CHAPTER 8

SELECTION AND PROCUREMENT OF NEW TECHNOLOGY

INTRODUCTION

This chapter reviews the issues and methodologies associated with selecting a new fare collection technology and procuring the necessary equipment. The chapter begins with a review of the technology evaluation and decision-making process, as carried out at our case study agencies (as well as various other agencies). This discussion considers the following:

- The nature of the decision-making process,
- Selection of fare media and equipment capabilities,
- Goals and expected benefits, and
- Specific concerns, including reliability of equipment and impact on fare evasion and abuse.

The chapter then addresses the financial implications of technology decisions; this section includes the following:

- Costs of alternative technologies and equipment and
- Potential cost savings and additional revenues from electronic fare media.

Finally, the chapter presents a suggested approach to evaluating fare technology options.

As explained in Chapter 4, four of the case studies focused on the technology selection process, and technology aspects were also discussed in two others (NJT and SCRRA). These "new technology" cases were as follows:

- CTA is procuring automated fare collection (AFC) equipment; fare payment will be made using a stored-value magnetic stripe card, although provisions are being made to permit eventual acceptance of smart cards as well.
- MBTA is currently in the process of procuring a new AFC system, which will also utilize a stored-value magnetic stripe card.
- Seattle/King County Metro—has installed ERFs, and plans to implement a smart card based on regional fare integration programs.
- MVRTA installed magnetic card readers on its buses in 1988.
- NJT installed ERFs on its buses in 1991 and 1992 and will be expanding its use of AVMs for commuter rail. It is now evaluating alternative future fare collection options, including smart cards.
- SCRRA acquired and installed POP-related fare collection equipment, including AVMs and TOMs.

The research team has also incorporated information on noncase study agencies and findings from other studies where appropriate.

THE EVALUATION AND DECISION PROCESS

The Nature of the Decision-Making Process

How transit agencies decide to implement new fare collection and distribution technologies or specific types of equipment varies widely, depending primarily on the magnitude and complexity of the change, including total cost and disruption to the transit system. Of course, the availability of funds and the nature of the general decision-making process at the agency are also factors.

The major factors affecting the decision process are the type of equipment or technology improvement being considered and the size of the agency and number of units required. If an agency is seeking to replace outdated fareboxes, for instance, it will simply request bids from farebox manufacturers and evaluate the alternatives on the basis of the proposed cost and features and references on the reliability of the proposed equipment. If, on the other hand, the agency decides that adding TPUs or validators to the fareboxes may be worthwhile, the agency may undertake a more rigorous analysis of the potential benefits and costs of such a procurement (i.e., to decide whether or not to proceed, and if so, what type of equipment is most appropriate). Alternatively, a smaller agency may quickly decide (i.e., without much analysis) to add low-cost magnetic card readers to existing fareboxes. A major capital investment (e.g., replacement of an entire heavy rail fare collection system) will require extensive consideration of the costs and benefits of alternative technologies. The basic evaluation and decision-making processes used in each case study and by other agencies are summarized below.

CTA

CTA has been working on developing AFC since the mid-1980s. As part of various studies, including a Long-Range Fare Collection Plan, CTA staff considered various means of improving the overall cost-effectiveness of the agency's revenue collection efforts. To investigate the potential for AFC, an Executive Overview Committee was established to consider policy issues, and an AFC Committee was formed to make detailed decisions. Order-of-magnitude costs of system alternatives were identified; actual costs would be based on negotiations with the successful bidder to provide the AFC equipment.

In addition, expected cost savings (i.e., through reduction or reassignment of rail ticket agents) were estimated; the actual savings will depend on the ability of the agency to achieve the theoretical staff reductions (because of labor contract restrictions). It is the hope of CTA top management that the capital cost of the new system can be recouped within 6 to 8 years.

MBTA

The development of alternative methods of fare collection for MBTA began in late 1989 with the hiring of a consultant to conduct a study. The study was conducted in three parts, each looking at the needs of a component of the rail system; the rapid transit evaluation was completed in 1990, and evaluations of the light rail and commuter rail fare collection systems were completed in 1992. In conducting these studies, the consultant estimated capital costs, operating and maintenance costs, and fare collection personnel required for each of several alternative system configurations; the alternatives ranged from a minimal change to the existing system to an AFC system that also accepts all existing media. The Final Report, which documented the final evaluation of two overall alternatives, was presented to the MBTA Board of Directors in June 1993. These two alternatives are both based on use of magnetic stored-value cards, but one would continue to accept existing media. MBTA received proposals in 1994 to install the new AFC system; a contract was awarded in late 1995.

Seattle/King County Metro

Metro's interest in acquiring ERFs was initiated in 1988 when an accounting firm reviewed revenue handling procedures and recommended that Metro consider ERFs to provide a more complete audit trail for tracking revenue. Other concerns regarding the reliability and dollar bill-handling capabilities of the existing fareboxes were also taken into consideration. Finally, beyond the need for improved fareboxes, the benefits of adding a transfer-issuing and ticket-reading unit were identified; many operators felt that such units would reduce transfer fraud and abuse—as well as many fare disputes with riders. These issues were raised during a 1990 fare structure review, and the staff was directed to investigate the possibility of acquiring ERFs and TPUs. On the basis of a review of the available types of equipment, Metro issued an RFP. Then, in contrast to the evaluation process at CTA and MBTA (i.e., prior to issuing RFPs), Metro identified the costs and expected benefits of the new equipment on the basis of the proposal results. This evaluation considered the proposed strategy versus alternatives (i.e., not purchasing new equipment at all and purchasing only ERFs). The full purchase alternative was selected, because it was the only option deemed capable of achieving the objectives of reducing fare disputes and fare evasion. As of early 1996, Metro had not decided whether or not to acquire and install the TPUs and, in fact, was proceeding with a plan for implementing a smart card system throughout the region; a comprehensive evaluation of regional integration approaches was completed in late 1995.

MVRTA

MVRTA installed ERFs in 1988. Although magnetic card readers were included in the initial purchase, the readers did not become fully functional until early 1989. To improve the accuracy of ridership reporting and to reduce the extent of operator-rider interaction, the agency decided to purchase fareboxes with the card swipe reader option. Apparently, no extensive analysis of alternatives was performed in making this decision.

NJT

NJT installed ERFs in 1991 and 1992 and planned to begin installing new AVMs (for commuter rail) in late 1994; these AVMs will accept credit cards. Funds have also been appropriated for the acquisition of magnetic card readers. The major goal in acquiring ERFs was to improve revenue and ridership data collection—for use in planning and management decision making. The effect of the new fareboxes on revenue and ridership was analyzed; this analysis included a survey of such effects at several other agencies (discussed below). The goals for acquiring AVMs for commuter rail are to increase rider convenience and to reduce the fare collection operating budget. Again, an analysis was undertaken to estimate the extent of the cost impact. It has been projected that the AVMs will result in a significant reduction in the number of fare collection personnel and, therefore, a substantial cost reduction. In early 1996, NJT began a review of options for its future fare collection strategies, including the potential use of smart cards.

SCCRA

As a totally new system, SCRRA had to acquire and install all new fare collection equipment; because SCRRA has a POP system, the equipment includes AVMs that accept credit and debit cards, as well as validators for riders who have multi-ride tickets, TOMs, and support computer equipment. The equipment and service contracts were all awarded using the competitive negotiated procurement method.

Other Agencies

The range of technology evaluation and decision procedures can be seen in the cases of two other (non-case study) agencies: the Capital District (Albany, New York) Transportation Authority's (CDTA's) acquisition of bus magnetic card readers and the NYMTA's development of its new AFC system.

Similar to the case at MVRTA, CDTA had decided to purchase new fareboxes. Because the swipe readers CDTA selected represented a relatively small increment to the cost of the fareboxes, management decided to acquire readers as well. The operations staff had recommended their purchase as a way to relieve the operators of the responsibility of checking flash passes. The swipe readers were put into use in April 1994, when the CDTA began to sell the magnetic "Swiper" pass.

In contrast to the CDTA and MVRTA examples, in which the decisions simply involved whether or not to expend incremental amounts for an equipment "add-on," the NYMTA AFC development process has involved a long-term (over 10 years), complex analysis and evaluation process. The NYMTA procurement of new fare collection technology began in 1983 with an in-depth report (*16*) considering the costs and benefits of various systems for the buses, subway, and commuter rail and comparing those assessments with a baseline that involved only the replacement of existing equipment. This report was performed by a consultant on behalf of the NYMTA, and the criteria considered included cost, reliability, versatility, fraud, human conditions, ease of implementation, and risk.

The costs and savings considered, for each of the different technologies, included equipment purchase, development and installation costs, operating and maintenance personnel requirements (including training costs), utility costs, different fare media costs and levels of reliability, costs of parts and miscellaneous supplies, and changes in revenue losses because of reduced fare evasion. The consultants evaluated these costs and benefits for each scheme, using the net present value, discounted over 25 years for operating and maintenance costs. Meanwhile, other work within NYMTA was being undertaken. After the publication of the report, NYMTA continued to evaluate different options until a specific system design was selected. The initial phase of the MetroCard stored value system has now been implemented—the equipment was installed on all buses and in many key subway stations by late 1995.

In summary, the NYMTA case is an exception to the type of evaluation transit agencies carry out in making fare collection technology decisions. More typical are the two basic decision-making scenarios followed by our case study agencies:

- Purchase of a specific piece of equipment (e.g., ERF and/or magnetic card reader on bus)—decision based on identification of costs and benefits of purchasing versus not purchasing (example: Seattle Metro, MVRTA, and NJT); and
- Procurement of a new fare collection system—decision based on identification of fare collection needs and goals and evaluation of costs and benefits of alternative technologies and configurations; decisions: 1) whether to proceed at all (i.e., issue an RFP), 2) type of technology and equipment, and 3) phasing (examples: CTA and MBTA).

In the first scenario, an agency views the new technology—or particular equipment—as necessary to address some particular need and makes an initial decision to upgrade the current system or introduce a technological improvement simply on the basis of consideration of 1) the purchase and implementation costs of the type of improvement and 2) the availability of sufficient funds or the potential for raising these funds. A full evaluation (e.g., involving the comparison of alternative scenarios through a detailed cost and benefit trade-off analysis) may not be conducted at all or perhaps only on the basis of different supplier proposals.

In the second scenario, essentially followed by CTA and MBTA, the agency initially identifies the need for—and potential benefits of—a general technological improvement (e.g., AFC). If the benefits are deemed sufficient (i.e., by top management), a full evaluation of the likely costs of several alternative system configurations is undertaken. Assuming that funding can be made available, the agency then selects a particular system approach and issues an RFP for provision of the new system. Following review of proposals, a vendor is selected and the implementation is initiated.

Selection of Fare Media and Equipment Capabilities

The above discussion addressed the overall evaluation process in deciding to implement AFC. With regard to selection of type of fare media in implementing AFC, magnetic-stripe-based stored-value cards have long represented the state of the art for AFC (i.e., since being introduced 30 years ago). Magnetic stripe cards continue to be the medium of choice for many agencies seeking to upgrade from non-electronic methods. For instance, NYMTA, CTA, and MBTA have selected magnetic stripe technology for their new AFC systems.

On the other hand, as discussed in Chapters 5 through 7, smart cards—particularly the contactless variety—have begun to receive increasing consideration, both for specific applications in AFC systems and as a primary fare medium in some cases. For instance, CTA has considered giving contactless cards to disabled riders, for use in special wheelchair-accessible faregates, as part of its new fare system. CTA also plans to use smart cards to allow authorized maintenance personnel access to the equipment. CTA is making provision for expanding the use of contactless cards on a widespread basis, by requiring the system vendor—Cubic—to install and program contactless card readers on each turnstile for fare payment, as well as for maintenance access. WMATA has also tested contactless cards, for use on transit and in parking lots, and the technology is being tested in several smaller bus agencies in Ventura County, California. MARTA is participating in a trial of a joint banking-transit contact card. Transit agencies in the San Francisco and Seattle regions have assessed the feasibility of using smart cards as the principal medium for achieving regional fare integration. Besides NYMTA and AATA, several other agencies, including NJT, Baltimore MTA, GCRTA (Cleveland), and Capital Metro (Austin) are studying fare technology options, including smart cards. Thus, U.S. agencies are beginning to include smart cards in their evaluations of technology alternatives, although the usefulness and cost-effectiveness of this technology for large-scale transit applications have not yet been established; the general nature of agencies' evaluation processes leading to selection of smart cards is discussed below.

Besides the nature of the technology itself, agencies planning to implement new fare systems or equipment must also address such issues as 1) whether the new system should continue to accept existing media (i.e., tokens and cash) in addition to the new media and 2) the nature of the new equipment in terms of read, write, and/or print capabilities than they do evaluating alternative types of media. With regard to the former issue, CTA has decided to accept tokens and coins at special turnstiles only; the present plan is that there will be only one token and coin turnstile per station. MBTA was considering a similar option (i.e., some turnstiles would continue to accept tokens), as well as a magnetic card-only option; in either case, MBTA would likely continue to accept tokens on an interim basis. MBTA had conducted full evaluations of several alternative configurations over the past few years.

Regarding the issue of printing remaining value (i.e., as is done at WMATA and BART), CTA has decided that the remaining value will not be printed on the farecards. In terms of how the card validators will be used, the card will be inserted into a slot in the turnstile or the TPU. The New York MetroCard system also does not print value on the card; on rail, the card is swiped through the reader, while insertion is required on bus. In both Chicago and New York, the remaining value on a card is displayed on the turnstile or TPU after the fare has been deducted; the value can also be read by using a separate card reader located in rail stations. In the Metrocard system in Southern California, a visual representation of the approximate remaining value is printed on the cards after the value drops below $10.00. Metrocards are inserted into the TPUs, although, because the agencies have zonal fare structures, the rider states his or her destination and the driver must enter the correct fare; the fare is then deducted from the stored value card.

