying situations when performance is degrading more quickly. Also, the system could control for factors such as vehicle load and acceleration when setting windows for acceptable fuel and oil consumption.

The manager of Contract Services sees some opportunities to use AVL in paratransit operations. This would allow more effective response to situations in which a vehicle fails to arrive for a pick-up at the scheduled time, and/or a client cancels a service request. Additionally, dispatchers could use the system to determine when vehicles enter and exit the bus yard. This reflects a concern that paratransit drivers may collect undue overtime by not checking in immediately upon entering the yard.

OCTA has already begun planning the AVL system. They are planning on acquiring a new radio system in the next year, and will ensure that it is AVL-compatible. They also expect to include a “basic AVL budget” in their short range transit plan. However, they hope to share AVL costs, with OCTA paying for the basic radio system and others (presumably Caltrans) funding the AVL feature. They expect to use satellite technology, probably using a system from Westinghouse and Trimble Navigation. They find Westinghouse attractive because it is a big company willing to “force the issue” of system integration, by dealing with many suppliers to get their different machines to talk to each other. In the view of the maintenance manager, the lack of U.S. companies willing to play this role is one of the major reasons why APTS technology diffusion in U.S. transit operators lags behind that in Europe.

OCTA staff expressed little interest in adding collision alarms or other safety devices to the bus. They compared such alarms with the buzzer used for wheelchair lifts, which many drivers presently disable using tape. According to the maintenance manager: “drivers are in the bus 10-12 hours a day — they get sick of buzzers.” Another drawback is that each new device both adds more cost and represents another thing that can break. It is easy, according to the maintenance manager, “to have the cost (of a bus) go from $220k to $500k and reduce reliability. The bus might look great on a good day (when all the systems are functioning properly) but not on an average day.”

3.3.6.4 Fare Payment

OCTA’s most recent APTS technology acquisition is ticket reading and imprinting, or TRIM, machines, manufactured by GFI. The machines generate magnetic tickets, and also read them to determine whether they are valid for boarding a particular bus. OCTA adopted this technology to replace its paper transfer system, abuse of which was thought to be costing the system substantial revenue. The general manager, however, indicated that another motivation was the ability to have automated ticket vending machines throughout the service area, perhaps eliminating the need for agents who presently serve this function. The system can handle multiple rides by issuing tickets for more than one ride and then deducting each time the ticket is used. It can also handle time windows. Among other things, this capability can be used to discourage ticket sharing by requiring a certain time interval between one use and the next.

OCTA was originally slated to be the third U.S. operator to install TRIM machines, but for various reasons has turned out to be the first. They have had a few problems, particularly with the machine dispensing multiple tickets stuck together, and with passengers who, since they are unused to the system, crumple up their tickets. Also, they are becoming more aware that the system will entail additional maintenance costs that they did not fully appreciate at the time they considered the investment. Still, they expect to recoup the $1.6 million acquisition cost within two years, through increased farebox revenue.

While several interviewees expressed interest in Smart Cards, they do not think that transit agencies are in a position to implement this technology on their own. In the words of one, implementing smart cards “is like introducing a new form of money” and would require state or national legislation.

3.3.6.5 Traveler Information and Paratransit

OCTA has pioneered an automated paratransit scheduling and dispatching system introduced as part of an UMTA demonstration project in 1980. The system offers real time scheduling, and features communication between the dispatcher and the vehicles via CRT terminals. When a service request comes in, the computer identifies the appropriate vehicle for the pick-up, which is then contacted through the terminal. OCTA considers their system the most advanced in the country. However, changing circumstances have led them to decide to replace it within the next few years. The change is necessitated by a shift away from real time to pre-scheduled service, in order to reduce circuitry of routings and cut back on the number of hours operators must be on duty. Also, their current system lacks certain features that are becoming increasingly important. For example, when a client is too heavy for the driver alone to assist, it is desirable to call another driver who happens to be close by rather than send one out from a base.

There are differing viewpoints concerning the success of the paratransit software. In the view of the paratransit service manager, the system has worked well, and its sophistication is evidently a source of pride. On the other hand, the manager of the Commute Management Division, while agreeing that the system works very well, regrets the fact that only OCTD uses the system. Because of this, in her view, development of the system must not have been a wise use of taxpayer dollars.

OCTA is giving serious attention to ATIS. The current telephone information system is entirely manual, and considered archaic by the general manager. They are exploring different possibilities for automating the system. One particular issue is whether they should develop a joint system with the Metropolitant Transportation Authority, in which case both operators would have to agree on a single vendor. OCTD itself is leaning toward acquisition of an off-the-shelf system, and one that involves a human operator keying in service requests and then conveying output through a variety of means, including voice, fax, and mail. There is little interest in an automated teleride-type system where stops are assigned phone numbers. OCTA staff considers this format too confusing to the customers, who “already have enough numbers” to deal with according to the manager of Commute Services.

In addition to the benefits to travelers, OCTD anticipates marketing advantages from an automated information system. Service request entries will generate information on customer travel needs. The Commute Services manager compares the advantages to those airlines realize from their computer reservation systems.

3.3.6.6 Conclusions

With respect to APTS, OCTA appears a well-informed, conservative, consumer. Management is open to innovation, and has given APTS technologies considerable thought and study. On the other hand, OCTA requires strong evidence of tangible benefit before allocating resources to a new technology. In the present economic and fiscal environment, the benefit must translate into cost reductions or revenue gains. Experience has taught OCTA management to be skeptical of claims that APTS or any other technology can cut labor costs. Its most recent APTS technology acquisitions, the MAPS system for maintenance management and the TRIM machines, yield other kinds of benefits — extending bus life and enhancing revenue respectively. If these technologies also produce labor savings, that will be “icing on the cake.”

The collaboration with the city of Anaheim has substantially increased the potential for APTS innovation at OCTA. While not convinced that AVL could generate adequate levels of internal benefits to justify its cost, OCTA envisions it as a key component of a multi-modal traffic management system. Through this vision, OCTA is able to pursue technological possibilities that would be out of reach if it were acting alone. Further, using OCTA buses as traffic probes will give the transit agency, currently a marginal player in an auto-dominated, conservative area, an expanded role in the regional transportation system.

3.3.7 Santa Barbara Metropolitan Transit District (Santa Barbara, CA)

3.3.7.1 Description

The Santa Barbara Metropolitan Transit District (MTD) service area consists of 52 square miles from Goleta to the Ventura County border, in the southern coastal region of Santa Barbara County. MTD serves the communities of Santa Barbara, Goleta, Montecito, Summerland and Carpenteria. The communities are linked by service through a central transfer facility in downtown Santa Barbara. Major destinations include the University of California, Santa Barbara campus, the municipal airport, downtown Goleta and Santa Barbara, and Santa Barbara City College.

MTD service consists of 26 individual lines operating on a fixed route and schedule. The District does not operate any demand responsive service. Buses operate year round with the exception of New Year’s, Thanksgiving, and Christmas. Most routes are in operation from 7 AM to 7 PM, while a few routes have hours extending to 11 PM and starting around 5 AM.

MTD uses 53 buses in the peak and 42 in the base periods. Saturdays and Sundays require 27 and 20 buses respectively. MTD maintains an active fleet of 69 vehicles with 4 inactive and 2 demonstration vehicles. The demonstration vehicles are electric powered and used for a free Downtown Waterfront Shuttle in Santa Barbara. In 1988 MTD received 20 small vehicles for use in residential environments.

The basic fare increased from 50 cents to 75 cents in September 1989. The district has a contractual agreement with the University of California, Santa Barbara that allows all students to ride for free with a valid registration card. MTD has discounted punch cards available to student, elderly, and disabled passengers, and a commuter pass program with firms employing more than 29 people. The passes are sold directly to the firm on the basis of 100 percent employee enrollment.

MTD's main concerns at the present time revolve around coping with an increasingly demanding political, economic, and operating environment. MTD believes government overregulates small transit operators, forcing them to "convert bus service into office workers" and to expend resources to convert buses to alternative fuels. Economically, the main problem is that the costs of living, particularly housing, in Santa Barbara make it difficult to attract qualified workers at typical transit pay scales. Many drivers also work other jobs, forcing MTD to "watch real closely that they're not too burnt out when they come to work for us in the morning from whatever else they've done." Operationally, MTD is having to cope with increasing levels of traffic congestion, slowing buses and thereby increasing the number of buses it must deploy to maintain the same headways, and with greater numbers of "problem passengers," whose antisocial behavior increases driver stress and creates discomfort for other riders.

3.3.7.2 General Outlook on APTS Technology

MTD's general manager considers his considerable experience with computer installation at transit agencies representative of the problems transit agencies face using APTS technologies. One lesson he draws is that a champion is necessary:

> Unless you can find somebody who's coming from the outside or internally (to champion the technology) it's not going to happen to the fullest potential. You have more of this wonderful information processing capability but you are using 10 percent of it... It just never works unless someone takes it all the way. You have to beat an organization up into working with it. It's an essential element.

MTD is in the midst of coping with what its general manager calls "a period of rapid technological change" — not in information technology but in alternative fuels. The perceived challenge is not so much the technology itself but the uncertainty over what is "the correct path to follow" and "which way the politicians (who are seen as the key decisionmakers because of their control over regulatory requirements) are going to go. At the present time MTD is concentrating on battery electric buses, but there is pressure from the local air quality district to also use compressed natural gas. Since each energy source requires its own infrastructure investment, there is concern that MTD will invest in the wrong alternative fuel technology and waste a lot of money, or end up with a fleet using several different types of fuel and thus have be saddled with multiple fueling infrastructures.