Evaluation of Costs and Benefits

The costs associated with implementing a new fare technology are important because an agency must cover these costs, either using existing resources or through a grant (i.e., for a demonstration of a particular application). Thus, it is necessary to identify the full range of anticipated costs. In building an argument for a particular technology, e.g., smart cards, an agency will also generally identify—if not actually quantify—the potential benefits.

Discussions with several agencies have made it clear that the decision to implement—or at least test—a smart card system is sometimes made without a full cost-benefit analysis comparing that option to other options (e.g., magnetic stripe). In each of these cases, contactless cards were selected because they were viewed as offering operational (e.g., throughput) and maintenance (e.g., reduced reader maintenance and repairs) benefits over other types of cards (i.e., magnetic stripe or contact smart cards). The costs of providing the cards, however, apparently received little consideration. The general manager at one agency explained that an important factor in the selection of smart cards was that they represent "a new and exciting technology" and that he felt that the other agencies in the region would eventually adopt this technology as well. Though not as explicitly stated, other agencies' staff indicated a similar sense (i.e., that smart cards are the cutting edge and that magnetic technology is "old-fashioned"). The absence of cost-benefit analysis is further documented in a separate study of advanced fare technologies; Coopers & Lybrand (*17*) reports that "Remarkably, very few of the interviewees had compiled sufficient cost data to complete a payback analysis; however, more often than not, they were able to get their respective projects into state budgets."

Most smart card projects initiated to date have been financed largely (if not fully) by a third party—generally either a bank, an equipment or card vendor (or system integrator), or a governmental agency (i.e., FTA in the United States). The smart card projects in the United States to this point have all been small-scale trials, and the costs are thus relatively low (i.e., compared to the overall fare collection costs for the whole system). A full-scale implementation clearly requires a more in-depth analysis of the cost implications and indeed full evaluations have been undertaken in Seattle and San Francisco. In both cases, contactless smart cards were found to represent the most appropriate card technology, both for regional fare integration and for use by individual operators within these regions. Both studies (*18,19*) concluded that the benefits of this technology offset the costs. A similar conclusion was reached in evaluating alternative technologies for use in Paris.

Although providing smart cards appears to be feasible, at least for a portion of an agency's riders, the technology's overall cost-effectiveness must be demonstrated in large-scale operational tests—and independently evaluated—before most transit agencies are likely to consider this as an alternative to magnetic stripe technology—or indeed to their current non-electronic systems. Evaluations of projects such as those in London, Paris, and Washington, for instance, would provide useful input into this decision process.

Issues Related to Goals and Expected Benefits

As found in the case studies, agencies seek to achieve a range of goals in introducing new technologies, and these goals typically translate into criteria used in evaluating alternative technologies or scenarios. The technological improvements are, in turn, expected to produce various types of benefits, to both the agency and the riders; these benefits are generally closely related to the goals. The key types of goals and benefits—along with the related issues—identified for the case study agencies when they considered introducing new technology are discussed briefly below. Most of the goals were shared by most, if not all, of the agencies.

Cost

Issues related to the cost of the new technology involve the purchase and installation of equipment, production and distribution of media, and other operating and maintenance expenses. In rail AFC projects, a major cost is retrofitting stations to accommodate the new equipment and associated communications systems. Another key cost may be the need to integrate new equipment into the existing fare collection system (i.e., unless all equipment is being replaced); this is discussed below, under system integration. The goals essentially are to minimize capital costs and reduce operating and maintenance costs. Cost issues are discussed in a separate section, below.

Revenue Accountability and Security

Concerns in this area can serve as a major impetus for consideration of new technology; this was the case with MBTA, where discovery of a major employee theft ring spurred an accelerated push for implementation of AFC.

Reduction of Fare Evasion and Abuse

Reducing rider fare evasion and counterfeiting of media or other fare abuse represents a major goal of new technology—and often an important impetus for active consideration of new technology. Fare evasion is discussed further below.

Flexibility

Although flexibility is a common goal and expected benefit, the decision to introduce new technology does not generally derive from a desire to alter the fare structure. For instance, whereas there has long been a feeling within the transit industry that certain types of fare strategies—distance-based pricing in particular—will become more feasible and worthwhile with AFC, none of the case study agencies—or other agencies reviewed—plans to introduce distance-based pricing with the implementation of AFC. Agencies installing an entirely new fare payment system (e.g., CTA and NYMTA) do see the flexibility of AFC as an opportunity to vary the pricing mechanisms offered without compromising the convenience for the rider. Both NYMTA and CIA conducted extensive studies of potential stored-value-based fare elements. NYMTA is taking the notion of flexibility a step farther with its multiple use plan.

Compatibility

The technology should be compatible—and allow for future fare integration—with the fare systems of other transit providers in the region. This was a key concern in the NYMTA evaluation. In some instances, such as the TransLink (San Francisco) and Metrocard (Los Angeles) programs, this goal has been the driving force behind consideration of new technology options.

Convenience

Convenience and ease of use of the fare system by riders is an important expected benefit of new technology; this applies to both buying and using fare media. One element of convenience is the availability of a range of payment options—but in a medium that is easy to understand and use.

Ridership Information

A key goal, especially in the installation of ERFs, is to improve the quality of ridership information generated from fare payments.

Reliability

A key goal—and evaluation criterion for specific pieces of equipment—is the reliability of the equipment and the fare media. This includes both minimal system malfunctions and a high degree of accuracy in accounting for fares paid. Reliability is discussed further below.

System Integration

The new technology must be able to be integrated with remaining fare collection equipment. Among the case study agencies, this is a major concern for CTA and MBTA, both of which plan on retaining their existing bus fareboxes when they install new rail AFC equipment. At CTA, this represents a significant challenge, because the AFC system vendor (Cubic) differs from the farebox manufacturer (GFI). CTA staff have undertaken the programming needed to link the Cubic TPUs to the existing GFI fareboxes. NYMTA is avoiding this type of problem by installing new farebox/TPU units made by the rail AFC vendor (Cubic). This is a key issue and must be given serious consideration by agencies seeking to replace only part of their fare collection equipment.

Operator and Agent Requirements

This applies to reducing the extent of cash handling by ticket agents on rail and reducing the need for bus operator-rider interactions—and hence disputes over transfer or flash pass validity. This is seen as an important operational benefit of electronic fare payment.

Support of Marketing Efforts

This goal relates to increases in prepayment, as well as the potential use of new technology to facilitate employer billing for actual trips taken by employees—and the related employer marketing efforts.

Agency-Specific Concerns

In addition to these general goals, each agency has its own specific concerns or criteria. For instance, Seattle Metro identified a goal of increasing the farebox capacity (for bills) by installing ERFs. Another example is that MBTA saw AFC as a means to introduce free or reduced price intramodal (bus-to-bus) and intermodal (bus and rail) transferring; the Authority allows free transfers only between intersecting rail lines. The ability to use the farecard for purposes other than transit has been an important goal in the development of NYMTA's MetroCard system.

Specific Issues in Evaluating and Selecting New Technology and Equipment

Reliability of Equipment

Reliability is a key concern in selecting a new technology and/or equipment. The problem in considering any newer technology is the lack of sufficient in-service data (e.g., on mean cycles between failures). For this reason, agencies typically rely on pilot tests or limited trials of new equipment—as well as reports from their use at other agencies—before committing to systemwide implementation. Of course, one problem with such tests is isolating equipment and media failures from rider-caused problems.

An example of this approach can be seen in Seattle/King Co. Metro's original plan to acquire transfer-issuing TPUs (i.e., ticket reader/issue machines, commonly known as the TRiM unit). The purchase contract with GFI/Genfare specified stringent performance criteria on the basis of the issuing of extra transfers, accuracy of the issuing count, the reliability of the machine (i.e., no more than 1 failure per 162,000 transactions, where the failure rate does not include those caused by passengers) and approval of the equipment by 66 percent of operators. As of this writing, however, Metro had not, as mentioned earlier, decided whether to proceed with purchase and installation of the TRiM units; the agency has conducted a comprehensive evaluation of technology options, and at this point, plans to implement a smart card-based system. Metro did, however, install new ERFs. The agency analyzed the failures of their new registering fareboxes carefully in the months following installation. The extent of the problems has varied widely from day to day, though it has fallen as drivers and the public have become more accustomed to the new equipment. On the worst day between March and October 1993, there was a 6 percent failure rate.

CTA has developed detailed specifications for coin, token, and bill acceptance (and rejection of counterfeit and foreign currency) rates for the new fare collection technology, which will be installed by 1997. The AVMs are to print 50,000 tickets without requiring replacement or maintenance attention. The bill escrow unit is to be designed so that maintenance personnel can install or replace a unit within 10 minutes. The goal, however, is to achieve mean cycles between failures and mean time between failures approaching infinity. The machines are also to include fault codes for tickets not issued, coin or bill jams, communications errors, and inoperative card readers.

Although the focus is usually on equipment, the reliability of the electronic media is also important. For instance, among the case studies, MVRTA experienced significant card encoding errors on its magnetic passes. This was a major problem, especially in the first 2 years of the magnetic card system. This meant that the cards could only be used as flash passes, and operators were required both to check for valid passes and to record the number of boarders at all stops. Hence, there was some loss of accuracy in ridership reporting. Moreover, the major benefit that had been expected—reducing operator-rider fare interaction—was not achieved initially. With regard to differences in reliability among media technologies, Echelon reported, following Phase II of its smart card test in Southern California, that both contactless and contact cards are "considerably more reliable" than magnetic stripe cards. However, the actual differences—as well as the impacts of these differences on cost—must be measured in controlled tests and independently evaluated.

In evaluating equipment reliability, different agencies use different measures. The *1993 APTA Rapid Transit Fare Collection Survey* (*20*) included a summary of the rail agencies' reliability measures for their fare collection and distribution equipment. Four types of measures were reported by the responding agencies. Mean cycles between failures (MCBF) is by far the most common measure, for both faregates and AVMs, and is used by 11 of the 13 agencies that provided this information; however, one agency each uses one of the following measurers:

- Availability in hours—used by WMATA for both its gates and its addfare and faregate vendor machines and
- Faults per vend—used by Sacramento Regional Transit District for its AVMs.

Finally, with regard to general equipment reliability experience, the APTA Survey also reported the rail agencies' assessments as to how their equipment compares to the manufacturers' specifications and their own expectations. More than half (i.e., 7) of the 13 agencies reported that the general reliability experience of their fare equipment was "equal to their expectations"; two of the agencies reported "higher than expected," and the final four felt that their reliability experience was "lower than expected." CTA and MBTA are included in the latter group, which suggests that these agencies will be particularly concerned with reliability in their new equipment.

Although much of the existing rail fare collection equipment is apparently reasonably reliable, the new AFC equipment, such as that being installed by NYMTA and CTA, is largely untested in service; thus, long-term reliability remains to be seen. A similar issue exists with bus validators/TPUs (such as the TRiM unit and similar products from Cubic and CGA). As explained in Chapter 6, a number of agencies are installing and/or testing TPUs. The equipment has simply not been in use long enough at this point to determine its reliability over time; moreover, because of the complexity of the technology, it may take a while for agencies to make the types of internal adjustments (e.g., improved maintenance capabilities) needed to use and maintain the new equipment properly. It is also necessary to educate the riders in the differences in the fare media; for instance, a magnetic transfer or ticket that is inserted into a reader must be treated somewhat differently from a paper transfer that is simply handed to an operator; apparently, the insertion of mutilated transfers has been a key source of TPU failures to date. As with any new technology, reliability should improve over time, as 1) significant in-service testing is completed, 2) agencies become better able to maintain the equipment, and 3) manufacturers continue to refine the equipment.

Fare Evasion and Abuse

Reduction in the level of fare evasion and abuse is a major goal in the introduction of a new fare collection technology.

Evasion and abuse generally refer to 1) the failure to pay the fare, either by jumping over or ducking under a turnstile or using a POP system without paying the fare; 2) counterfeiting of fare media; and 3) illegal use or resale of fare media, including transfers. Minimizing these occurrences benefits an agency by increasing the fare revenue collected. New equipment and technology can reduce evasion and abuse in several different ways, as discussed below. However, identifying the extent of the reduction, and the resulting revenue, is highly speculative; as discussed below, even identifying the existing rate of fare evasion and abuse is difficult.

Barrier (Heavy Rail) Systems. The nature of the specific fare evasion or abuse problem an agency faces depends on the type of fare collection system and media it uses. In a rail system with turnstiles, evasion occurs, either by jumping over or ducking under—or perhaps by more than one person squeezing through the turnstile on a single fare. Agencies are seeking to combat this problem with new turnstiles designed to simply make it more difficult to evade. NYMTA and CTA are installing such turnstiles. Although these will not prevent all evasion, they will discourage it. Improving the detection of fare evaders is also being required in the specifications for this new equipment. CTA has included such requirements.

With regard to identifying the existing rate of fare evasion, MTA-NYCT conducts quarterly fare evasion surveys; these are 1-day snapshots of the fare evasion on the system. All token booth clerks record the number of fare evaders they observe each hour. The rates were running at roughly 2.3 to 2.6 percent (i.e., evaders as percentage of total fare registrations plus evaders) in 1994 (*21*); similar surveys in the early 1980s found very similar levels (about 2.4 to 3.4 percent).

The agency also tests the accuracy of these rates through two other types of evasion surveys. One approach uses employees of a data collection firm to observe fare evasion at turnstiles discretely; a second uses plainclothes MTA-NYCT police to observe the evasion rates at slamgates. When such efforts were conducted as part of the AFC study in the early 1980s, the evasion rates were observed to be between 2 percent and 2.7 percent, thus slightly lower than the agent observations. The AFC report also established that the evasion rates varied between .03 percent and 18.7 percent for different subway stations. Control areas without slamgates had higher fare evasion rates through the turnstiles. The preferred entrance for evaders was the slamgate, as shown in Table 53.

Thus, on the basis of the above finding, it appeared that the elimination of slamgates, one of the options under consideration with the new technologies, offered the greatest potential for reducing fare evasion. Slamgates were in use at 72 percent of stations on the system, and these stations had, on average, a 44 percent greater fare evasion rate than at those without slamgates. Eliminating the slamgates from the system was thus predicted to result in potential reduction in fare evasion systemwide by a third, or a yearly increase in revenue of $8 million. Although the agency has decided that it cannot remove the slamgates, there are plans to make them electrically-operated, so that they can be opened only by a station clerk (i.e., pushing a button). MTA-NYCT has also begun to install new turnstiles designed to make such fare evasion much more difficult than it is today. In measurements of evasion in stations in which the new equipment had been installed, the agency found, after 4 months in service, a 32 percent drop in the evasion rate (from 2.3 percent to 1.6 percent).

MBTA is also requiring that the new turnstiles acquired as part of its AFC system reduce the opportunity for fare evasion. A report on different fare collection approaches for MBTA determined that the level of fare evasion at MBTA (in 1989) was less than 1 percent (*22*); however, the rate did increase significantly in the slower mid-day periods. The rates were also higher for the "collectors area gates" than through turnstiles. Cash can be used in the gates, but not in the turnstiles.

Barrier-Free (Light or Commuter Rail) Systems. On POP (i.e., barrier-free) systems, fare evasion takes the form of riders not buying tickets and hoping not to be caught by inspectors. The chief concerns are the rate of evasion and the cost of minimizing evasion (i.e., the number of inspectors required). Reducing evasion in these systems is not a technological issue but related to the level of inspection and the penalties associated with being caught.

The evasion and inspection rates vary significantly among the agencies. For instance, a survey of light rail POP systems in 1989 (see Table 54) reported that the number of inspectors and percentage of riders checked range from 3 (San Jose) to 32 (Calgary) and from 10 percent (Portland) to 31 percent (Sacramento), respectively. (*23*) Of course, the size of the system (in terms of ridership) must be kept in mind in considering the number of inspectors; San Jose's 3 inspectors can check 28 percent of the riders, while Calgary's 32 inspectors check 25 percent. As shown in Table 54, the evasion rates at these

TABLE 53 Subway entrances used by MTA-NYCT fare evaders

Entrance	% using as entrance (%)
Slamgate	63%
Turnstile	21%
Other non turnstile	16%

Source: Arthur D. Little, Inc. *Evaluation of Automatic Fare Collection Technology,* prepared for NYMTA, September 1984.

TABLE 54 Proof of payment (LRT) fare enforcement data

Location	Number of Inspectors	Inspection Rate	Evasion Rate	Full Cash Fare	Fine	
					1st Offense	Highest*
Buffalo	12	25%	1-3%	$1.00	$20	$140
Calgary	32	21%	<1%	$1.25	$25	$2,500
Edmonton	19	15%	1.7%	$1.25	$25	$2,500
Portland	15**	10%	2.2-6.8%+	$.85-1.15	$36	$250
Sacramento	8	31%	0 7%	$1.00	$20	$250
San Diego	23	19%	1.4%	$0.50-2	$25	$500++
San Jose	3	28%	1.3%	$0.75	$50	$250
Toronto	16	12%	<1%	$2.50 (avg.)	$54	$2,000

Source: A. Joshi. Fare Enforcement Methods and Experience of North American Properties Using Proof of Payment Fare Collection, APTA Fare Collection Workshop, Nov. 1989

* highest theoretical fine; property has not necessarily charged this amount
** 9 full-time, 6 part-time
\+ 6.8% includes verbal and written warnings and citiations
++ plus jail time

agencies are all relatively low, most falling below 2 percent of riders. The evasion rate does not appear to be directly related to either the inspection rate or the level of fines issued (first offense or highest potential fine). Although Sacramento reported the lowest evasion rate—0.7 percent—and the highest inspection rate, its first offense fine is also the lowest (along with Buffalo). The other agencies with evasion rates below 1 percent (Calgary and Toronto) had among the lowest inspection rates, although both reported very high maximum fines; in general, the Canadian agencies have much higher maximum fines than the American agencies, although the first offense fines are comparable in the two countries.

Regarding the cost and revenue implications, the 1989 study did not include data on fare revenue; however, an earlier study of fare collection on the San Diego Trolley found that, in 1982, the estimated lost revenue from fare evasion in San Diego was $19,500, while the return from the court system was roughly $21,200. (*24*) Hence, the returned revenue more than offset the lost fare revenue. The yearly cost (i.e., labor, overhead, and expenses) of inspection, however, was estimated at more than $185,000; thus, an agency must decide on the appropriate expenditure for inspection, on the basis of the likely return from catching fare evaders and, more importantly, deterring further evasion.

Pay on Entry (Bus) Systems. The fare abuse problems on buses relate primarily to illegal use and/or resale of transfer slips and underpayment of cash fares. Electronic fareboxes and ticket validators/transfer issuing units have been designed largely to address these problems. ERFs display the amount deposited, thereby allowing the operator to detect underpayment. By issuing and accepting transfers, validators prevent the use of invalid transfers and remove the onus of checking validity from the operator; magnetic pass readers have a similar effect. Besides the problem of abuse, operator-rider arguments over these issues represent a major concern for many agencies. At Seattle/King Co. Metro, for instance, these concerns were a major reason for pursuing the acquisition of ERFs and TRiM units.

Although a reduction in fare abuse was one of the key motivations behind the planned introduction of new technology, Seattle/King Co. Metro did not estimate the degree to which the new equipment would increase revenue—although the staff report did note that other transit agencies had reported "revenue increases ranging from 3 percent to 30 percent" with such equipment and that the system would pay for itself within 10 years if it increased revenue by at least 4 percent per year. Fare abuse on buses is difficult to quantify; in fact the research team has not found any agencies that have good estimates of the extent of this revenue loss. Nevertheless, the notion that fare and transfer abuse is a major problem, costing agencies considerable amounts of lost revenue, is common throughout the industry. This concern, coupled with those over operator-rider fare disputes and the actual theft and resale of transfers, is producing a growing interest in the new fare technologies for bus fare collection.

The final category of fare abuse is the counterfeiting of—or tampering with—fare media. This has been a concern with every existing medium. The current capabilities of computer graphics packages and color copiers make it feasible to reproduce virtually any printed paper fare instrument (i.e., tickets and flash passes), and counterfeiters have also successfully reproduced tokens. As noted in Chapter 5, the incidence of counterfeiting of magnetic stripe cards in transit has been quite limited to date. The difficulty of duplicating these cards has increased with higher density magnetic encoding and the use of hard magnetics. Meanwhile, anti-counterfeiting and tampering technological improvements continue to be developed (see Chapters 5 and 6). Counterfeiting and tampering of magnetics is much more common with credit and ATM cards, and this has been a major argument in favor of the use of more secure smart cards in banking and other industries; this issue is discussed in Chapters 6 and 7. In addition to the magnetic media being more difficult to duplicate than printed media, AFC equipment can more easily detect invalid media. The CTA has specified requirements for the rate of rejection of foreign and counterfeit currency and tokens in its new turnstiles, for instance.

In summary, reduction of fare evasion and abuse is an important goal and expected benefit of new fare collection technology. Agencies typically expect to generate additional revenues by minimizing the extent of evasion, although the level of the added revenue is difficult to estimate. The new equipment addresses this goal either through establishment of physical barriers (i.e., new turnstiles) or through automated issuance and validation of fare media and transfers. Besides reducing the revenue lost through evasion, the latter type of technology also benefits bus systems by minimizing the extent of operator-rider arguments over the validity of a fare instrument or transfer.

FINANCIAL IMPLICATIONS OF NEW TECHNOLOGIES AND EQUIPMENT

Overview

The financial implications of particular fare technologies represent an important—often the most important—factor in making decisions in this area. The Echelon *Advanced Fare Payment Media Study* (*25*) included a survey of 150 transit agencies and found that cost was the chief concern regarding fare collection; 83 percent of the respondents cited cost as either the most important or one of the most important factors.

The two basic categories of cost to be considered are as follows:

- Capital costs. These are one-time expenditures for hardware purchase and installation (including station configuration or modification), as well as software purchase or development and support services (including training of staff, preparation of user manuals, and testing of equipment).
- Operating and maintenance costs. These are ongoing expenses, including production and distribution of fare media, equipment servicing and repair, and actual fare collection labor costs (e.g., fare inspectors or ticket agents and collectors).

Cost is only one side of the equation. In light of the high costs that are typically involved in changing fare collection systems, it is also important to consider potential cost savings and additional revenues that may be associated with upgrading the system. The remainder of this chapter reviews the process of estimating capital and operating costs—as well as potential cost savings—associated with implementing new fare payment and collection technologies.

Estimation of Capital Costs

Factors Affecting Capital Costs

Fare collection equipment tends to be a customized product. There is no "typical" cost; rather, a range of costs can be estimated, keeping in mind that many conditions and assumptions may be involved in the estimate. Unit costs are generally developed for each type of equipment on the basis of the supplier quotations, equipment characteristics, experience with recent purchases, and appropriate multipliers to allow for economies of scale and escalation for the time value of money. In addition, costs for engineering and support services depend on the purchasing experience of the agency, the local contracting environment, and the skills available within the agency's personnel—and also whether the agency is purchasing this type of equipment for the first time or it is a new generation replacing "old" equipment. It should also be kept in mind that much fare collection equipment is largely built in response to individual orders. Each agency's requirements invariably impose different performance features, even if major modules or subassemblies are the same among several orders. Final configurations of even very similar equipment for different agencies are rarely alike.

The price for any type of equipment is therefore sensitive to such factors as the following:

- The equipment specifications for the individual agency, including performance requirements and features; this affects the amount of customization required for a product, and this customization can represent a substantial portion of the overall price;
- The quantities of the particular equipment being ordered;
- The extent to which the new equipment will have to interface with existing equipment (i.e., that is not being replaced);
- The nature of the vendor selection and negotiation process (e.g., type of contract: low bid, two-step or negotiated);
- The timing of the procurement (relative to the procurement of similar equipment by other agencies—and therefore the extent of refinement of the technology);
- Growth potential (e.g., opportunities for new or extended lines);
- Warranty terms—warranties are generally for 1 year, but this period can be extended on the basis of other clauses associated with equipment performance;

- Documentation requirements (i.e., striking a balance between what is offered as manufacturer's "standard" and degree of customization for the agency);
- Software requirements—some software customization is expected, but requests for additional functions, features and reports will be considered extra and will increase the cost;
- Vehicle, station, and facility modifications: the cost of modifications to vehicles, stations, bus garages, or other facilities also need to be considered; and
- Americans with Disabilities Act (ADA) requirements—fare collection equipment must address ADA requirements; these include accommodation of wheelchairs in turnstiles, provision of sufficient room on buses to pass the farebox in a wheelchair, compliance with height requirements for buttons on AVMs, and accommodation of needs of blind riders in purchasing and using fare media.

Thus, many factors must be considered in developing the capital costs for a new fare collection system. The more extensive and complex the procurement, the greater the number of factors. Cost information for different types of equipment and fare media is presented below.

Equipment Cost Information

Cost issues are critical in selecting a fare collection technology. The choice of specific media and equipment options has major cost implications, both in terms of initial capital expenditures and ongoing operating and maintenance expenses. Within both cost categories, the actual cost levels are highly dependent on the specific requirements and specifications of the individual transit agencies. Each agency's requirements often impose different performance features for the equipment, meaning that customization is often responsible for a substantial portion of the purchase price. Furthermore, equipment price is also sensitive to the timing of the procurement; equipment is constantly being refined, and costs can change over time. Finally, for some costs, particularly the production of media, the unit price can vary by the volume produced. With these points in mind, it is still useful to develop order-of-magnitude cost estimates for various types of equipment and media. This enables a transit agency to conduct a preliminary evaluation of the relative costs of the different technologies or equipment options.

The overall cost for an agency's fare collection system depends largely on the size—and modal composition—of the agency. In other words, a heavy rail agency will have very different equipment needs from a small bus agency. Furthermore, the nature of the technology and equipment capabilities selected will greatly influence the ultimate cost. Equipment cost estimates are presented below for several different-size agencies and for alternative types of equipment. Unit cost estimates presented here are based on bids and/or price proposals received for similar equipment purchased by various agencies during the last 3 years.

Bus Cost Estimates. The two major types of fare collection equipment an agency operating bus service only would most likely consider at the present time are 1) an ERF system and 2) an ERF system upgraded to include BTVs or TPUs. "Typical" costs for these components are presented below. Over the coming years, an agency may also consider some type of smart card (contact or contactless) system, which would require an appropriate card reader, presumably affixed to—and integrated with—the existing farebox in most cases; costs associated with this option are discussed further below.

Costs are presented here for several different-size bus agencies. For purposes of comparing costs, a Small system is defined as one that has from 1 to 50 buses, a Medium system is one that has from 51 to 250 buses, and a Large system is one with more than 250 buses. As a general rule, the unit price of the standard products (i.e., ERF or TPU) is comparable for medium and large systems under 1,000 vehicles. For the small systems, however, the cost of the main products can be significantly higher, because the overhead costs, such as for software, installation and training, are spread across a smaller number of units.

The options presently available for upgrading a basic ERF system include the following:

- Swipe reader,
- TPU or ticket validator,
- Non-magnetic transfer issuer,
- Magnetic transfer issuer, and
- J-1708 VAN connection.