The driver's union poses another type of challenge in the shift to alternative fuels that may also be of relevance to certain APTS technologies. The drivers of electric vehicles require special training, and MTD therefore desires to concentrate the first electric vehicle assignments among a handful of drivers. Since this would represent a departure from normal bid procedures, union agreement is needed. The union has, however, firmly resisted this change. However, when management raised the prospect of contracting out the electric vehicle routes, the union became more cooperative.

Another major item on MTD's technology agenda is the installation of a PC computer network along with new software to handle maintenance, scheduling, and other activities. The new system will replace a Quantel minicomputer and several stand-alone PCs. MTD staff expect the new system will allow "management to work in a more efficient manner and use less paper and save time by having quicker access to the information that we all need from each other." Hardware and software decisions have yet to be finalized. With regard to the software search, MTD is undertaking a "multi-faceted approach" to finding the best products, including consulting with private contractors, the American Public Transit Association (APTA), and others. It appears that the new system will increase the level of computerization at MTD. For example, the scheduling, run-cutting, and bidding processes will probably be computerized for the first time.

MTD is also planning on equipping its non-electric buses with D-Deck electronically diagnosed engines, hoping their sophisticated diagnostic capabilities will streamline maintenance and extend vehicle life.

These above items constitute a large technological agenda that has stretched managerial resources at MTD. "Everyone is occupied with something more important to the daily effort" than the pursuit of APTS. Further, MTD is loath to rely on consultants in these circumstances, because they usually wind up taking more time and money than is worthwhile. Thus, "if we can't do it in-house, we usually don't do it."

3.3.7.3 Vehicle Monitoring

MTD is planning on acquiring a new radio system in the next few years. They are not moving on this at the moment, in part because other items have higher priority, and in part because they see the technology evolving rapidly, and want others "to work out the bugs." Two features that they want to include in the new system are a way of identifying what bus is calling in, and a silent alarm. There are conflicting opinions of the latter, however. The assistant general manager considered this feature a top priority, and a driver stated that it would be "a great idea." The general manager is less enthusiastic, estimating that incidents calling for a silent alarm occur only once every 5-6 years.

Although MTD management is quite familiar with AVL technology, they do not consider it to be of much value for their system. With no more than 55 vehicles on the road at any one time, they consider radio communication adequate for tracking vehicles. According to their general manager, the dispatcher has "a map of Santa Barbara in his head" developed a "sixth sense" that enables him to know the location of vehicles, as well as the availability of "booster" buses that can respond when extra capacity is needed, without frequent monitoring. Since this individual is blind, conventional AVL technology clearly has little to offer him. Further, management does not consider MTD's schedule adherence a serious problem, and the system is small enough that, according to the assistant general manager, "I can tell you just off the top of my head exactly where we have a scheduling problem." Although there is only one on-street supervisor available for time checks, most routes stop at the downtown Transit Center, allowing MTD staff to regularly monitor schedule adherence at that point, while also providing this information to travelers. The additional time-check capabilities of AVL are thus not considered critical, even though schedule monitoring is "very important, just down from drug tests."

Vehicle tracking was considered potentially useful in two contexts, however. The first was the downtown shuttle service, where short headways make a given level of schedule deviation more significant. With a tracking system, more even spacing between buses on the line could be maintained. The second was emergencies, particularly when the driver is too shaken or otherwise affected to correctly identify his location, or when a bus has to remain stopped in order to wait for emergency assistance to reach it. With a tracking system, the bus could in some cases continue on its route, reducing the degree of schedule disruption.

Interest in vehicle control technologies varied among those interviewed. The driver, although clearly concerned about safety ("At the end of the day I thank the Lord I made it through the day without hurting anybody or myself.") does not see much promise for technology to improve it. On the other hand, the assistant general manager, while not expecting to pioneer this area, thought that the benefits could be significant, particularly as a defense against liability claims.

3.3.7.4 Fare Payment

MTD, like Bakersfield, acquired Cubic Western fareboxes several years ago. Although the units include devices for processing magnetic farecards, MTD does not use them due to reliability problems. The devices read fare cards correctly only 80 percent of time, and write on them correctly only 50 percent of time. According to the general manager, the reliability is low because the environment on the bus is "too harsh." MTD believes that many proponents of advanced transit technologies do not adequately consider this factor. To illustrate, he spoke of how buses are cleaned:

> A guy gets in the back with an air hose and blows all this [dirt and dust] up into the air and it gets sucked out from the door right through the farebox and card reader. That's a key consideration. I think it gets lost. There's your (speaking of the interviewer as a proponent of APTS) side of the business where you see things as really beneficial, but nobody realizes this is how they clean the buses.

The Cubic Western fareboxes require drivers to enter route identification information at the beginning of their run, and then at the beginning of each trip along their route. The reliability of this process has been a problem at MTD. The biggest problem occurs when a driver must shift from one route to another during his shift and forgets to reset the farebox. Also, although attempts have been made to collect data on different sections of a route by having the driver reset the farebox at the beginning of each section, drivers often fail to do this. It is also not unusual for drivers to inadvertently press the wrong keys, partly because the keypad is poorly lit and difficult for drivers to reach.

3.3.7.5 Traveler Information and Paratransit

The general manager “has always been kind of intrigued with” automated traveler information systems, but he is not excited by the potential for a small operator such as MTD. First, he feels that MTD should continue to project a “homespun” image. Second, he sees little opportunity for labor savings, since the same Transportation Center advisors who provide phone information also perform other duties such as ticket sales and answering questions from “walk-ups,” and “it hasn’t been a great burden on them to perform those duties simultaneously.” The assistant general manager, while concurring that automation in this area would not save money, thought that it could be of value from a marketing standpoint by increasing the number of locations where transit information is available.

MTD does, however, expect to take one step in the direction of computerized information when it installs the new computer network. The network will include terminals at the downtown Transportation Center, from which advisors will be able to get up-to-date (though not real time) schedule information.

MTD is looking for other low-cost ways of improving the quality of transit information. Through using the service himself, the manager of transit development has become aware of the “anxieties somebody goes through that’s not familiar with riding the bus. There is a simple little sign that says what you’re line number is up there. I had no confidence that I was going to get to my place on time or that I knew where I was going.” He and the general manager agree that “there’s got to be something we can do without spending $2 million — I’m sure we could find something if we had that money — that makes the system friendlier” particularly to new riders or riders going to new destinations. One specific need is a way of informing passengers when they should get off the bus. The Washington Metro, in which all stops and transfer points are announced over an in-vehicle speaker, was cited as an exemplar in this regard.

3.3.7.6 Conclusions

MTD is a comparatively small and simple transit system, and its information technology needs are comparatively modest. Its current APTS efforts revolve around attaining a level of technology reached a long time ago at many other systems. Although MTD staff recognize the potential benefits such APTS technologies as AVL and advanced traveler information, these are low priority items compared to vehicle electrification, electronic engine diagnosis, and computerization of management functions. It seems likely, therefore, that MTD will continue to be fall into the “late adopter” category with regard to APTS.

Like Bakersfield, MTD is taking a more aggressive stance in alternative fuels technology than in APTS. There are several reasons for this. First, there is far more external pressure to eliminate diesel engines than to improve schedule monitoring or passenger information. Second, whereas vehicle electrification harmonizes with (or at least doesn’t undermine) MTD’s “homespun” image, the agency perceives APTS technologies to be less compatible in this regard. Finally, the benefits of electrification do not hinge on labor savings, which, in a small organization where many individuals play multiple roles, are hard to attain by automating specific tasks.

3.4 Synthesis

We now attempt the bring together the findings from the seven case studies in order to answer the research questions posed in our introduction. Each of the following sections proposes an answer to one such question.

3.4.1 Under What Circumstances do Transit Operators Give Active Consideration to APTS technology Adoption as a Possible Course of Action?

The mere existence of a technology does not ensure that operators will consider adopting it. As a first prerequisite, members of the transit organization must know that the technology exists, and that their organization could conceivably make some use of it. We found that this prerequisite was generally satisfied. Virtually everyone we spoke with was aware of the various APTS technologies, and of some of their possible uses. Such knowledge is not, however, sufficient to make operators actively consider adoption of a technology, since there are many other items competing for the attention that such active consideration would require.

When is an APTS innovation able to surmount this obstacle? We identified several types of circumstances under which this occurred in our case studies.

1. A special opportunity to acquire an APTS technology may arise.

All of the operators who acquired AVL did so because it was available as a feature of a radio communication system, which they had already decided to acquire. Thus the radio system acquisition provided an opportunity to adopt AVL.

OCTA's interest in AVL has been spurred by an opportunity to participate in an IVHS project, and receive financial assistance for the AVL in return for sharing the information it generates with traffic operations centers. Similarly, OCTA is considering traveler information technologies because it has the opportunity to participate in a common system with a neighboring transit operator.

2. A member of a transit organization decides to serve as a "champion" for the technology.

All three AVL adopters included individuals that acted as champions — the radio engineer at MTA, the head of the Planning Department at TRT, and the superintendent of transportation at ATA. The head of Marketing at ATA is championing traveler information technology. Paratransit managers at MTA, GET, and OCTA are championing computer scheduling technology.

Motivations for adopting the champion role vary. At MTA, the initial advocates seem to have been attracted because of their technical orientation and resulting belief that a AVL-equipped radio system was both feasible and far superior to one providing voice communication only. TRT's AVL champion was motivated more by a general predisposition toward technical innovation, while at ATA both the AVL and traveler information champions were aware of specific problems in their area of responsibility that the technologies would address. The various paratransit managers have similar motivations for championing computer scheduling.

3. The transit agency has sufficient managerial resources to add an APTS adoption decision to its agenda.

Respondents in several agencies expressed the view that they had too many other issues to deal with, precluding consideration of APTS. For example, MTD is in the midst of important decisions regarding alternative fuel technology. TRT is still preoccupied with getting its AVL to work properly. At both of these agencies, sources cited these points as an explanation for not pursuing some APTS technology. These examples suggest that technology adoption decisions compete with one another for a place on a transit agency's agenda. Perhaps agencies implicitly establish a "budget" — a fixed amount of managerial time and effort — for such matters.