The equipment cost components included in procuring and installing an ERF system are as follows; the applicable unit costs are summarized in Table 55:

- ERF unit (plus options if applicable),
- Support services (e.g., training, manuals, test equipment, revenue testing, and warranty),
- Spare parts and modules,
- Garage equipment (e.g., data probes, vaults, receivers, and computer system), and
- Central computer system.

For all systems, various maintenance options are available from the supplier. Option costs depend primarily upon requirements and personnel needs to suit the desired level of service. The level of service can range from one person on site to assist and guide the agency's maintenance staff to on-call maintenance to complete maintenance coverage 7 days a week, 24 hours a day. In addition to the equipment cost factors, there are also recurring annual costs to be considered. These costs include operating costs (such as ticket stock and other consumable items) and maintenance costs (including personnel costs and purchase of additional spares when required). These costs are discussed further below.

Costs for three sample transit agencies are illustrated below:

- Small Agency—This agency has 25 buses and 1 garage, does not require a central computer system, and uses standard reports. The total system cost for this agency is as follows:

TABLE 55 Cost estimate for ERF systems

Cost Element	System Type: Small	Medium	Large
Fareboxes, Installed			
Only ERFs	$4,300	$3,800	$3,650
Add Swipe Reader	$1,750	$1,500	$1,200
Add TPU, Integral	$3,200	$2,550	$2,300
Add TPU, Remote	$4,200	$3,500	$3,200
Add OCU	$900	$650	$550
Add Printed Transfer Issuer	$1,800	$1,400	$1,200
Add J-1708 VAN Connection	$850	$600	$500
Cost per Garage (see below)	$84,000	$135,500	$135,500
Central Computer System			
Standard System	Not	$60,000	$60,000
Custom Reports (additional %)	Required	+75%	+65%
Spare Parts (As % Total Equipment Cost)	25%	12%	10%
Support Services			
(Flat Cost)	$55,000		
(As a % of Total Equipment Cost)		16%	12%

Cost Estimate per Garage

Additional Cost/Garage (Type 1)	Quantity	Cost	Total
Vault Housings, installed	1	$13,000	$13,000
Vaults	3	$6,500	$19,500
Audit Unit	0	$1,000	$0
Cashbox Carts	1	$500	$500
Data Probes and Cabling	1	$24,000	$24,000
PDU	1	$7,000	$7,000
GCS	1	$20,000	$20,000
Total Cost/Garage			$84,000
Additional Cost/Garage (Type 2 & 3)	**Quantity**	**Cost**	**Total**
Vault Housings, installed	2	$13,000	$26,000
Vaults	5	$6,500	$32,500
Audit Unit	1	$1,000	$1,000
Cashbox Carts	2	$500	$1,000
Data Probes and Cabling	2	$24,000	$48,000
PDU	1	$7,000	$7,000
GCS	1	$20,000	$20,000
Total Cost/Garage			$135,500

Note: costs are shown in 1993 dollars.

1.	ERFs (25 @ $4,300 ea)	$107,500
2.	Garage System (From Table 55)	$84,000
3.	Spare Parts (25 percent multiplied by $191,500)	$47,875
4.	Support Services (From Table 55)	$55,000
	Total System Cost	$294,375

- Medium Agency—This agency has 75 buses and 2 garages, will employ swipe readers, and uses standard reports. The total system cost for this agency is as follows:

1.	ERFs (75 @ $3,800 ea)	$285,000
2.	Swipe Readers (75 @ $1,500 ea)	$112,500
3.	Garage System	$271,000
4.	Central Computer System	$60,000
5.	Spare Parts	$87,420
6.	Support Services	$116,560
	Total System Cost	$932,480

- Large Agency—This agency has 700 buses and 4 garages, has purchased ERFs with integral TPUs, and requires the J-1708 interface. The total cost for this agency is as follows:

1.	ERFs (700 @ $3,650 ea)	$2,555,000
2.	TPUs (integral) (700 @ $2,300 ea)	$1,610,000
3.	Garage Systems	$542,000
4.	Central Computer System	$60,000
5.	Spare Parts	$315,700
6.	Support Services	$378,840
7.	Custom Reports	$36,000
8.	J-1708	$350,000
	Total System Cost	$5,847,540

The cost implications of a smart card system are discussed below, following the rail system estimate.

Rail System Estimates. Presenting meaningful cost data for rail equipment is more problematic than for bus. This is because the nature of customization is typically much greater, and installation of the equipment is much more complicated. Several types of equipment are also invariably involved. The typical rail agency fare collection upgrade will involve stored-value technology. A cost estimate is provided here for a stored-value magnetic ticket system for a sample rail agency (based on preliminary estimates prepared for MBTA). This agency includes both heavy and light rail; the underground light rail stations have barrier-type fare collection, while the surface stations use POP. Approximately 544 turnstile aisles and 88 gates for the elderly and those with disabilities are provided for fare collection. Each turnstile must be serviced by revenue servicing personnel. There is no on-line data collection.

The following equipment is required for the proposed stored value fare collection system:

- Ticket processing turnstiles,
- Wheelchair-accessible gates for the elderly and those with disabilities,
- AVMs,
- Surface ticket validator and printers,
- Station computers, and
- Central data collection system.

Closed-circuit television and passenger assistance phones have been proposed for station surveillance and passenger aid.

The equipment has the following features or functions:

- Turnstiles—accept, read, deduct value, write, and return the stored-value ticket to the rider; indicate remaining value and fare deducted;
- AVMs—accept coins, bills, and credit and ATM cards; give change; encode and print tickets; communicate with a central computer for alarms, revenue servicing, and data reporting;
- Surface ticket validator and printers—validate prepurchased tickets prior to boarding a vehicle; this equipment would be used in POP fare collection on the surface part of the light rail line and the commuter rail network;
- Station computers—used to monitor all fare collection equipment in a subway station (i.e., recording fare transactions, handling communications with a central computer, and processing alarms); and
- Central data collection system—a computer system that processes all data from the station computers, controls the bad ticket number list, remotely controls station equipment, prepares management reports, and communicates with bank networks for credit and debit transactions.

The estimated unit costs for this equipment are presented in Table 56. The cost for this agency would also include equipment for the bus fleet, including adding TPUs to the existing ERFs.

Smart Card Equipment. The cost of adding smart card capabilities to existing fareboxes or turnstiles depends on the specific capabilities and configuration of the unit and the type of smart card (i.e., contact versus contactless). In looking at some recently developed smart card systems, for instance, the costs of the bus card reader-writer units varied considerably as follows:

- Manchester—$1,800 apiece for 120 contactless card reader-writers;
- Dublin—$1,900 apiece for 25 contact card reader-writers; also, hand-held readers at $300 apiece; and
- Chattanooga—$2,550 apiece for 15 contact/contactless card reader-writers.

Thus, the cost of a smart card processing unit may be somewhat lower than a magnetic TPU, which ranges from about $2,300 to over $4,000, depending on the size of the order and whether or not the unit is integral to the farebox or added later. The differences are accounted for partly by the types of functions

TABLE 56 Rail system equipment cost estimate

Cost Element	Quantity	Unit Cost	Total Cost
Subway Equipment			
ticket processing turnstile	466	$21,000	$9,786,000
exit only turnstile	78	$4,500	$351,000
elderly/disabled gate	88	$24,250	$2,134,000
automated vending machine	255	$50,000	$12,750,000
station computer	80	$21,000	$1,680,000
Surface LRT Equipment ticket validator	500	$4,000	$2,000,000
Other support equipment*			$150,000
Central data collection system			$400,000
Total equipment cost			$29,251,000
Engineering cost			**

note: Estimate based on order of magnitude (1993) costs for MBTA (Boston).

* Other support equipment costs - These typically include items such as revenue carts, money room racks, test equipment, etc.; typical range of costs is $100,000 - $200,000.

** Other engineering costs - These include services such as installation, testing, software, reports, warranty, manuals, training and materials. This lump sum cost can vary depending on the requirements and terms and conditions of the agency.

the units can carry out; for instance, the TPU includes automatic transfer issue capabilities, while the smart card reader may not.

Of course, as with the fare collection systems described earlier, there is also support, or "off-line" equipment, necessary for a smart card system. For example, the London Transport demonstration has included the following off-line equipment: a personal computer, a video camera, associated software, and a machine that "lasers" the photo image of the card buyer onto the card; there are four sets of equipment, for different sales locations (cost information was not available for this equipment). The maintenance cost is included as part of the entire trial program; it is important to keep in mind that many pilots and demonstrations have sputtered or faded because a full maintenance (hardware and software) commitment was not made up front. This is especially true with emerging technologies. Operating and maintenance cost issues are discussed below.

Estimation of Operating and Maintenance Costs and Potential Cost Savings

Ongoing operating and maintenance costs are also a key concern in the evaluation and selection of new technologies. These costs fall into three basic categories: production and distribution of fare media, equipment servicing and repair, and fare collection and accounting labor. These costs are related to the type of fare collection system and technology in place. However, the latter two categories in particular are heavily dependent on 1) whether the service is contracted out or performed in-house and 2) the hourly wage rates—and union work rules—for labor at each agency. It is the third category in which cost savings are generally anticipated as a result of AFC. The key factors—as well as actual costs—that must be considered in each of these categories are as follows.

Production and Distribution of Fare Media

Although the cost of the equipment is not insignificant, the key difference in the alternative fare payment technologies is the cost of producing the fare media. Two aspects of the cost of media must be considered: purchase and production price and life cycle cost.

Media Purchase Price. The issuing cost per ticket or farecard (for those rail agencies providing information to the *APTA Rail*

Fare Collection Survey) varies, from less than $0.01 for paper tickets printed in house (NFTA in Buffalo) to $0.18 for preencoded magnetic stripe tickets (PAT and SEPTA). GCRTA's pre-encoded paper tickets cost an average of $0.01, while WMATA's magnetic cards, encoded by the rider, cost $0.13 per card. Cards made of stronger materials (plastic) or using one of the advanced forms of anti-counterfeiting treatment can be more expensive, but the top of the range at the present time is approximately $0.60.

In contrast, smart cards, depending on the capabilities of the specific type of card and the volume purchased, generally cost in the range of about $1.00 to $15.00 per card. At the low end of the cost scale is a memory card, such as the one-use and throw-away phone cards used by most European telephone companies. Contactless cards fall in the upper half of this range. The media costs for several current or recent smart card projects are as follows:

- Manchester—contactless cards (GEC, Racom, and Sony) are $4.00 to $8.00; about 5,000 cards have been issued;
- Dublin—contact cards (Schlumberger) were roughly $5.00 each; 1,500 cards were issued;
- London Transport—contactless cards (GEC) are $6.00 to $7.50 apiece; about 4 months into the trial, approximately 10,000 cards were in use; London Transport expects the cost of the cards to drop to less than $3.00 if and when the program is expanded systemwide;
- Chattanooga — contactless cards are approximately $10.00 each, for 500 cards; and
- Washington — contactless cards (Cubic) are approximately $6.00 each; 5,000 cards have been issued.

The price of the smart cards that have been employed in—or specified for—other transit applications also generally falls within a range of $4.00 to $10.00 apiece. Thus, these prices are much higher than magnetic stripe cards.

In considering the cost of smart cards, it should be noted that the technology, particularly contactless cards, is still in its relative infancy. The first contactless card demonstrated in a transit setting was the Western-Cubic Go-Card tested in the Touch and Pass project on London Underground in 1990 and 1991. The cost of the cards was estimated to be between $10.00 and $12.00 (1991 costs). A refined version of the Cubic Go-Card is being used in the WMATA demonstration; the cost per card, for 5,000 cards, is approximately $6.00 (1995 costs). For contact cards, the typical cost 2 years ago was in the $7.00 to $10.00 range. Today, with increased applications (mostly in Europe), this cost is estimated to be in the $4.00 to $6.00 range for similar quantities. Thus, the cost has dropped somewhat over the past few years.

The cost of cards should continue to decline as more vendors enter the market and economies of scale are realized with increased applications and higher production rates. For instance, Cubic estimates that the price of a contactless card should drop to around $3.00 with an order of 2 million or more. Thus, as larger agencies expand trials to their full systems, the cards should become less expensive. A "critical mass" could also develop through expansion of Federal program applications such as EBT (see Chapter 7). Development costs could drop as well, although the card makers continue to develop more advanced cards, suggesting that the basic price of the latest and most advanced cards (e.g., a combined contact-contactless card) will remain high. By purchasing cards with somewhat less than the maximum capabilities, though, transit agencies could well realize lower costs. Finally, transit card costs will be low if the agencies become participants in multiple use/electronic purse programs initiated by other entities (e.g., telephone companies or banks)—or utilize some form of vendor financing—and thus do not have to purchase the cards themselves. As is explained below, there are also differences in life cycle cost for the two types of media, and initial production cost of a fare card is less of an issue if most users can be convinced to keep the same card for a long period of time (e.g., a year or more). This will depend on the nature of pricing incentives associated with the card. In general, though, the cost of issuing fare media tends to increase with newer fare collection technologies.

Life Cycle Cost/Useful Life. Although the actual price of the card is an important issue, an agency should also consider the "effective cost" of the media, based on how long cards are retained by the users (i.e., the useful life of the medium). This affects the numbers of cards that must be purchased and distributed. If the card is sturdy enough and offers enough of an incentive to the user to keep it and reuse it for a long period of time, then the effective cost of the card to the transit agency drops considerably. If, for instance, a single $4.00 smart card is kept for a year, the effective monthly cost to the agency becomes $0.33, comparable to the cost of issuing a magnetic stripe card each month. Smart cards will, at least in theory, last longer than magnetic stripe cards, because they have no magnetic stripe that can wear out; indeed, smart cards without internal batteries are estimated to last 5 to 10 years.