4. The transit agency becomes aware of a particular problem which may be helped through use of an APTS technology, or of an APTS technology that may help a recognized problem area.

All three agencies that adopted AVL considered schedule adherence a serious problem. MTA had found through passenger surveys that poor reliability was a major reason for its loss of ridership in the 1980s. ATA had become aware of problems with driver discipline, while TRT's adoption of pulse transfer scheduling made schedule adherence, and appropriate response to schedule deviation, critical issues. Also, at TRT, upper management considered street supervision to be excessively costly.

TRT and OCTA considered adoption of TRIM machines soon after their introduction, because they considered transfer handling a major problem area. Similarly, the widespread recognition of the problems with manual fare collection — particularly as use of paper money increased — spurred a rapid transition to electronic fare collection both in our case study operators and throughout the industry. The Translink program at CCCTA stemmed from recognition of a more specific problem — the need to preserve autonomy of individual transit operators in setting fares while facilitating transfers between the operators.

Likewise, the obvious inefficiencies and inconvenience resulting from having each transit operator providing information about its own system only prompted CCCTA's interest in traveler information technology. At ATA, interest in traveler information technology resulted from recognition of problems with the existing information system, including limited hours of operation, operator stress, and tendency for operators to make mistakes.

Finally, the widespread interest in computer paratransit scheduling observed in our case studies stems from recent passage of the Americans with Disabilities Act. The resulting prospects for increased service demand and requirements for expanded services have created pressure to contain costs. At the same time, and probably for the same reason, a new generation of scheduling software products is reaching the market.

5. The Agency has a Positive Attitude Toward Technological Innovation

Certain transit agencies take an aggressive stance toward the adoption of new technologies, while others take a conservative posture. TRT, for example, has been a consistent early adopter of new technologies, while GET and MTD have been generally been unwilling to play this role. These tendencies appear to correlate with attitudes that predispose agencies toward or against the adoption of new technology. For example, TRT became interested in AVL partly because of the perception that it was "flashy and high-tech." At MTD, in contrast, there was little interest in certain APTS technologies because they were perceived to conflict with the agency's "homespun" image.

The contrasting attitudes derive from several sources, including the character of the community, the educational background of decision makers, or the prior experiences of the agency or its decision makers with adoption of new technology. Whatever the underlying causes, there is evidence of a scale effect, with small operators less likely to lead innovation. This effect is consistent with findings of many other studies of technological adoption and innovation (Tornatzky and Fleishcer, 1990, pp. 161-162). Our case studies suggest several factors that may account for the relationship between scale and innovativeness. These include the organization costs associated with the investigation and implementation of new technologies. For example, while MTA had an entire group devoted to Systems Technology that could take responsibility for assessing AVL technology, at MTD this would fall on the general manager and his staff, who have many other matters to contend with. In addition, the benefits of certain APTS technologies may be greater for larger operators. For example, since the areas served by such operators tend to have more traffic and crime, AVL may be more attractive. Likewise, since large operators have larger, more complex, route systems, automating travel information services may promise greater benefits.

3.4.2 What Factors do Transit Agencies Consider in Deciding Whether to Adopt these Innovations?

After an APTS innovation receives active consideration, a decision on whether to adopt it must be made. Just as an agency must limit the number of items reaching its agenda, it must also reach decisions about items on the basis of limited information and analysis. On the basis of our case studies, several generalizations emerge concerning the factors that agencies consider in arriving at these decisions. These include:

1. Operating Cost Impact

The impact of adoption of a technology on operating costs is a primary concern. Federal capital subsidies tend to reduce the importance of capital cost as a consideration: if a federal grant is available, the capital cost is very low; if not, adoption is unlikely to be seriously considered. Transit managers are extremely concerned, however, with the prospect that adoption of a new technology will result in unanticipated operating cost penalties. Since implementing a new technology is likely to entail additional operating expenses, a key question is whether these can be offset by savings in other areas. In practice, such savings often prove to be elusive, and operators therefore tend to discount the potential for such savings. Operators are most likely to give credit to such claims when they involve expense items other than labor, or, if they do involve labor, when they do not require layoffs or other significant dislocation. For example, elimination of computer leasing fees at ATA, and of transfer printing costs at TRT, were considered important factors favoring adoption of APTS technologies. At MTA, planners anticipated significant savings from replacing part-time passenger counters, generally retired drivers already drawing a substantial pension, with automated counters. On the other hand, operators did not anticipate savings from layoffs of on-street supervisors in assessing AVL, or of information operators in assessing ATIS.

2. Technological Maturity

A second factor considered extremely important by many of the agencies was the maturity of the technology. At virtually all of the case study operators, interviewees expressed the concern that vendors bring transit APTS technologies to market before they have adequately tested or refined them. Agencies rely on peer networks, consultants, and in-house expertise in an effort to assess whether a given technology is sufficiently mature for their organization. The level of maturity required varies from property to property. Some (GET for example) are highly suspicious of any system that is not already in operation at a significant number of other operators. Others (such as TRT) are prepared to adopt systems so long as they are "off-the-shelf," even if they are "Version 1.0" and have not been proven by others. Finally, the most technologically adventuresome operators (MTA among our case study operators) did not limit themselves to "off-the-shelf" systems, although they still sought systems whose individual components they considered mature.

3. Consultant Recommendations

Finally, as already indicated, consultant recommendations are influential to adoption decisions. In the cases of TRT's and ATA's adoption of AVL, the consultant's strong support for the technology appears to have been crucial to the adoption decision. The fact that these two very different agencies, who happened to hire the same consultant, acquired identical AVL systems suggests that the influence of the consultant is considerable. It also suggests (but certainly does not prove) that consultants tend toward standard recommendations that do not vary according to the individual circumstances of their clients.

3.4.3 How Deliberate and Rational are APTS Adoption Decisions?

In the transit agencies we visited, decisions to adopt APTS technology were not made casually. Neither, on the other hand, were the analyses supporting these decisions exhaustive. How can we generalize as to where between these extremes the decision making fell? We found that decision making fell short of the rational ideal in two main respects.

1. Limited Alternatives were Considered

Generally, the decision was framed as one of whether to adopt or not adopt a given technology.

Since in most cases a technology reached a transit agency's agenda because it promised to remedy some problem, one would expect that a wide range of alternative responses to that problem — some involving APTS, and some not — would be considered. In reality, operators rarely did this. One possible exception to this is ATA's traveler information project. Unlike the others, this decision making process is beginning with a problem, and ATA and its consultant are planning to consider many alternative solutions to it.

2. Little Effort was Made to Quantify Benefits

Quantification was attempted only when it was very straightforward, such as the cost savings from avoiding computer lease fees at ATA, or the elimination of transfer printing costs at TRT. Most of the benefits of APTS technologies are not nearly so easy to assess in monetary terms. AVL is a good example. Improved schedule adherence is often cited as a benefit of this technology, and it was clearly a motivating factor in our case studies. It is difficult, however, to predict the degree of improvement that AVL can deliver, or assess the value of that improvement. The agencies we studied attempted neither of these. Satisfied that adopting this technology would cost little (at least of their own money), they relied largely on their subjective judgment that the benefits were sufficient to justify adoption.

3.4.4 How are APTS Innovations Implemented?

The process of implementation involves selection of the vendor or vendors to supply the system, development of data bases required by the system, training of agency personnel, and modifications of standard procedures necessary for the system to operate properly.

Although vendor selection is ostensibly a competitive process, we found that operators were usually strongly predisposed toward particular candidates. In part, this reflects the limited number of possible suppliers of new technology. Furthermore, since the technology is immature, products offered from the various vendors are fairly distinct from one another, and operators are thus unlikely to be completely indifferent among them. Finally, as already noted, consultants play a strong influence in agency decisions concerning APTS, and we saw evidence that consultants are predisposed toward certain vendors.

Agencies sometimes used the specification process to tilt the selection process toward preferred vendors. In light of the differences among the various products, it was not difficult to write specifications that strongly favored certain competitors. This process was not entirely manipulative, since the specification included many of the same attributes that made the preferred vendor's products desirable to begin with. However, it appeared that there were also instances where products were overspecified in order to achieve a desired outcome.

Development of data bases proved an unexpectedly difficult challenge for many of the operators. This derived both from the volume and the accuracy of the data required. The TRT AVL experience, in which distances between radio signposts were measured three times before the desired accuracy was obtained, is indicative of the problems operators encountered with data base development.

Training of agency personnel varied in extensiveness and effectiveness. Drivers trained on AVL in 15-30 minutes, and those responsible for monitoring the system also seemed to have learned the system fairly easily. The greatest deficiencies in training were those reported by TRT, where staff learned neither the full range of their AVL system's reporting capabilities, nor how to program the system to exploit them. This suggests a pattern in which training for routine activities associated with the system proved more successful than training for non-routine activities. Occasionally, even routine use proved difficult. For example GET's electronic farebox, because of its complicated keyboard, proved difficult for drivers even after they had been using the units for some time.

Implementation of an APTS technology often required adjustments to system operations that agencies had not anticipated when they made the adoption decision. The need for such adjustments derive from limitations in the range of inputs to which the new system could appropriately respond. For example, the signpost AVL required that drivers always use the same route in turning around their buses at the end of a run. Some time points also had to be relocated in order to allow consistent monitoring of schedule adherence. The need for passengers to treat magnetic card transfers more carefully than paper ones is also an instance where adoption of an APTS technology has imposed new constraints on a system. While not of great significance in and of themselves, these requirements, particularly in the case of AVL, contributed to the impression that implementation was more difficult and complicated than the adopting agencies had anticipated.

3.4.5 How are APTS Innovations Utilized?

As discussed in Chapter 1, one can categorize the benefits of APTS according to the manner in which they help the transit operator (or any other adopter) monitor and respond to disturbances impinging on it from its environment. The APTS technology may reduce the cost of monitoring disturbances (for example, cutting labor costs for on-street supervision). The APTS technology may also improve the ability of the transit operator to respond appropriately to various disturbances. It may provide better information on the disturbance, for example, identifying the exact location of a disabled bus so that it can be assisted more quickly. It may also increase the range of possible responses, for example, diverting a nearby bus from its normal route in order to pick up the passengers on a disabled bus. These different categories of potential benefit provide a convenient basis for discussing the patterns of APTS utilization observed in our case studies.

APTS technologies are frequently used with the intention of reducing monitoring costs. All three agencies that adopted AVL have substantially cut back time checks by on-street supervisors. TRT has reduced the number of on-street supervisors. At MTA and ATA these personnel are expected to enhance their activities in other areas, such as customer relations. Even at TRT, the on-street supervisor cutbacks have been more than offset by increased staffing in the radio room for purposes of monitoring the AVL and by the additional labor required to maintain the system. These experiences support the view, voiced often in our case study interviews, that labor cost savings rarely result from new technologies. On the other hand, if freeing on-street supervisors from time-check responsibilities actually enhances their performance in other areas, there may still be a substantial benefit.

There were several other examples of APTS technologies being used to attain cost reductions. In the area of advanced fare payment, TRT expects to save transfer printing costs as a result of adopting TRIM machines, as well as some run-time savings (and reductions in driver stress) from the reduction in fare disputes resulting from this technology. CCCTA's Translink system will reduce "transaction costs" — primarily in the form of passenger inconvenience — associated with payment of fares for trips using more than one transit operator.

Although our case study operators had limited experience with traveler information technology, it was clear that cost reduction — to both the agency and its customers — would be a major consideration in the use of such systems. Agency cost savings included reductions in training time, and possibly staffing levels, for telephone information systems. Respondents anticipated cost savings to passengers in the form of increased convenience, including reduced queuing for service, and extended hours of service availability.

Utilization of APTS technologies for purposes of improving regulation of the system was also fairly common. With regard to AVL, the most important form of regulatory enhancement was the "closed loop" feedback to drivers, which enabled them (within limits) to speed or slow their vehicles to reduce schedule deviations. In addition, AVL enabled dispatchers to play a larger role in regulating schedule adherence, by either contracting drivers directly or alerting on-street supervisors in the event of an apparent deviation. Finally, operators used AVL information to adjust schedules to reflect run times more accurately.

Advanced fare payment technologies are used primarily to enhance regulation. TRIM machines increase the ability to correctly determine whether a transfer is valid. Staff at CCCTA expect the Translink system to both increase the probability of correct fares being paid, and to allow agencies increased flexibility in setting fares (faresetting itself being a regulatory process). Regulatory enhancement benefits of traveler information include more accurate determination of routes and schedules, both because of a reduction in human error and (possibly) availability of real time schedule information.

Although the case studies showed that APTS technologies are being used to enhance transit agency regulatory processes, it appears that only a fraction of the potential is being realized. Examples of opportunities that are not being exploited are numerous. None of the AVL operators attempt to use location information to prevent bus pairing (for example, by delaying a bus that is gaining too rapidly on the bus in front of it). Nor are aggressive efforts being made to supply AVL information to information operators or directly to travelers. Operators use mechanical alarms simply to alert the driver to look for an on-vehicle warning light, rather than to alert maintenance personnel and thus speed their response to a breakdown. Emergency alarms are sometimes ignored because drivers often trigger them inadvertently. Although TRIM machines allow vastly more sophisticated pricing strategies, there appears to be little interest in exploiting this capability.

There are several explanations for these foregone opportunities. Doubts — often justified — about the reliability of the technologies results in a cautious attitude toward using them: the greater the reliance on the information, the more that can go wrong if the information is incorrect. Second, increased use of these technologies requires, at a minimum, changes to standard operating procedures, and perhaps changes in organization structure. The efforts and resources required to make these changes can be extensive, and unlike the technologies themselves federal grants do not pay for them. Third, in many instances the fundamental knowledge necessary to decide upon these changes is lacking. Although much could be learned from experimentation, such activity is also resource intensive from a managerial standpoint, and again generally not supported by grants.

3.4.6 How can Transit Operators be Encouraged to Make Appropriate Choices Concerning the Adoption of APTS Technology?

A central objective of federal transit policy is to encourage technological progress within this sector. Policymakers intended capital subsidy and demonstration programs to encourage adoption of new technologies by reducing the costs and risks of doing so. As with other Government R&D programs, this policy is based on the premise that innovation generates external benefits, in the form of technical knowledge that may be of value to other operators. Our case studies provide support for this premise. At virtually every agency, respondents cited the benefits that later adopters of a new technology gain from the experience of earlier ones.

Despite the importance of the external benefits, the ultimate value of technologies depends on how they benefit individual operators. Operators who make adoption choices with the goal of maximizing the benefits of new technology for their own agencies are also likely to generate the most valuable lessons for those who follow them. The goal of policy, then, is not merely to encourage the adoption of new technologies, but also the choice of appropriate technologies to adopt. This suggests that policy analysis focus on identifying, and proposing mitigations for, biases and barriers that distort adoption choices of individual operators. Our case studies suggest a number of such measures, which fall under two general headings.

1. Encourage Adequate Consideration of Internal Resource Requirements

Adoption of an APTS technology requires an investment, not just of money, but of organizational time and effort. In several instances, most notably those involving AVL, decision makers underestimated the latter. In some instances, this may result in diversion of internal resources away from other, potentially more valuable, activities. In other cases, the necessary internal resources may not be provided, resulting in curtailed implementation, or even abandonment, of the innovation. Transit agencies can avoid these outcomes through better foresight of the organization resources that adoption of a new technology entails.

One way of addressing this problem is to shift as much adoption responsibility as possible from the organization to outside suppliers. This approach has a number of advantages, and is further discussed below.

Still, no significant adoption can occur without considerable organizational effort. To better gauge the internal resources required, and ensure that they are provided, three measures should be considered. First, information concerning the nature and quantity of internal resources required for adoption of various APTS technologies should be developed and disseminated. Second, proposals for capital improvement projects involving adoption of new technologies should include estimates of internal resource requirements, along with a commitment to fulfill them. Third, policy makers should give consideration to providing partial reimbursement for these in-kind contributions — which we have argued represent “investments” just as much as purchases of capital goods-through existing capital subsidy programs.

2. Encourage Problem-Driven Decisionmaking

As noted above, the transit agencies typically view adoption decisions as binary choices pertaining to particular technologies. This approach has several disadvantages. First, decision makers view new technologies in isolation, rather than as part of integrated strategies for solving well-defined problems. Although AVL adopters frequently cited improving schedule adherence as a reason for acquiring AVL, none of them had developed a comprehensive strategy for dealing with this problem. Second, decision makers did not consider alternatives to adoption, other than no-action. Even if a new technology promises significant benefits, there may be superior alternatives. For example, traveler information could be improved through some advanced technology system, or by posting scheduled arrival times at bus stops. Likewise, agencies can acquire TRIM machines as one means of reducing costs and revenue leakage associated with transfers, but they could also consider vastly simplifying, or even eliminating, transfers.

If such reform in APTS adoption decision making is to occur, appropriate incentives from federal and state funding sources will be necessary. One avenue for accomplishing this would be to require grant proposals to include alternatives analysis. Realistically, such an approach can work only if funding agencies provide support for a preferred alternative based on its anticipated effectiveness, not its level of technological sophistication.

These reforms would entail a considerably larger effort in the preparation of grant proposals. Policymakers should recognize that this effort represents a capital investment just as much as facility construction or equipment purchase does. Accordingly, such efforts should qualify for capital subsidies. Perhaps, therefore, the application of capital subsidies for APTS technologies (or some more cost-effective alternative) would have two parts. In the first phase, agencies would apply for a grant to study a specified set of problems and assess alternative actions for addressing them. In the second phase, agencies would request funding to implement their preferred solution. In both phases of this process, funding agencies would evaluate proposals on the basis of their promise for remedying significant problems in a cost-effective manner, rather than on the basis of the specific technologies they involve.

3.4.7 How can the Process of APTS Technology Implementation be Facilitated?

There is much that can go wrong when a transit operator implements an APTS technology. Much of the problem results from the fragmentation of responsibility between the vendor and the operator, and sometimes between different vendors. For example, AVL and ATIS systems require the operator to assemble large data bases required as inputs by these systems. Similarly, vendors and agencies share responsibility for training. The former must impart the knowledge required to operate and maintain the system, while the latter must both attain this knowledge and determine when their training is sufficient.

This division of responsibility often results in the premature departure of vendors from the implementation process. Vendors can claim that they have fulfilled their obligations, even though the system is not yet running properly. While this position may be legally supportable, it is extremely damaging to the prospects for implementation, since the vendor is in a much better position to diagnose problems with the new system.

Some operators, such as TRT, have attempted to confront this problem through an acceptance process designed to ensure that the system is operating properly before the agency accepts that term of the contract has been fulfilled. Funding agencies should mandate such acceptance process, as a condition for grant support, for all APTS technology acquisitions. The acceptance process should require passage of a rigorous set of tests that ensure that hardware is operating properly, that data bases are accurate, and that training is adequate.

Such strict requirements have the effect of shifting overall responsibility for implementation to vendors, since their financial interest will be tied to successful operation of the overall system, rather than just the components they deliver to that system. This may induce vendors to take an expanded role in implementation. Vendors may, for example, develop the data bases themselves, or substantially upgrade their training activities. Such changes entail additional costs, which they must pass on to their customers. Even if the nominal cost for acquiring the system increases, the reduction in agency resources required both for initial installation and subsequent fine tuning should more than compensate for this.