Of course, whether riders will actually retain a smart card any longer than a magnetic card is unclear. A strong incentive must be provided for recharging the card; in London, for instance, the card user receives a discount only when the card is "topped up" (i.e., when a certain amount of value is added), and not on initial purchase. Another approach is to require riders to actually pay for the smart card (i.e., in addition to the amount of stored value purchased); this will also provide an incentive to keep the same card longer. However, in addition to such incentives, substantial re-education of transit riders will be necessary—to change their fare media purchase habits and convince them to treat their farecards more like they treat their credit cards. If a card can be used for multiple purposes beyond transit, there is greater likelihood that more riders will reuse the cards rather than discarding them after expending the initial value.

Although the regular rider may well see advantages in keeping a farecard for a long time, however, the need to accommodate the one-time or occasional rider cost-effectively remains a problem in a system based on a high-cost medium. Agencies implementing smart card systems will have to retain a lower-cost fare option (i.e., a magnetic stripe or paper ticket or token, or at least cash) along with the smart cards. This is the plan for some of the smart card systems being developed; in Oslo, for instance, single trips will be handled using paper tickets, while Melbourne plans to use magnetic tickets for small denomination multi-ride purchases (less than 10 rides). NYMTA envisions a similar plan. In such a system, smart cards could be restricted to relatively high minimum initial purchase values (e.g., $20.00 or more); a discount could then be offered only when value is added to the card, as mentioned above.

The cost of distribution of fare media is also influenced, in part, by the extent of reuse and retention of cards; in general, the greater the number of cards or tickets sold during any given period of time, the higher the distribution cost. The retention and reuse of cards, however, will actually have less of an impact on distribution costs than will the sales methods (i.e., AVM or token vending machine versus retail outlets or ticket agents). In fact, the replacement of the fare sales role of ticket agents with vending machines represents one of the key potential cost savings generated by technological improvements; this is discussed further below. It should also be noted that there are operating costs associated with EFT for the use of credit cards in AVMs. Metrolink in Southern California (SCRRA) reports that the EFT costs for Metrolink's credit card fare payments vary between 1 percent and 2 percent of credit card sales volume. The cost of producing, purchasing, and distributing fare media should thus be a major concern to transit agencies, at least over the long term.

Equipment Servicing and Repair

The costs associated with service and repair of new fare collection equipment are related to two essentially competing issues. On one hand, the new equipment is presumably more reliable than the equipment it is replacing, pointing toward a lower maintenance cost. The use of contactless smart cards in particular should reduce maintenance costs for read-write units, because of the elimination of moving parts (i.e., as in a ticket transport unit) and direct contact between card and reader (i.e., as in a swipe or "dip" reader). Although it makes sense that a card reader that does not receive repeated contact from cards will last longer and break down less than one that does, there is insufficient revenue service experience at this time with contactless card readers to know if they will prove more reliable over the long term than magnetic card or contact smart card readers. Because many such new applications are limited trials, maintenance costs are often included in the whole program as a "buried" cost. Contactless card trials such as those in Washington and Ventura County should eventually provide a useful means of estimating these costs. The long-term reliability of magnetic TPUs also remains a question, because of limited in-service experience to date. As with the smart card tests, the experiences with bus stored-value applications, such as those in the Los Angeles, New York, and Chicago areas, will provide useful information on maintenance requirements.

On the other hand, while reliability and frequency of repair will presumably improve, the increasing sophistication of new fare collection equipment creates new challenges for an established maintenance organization, and any improvements in reliability could well be offset by the increased complexity of the new equipment; this complexity can require more frequent service or monitoring and/or more highly trained personnel. The capabilities of the existing core maintenance staff must be evaluated by management with regard to the skills required for the new equipment. Retraining programs must be initiated or, if not possible, reassignment of personnel may be needed. In the meantime, the maintenance personnel must continue to maintain existing equipment while being trained in repair procedures for the new equipment. Changing equipment also introduces an opportunity to change the structure of the maintenance organization. New positions may be defined and old approaches discarded.

In looking at the case study agencies' experiences regarding maintenance costs, the acquisition of new bus equipment has generally resulted in—or is expected to produce—net increases in maintenance cost; this appears to hold true especially for fareboxes. Seattle/King Co. Metro estimated that its new ERF units (if they included TRiM units) would result in a net increase in operating costs of between $350,000 and $500,000 per year. In contrast, Metro has subsequently estimated that its recommended contactless smart card system would have an impact on current operating/maintenance costs ranging from an annual increase of $140,000 to an annual reduction of $300,000 (*18*).

MVRTA has experienced increased maintenance costs with its new fareboxes and swipe readers; the Authority reports that it has one full-time fare collection maintenance person and that without the more complex fareboxes and readers this requirement would be roughly cut in half. MVRTA also notes that there is a significant cost in finding and training staff to service the units.

On the rail side, MBTA has estimated that it too would need to increase the number of fare collection maintenance personnel in an AFC system. The preliminary estimate is that the staff level would rise from its current 44 to 73 under the full AFC implementation. Of course, as discussed below, there was predicted to be a net decrease in fare collection personnel in the new system, because of a substantial reduction in the need for operating staff. Finally, for an agency adding a new type of equipment for the first time, there will be an additional maintenance expense; this is the case at NJT, for instance, which has estimated the annual maintenance cost for its new AVMs at $2.7 million.

Fare Collection Labor and Cost Savings

The final major component of fare collection operating and maintenance cost is personnel directly responsible for fare collection and processing activities. These personnel include rail ticket agents, clerks, and collectors and revenue processing and accounting personnel. For instance, at CTA, the bulk of riders currently enter rail stations by paying (using cash or token) ticket agents; while all stations have turnstiles, most entries occur via the ticket agent gate. At MBTA, tokens have traditionally been sold by clerks in the rail stations, although token vending machines have been installed in recent years. Entry to the rail lines is done through turnstiles, using tokens or swipe passes. On NJT's commuter rail service, tickets are sold—prior to the installation of AVMs—by ticket agents and collected by on-board ticket collectors.

In all three of these agencies, one of the key goals in implementing new technology has been to reduce the number of fare collection personnel required. For instance, CTA seeks to significantly reduce revenue collection and processing costs over the long term; CTA top management hopes to recoup the capital cost of the new equipment within 6 to 8 years. The complicating factor in achieving the desired reduction is the reality of labor agreements that effectively prevent any immediate staff reduction. Thus, in a number of cases, job functions will simply change rather than positions being eliminated outright; in particular, the Authority plans to replace rail ticket agents with "customer assistants."

MBTA estimated that its originally planned AFC system would have resulted in a significant net operating and maintenance cost savings, despite the increased maintenance expenses assumed for the new equipment. The preliminary estimate of cost and percentage savings were as follows:

- Present system: $44.5 million;
- AFC: $39.8 to $42.5 million; and
- Estimated savings: 4.7 percent to 11.8 percent.

The lower dollar figure shown represents the maximum potential savings, i.e., if all possible reductions could be achieved. The higher figure represents a more conservative estimate, assuming that MBTA's labor agreements would, as at CTA, prevent the realization of the maximum reduction. The most likely scenario was that the full savings could be achieved over time, primarily through attrition.

Finally, NJT has estimated that its implementation of AVMs will considerably reduce the numbers of fare collection personnel needed. For its Phase I implementation, the agency made an initial projection of a possible net elimination (depending on labor negotiations) of 66 to 96 fare collection positions (including some reassignments or new service positions); the total estimated net annual operating cost reduction, accounting for new AVM maintenance costs, is therefore roughly $0.9 to 2.7 million.

One factor that must be considered in estimating operating and maintenance costs is whether revenue servicing of fare collection equipment, agents' booths, and outlets will be done by in-house personnel or contracted to an outside entity. For a new start-up, an economic analysis may show that contracting revenue service is a viable option to handling this service in-house. The drawback is lack of "control" even with good audit and monitoring procedures. An established agency that has already incurred the capital costs of creating a revenue service function may view the servicing of additional or replacement equipment as a marginal cost. In fact, the agency may be contractually obligated in such a manner (through labor agreements) that outside contracting may be impossible or prohibitively expensive. For in-house service, estimating the personnel requirements must consider the following factors: time to service machine, geographic distribution of equipment, travel time from base to location of equipment and between locations, and crew size.

Other Potential Financial Benefits

Beyond operating cost savings, the potential financial benefits of new technology are increased revenues. Such increases are generally assumed to come about from the following two basic sources:

- Reduction of fare abuse and fraud and
- Increased ridership because of greater convenience or reinforced marketing efforts.

The most common source of increased revenue—and ridership—is simply the improved revenue and ridership accounting offered by the new equipment. For example, NJT analyzed the impact of its new ERFs on revenue and ridership by conducting a before-after review on buses on certain routes. Staff had theorized that these figures would indeed increase because of the record-keeping and fare reporting limits inherent in the old fareboxes; in particular, the old fareboxes limited the operators' ability to ascertain that the proper fare had been deposited, especially during heavy boarding periods. The new fareboxes display the amount paid and also more accurately record fare amounts. NJT found that revenue and ridership "increased" by about 3 percent on the routes evaluated following the installation of the ERFs; the change was as high as 12 percent on some routes. This impact actually exceeded NJT's expectations based on a survey of several other agencies that had installed ERFs; these six agencies all reported some revenue increase, but none more than 2 percent.

Thus, given the comments about the prior fareboxes and enforcement limitations, at least a portion of NJT's revenue increase can be attributed to new revenue (i.e., from reducing fare abuse). Quantifying how reducing fare abuse affects revenue is difficult, especially when identifying the extent of this abuse is difficult in the first place; however, by making it more difficult to avoid paying the full fare or using an invalid transfer or other fare instrument, an agency will diminish the incidence of such abuse.

The impact of fare technology improvements on attracting new riders and increasing usage among existing riders is similarly difficult to identify. Surveys of riders taken before and after a technology change are probably the best way to attempt to assess such changes. Of course, it is also difficult to isolate the effect of the technology from that of any changes in the fare structure, although the latter may come about because of the flexibility offered by the new equipment. This is especially true in the implementation of stored-value-based AFC systems; new pricing options made possible by the new technology may significantly influence usage of the service.

With regard to financial benefits of smart cards in particular, there are three areas (i.e., other than possible reduction in reader-writer maintenance costs) in which such a system could, at least in theory, result in benefits. These are as follows:

- Reduction in bus operating costs—or perhaps the provision of additional service for the same cost—because of faster boarding times,
- Reduction in counterfeiting of fare media, and
- Improvement in the reliability of the technology.

The first of these benefits, along with the reduction in maintenance costs, is attributable to contactless cards only; use of a card that must be inserted into a slot obviates both of these potential benefits. The extent to which either benefit can actually result in lower costs is unclear at this time; comprehensive evaluations of contactless card projects must be carried out to determine the level of any cost savings.

Regarding boarding times, contactless cards should facilitate some time savings. Whether this will result in a cost impact depends on 1) whether the cumulative savings are sufficient to allow for any significant reduction in overall vehicle travel time and 2) whether the schedules of individual routes are flexible enough to allow significant changes. In other words, if a bus route has a 30-minute headway, the agency is unlikely to make this a 25-minute headway simply because 5 minutes can be shaved from the running time. What is possible is that, given a significant systemwide reduction in boarding times, an agency may be able to ultimately reallocate its resources among different routes and realize some overall operating cost reduction. What is more likely, though, is that the improved boarding times will simply facilitate better reliability on individual routes that may currently have trouble keeping their schedules. Of course, this is an important benefit in its own right and should serve to increase ridership over time; this in turn will result in additional revenue. Again, a comprehensive evaluation, including before and after measurements, would be necessary in order to estimate the revenue gain from such a system.

Because of their enhanced security characteristics, smart cards are expected to reduce the potential for fraud and counterfeiting (i.e., in comparison to paper or magnetic stripe cards). It is not clear that their use would produce significant increases in revenues, however, because counterfeiting of magnetic cards has not been found to be a significant problem in the transit industry. As indicated in Chapter 5, advances in protection technology have made magnetic cards increasingly difficult to duplicate. Nevertheless, the reduction and prevention of fraud have been cited by several agencies as a primary reason for deciding to use smart cards. With regard to reliability of the media, smart cards have been found to offer improvements over magnetic stripe cards. Whether this will result in increased revenue will depend on the nature of the failures (i.e., is revenue actually forfeited, or is boarding time simply slowed down?) and the actual differences in reliability.

In summary, it is safe to assume that technological improvements will generate some increase in revenue through 1) reducing fare abuse and 2) improving convenience for the riders, reinforcing marketing efforts, and perhaps facilitating seamless transit travel between modes or operators. The more significant financial benefit of a technological improvement, however, will likely occur through the reduction in fare collection operating costs (i.e., through reduction in personnel requirements). Other potential benefits, such as reduction in maintenance costs and overall operating costs, have been attributed to certain emerging technologies; these benefits, along with the full range of costs must be determined through independent evaluations of in-service applications.

EVALUATION OF FARE TECHNOLOGY OPTIONS

The final section of this chapter presents a general approach for evaluating fare technology and system options, based on the findings of the research.

As explained in Chapter 5, the fare collection and payment system consists of the following basic elements:

- Type of fare collection system,
- Fare media technology (and fare purchase and payment options), and
- Fare equipment.

In developing a fare system, each of these elements must be addressed. Therefore, it is necessary to evaluate the options within each element. In line with the overall fare decision-making process outlined in Chapter 2, the research team presents here a suggested evaluation methodology related to these elements. As seen in reviewing the case study agencies' experiences in selecting technology options, each agency has its own set of requirements and constraints and will take an appropriate evaluation approach. Nevertheless, as with the suggested methodology for evaluating fare strategies presented in Chapter 3, it is felt that some general guidelines should prove useful to transit operators.

Types of Fare Collection

As indicated in Chapter 5, the type of collection system is generally the first decision made in developing a new overall fare system. Although many transit agencies will choose to follow the general trends (e.g., the recently implemented light rail lines have all chosen POP systems), in some cases, agencies may wish to evaluate the options. In particular, an agency introducing light rail—or considering revamping its light rail fare collection system—may want to consider the three options currently in use, and a rapid rail operator looking to upgrade its system or open a new line will have to consider the two forms of barrier fare control.

Table 57 presents the evaluation criteria and the resulting ratings of the two LRT fare collection system options, as well as the two types of barrier systems. As explained in Chapter 2, the criteria used to evaluate the fare system elements differ considerably from those applied to the fare strategies. The fare system criteria are related more to financial and management goals than to customer-related goals, although convenience is certainly a key criterion in evaluating fare system elements.

As shown, POP is rated higher than (or equivalent to) the other options for all criteria except "impact on fare evasion/abuse." Although POP systems include security personnel charged with enforcing fare payment compliance, the fact that this is essentially an honor system means that fare

TABLE 57 Type of fare collection system evaluation

Evaluation Criteria	Rating of Type of Fare Collection System			
			Barrier	
	Proof-of Payment	Payment on Entry	Entry Control	Entry/Exit Control
convenience (ease of use)	3	1	2	1
impact on fare evasion/abuse	1	3	2	3
cost of equipment and facilities/stations	3	3	2	1
fare collection cost	3	1	2	2
flexibility (re changing or adding fare options)	3	3	1	2
operations impact (e.g., on throughput)	3	1	2	1
reliability of technology	3	2	2	1
Total Score	19	14	13	11

Rating Key: 3=High, 2=Medium, 1=Low

evasion will likely be higher than on systems that require payment to board a vehicle (or enter the boarding area). Among the other options, pay on entry has a total rating slightly higher than barrier with entry control. For the barrier systems, entry and exit control is rated lower than entry control for four of the criteria and receives a lower overall rating. Of course, if an agency wishes to implement automated distance-based pricing, an entry and exit option is required.

Fare Media Technology Options

In identifying fare payment technologies, the key is the types of fare media options being considered; the basic media options, as defined earlier in this chapter, are as follows:

- Cash,
- Token,
- Paper ticket,
- Magnetic ticket, and
- Smart card.

As with fare strategies, a single fare system can use more than one of these options; most systems at least accept cash in addition to one of the other types of media. Some larger multi-modal transit systems use four types of media, although not all are generally accepted on all modes.

There are several ways in which the various media can be purchased, depending on the equipment capabilities and agency purchase policies. The major purchase methods are cash, credit cards, debit/ATM cards, or, where available, transit vouchers (such as TransitChek in New York). However, tokens can also be used to purchase tickets in some AVMs, and stored-value magnetic and smart cards can also conceivably be used to purchase media. (Purchase methods and related technologies are reviewed in Chapter 7.)

The fare media can be used for different fare payment options (i.e., single-ride, multi-ride, period pass, stored value, and post payment), which are described in Chapter 3. Magnetic tickets and smart cards are the most flexible of the media and have the potential for use in any of the payment options. Cash offers the fewest options as a payment medium, although it is important as a purchase method for any of the media. Tokens can be used in a multi-ride option through volume purchase (e.g., a 10-pack). Paper tickets can be used for single-rides (and are the most common form of transfers), multiple rides (e.g., a 10-ride punch ticket or a book of tickets), or period flash passes. Credit cards, which are just beginning to see use as a fare payment option, can be used for single-rides only, and—along with debit/ATM cards—are also used as methods of purchase. These media are not included in this evaluation discussion.

The criteria used in evaluating fare payment media technologies, along with the resulting ratings, are shown in Table 58. These criteria are generally the same as those used for types of collection systems, except that "security" (related to resistance to counterfeiting) replaces "impact on fare evasion/abuse" and the two cost criteria address somewhat different aspects: "cost of production of media" versus "overall fare collection cost," and "cost of equipment" versus "cost of equipment and facilities/stations."

In differentiating between the criteria used in evaluating fare strategies from those used for fare system elements, the specific technology or type of media used in itself has little direct impact on such goals as ridership, equity, revenue, and political acceptability. The type of media certainly affects these goals through their capabilities to allow for flexibility in changing or adding fare strategies or through their impact on throughput, for instance. Furthermore, the ability to improve data collection may help an agency improve its service, which in turn should increase ridership. The criteria used to evaluate fare strategies, however, simply do not reflect the major goals and concerns related to selection of a type of media or a technological approach.

Unlike the fare strategy criteria, the media criteria are based on properties of the options themselves more than the specific manner in which they are applied. In other words, it is possible to evaluate the media technology options before developing specific fare structure alternatives and estimating the impacts of these alternatives. Whereas roughly half of the fare strategy criteria cannot be fully applied until specific alternatives (with pricing levels) have been established and market research and modeling have been completed, the only media criteria that require detailed specification to fully evaluate are those pertaining to cost—and perhaps to convenience. Of course, even the cost criteria can be applied initially using typical unit cost data available from suppliers or existing applications. Convenience may vary, depending on the particular fare payment option(s). For instance, if the paper ticket option is in the form of a pass, it can be quite convenient for riders. Also, the degree of convenience of using cash depends to a large extent on the fare level (e.g., a $1.00 fare is relatively convenient, while a fare of, say, $0.85, is much less convenient).

Thus, at least in theory, the comparative evaluation of media is much less subjective than is the preliminary evaluation of fare strategies. What complicates the objective evaluation of media, however, is the constantly advancing state of the art, coupled with the lack of sufficient comparable experience with all of the technologies. While cash, tokens, and paper tickets

TABLE 58 Fare media evaluation (unweighted)

Evaluation Criteria	Weight	Relative Impact of Payment Media					
		Cash	Token	Paper Ticket	Magnetic Ticket	Contact Card	Contactless Card
convenience (ease of use)	1	1	2	2	2	2	3
security (ability to prevent duplication)	1	2	1	1	2	3	3
accountability (impact on revenue control)	1	1	2	2	3	3	3
cost of purchase or production of media	1	3	3	3	3	1	1
cost of equipment	1	3	2	3	1	1	1
flexibility (re changing or adding fare options)	1	2	1	2	3	3	3
operations impact (e.g., on throughput)	1	1	2	1	2	2	3
reliability of technology	1	1	2	2	2	3	3
Total Score		14	15	16	18	18	20

Rating Key: 3=High, 2=Medium, 1=Low

have been in widespread use for years, the use of magnetic tickets is still relatively limited (i.e., primarily to a handful of the largest rail transit systems), and the use of smart cards in transit is in its infancy. Although there have been several demonstrations of the latter technology around the world (see Chapter 6), there has been little systematic evaluation of its costs and benefits.

Nevertheless, preliminary assessments of the results of applications that have taken place, coupled with analysis of theoretical advantages and disadvantages of the different technologies, permit the rating of the media in the interim, as presented in Tables 58, 59, and 60. The latter two tables represent alternative weighting scenarios similar to those employed in evaluating fare strategies, emphasizing the customer (i.e., convenience) and financial aspects (i.e., cost, accountability, and security criteria) of the options.

In reviewing these ratings, it can be seen that the electronic fare media (i.e., magnetic tickets and the two types of smart cards) offer improvements over the more traditional media in the areas of security, accountability, flexibility, and operations impact. With regard to convenience, all of the prepaid options (i.e., all but cash) are relatively convenient to a rider. The more precise degree of convenience depends both on physical ease of use in the fare collection system (i.e., does the medium have to be deposited, inserted, and removed—perhaps at entry and at exit, presented to an agent, or simply carried for proof of payment) and the ease and number of interactions required in purchasing the medium (i.e., based on the type of fare payment option). Thus, a contactless card should be the most convenient option in terms of physical ease of use, because the card does not have to be physically inserted—and may not have to be removed from a wallet or purse to be used. Any medium, however, that is available as a period pass will be more convenient than one that requires frequent replenishment or repurchase. Ultimately, convenience also depends on the ease of use of the fare purchase and collection equipment.

Security, in terms of difficulty to counterfeit, represents an advantage of smart cards over the other media. Paper and magnetic tickets, as well as tokens, have been successfully duplicated in various locations. Smart cards, especially those with built-in microprocessors, are inherently more difficult to counterfeit. Of course, an argument has been made that people will ultimately figure out a way to counterfeit or modify any technology, regardless of its complexity (i.e., once smart cards are more widely used, they too will ultimately be duplicated). At this point, though, the technology is considerably more secure than the others considered.

The electronic media also offer better accountability, in terms of revenue control than do the other media, particularly cash and tokens. In fact, some agencies' decisions to implement electronic fare collection have been spurred primarily by theft of cash or tokens by employees. The improved data collection and monitoring capabilities offered by the electronic technologies make it much more difficult for employees to skim fare receipts. Moreover, the reduced amount of cash in any type of prepayment program simply provides less opportunity for employee theft.

With regard to flexibility, the electronic technologies are rated higher in that they (and/or the accompanying equipment) can be programmed to accept any type of fare structure, and

TABLE 59 Fare media evaluation (customer-driven)

Evaluation Criteria	Weight	Relative Impact of Payment Media					
		Cash	Token	Paper Ticket	Magnetic Ticket	Contact Card	Contactless Card
convenience (ease of use)	5	5	10	10	10	10	15
security (ability to prevent duplication)	1	2	1	1	2	3	3
accountability (impact on revenue control)	1	1	2	2	3	3	3
cost of production of media	1	3	3	3	3	1	1
cost of equipment	1	3	2	3	1	1	1
flexibility (re changing or adding fare options)	3	6	3	6	9	9	9
operations impact (e.g., on throughput)	3	3	6	3	6	6	9
reliability of technology	5	5	10	10	10	15	15
Total Score		28	37	38	44	48	56

TABLE 60 Fare media evaluation (financial-driven)

Evaluation Criteria	Weight	Relative Impact of Payment Media: Cash	Token	Paper Ticket	Magnetic Ticket	Contact Card	Contactless Card
convenience (ease of use)	1	1	2	2	2	2	3
security (ability to prevent duplication)	3	6	3	3	6	9	9
accountability (impact on revenue control)	5	5	10	10	15	15	15
cost of production of media	5	15	15	15	15	5	5
cost of equipment	5	15	10	15	5	5	5
flexibility (re changing or adding fare options)	3	6	3	6	9	9	9
operations impact (e.g., on throughput)	3	3	6	3	6	6	9
reliability of technology	3	3	6	6	6	9	9
Total Score		54	55	60	64	60	64

Unweighted Rating Key: 3=High, 2=Medium, 1=Low
Weighting: 5=Highest Priority, 3=Medium Priority, 1=Low Priority

the structure can be modified relatively easily (at least from a technical viewpoint; modifications also have marketing and accounting implications).

The operations impact criterion is defined in terms of the rate of throughput that is possible with the technology (i.e., on a barrier, pay on entry, or conductor-validated system). This impact is related to both the speed of the equipment itself in processing and accepting the fare medium and to the speed with which the rider can use the medium. Thus, a technology that does not require the actual insertion of the medium into some sort of receptacle will allow faster boarding of the vehicle or entry through the gate. This accounts for the high rating given the contactless card. A flash pass (in whatever medium) does not meet this requirement because it generally must be inspected by a bus driver or ticket agent.

Regarding reliability, magnetic ticket processing equipment is just beginning to see use on buses, and improvements are still being made. While smart cards have similarly seen limited in-service testing to date, this technology is believed to be more reliable than magnetic ticket technology. Contactless card readers in particular are expected to be very reliable—and require little maintenance—because of the absence of moving parts and direct contact between card and reader. For this reason, the researchers rated smart cards higher than magnetic tickets in terms of reliability.

Finally, the cost-related criteria are crucial in evaluating these options. The cost of producing smart cards is much higher than the cost of any of the other media; as indicated earlier, the unit cost of a smart card, even in large quantities, will be $3.00 or more (and currently much higher), while a magnetic ticket costs $0.60 or less to produce. Although the "effective cost" of smart cards could conceivably be quite low—due to their much greater durability—this initial cost differential represents perhaps the biggest current drawback to the smart card technology. The cost of procuring, installing, and maintaining equipment is, at the present time, high for both magnetic and smart cards. Of course, as explained earlier in this chapter, the cost of any improvement will depend largely on the nature of the current equipment and the extent of modifications or new equipment needed. The ultimate cost will depend on the types of basic fare collection and control and auxiliary (e.g., vending) equipment desired.

As indicated in Table 58, contactless cards rank highest, while contact cards and magnetic tickets are tied for second place. Essentially, contactless cards outweigh their high costs with high ratings for all of the other criteria; contact smart cards are rated below contactless cards in convenience and operations impact. Magnetic tickets are rated below contactless cards for convenience, security, and reliability but higher for the cost criteria. It is difficult to distinguish among the media options using an unweighted rating scheme. Slight changes in any of the cells of the matrix can alter the overall ranking. What is needed is to weight specific criteria according to the agency's priorities or major constraints or concerns. Table 59 presents the customer-driven weighted scenario. The ranking of the six options is similar to that in the unweighted scheme, the major exception being that the contact card is now several points above magnetic tickets. In this scenario, the greater convenience offered by the contactless card is magnified because of the importance placed on that criterion.

In the financial-driven scenario (Table 60), the cost advantage of the magnetic ticket boosts it equal to the contactless card. Contact cards drop to third place in this ranking, tied with paper tickets. As in the other two scenarios, cash ranks last.