3.4.8 How can More Effective Utilization of APTS Innovations be Encouraged?

Effective utilization of APTS technologies by transit operators is hampered by the problems previously described. If internal resources are insufficient, if adoption choices are made outside of integrated, problem driven strategies, if implementation results in inadequate training or a malfunctioning system, then utilization of the technology is bound to fall short of its potential. Measures to reduce these shortcomings will improve utilization as well.

Beyond this, effective utilization of APTS technologies requires thorough analysis of how information technologies, whether advanced or primitive, shape and constrain regulatory processes within a transit organization. Such analysis may result in strategies very different from those in use today. For example, operators view AVL as a means of improving schedule adherence. However, if information from AVL were readily available to travelers, perhaps schedules could be eliminated. Dispatchers could concentrate on maintaining headways and ensuring reliable arrival times over a short time horizon. Likewise, TRIM machines, whose adoption is generally motivated by simple aims such as reducing costs from printing and fraudulent use of paper transfers, also offer the potential for vastly more sophisticated pricing strategies, based on a time-of-day, route characteristics, and other variables.

It is unrealistic to expect these ultimate capabilities to be immediately realized. However, explicit attention to information technologies and their limitations in ongoing planning efforts can encourage progress. A logical beginning point is to inventory regulatory processes and the key information bottlenecks that hamper them. Examples of such bottlenecks might include:

-lack of real-time schedule information requires use of fixed, printed schedules;
-fare structures are constrained by the limited ability of the collection system to apply complex rules;
-lack of adequate passenger count information and reliance on fixed schedules hampers ability to detect and remedy poor-performing routes;
-lack of adequate engine performance data limits ability to perform preventive maintenance.

An inventory of this sort, when combined with knowledge of how different technologies can remove information bottlenecks, allows systematic identification of opportunities for exploiting APTS technologies. Transit agencies can use this information either as an input to the problem-driven decision process described previously, or as means of improving utilization of technologies they have already adopted.

These endeavors, like those advocated for adoption and implementation of new technologies, entail substantial internal resources. We reiterate that operators make such expenditures, like other capital investments, in the present to secure gains in the future. This returns us to the basic point that funding agencies should not limit capital subsidy to the purchase of equipment and construction of facilities. Such a bias will invariably result in transit operators with access to sophisticated technology, but without the sophistication to choose, or use, that technology effectively. Without a balanced program of investment in physical, organizational, and human capital, transit operators risk becoming casualties, rather than beneficiaries, of the Information Age.

Chapter 3 References

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CHAPTER 4:
TRANSIT OPERATOR VIEWPOINTS OF APTS TECHNOLOGIES — A SURVEY

4.1 Introduction

In this chapter, we report on the results of a survey of transit agency staff concerning their experiences with and attitudes toward transit applications of APTS technology. The survey was a follow-up to the case studies discussed in the previous chapter. Unlike the case studies, the survey emphasised closed-ended questions so that responses could be statistically analyzed. The survey also targeted a larger number of agencies, making its results more representative of the U.S. transit industry as a whole. Of course, these advantages come at the sacrifice of the richness of detail and fullness of perspective that the case studies provide. The two research approaches are therefore intended to complement one another.

The remainder of this chapter is organized in three main sections. First, we discuss the survey design. Next, we analyze survey results. The final section offers conclusions.

4.2 Survey Design

4.2.1 Questionaire

Appendix 1 contains a copy of the survey. It was designed to obtain two main types of information. First, we wanted to characterize transit operators' experience with APTS technologies. Toward this end, we asked (Questions 2a-x) whether the operator had acquired various APTS technologies. For each that it had acquired, we asked several questions pertaining to the adoption decision and the experience with implementation.

While our interest in Question 2 is in the experience of operators that have adopted APTS technologies, in Question 3 we focus on experience prior to the adoption decision. We are particularly interested in determining what sources of information adoption decisions are based on, what steps non-adopting operators have taken to find out about various technologies, and whether their non-adoption represents explicit rejection or deferral of a final decision.

In formulating the questions about experience, we used the same categorization for transit APTS technologies employed in earlier phases of this research. The three categories are: advanced traveler information systems (ATIS), automatic vehicle monitoring systems (AVM), and advanced fare payment systems (AFP). In addition, for purposes of this survey we included the electronic farebox (EFB) as an APTS technology, even though it is not usually viewed as such. We did this for two reasons: in order to have a widely-used technology as a benchmark against which experiences with other technologies could be compared, and in order to sustain the interest of respondents from agencies who have not adopted any of the other, more "advanced", APTS technologies. Also, since some respondents may consider an innovation outside our categories to be "advanced technology," we added an "other" category. (In practice, the technologies mentioned under this heading turned out to be "low-tech" ones such as fast passes and multi-ride tickets that are not within our research scope.)

In Questions 4-11 we explore respondents' attitudes toward APTS technologies. In Questions 4-9, we determine the prevalence of certain general attitudes that case study participants expressed. Questions 10-11 ask respondents to assess obstacles to APTS adoption that had been identified in the case studies.

In addition to the technology-related questions, we also asked a few questions about the characteristics of the respondents' agencies, with the intention of analyzing the effect of these characteristics on experiences with and attitudes toward APTS technology. Question 1 asks the respondent to identify the agency's "top priority for change." Questions 12 and 13 are designed to assess the level of technical knowledge available within the agency. Finally, Question 14 concerns the agency's organizational structure. Answers to these questions did not prove very useful in our analysis, and we do not discuss answers to them here.

4.2.2 Sample Selection

We used a cluster sampling strategy, in which we first identified a sample of operators, and then targeted particular personnel representing those operators.

The operators were drawn from two groups. The first included all operators who had been identified as having adopted either AVM or ATIS. The group was identified based on information provided in the Federal Transit Administration (FTA) publication "Advanced Public Transportation Systems: The State of the Art" (FTA, 1991). In light of resource constraints, we did not include operators who had adopted advanced fare payment technology in this group. Consequently, the number of surveyed operators with advanced fare payment technology is far smaller than the numbers of AVM and ATIS adopters.

The second group consisted of bus operators not on the FTA list, and with at least 25 vehicles in peak period service (based on the Federal Transit Administration Section 15 Statistics for 1990).* A random sample of 21 operators was chosen from this group, using a random digit table.

For each selected operator, we targeted three individuals for the survey. Generically, these were the "director of transporation," "the director of planning," and "the director of marketing." Since organizational structures and position titles vary, these targets served merely as a guide during our initial inquiries. Once an agency was contacted, the actual individuals targeted were based on a combination of their managerial responsibilities and their levels of involvement with and knowledge of APTS technology.

As the survey progressed, we found that time and resources would not allow contacting every targeted individual at every agency. We then decided to give priority to gaining as wide a representation of transit operators as possible, rather than getting multiple respondents from any one agency. The individual chosen in these circumstances was generally the first with whom we were able to set up an interview.

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*One smaller operator, the Western Contra Costa County Transit Authority, with seven buses in peak service, was also included.

Table 4-1 summarizes the final sample of survey responses. Altogether 71 surveys were completed. Of these, 35 stated that their agency had adopted some form of advanced technology for traveler information, vehicle monitoring, or advanced fare payment (other than electronic fareboxes). The remaining 36 reported no such adoption.

4.2.3 Survey Mechanism

We administered the survey via telephone. Compared to a mail survey, the advantage of this method is that it generally increases the response rate. The disadvantage is that it dramatically increases the cost per completed survey. We considered the response rate to be particularly critical for this survey because of the significant potential for self-selection bias. When the response rate to a survey is low, the validity of the survey results depends upon the extent to which survey respondents are representative of non-respondents. If we had used a mail survey, it is likely that the respondents would have been those with particularly strong interests in APTS. This would have skewed our results substantially. Although the process of completing telephone interviews proved time consuming and frustrating, and the size of our sample was was well below our initial hopes, we are confident that the sample is relatively free of self-selection bias.

To facilitate the telephone interviewing process, we usually faxed a copy of the survey, along with a sheet explaining the terminology used, to the respondent in advance. In a few cases, the participant had actually prepared answers by the time we called, and simply read them back over the phone. In most cases, the faxed copy served as an additional cue to assist the respondent in understanding and remembering the questions and alternative answers as they were read over the phone.

4.3 Results

Tables 4-2 and 4-3 summarize responses for Question 2, concerning operators' experiences with APTS technologies. Table 4-2 shows that the majority of respondents reported that their agency had adopted electronic farebox technology, while most did not report experience with the other technologies. Similar proportions are obtained when results are aggregated to the transit operator level.[*] These results are not, of course, representative of the population of transit operators, since they were intentionally drawn to oversample APTS adoptors. A low number reported adoption of advanced fare payment technology for the reason given in Section 4.2.2.

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[*] There were a number of cases when respondents from the same agency differed about whether a technology had been adopted. There was divergent responses at six agencies over whether advanced traveler information systems had been had been adopted. With regard to vehicle monitoring and advanced fare payment adoption, the number of agencies with such different responses were two and three, respectively. These discrepancies are probably due to a variety of causes, including limitations in knowledge, uncertainties concerning definitions, and a few instances where, because adoption was imminent, respondents had different interpretations of the phrase "currently have" as used in Question 2.

For purposes of developing Table 4-2, an agency is considered to have adopted a technology if any one of the respondents from that agency so indicate.

Table 4.1
Survey Participants

Operator	Number Surveyed	Peak Buses	Electronic Farebox	Traveler Info	Vehicle Monitoring	Fare Payment
AATA, Ann Arbor MI	2	84	Yes	No	Yes	No
AC Transit, Oakland, CA	2	607	Yes	No	No	No
APT, Augusta GA	1	26	Yes	No	No	No
Cat, Harrisburg, GA	1	63	Yes	No	No	No
COTA, Columbus, OH	3	281	Yes	Yes	Yes	No
CoTran, W. Palm Beach FL	1	82	Yes	No	No	No
County, Milwaukee, WI	3	445	Yes	No	No	No
CTA Chicago, IL	3	2820	Yes	Yes	No	Yes
DART, Wilmington DE	3	87	Yes	No	Yes	No
DTA Duluth, MN	1	76	Yes	Yes	No	No
Evertt, Seattle, WA	1	31	No	No	No	No
GGT, Marin County, CA	2	224	Yes	No	No	No
Marta, Atlanta GA	2	732	Yes	No	No	No
MATA, Memphis TN	3	174	Yes	No	No	Yes

Table 4.1 cont.

Operator	Number Surveyed	Peak Buses	Electronic Farebox	Traveler Info	Vehicle Monitoring	Fare Payment
Max, Birmingham AL	3	113	Yes	No	No	No
MBTA, Boston MA	1	1419	No	Yes	No	No
MDTA, Miami FL	2	561	Yes	Yes	No	Yes
Metro, Houston TX	3	909	No	No	No	No
Metro, Indianapolis IN	1	172	Yes	No	Yes	No
MTA, Nashville TN	1	151	Yes	Yes	No	No
MTC, Minneapolis MN	2	869	Yes	Yes	No	No
NCTD, San Digeo CA	2	120	No	No	No	No
New Jersey Transit	1	2376	Yes	No	Yes	No
Pentran Newport News VA	1	135	Yes	Yes	No	No
RT, Sacramento CA	2	181	No	No	No	No
RTA, New Orleans LA	2	438	Yes	No	No	No
RTD, Denver CO	3	591	Yes	Yes	No	No
RTD-Pace, Chicago Il	2	678	Yes	No	Yes	No
RTS, Rochester NY	2	204	Yes	Yes	No	No
SamTrans, San Mateo CA	1	269	No	No	No	No
SMMB, Santa Monica, CA	2	206	No	No	Yes	No

Table 4.1 cont.

Operator	Number Surveyed	Peak Buses	Electronic Farebox	Traveler Info	Vehicle Monitoring	Fare Payment
SCCTD, San Jose CA	2	425	Yes	No	Yes	No
Tri-Met, Portland OR	3	487	Yes	Yes	No	No
UTA, Salt Lake City, UT	1	391	No	Yes	No	No
VIA, San Antonio TX	3	538	No	Yes	Yes	No
WestCat, Contra Costa County CA	1	7	No	No	No	No
WMATA, Washington DC	2	1888	Yes	Yes	No	No

Table 4.2
Reported Adoption Experience

	Electronic Farebox	**Traveler Info**	**Vehicleg Monitoring**	**Fare Payment**
Respondents Reporting Adoption	53(75%)	24(34%)	17(24%)	3(4%)
Respondents Reporting Non-Adoption	17(24%)	47(66%)	54(76%)	68(96%)
Don't Know	1(1%)	0(0%)	0(0%)	0(0%)
Total Repondents	71(100%)	71(100%)	71(100%)	71(100%)
Properties Reporting Adoption*	28(76%)	15(40%)	9(24%)	3(8%)
Properties Not Reporting Adoption	9(24%)	22(60%)	28(76%)	34(92%)
Total Properties	37(100%)	37(100%)	37(100%)	37(100%)

* Includes any property where at least one respondent reported adoption.

Table 4.3
Assessment of Technologies

Rating Factor	Statistic	Electronic Farebox	Traveler Info	Vehicle Monitoring	Fare Payment
Ease of Implementation (1=most difficult, 5=easiest)	Mean	3.46	3.26	2.40	4.00
	S.D.	0.99	1.10	1.35	0.00
	n[1]	50	19	15	2
	p(EF)[2]	—	NS	<.02	—[6]
	p(TI)[3]	NS[5]	—	<.10	—
	p(VM)[4]	<.02	<.10	—	—
Satisfaction with Vendor (1=least satisfied, 5=most satisfied)	Mean	3.57	3.32	2.60	4.00
	S.D.	1.12	1.16	1.35	0.00
	n	49	19	15	2
	p(EF)	—	NS	<.02	—
	p(TI)	NS	—	<.15	—
	p(VM)	<.02	<.15	—	—
Performance Relative to Expectations (1=most below, 5=most above)	Mean	3.27	3.16	2.71	3.00
	S.D.	0.84	0.84	1.20	0.00
	n	49	19	14	1
	p(EF)	—	NS	<.15	–
	p(TI)	NS	—	NS	–
	p(VM)	<.15	NS	—	–

[1] Number of usable responses. Unusable responses include don't know, no opinion, or multiple ratings.
[2] Significance level at which hypothesis that mean rating equals that of electronic farebox can be rejected. Based on two-tailed t-test assuming unequal variances.
[3] Significance level at which hypothesis that mean rating equals that of traveler information technology can be rejected. Based on two-tailed t-test assuming unequal variances.
[4] Significance level at which hypothesis that mean rating equals that of vehicle monitoring technology can be rejected. Based on two-tailed t-test assuming unequal variances.
[5] Not significant. Used when p()>.15.
[6] Significance tests not carried out due to small number of responses for advanced fare payment

Table 4-3 summarizes ratings of adopted technologies. Although we present results for AFP, they cannot be meaningfully interpreted because of the small number of responses on which they are based. Of the other three technologies, the EFB was rated highest, followed by ATIS, and finally by AVM. The difference between the former two technologies is statistically insignificant: one cannot reject the null hypotheses of equal population means for their ratings with regard to ease of implementation, satisfaction with vendors, or system performance. On the other hand, AVM ratings are well below those for EFB, with the differences statistically significant at the .02 level for ease of implementation and satisfaction with vendors, and at the

.15 level for system performance. Ratings differences between ATIS and AVM are smaller and less statistically significant. The hypothesis that these technologies offered equal ease of implementation can be rejected only at the .10 level, while the hypothesis of equal satisfaction with vendors can be rejected only at the .15 level. The difference in the overall performance of these technologies is statistically insignificant. Overall, these results indicate that the greatest differences in respondents' assessments of EFB, ATIS, and AVM concern the ease of implementing them, while ratings of their performance, once implemented, are fairly similar.

Table 4-4 reports the experience of non-adoptors with APTS technologies, based on Question 3. The results presented in the table are based only on respondents from what we term "definite non-adopter" agencies — those whose survey participants all stated that a given technology had not been adopted. Each entry reports the percentage of such properties where at least one respondent reported the event in question. In general, the level of awareness of non-adopters is high. This derives in part from our vibrant system of free enterprise — for every technology, a majority reports contacts from salespeople. Many non-adopting agencies have also taken active steps to explore these technologies. The most common such steps are designating an individual or group to investigate the technology, and visiting another agency to see the technology in use. Depending on the technology, between 41 and 75 percent of non-adopter agenices report at least one of these steps have been taken. Smaller proportions of non-adopter agencies report

working with consultants or other government agencies to investigate the technologies. Since these steps typically entail monetary expenditures or other organizational commitments, it is not surprising that they are less common. Among the new technologies, AVM is the one for which these steps have been most commonly taken. This is surprising in light of the substantially lower ratings this technology received from those who have adopted it (Table 4-3).

Table 4-5 characterizes definite non-adopting operators' pre-adoption experience based on Question 3g, in which respondents were asked what stage their investigations of each technology had reached. As in Table 4-4, we consider here only the responses of those representing definite non-adopters, and aggregate these responses to the individual property level.* EFB non-adopters have progressed the furthest, with 44 percent about to implement and 56 percent past the point of information gathering. In contrast, 72 percent of the agencies who have not adopted ATIS report that their agencies are not past the information gathering stage. Of the 24 percent having reached some decision (that is, that have made a grant application, are about to implement, or have decided not to pursue) two-thirds have decided not to pursue this technology. With regard to AVM, non-adopters report having progressed further than they have with ATIS but not as far as they have with EFB. 61 percent report that they are past information gathering, while 46 percent have

* The aggregation procedure was as follows. For agencies with two respondents, we used the response indicating the furthest progress. For agencies with three respondents, we used the median of the three responses. In one case the responses to this question directly contradicted one another; this case was thrown out..

Table 4-4. Pre-Adoption Experience with APTS Technologies
(Percent of Non-Adopting Properties Reporting Each Event)

	Statistic	Electronic Farebox	Traveler Info	Vehicle Monitoring	Fare Payment
Approached by Salespeople	Percent n*	89% 9	64% 22	82% 28	74% 34
On-site Demonstrations	Percent n*	44% 9	36% 22	46% 28	32% 34
Designated Individual/ Group	Percent n*	44% 9	41% 22	57% 28	50% 34
Worked with Consultants	Percent n*	22% 9	14% 22	46% 28	18% 34
Visited Another Agency	Percent n*	75% 8	41% 22	63% 27	58% 33
Research with Gvt. Agency	Percent n*	22% 9	32% 39	41% 27	35% 34
Implementation with Gvt. Agency	Percent n*	22% 9	22% 40	32% 28	12% 34

*Number of usuable responses from definite non-adopters. Unusable response was don't know.

reached a decision, two-thirds of these in favor of implementation. Finally, 37 percent of AFP non-adopters report being past the information gathering stage, and of the 15 percent who have reached a decision all are either about to implement or are applying for a grant to do so. These results are consistent with those from Table 4-4 in suggesting that vehicle monitoring technology, despite receiving lower ratings from adopting operators than the other APTS technology categories, is diffusing more rapidly.