This is clearly an overly simplified approach. One shortcoming is that the rating key does not indicate the distance between low, medium, and high; in other words, "3" may be much better than "2" in certain cases. Furthermore, the ranking of the media options is heavily dependent on the nature of the weighting scheme and the relative size of the weights. Each transit agency must ultimately decide on these parameters. An agency may, for instance, give the cost criteria a very high weight and not really consider operations impact or convenience. Thus, while this basic approach is useful for providing general guidelines in selecting technology options, each agency must carefully consider its own needs and constraints in evaluating the different options.

CHAPTER 9

SUMMARY OF FINDINGS

INTRODUCTION

TCRP Project A-1 has involved a comprehensive study of the major parameters of the transit fare decision-making process: fare policy, fare strategy and structure, and fare technology. Every transit agency must eventually address each of these areas, and, although each has typically been evaluated separately, it is important to understand the interrelationships among them. Policy generally guides the direction for strategy and structure, but technology decisions can also affect decisions regarding structure—as well as policy. Electronic fare payment, for instance, offers the agency the ability to provide a broad range of fare options while improving its own revenue control and operations planning capabilities. Emerging technological developments can also facilitate the expansion of the existing use of fare instruments to a broader base, possibly including other transit operators and non-transit functions. Thus, as transit agencies face pressures to maximize their operating efficiencies, increase revenues, and expand their ridership, the need to be aware of capabilities of the emerging technologies becomes more important than ever.

To assist agencies in making decisions about fare-related areas, Project A-1 has reviewed the nature of options available in each parameter—those in widespread use as well as those in the early stages of development and testing. This report has presented the results of this review, highlighting the issues to be considered in making fare-related decisions, the experiences of transit agencies in selecting and utilizing the various approaches, and the advantages and disadvantages—and future promise—of emerging developments. The key findings of the study are summarized below.

FARE POLICY AND STRUCTURE OPTIONS AND DEVELOPMENT PROCESS

Fare Policy Goals and Decision-Making Process

Fare policy is used in this study to refer to the principles, goals, and/or objectives a transit agency establishes in making fare-related decisions. Although some agencies develop formal fare policy statements to guide future fare restructuring and technology development, many agencies simply identify policy goals in reaction to financial crises or other outside influences. Very few agencies (3 percent) make regularly scheduled (annual or other) fare changes; thus, the vast majority change fares as needed.

Fare-related decisions are made in a variety of ways, on the basis of such factors as the agency's size, modal composition, organizational structure, and institutional setting, as well as on the nature of the change being considered. In general, however, there appear to be three basic decision-making scenarios: policy-driven (i.e., changes are based on pre-established goals), technology-driven (i.e., changes are based on the type of technology selected), and service-driven (i.e., changes are based on the need to integrate a new mode or service into the system).

The major fare policy goals can be categorized as customer-related, financial, management-related, or political. Establishment of these goals recognizes that fare policy is essentially a tool for achieving broader transit goals (e.g., related to providing high-quality service, improving cost efficiency, and improving environmental quality). Because certain goals are inherently competing, it is necessary, in making fare decisions, to prioritize the major goals. Because of the widespread decline in ridership in recent years, the general emphasis in the industry has shifted somewhat over the past decade or so from a primary concern with generating additional revenue to an often equal emphasis on increasing ridership. This change has been generally marked by a greater focus on the customer—through simplification of fare structures (e.g., eliminating or reducing the number of fare zones), improving convenience through the addition of prepaid options, or introducing discounted fare media.

Selection of Fare Strategies and Structures

As defined in this study, fare strategies are of two basic types: flat and differentiated; differentiation can be based on distance traveled, time of day of travel, or speed or quality of service. Fares can also be targeted to different market segments on the basis of rider characteristics such as frequency of transit use and willingness to prepay fares. The last strategy is generally referred to as market-based pricing. The transit industry has debated the advantages and disadvantages of flat versus differentiated fare strategies for years. It is argued that differentiation is beneficial—through the ability to generate higher revenues—and warranted—because of the higher operating costs associated with serving long trips, operating during peak hours, and providing premium service. Although differentiated fare strategies are used by some agencies, the industry has, by and large, leaned toward flat fare schemes—with market-based elements. As of 1994, 37 percent of North American bus agencies reported distance-based (actually zonal) pricing, 27 percent had some type of service-based differentiation, and 6 percent offered a time-of-day differential. The distribution is not appreciably different on heavy and light rail services; only commuter rail features extensive use of differentiation—virtually all of the agencies have distance-based pricing, and nearly a quarter also provide time-of-day differentials.

With some notable exceptions, agencies have increasingly opted for the simplicity of flat fares, because they have felt that the potential economic benefits of differentiation are not great enough to overcome the obstacles. Difficulties related to design, implementation, and use by riders are generally seen as the key disadvantages, with technological limitations often cited as the major barrier to distance-based pricing in particular. Although electronic fare collection systems can make it easier to implement and administer a distance-based strategy, the barrier appears to be more perceived than real. At this time, it appears unlikely that the spread of electronic fare collection will lead to expansion of distance-based pricing. On the other hand, the greater flexibility offered by electronic fare collection may in fact spur increased interest in time-based pricing—i.e., peak/off-peak differentials.

Although remaining cool to differentiation on the basis of distance, time of day, and service quality, the transit industry has increasingly embraced market-based pricing, recognizing the benefits of targeting different rider markets. This approach involves offering various types of prepaid options—passes and multi-ride instruments—and centers on providing a choice of payment options to riders. One of the key elements of a market-based strategy can be the use of deep discounting, which entails offering a substantial discount from the single-ride fare if the rider is willing to pay for multiple rides in advance of use. Transit agencies have employed market-based strategies to address a variety of goals—related to reducing cash and overall revenue management costs, as well as marketing and policy issues. Deep discounting, in particular, has also resulted in positive ridership and revenue impacts in a number of transit agencies, providing an indication that, at least during a period of otherwise stable ridership, it can successfully meet revenue targets while avoiding the ridership loss that invariably accompanies a general fare increase. In some cases, ridership has actually grown along with revenue. Of course, there are also certain drawbacks to the concept. For instance, the provision of multiple options complicates the fare structure somewhat. More importantly, introducing deep discounting is typically accompanied by a greater cash fare increase than would be instituted without the discount. This may prove politically infeasible, even with a substantial discount.

The benefits are seen as outweighing the obstacles, however, because market-based pricing strategies are quite widespread among all sizes of transit agency. Over three-quarters of North American transit agencies offer some type of discounted prepaid option (one or more type of unlimited-ride pass and/or some form of volume or multi-ride discount). These options are increasingly seen as fundamental elements of a transit fare structure.

Selection of Fare Payment Options

The types of fare payment option offered represent a key element of the overall fare structure (along with strategy and fare levels). The basic types of payment option include single-ride, multi-ride, period pass, stored value, and post payment. These can be in various forms of payment media, including cash, token, paper ticket, magnetic ticket, smart card, debit card, credit card, and transit voucher; media considerations are discussed below.

Each payment option offers certain advantages and disadvantages relative to the others. Although all transit agencies continue to offer a single-ride option, there is an ever-increasing emphasis on providing prepayment options, as seen in the widespread use of market-based pricing. Multi-ride tickets or tokens—or, increasingly, stored value—are the key option in a deep discount strategy. These offer the advantage (compared to a period pass) that they are not time-limited and thus appeal to the occasional rider; multi-ride fare instruments are also generally less costly to purchase than are passes—although a weekly pass may be equivalently priced. The primary benefits to the user of a period pass are the convenience of making a single purchase per period and the potential for savings as compared to paying for single-rides.

The agency benefits from any form of prepayment through reduced cash handling, improved cash flow, and, perhaps, decreased boarding times (depending on the fare collection technology in place). Of course, there is a significant cost to the agency in terms of production and distribution of the prepaid media. Passes also present a major disadvantage through "lost revenue" from high-frequency usage. The extent of this forgone revenue depends on the pass breakeven rate, as well as the frequency of usage patterns. Additional revenue loss occurs through illegal sharing of passes and through counterfeiting. The negative revenue impact of period passes remains a major concern among transit agencies, and they seek to minimize the impact by carefully setting the pass price and breakeven level, as well as seeking to develop ever more secure media. Some agencies have gone so far as to propose the elimination of period passes, and one of the largest—CTA—did just that, although it subsequently re-introduced monthly passes 6 months later, at a significantly higher price.

The advent of electronic fare payment has facilitated the use of stored value as the primary prepaid option. Stored-value options allow for considerable flexibility in pricing, and the same media used for stored value can be used for period passes, stored multi-rides or even single-rides. Stored value offers the convenience associated with any type of prepayment and allows the rider to decide how much to prepay at a given time. This option can also "mask" the complexity of a fare structure to the rider, in that he or she does not have to know the exact fare for a particular trip. Stored-value options—and electronic payment in general—benefit transit agencies through the pricing flexibility they provide; the option can also facilitate integration of multiple operators in a region. The major drawback to stored value is the cost involved (equipment and media); electronic payment options are discussed below.

Key Fare Development and Evaluation Issues

On the basis of the set of case studies conducted in this study, the key fare development and evaluation issues and approaches can be summarized as follows.

Frequency of Fare Changes

The frequency of fare changes varies widely in the transit industry. Some agencies make some type of fare modification every 1 to 3 years, although in most cases these are not major restructurings; in contrast, many agencies wait 5 years or more between fare modifications. Frequency is not necessarily linked to the reasons for c hange but is related largely to the size of agency; the larger agencies review fares considerably more often than do the smaller ones. Of the agencies conducting frequent reviews, few appear to have an official policy calling for regular reviews; much more common is to study fares in response to a particular need or problem.

Fare Policy Goals and Evaluation Criteria

The key goals pursued in fare development studies are typically closely related to the types of reasons that prompted the review. Ridership and revenue requirements are the major considerations for most agencies, and other goals are generally supportive or directly tied to these two. The goals and evaluation criteria least often cited are those related to political goals, including maximizing political acceptability and achieving a recovery ratio requirement.

Evaluation criteria are usually developed directly from policy goals. To identify the relative importance of the criteria, some agencies assign weights to the different criteria; these are generally based on staff ratings. The conflicting goals of increasing ridership and increasing revenue are invariably assigned the highest—and often equal—weightings. This conflict between these two goals sometimes results in a new goal linking the two—e.g., increase revenue without losing ridership; this is the fundamental goal in deep discounting strategies. The criterion often assigned the lowest weight is equity. Of course, this concern can become more important in cases where the public is included early in the development process. Whereas public input is typically not sought until after preliminary recommendations have been developed, some agencies make early public participation a feature of their review processes. Equity issues may well become more important in many locations in the wake of the recent legal actions against the LACMTA and NYMTA following proposed fare increases.

The Role of Task Forces and the Board of Directors

Because fare issues affect many different aspects of a transit operation, most agencies reviewed have ongoing or specially convened fare policy task forces consisting of staff representatives of various departments. Generally, these task forces (which, on occasion, include Board members or even private citizens) review findings during the evaluation period and make key decisions and participate in the criteria weighting process. With regard to Board involvement, the larger agencies' Boards are not typically involved until recommendations have been developed; the smaller agencies' Board members are more often involved throughout the fare study.

Strategies and Issues Considered and Study Recommendations

Few of the agencies reviewed in this study consider all of the basic fare strategies (distance-based/zonal, time-based, service-based, market-based, and flat fare) in any particular study. The zonal options are generally not considered at all by smaller agencies, and frequently there is no consideration of an express surcharge or peak/off-peak differential by these agencies. These agencies tend to focus on changes in fare levels or prepayment options (including deep discounting and various types of passes). The larger agencies tend to take a broader approach, and most have performed comprehensive evaluations of their fare structures within the last few years. Typically, each agency conducts one major review of all strategies (i.e., including a distance-based option) and then does not seriously reconsider the rejected strategies in subsequent studies.

Development of Fare Elasticities

U.S. transit agencies employ a range of sources and techniques for developing fare elasticities; the major sources and techniques include the following:

- Time series analysis;
- Before and after analysis for a particular fare change;
- Use of a demand function, often from a stated preference survey;
- Review of industry experience; and
- Use of professional judgment (in conjunction with one or more of the above sources).

Some agencies use several of these sources and techniques, and the particular calculation method can significantly affect the elasticities developed. A common approach is to calculate elasticities on the basis of historical data and then corroborate—and possibly adjust—these figures on the basis of elasticities used by similar-size agencies. Regarding analytical techniques, the use of stated preference data has begun to expand, especially in the consideration of stored value options. Finally, many agencies continue to use the Simpson-Curtin formula. There is, however, no standard in terms of the most appropriate technique.

Identifying Ridership and Revenue Impacts of Fare Changes Versus Other Factors

It is clear from the review of the ridership and revenue impacts of fare changes that fare levels and strategies affect transit usage; however, it is just as clear that a range of other variables can have at least as strong an influence. Furthermore, the timing and relative intensity of the impacts can vary considerably. On the basis of the case study analyses conducted in this study, important non-fare factors affecting transit demand include the following:

- The state of the local economy—this includes employment and unemployment levels and gasoline prices; in economic "boom" periods, agencies have seen ridership growth despite multiple fare increases; conversely, significant ridership losses have invariably followed economic downturns;

- Residential and employment shifts—suburbanization and a general increase in lower-density development have resulted in travel patterns that can no longer be well-served by CBD-oriented transit routes; this has directly contributed to reduced demand and has also led to a reduction in the local funding base (e.g., where transit is supported by sales tax revenue), thereby leading to service reductions; and
- Level of service—the amount of service provided clearly affects demand; high-frequency service and wide coverage of the urban area are important features in maintaining ridership; thus, service cuts invariably result in ridership declines.