Tables 4-6 and 4-7 summarize results concerning attitudes toward APTS technologies. For these questions, individual responses, rather than ones aggregated to the transit property level, are considered. Table 4-6, based on Questions 4-9, summarizes respondents' level of agreement or disagreement with a set of statements. Results are disaggregated by whether the respondent's agency has adopted some APTS technology, excluding EFB. The significance level for rejecting the hypothesis that the levels of agreement for the adopting and non-adopting groups are equal is also presented. The lower the significance level, the more significant the difference in response between the two groups.

Respondents in both categories largely disagreed with the statement that APTS technologies “are more trouble than they are worth.” Adopters disagreed somewhat more strongly than non-adopters. This difference, which is of marginal statistical significance, may be due to the fact that a more favorable a priori view of APTS technologies encourages adoption, but also indicates that this attitude is maintained (although it may be weakened or strengthened) through the adoption experience. Both adopting and non-adopting respondents agreed that their agency would adopt additional APTS technologies if the money were available. There was little agreement with the proposition that personnel hours could be reduced by adopting these technologies. Thus, while respondents have a positive view of APTS technologies, they do not expect them to pay for themselves through labor savings.

Adopter and non-adopter respondents were, on average, in weak disagreement with the statement that lack of information about APTS technologies is a barrier to adoption. Lack of information is clearly perceived to be a less important factor than lack of money. Since adopters and non-adopters expressed about the same level of agreement, it does not appear that access to information is an important determinant of whether adoption occurs.

While adopters and non-adopters both indicated that lack of money constrained their implementation of APTS technologies, and that lack of information was a minor constraint, their views diverged on the need for organizational changes to successfully implement these technologies. Non-adopters agreed more with the statement that successful implementation of APTS technologies requires organizational changes. This is the only difference in attitudes between adopters and non-adopters that is significant at the .05 level, and suggests that concern about the organizational ramifications of implementing APTS technologies may be a significant hindrance to adoption. On the other hand, size of the metropolitan area is not viewed as an important factor: both adopters and non-adopters expressed, on average, slight disagreement with the statement that APTS technologies are most appropriate for major metropolitan areas.

Table 4-7 summarizes results of Question 10, in which respondents are asked to rate the importance of various obstacles to APTS adoption. As above, money is seen as a paramount concern. Operating cost is the most important, but capital cost is only slightly less so. Thus, despite the high level of capital subsidies provided by the federal government, a capital expenditure for an APTS technology is not perceived as “free.” This may reflect opportunity costs when the supply of capital is fixed, or the local match required to obtain the federal assistance.

Uncertainty of benefits and precedence of other initiatives are also seen as important obstacles to adoption, although they are somewhat less important than those related to cost. While adopters and non-adopters attach the same importance to benefit uncertainty, the latter attach a somewhat higher importance to precedence of other intitiatives, although the difference is statistically significant only at the .15 level. This suggests that some agencies may not adopt APTS technologies because they have more pressing concerns in other areas.

Table 4-5. Stage of Consideration of APTS Non-Adopters
(Percent of Non-Adopters Reporting Each Stage)

	Electronic Farebox	Traveler Info	Vehicle Monitoring	Fare Payment
Have Not Researched	22%	24%	12%	21%
Information Gathering	22%	38%	27%	42%
Experiment/ Demonstration	0%	10%	15%	9%
Deciding about Adoption	0%	0%	0%	12%
Grant Application	11%	5%	0%	3%
About to Implement	44%	5%	31%	12%
Decided not to Pursue	0%	19%	15%	0%
Total Usable Responses*	9	21	26	33

Percentages may not add to 100 due to rounding.
*Number of usable responses from definite non-adopting agencies. Reponse is unusable when different respondents from agency give irreconcilable answers, or when response is don't know.

Of the obstacles identified, lack of staff time is seen as the least important. Since the importance of this obstacle is judged to be considerably less than that of other initiatives taking precedence, we must conclude that competition from other initiatives is related primarily to resources other than staff time. Rather, such competition probably involves capital and operating funds, and possibly managerial resources as well.

4.4 Conclusions

Several findings emerge from this survey. First, ratings of the various APTS technologies by personnel in adopting agencies indicate that vehicle monitoring has been considerably less successful than the other technologies considered. Notwithstanding this, vehicle monitoring has the strongest near-term prospects for further diffusion. This could be an indication that operators are choosing the wrong technology to pursue. Alternatively, it may be that with the recent improvements in vehicle monitoring technology — in

Table 4-6. Level of Agreement with Attitudinal Statements, by APTS Technology Adoption Status

Statement	Mean Level of Agreement (1=Lowest, 5=Highest)			Sig. Level
	Adopters	Non-Adopters	All Respondents	
Technologies more trouble than they are worth.	2.03	2.39	2.21	.13
Would try some additional APTS Technologies if we had the money.	3.94	3.97	3.96	.91
Lack on information about APTS Technologies hampers decisionmaking.	2.71	2.94	2.83	.43
Successful implementation requires organizational changes.	2.69	3.28	2.99	.05
APTS technologies are most appropriate for major metropolitan areas.	3.17	3.14	3.15	.92
Adopting agencies will require fewer personnel hours.	2.26	2.44	2.35	.46

particular the move from signpost to route independent systems — its emerging popularity is justified despite the limited success of the systems currently in place. In any event, we would like to know more about why diffusion of AVL is outpacing that of other technologies at the present time.

Transit operators who have not adopted the various APTS technologies are, by and large, taking steps to investigate them. Strong majorities of non-adopting agencies report having at least begun gathering information, and a substantial proportion (in the vicinity of 50 percent, but varying by technology) have designated a person or group to lead these investigations. It is likely that visits by salespeople, reported by a majority of operators for all four technology categories, have played an important role in precipitating these activities.

Although most non-adopting agencies have begun investigating these technologies, the majority

Table 4-7. Perceived Importance of Obstacles to AIT Adoption, by APTS Adoption Status

Obstacle	Mean Stated Importance of Obstacle (1=Lowest, 5=Highest)			Sig. Level
	Adopters	Non-Adopters	All Respondents	
Initial Cost	3.86	4.25	4.06	.15
Operating Cost	4.03	4.39	4.21	.11
Uncertainty of Benefits	3.49	3.61	3.55	.63
Other Initiatives Take Precendence	3.37	3.74	3.56	.15
Not Enough Staff Time	2.74	3.03	2.88	.37

have yet to reach a conclusion about adoption. The decisions of those who have reached closure offer some interesting harbingers for the future. For example, of the six properties who have reached a decision about traveler information technologies, two-thirds have decided not to adopt, while two-thirds of the nine agencies who are decided have made the opposite choice for vehicle monitoring technologies. These results, like those cited above, stand in sharp contrast to the ratings of the technologies by operators who have adopted them; however the small sample size dictates caution in interpreting the results.

Results from the attitudinal questions enable us to paint a fairly coherent picture of the main factors that determine APTS adoption decisions. Funding is clearly of paramount importance. This reflects not only that these technologies cost money, but also that their benefits are not expected to appear in transit agencies' financial results. In addition to monetary considerations, we found evidence that non-adopting operators are significantly more concerned with the organizational ramifications of adopting APTS technologies, and a little more likely to attach high priority to other items on their agendas. All of these results are consistent with the findings from our case studies. On the other hand, the survey results suggest that access to information about the technologies and urban area size are relatively unimportant factors in adoption outcomes. These findings, particularly the latter one, conflict with the attitudes expressed in the case studies. Further research is necessary if this discrepancy is to be resolved.

In summary, the results of the survey show that APTS activity is following the decentralized model of technical innovation that federal transit research and development policy has favored for the last two decades (see Chapter 1). Most operators who have not already adopted a technology are considering it. They appear willing to devote staff time and other internal resources to determine whether a given technology is appropriate for them. Moreover, operators visit (and, presumably, otherwise communicate) with one another to learn how well the technologies work. On the basis of these activities, operators make decisions about whether to implement technologies, and from limited evidence it appears that most will choose to do so. Such an outcome, however, depends on a continued supply of federal and state funding for APTS capital investments, since APTS investments are not generally perceived to "pay for themselves" in an accounting sense. It thus remains for the state and federal governments to assess transit agencies' claims in favor of these technologies, and balance these against the benefits of other forms of transit capital expenditure, and other uses of money generally.

Chapter 4 References

Federal Transit Administration (1990), *Data Tables for the 1990 Section 15 Report Year.*

Federal Transit Administration (1991), *Advanced Public Transportation Systems: the State of the Art.*

Appendix 1.
Survey Questionnaire

CHAPTER 5:
RECOMMENDATIONS

5.1 Introduction

In Chapter 1, we argued, in general terms, that state and federal governments can play a constructive role in facilitating transit innovation with APTS technologies. In Chapters 2-4, we have developed information about these technologies, and about transit operators' experiences with and attitudes toward them. Also, in Chapter 3, we identified some general ways in which the APTS innovation process could be improved. We are now in a position to return to the question of government roles discussed in Chapter 1. Based on our findings from the previous chapters, we argue that Caltrans should take a pro-active role in improving the process of APTS innovation among California transit operators. We also argue that Caltrans' activity should be carefully targeted, and designed to complement existing programs.

5.2 The Need for Action

There is already considerable activity on the part of individual transit properties, federal, state, and local governments, and the private sector designed to promote APTS technologies. It is natural to ask whether there is a need for yet another program. Based on our findings, we believe that there are important gaps and shortcomings in existing APTS efforts, and that a coherent, focussed program can and should be developed to address these problems. The specific shortcomings that the program should address are as follows:

1. Inadequate Decisionmaking

As discussed in Chapter 3, transit operators often fail to give adequate consideration to decisions involving adoption of APTS technologies. They often do not anticipate the internal resources needed to successfully implement and utilize these technologies. Moreover, adoption decisions rarely involve systematic consideration of APTS alternatives that may further the same goals. Consequently, action is required to encourage more informed and systematic APTS adoption decisions.

2. Inefficient Implementation

The process of implementing APTS technologies is prone to problems and failures that can undermine the effectiveness of an otherwise promising system. It is all too common for vendors to walk away from a system before its installation has been thoroughly debugged or personnel adequately trained. Action is needed to reduce such occurances.

3. Limited Utilization

Even when implementation is successful, our case studies suggest that, in many cases, only a small fraction of the potential benefits of APTS technologies are actually realized. These technologies are often adopted in response to a specific problem, so that potential applications unrelated to that problem may be overlooked. Further, many potential benefits cannot be realized without modifying the responsibilities and discretionary authority of positions throughout the organization. Finally, since the consequences of many potential applications are difficult to forsee, and operators often weigh the potential costs of failure more heavily that the potential benefits of success, there is a natural bias against APTS applications involving too much of a departure from conventional practice. For all of these reasons, action is required to enable more effective, imaginative, and aggressive utilization of APTS technologies.

5.3 Shortcomings of Current APTS Efforts — A Diagnosis

Why do the above problems exist? We believe that the essential reasons are that existing APTS programs are:

Hardware-oriented. These programs are oriented primarily toward assisting agencies in purchasing particular hardware systems. In this respect, the purchase of a new APTS system is treated in much the same way as the purchase of a bus. But it is obvious that these are very different situations in almost every respect — from how purchase decisions are made, to the procurement process, to implementation, to utilization. The fundamental difference is that in the case of a bus, the software is already in place.* Agencies know how what they need, how to obtain it, and how to use it — they just need the money. Similar software for APTS systems is not in place. Agencies have little idea of what APTS systems to acquire, how to acquire them, or how to use them. The APTS program should therefore provide transit agencies with support in developing software as well as purchasing hardware.

Fragmented. APTS assistance programs are fragmented in two respects. First, as already noted, assistance is normally in the form of funds for acquiring a specific technology. This may discourage operators from developing coordinated APTS programs designed to exploit synergies between different technologies. Also, since the often monumental task of developing software for any given technology is left to the operators, they show a natural tendency to move incrementally. To illustrate, although there seems to be a natural fit between AVM and APTS technology, most agencies acquire these systems separately. At best, this means that one of these systems will be operating for a time without yielding its full potential benefit. Even worse, such piecemeal acquisition may compromise the ability of these systems to function in an integrated fashion.

APTS assistance is also fragmented in the sense that it often fails to recognize that APTS technology represents no more than a subset of the means available to improve transit performance. For example, many operators acquire AVM technolgy because they perceive schedule adherence to be a problem. But, as opera-

*We use the term “software” to mean the rules governing how hardware — which includes any physical device from a computer to a bus — is used and operated.

tors soon learn, it takes more than AVM to solve this problem. It is even possible that the more cost-effective strategies for doing so would not even include AVM. Instead of supporting concerted efforts on the part of transit operators to address well-defined problems, APTS assistance supports operators in taking a single isolated step which may or may not be a part of the optimum solution.

Diffuse. It is in the nature of government programs to distribute resources widely in order to maintain broad-based political support, and on equity grounds as well. The inclination to distribute APTS support, along with other forms of capital assistance, widely and shallowly has much to do with the shortcomings identified above. It encourages APTS efforts oriented toward funding an AVM system here, and a smart card system there. It does not encourage integrated programs including both hardware and software elements, or involving multiple APTS technolgoies that work synergistically, or that encompass a coordinated series of steps designed to address specific problems.

5.4 A Proposed Solution: The MOTUS Program

MOTUS stands for Model Technology User. The MOTUS program is designed to be strong in precisely those areas in which existing programs are weak. It would included both hardware and software elements. It would be highly integrated and intensive. Of necessity, it would also be highly selective, concentrating resources on a handful (perhaps as few as two at any one time) transit agencies which can serve as exemplars for other agencies   If there is a model for the MOTUS program, it is the Object Lesson Roads of the early 20th century (Federal Highway Administration, 1976). At that time, the Office of Public Road Inquiry (part of the Department of Agriculture) sought to diffuse knowledge of roadbuilding techniques by building a short stretches of “model” roads at many locations around the country. Experts employed by the agency traveled from place to place, working with locals to build the roads, and hopefully imparting to these individuals know-how that they would continue to put to use. At the same time, by building roads throughout the county, the experts were able to refine their techniques to suite a wide range of local conditions. Like the Object Lesson Road program, MOTUS is predictated on promoting best practice in a small part of the industry on the expectation it will subsequently diffuse more widely. Although including capital assistance for acquiring new technology, MOTUS is also fundamentally a program for developing human capital. Lastly, even more than the Object Lesson Road program, MOTUS is a program of two-way learning — the experts will learn from the participating agencies while the agencies learn from the experts.

A rough outline of the MOTUS program is as follows. Caltrans would select a small number (2-4) transit agencies to be MOTUS operators. Selection would be on a competitive basis, based on (1) agency recognition of opportunities to improve its performance through APTS technology; (2) agency willingness to collaborate with outside parties for the 5-year duration of the agreement, particularly by having its representatives participate in a working groups with outside experts and Caltrans personnel; (3) agency agreement to implement recommended actions, ranging from acquisitions of new technology, to changes in agency operating procedures, to reorganization of line personnel, recommended by the working group; and (4) agency willingness to support and participate in performance monitoring efforts designed to evaluate the effectiveness of these actions. In applying these criteria, it will be necessary to not merely rely on the material contained in a written application, but also on contacts with individuals from throughout the organization. Successful particpation in the MOTUS program will require organization-wide interest and commitment.

In exchange for this participation, transit agencies will receive substantial financial and in-kind assistance. The assistance will take the form of funds for equipment purchases, personnel training, and compensation for staff costs arising from participation in the program. In-kind benefits will be in the form of learning of individuals throughout the organization in how to effectively manage and participate in APTS programs.

The program would proceed as follows. Initially, a working group, consisting of agency representatives, consultants from industry and academia, and Caltrans representatives would be formed. This group would identify a set of performance areas in which (1) improvement is desired and considered a high priority and (2) application of APTS technologies promise substantial benefit. Out of this set, a set of one to three priority areas would be identified. The remainder of the program would consist of developing and implementing agency-wide initiatives designed to improve performance in the priority areas.

In developing these initiatives, the working group (which may at this point divide into subgroups) would emphasize a coordinated program consisting of a variety of elements, including but not restricted to APTS technologies. It might even be determined that the most cost-effective program would include no such technologies. If such technologies are included, then it would be necessary for the program to specify how they are to be used to further performance objectives of the initiative. Regardless of the role of APTS technologies in the initiative, the agency would receive assistance from the program in implementing it. It is central to the MOTUS concept that assistance not in any way be tied to the specific elements an initiative includes. The only requirement is that it be deemed the most cost-effective approach to addressing an important agency concern.

Once the program is designed, it would be implemented. Caltrans would pay for all one-time costs associated with implementation. It would not be responsible for recurring costs, since the agency should be willing to absorb these once its participation in the MOTUS program has ended. However, it is recognized that implementation costs may be incurred over an extended length of time, so that problems can be worked out and refinements made. Thus, the program must extend over a considerable number of years.

In the event that intitiatives involve APTS technologies, there would also be an ongoing program to extend application of these technologies beyond their initial use. This program would consist of identifying "information bottlenecks" — as described at the end of chapter 3 — that the technology could eliminate. Thus the MOTUS program would combine two modes of technological inquiry: assessing technologies as solutions to problems, and looking for problems that particular technologies may help solve.

An additional element of the program is a systematic process of performance monitoring designed to measure the effectiveness of the intiatives. This would begin soon after the identification of the priority performance areas and extend through implementation.

Finally, the program would include elements designed to ensure that the lessons learned are widely shared. These would include direct contacts between MOTUS agencies and other transit operators, as well as technology transfer activities on the part of Caltrans.

5.5 Closure

This chapter has developed the concept for a program designed to increase the capacity of transit agencies to effectively employ APTS technology. The program differs from existing ones because it is intensive, balances hardware and software elements, and emphasises intergrating APTS technologies into broader efforts to improve performance. While we have attempted to add further definition to the proposed program, we recognize that the design is rough and incomplete. It is the core concept that we wish to emphasize.

The MOTUS program will be expensive on a per agency basis — with costs running into the millions of dollars. The payoffs, however, could be substantial. Transit operators would learn how to use specific APTS technologies wisely, and the entire industry would learn where the high and low-payoff APTS opportunities really are. Equally important, though less tangible, is the potential for transit operators to learn more general lessons concerning how to harness continually evolving technologies into broad-based efforts to improve agency performance.

Moreover, creative financing methods could substantially reduce the State's burden. Just as manufacturers donated roadbuilding equipment for the Object Lesson Roads, so they might be convinced to donate products to MOTUS participants. It may also be possible to link MOTUS to existing Federal capital assistance programs, perhaps by setting aside some of these funds for MOTUS operators. Finally, mechanisms for capturing the value of the program to the transit agency and the community it serves should be explored. These include encouraging, through the selection criteria, matching contributions from local governments, as well as agreements to return to the State a portion of any cost reductions or revenue gains attributable to the program.

It is recognized that, in these times of constrained resources, justification for Caltrans' involvement in a major new initiative must be compelling. It is beyond the scope of this research to assess what Caltans' role in the California transit industry should be. At the present time, it is also unknown whether APTS technologies can stand up to rigorous economic scrutiny. It is clear, however, that if promoting APTS is to be part of Caltrans' mission, the most important contribution it can make it to increase the capacity of individual transit agencies to deploy and use this technology judiciously and aggressively. Given this end, we believe that a program like MOTUS is the most appropriate means

Chapter 5 References

Federal Highway Administration (1976), *America's Highways: 1776-1976*.