Determining the relative impacts of the various factors (i.e., through time-series regression techniques) is always a challenge and can be complicated considerably by gaps or inconsistencies in the data available for key variables. Such problems can make it difficult to isolate the effects of these different factors and use the results to accurately predict the effects of a prospective fare change. The constraints associated with such analyses have led transit agencies to consider and employ a variety of methods for estimating the effects of future fare change. Regardless of the technique chosen, however, professional judgment must play a significant role, and the dynamic nature of the external environment must be considered in all analyses.

FARE TECHNOLOGY OPTIONS AND DEVELOPMENT

Equipment Options and Trends

Fare technology refers to the types of fare payment media and equipment used for fare collection and sale of media. Fare collection equipment ranges from simple drop fareboxes to ERFs for bus systems and station agent ticket-selling to complex AVMs for rail systems. Technological developments of the past several years (e.g., ERFs, more flexible AVMs, and TPUs) have resulted in significant improvements in the efficiency and flexibility of fare collection and media distribution procedures; however, the expansion of technological advancements—at least in the United States—can be a slow and deliberate process.

Improvements in equipment design have significantly contributed toward—or offer the potential to contribute to—various improvements in fare payment and collection functions. The key developments in this area include the following:

- AVMs. The leading factor that has contributed to acceptance of AVMs has been the much improved reliability of the bill handling system—in particular, the validating and escrowing of bills. Coupled with this is the use of fast, programmable printing formats that are available to produce tickets with a variety of graphics and text. Recent developments include the ability to validate more than four denominations of bills. This opens the possibility to accept a "value document" such as a transit voucher. Also the use of the credit and debit/ATM cards to purchase tickets has seen increased growth.
- Turnstiles. Turnstile improvements include better designs for coin, token, and magnetic ticket acceptance. Magnetically encoded tickets provide a means for turnstiles to read a ticket and then rewrite the ticket after having deducted a ride or monetary value. New designs have been introduced to minimize fare evasion by backcocking the barrier. Smart card readers have been affixed to turnstiles in some cases.
- ERFs. Beyond simply collecting fares, fareboxes have evolved into sophisticated data collection, fare security, and control devices. The availability of large memory size at low cost has permitted an expansion in the amount of data collected and the use of card readers, transfer issuing and ticket processing units. Furthermore, ERFs can now be equipped with a transactional data base system, which can facilitate post payment (i.e., billing for trips actually taken).
- Ticket Validators and TPUs—Ticket validators, which only print or print and notch a ticket to validate, are used predominantly by POP system agencies for the passenger to validate a prepurchased single- or multi-ride ticket. BTVs and TPUs capable of reading magnetic tickets and printing remaining value permit use of electronic stored value fare media. Smart card readers have also been added to TPUs in some cases.
- Hand-Held Devices. Hand-held devices are now available to produce tickets, store transaction data, and retrieve fare information. They greatly improve the reconciliation efficiency of on-board ticket sales. Commuter rail systems, as an example, have a multitude of zones and fare categories. Stored fare tables can speed up ticket issuing and ensure greater fare accuracy. Other emerging applications are notebook-size or smaller devices for data transmission by cellular telephone technology.
- POP Systems. Although POP fare collection is much more common in Europe (i.e., on buses, as well as light rail and commuter rail) than in North America, most North American light rail and commuter rail systems use POP; the trend is definitely in this direction—all of the newer systems have opted for this approach. POP systems can be introduced with lower operating costs for fare collection, because the burden for fare payment is placed on the passenger. The nature of fare enforcement varies with each agency, because each develops its own strategy for optimal balance between the extent of inspection to be done and the catch rate (i.e., fare evaders caught as a percentage of persons inspected). With a POP system, a floating zone or station-to-station fare structure can be implemented at less cost than in a gated system.

Electronic Fare Payment Options and Trends

Most transit agencies have, until recently, limited their fare media options to cash, tokens, and paper tickets and transfers. The past few years, however, have seen increasing interest in electronic media and fare collection equipment. As indicated above, the basic electronic payment option is stored value (and the full range of prepayment options). A stored-value or prepaid fare card typically contains a dollar value but can also be trip-based (i.e., predetermined number of trips) or time-based (i.e., good for a specified period). A stored-value card provides the advantage—to both the rider and the agency—of permitting a range of fare options to be offered with a single fare medium. The stored-value card can be configured in a number of ways, although the basic alternatives are pre-encoded with a fixed amount or user-encoded with any amount desired. Cards can be programmed to include various types of purchase or usage-based bonus or discount, although the simplest approach is a bonus on purchase or adding value (e.g., when a rider buys a card for $20.00, he or she receives $21.00 worth of value on the card).

Advantages and Disadvantages of Electronic Media

The use of electronic fare media can have a significant impact on the development of fare policy and structures, as well as on an agency's general planning and operations functions. Although financially oriented goals such as improvements in revenue control often provide the fundamental impetus for consideration of technological enhancements, planning- and operations-related goals, including the ability to offer a wider range of fare options, are also key benefits. The types of benefits associated with electronic media include the following:

- Improved flexibility, in terms of the range of fare options that can be offered and the ability to modify the fare structure;
- Improved revenue accountability and security, in terms of improved ability to track transactions and discourage employee theft or mishandling of fare revenue;
- Reduced fare abuse, including counterfeiting of media and short payment or illegal reuse of media;
- Improved ridership data generated from fare payment;
- Reduced operator-rider interaction and administrative and operational requirements (i.e., related to the need for operators to sell and verify the validity of media [flash passes and transfers, in particular]);
- Improved convenience for riders, for both purchasing and using the media; and
- Ancillary revenue from unused value on stored-value cards.

Furthermore, electronic payment offers opportunities related to expanding the existing capabilities of the fare media themselves (e.g., through regional fare integration, multiple use cards, and post payment/employer billing applications). Of course, the complexities of these payment methods that produce many of the benefits also result in certain disadvantages and barriers; these include the following:

- High cost of equipment (and production of media, if smart cards are used);
- Greater lead time for implementation, because of an often lengthy procurement process, followed by the need to test equipment, modify and/or prepare stations or vehicles, and phase in introduction of system (depending on size and complexity);
- Possibly long "break-in" period, because of limited in-service testing of equipment and possible reliability problems with very new designs;
- Greater planning required for developing new fare structures, in light of the broad array of possibilities; new planning and modeling techniques are needed to understand riders' potential reactions to and usage of new fare options—and new media;
- Possible union resistance, given that a key benefit is reduced operating and maintenance costs — primarily through personnel reductions; and
- Privacy concerns on the part of riders; card users may not want the transit agency to be able to track their ridership patterns.

Comparison of Electronic Media Technologies

The major electronic transit fare media technologies are magnetic stripe and smart cards; smart cards can generally be classified as either contact or contactless. Magnetic stripe cards represent a proven media technology, used in transit applications for 30 years. Stored-value applications have been in place for nearly that long, and two of the oldest systems (i.e., BART and WMATA) are reasonably sophisticated, even by today's standards. Despite the long track record, however, the use of stored-value fare collection techniques has spread slowly among U.S. agencies. A number of heavy rail systems have magnetic swipe pass readers, but the use of stored-value technology is just beginning to accelerate—three of the largest U.S. rail systems (i.e., NYMTA, CTA, and MBTA) are installing and/or procuring new fare collection systems.

In contrast to rail equipment, magnetic bus card readers are a relatively recent innovation, having been introduced less than a decade ago; TPUs, capable of processing stored-value tickets, are even more recent. Magnetic stored-value systems are thus only now beginning to see appreciable growth in the U.S. transit industry. The reliability of the existing equipment remains to be proven, but as units are installed and used by more agencies and the manufacturers continue to make refinements, the industry is expected to embrace electronic payment on a wider scale.

Smart card has become a generic term describing a range of automated types of integrated circuit cards, with and without built-in microprocessors. For purposes of evaluating potential transit applications, the various card types can be divided into two basic categories—on the basis of whether or not the card has to be actually inserted into a reader slot. Contact cards must be inserted, although contactless cards must only be held close to—or, depending on the particular card technology—actually placed on—the reader-writer. Since their invention in France in the early 1970s, smart cards have seen very limited use in the United States. The technologies are just beginning to see serious development efforts here, particularly in the banking, telecommunications, and government sectors.

The use of smart cards in transit applications has received considerable attention over the past couple of years, and there are now more than 50 ongoing or planned tests of the various technologies around the world; several tests are underway or in development in the United States. The majority of these are or will be using contactless cards, which are considered well suited to transit primarily because of the interest in fast throughput and the potential for reduced equipment maintenance costs. On the other hand, most of those applications involving multiple use cards—often initiated by banks or other non-transit entities—employ contact cards.

On the basis of the review of the card technologies, the most important advantages of magnetic stripe technology over smart cards in general are the following:

- Magnetic tickets and cards are much less expensive: \$0.10 to \$0.60 versus \$4.00 to \$10.00 apiece for smart cards; the specific price in both cases depends on the specific characteristics of the card and the volume purchased.
- Magnetic technology is proven in both transit and general commercial applications (e.g., credit and debit cards); however, only read-only applications have been tested to any significant extent on buses; stored-value magnetic applications are just beginning to be implemented.

Smart cards in general offer the following advantages over magnetic stripe technology:

- Smart cards are more secure (i.e., more difficult to counterfeit).
- Smart cards have considerably greater data storage and logic capabilities, making them better suited to applications such as regional fare integration and multiple use.
- Smart cards tend to be more durable and reliable and thus should have a longer useful life than magnetic cards (largely because of the absence of a magnetic stripe that can wear out with repeated use).

Contactless cards are considered to offer certain advantages over both contact smart cards and magnetic cards:

- Contactless cards offer greater convenience to the rider in that they do not have to be inserted or swiped; this is felt to be especially important for the elderly or those riders with disabilities who may have trouble using another medium.
- Contactless cards allow faster boarding of buses; of course, systems that require the driver to issue a ticket in conjunction with the rider's use of the smart card provide no such advantage.
- Contactless cards offer the potential for lower maintenance costs because there is no physical contact with the turnstile or farebox and the read-write unit has no moving parts.

However, contactless cards suffer at the present time from the absence of standards, although standards are now being developed. Each product has a proprietary architecture, reducing the ability of an agency to competitively bid the production of media. In contrast, international standards and specifications have been established for contact cards, which are becoming increasingly widely used throughout much of the world (though outside of North America, thus far) in the commercial banking and telecommunications industries. Therefore, multiple use programs, which have most often been initiated by non-transportation entities, have typically introduced contact cards as their basic medium.

Thus, smart card use in transit is following two rather different paths at the present time:

- In smart card programs initiated by banks or other non-transit entities—and intended for use on transit and other uses—contact cards are more often selected.
- In smart card programs initiated by transit agencies—and generally intended for use on transit and perhaps other transportation uses — contactless cards are typically selected.

Because of the high unit cost of all types of smart cards, there is an advantage to the first scenario to agencies concerned about minimizing their fare collection costs. This must be weighed, however, against the strong preference the industry has displayed for contactless cards—as well as the reluctance an agency may have to yield control over a key aspect of its fare collection system. The emergence of public-private partnerships in the financing of transit smart card programs has now made the latter approach more economically feasible. Financial considerations are discussed below.

Financial Implications of Electronic Fare Payment

The capital costs associated with both electronic fare equipment and media are highly dependent on two factors: the processing capabilities and the quantity to be purchased. With regard to equipment (i.e., card readers-writers), the basic cost is tied to the specific capabilities and configuration, more than to the media technology. Of course, ongoing operating and maintenance costs are likely to be of greater ultimate concern to an agency than the one-time costs. These costs fall into three basic categories: production and distribution of fare media, equipment servicing and repair, and actual fare collection labor costs (e.g., fare inspectors or ticket agents and collectors).

Production and Distribution of Fare Media. The production costs are dependent on the characteristics of the specific medium, including size, thickness, and the nature of encoding (i.e., pre-encoding or not), as well as the technological basis (e.g., high- versus low-coercivity magnetic stripe versus smart card). At the present time, smart cards are much more expensive to produce than magnetic cards; the smart cards used in transit applications generally cost $4.00 to $10.00 apiece (depending on quantity, data capacity, and on-board processing capability), although the unit cost of a magnetic stripe card is less than $0.60. The prices of smart cards are declining relatively quickly, as increasing numbers of vendors enter the market and card usage expands; furthermore, the unit price is expected to be considerably lower ($3.00 or less) if purchased in large quantities. Moreover, smart cards are expected to be more reliable (in terms of failure rate) and have a longer useful life than magnetic cards; depending on how long smart cards are retained and reused, the life-cycle cost could become comparable to that of magnetic media.

In considering the durability issue, though, it is important to keep in mind that the cards must provide sufficient incentives (e.g., in the form of discounts or bonuses) for riders to hold onto them for an extended period. Such incentives are feasible for riders who use the card regularly. Occasional—and particularly one-time—riders will neither benefit from nor be interested in keeping a card for a long period of time. Thus, in order to maintain any reasonable cost-effectiveness in its fare collection system, an agency introducing smart cards will also need to provide a lower-cost fare option for these riders. A cost-effective approach may therefore be to offer smart cards only for riders interested in maintaining high stored values and magnetic cards—or perhaps tokens, paper tickets, or cash—for other riders.

The distribution costs related to a technological improvement will depend on the manner and locations at which the media are sold, as well as the nature of usage patterns (again related to length of retention of a card).

Equipment Servicing and Repair. Service and repair costs for new fare collection equipment are affected by two factors: 1) the reliability of the new equipment, compared to the equipment it is replacing; and 2) the complexity of the new equipment. The long-term reliability of the newer electronic fare collection equipment is unknown at this time, given the limited extent of in-service usage of both smart card readers and TPUs. It is expected that contactless smart card readers in particular should experience low maintenance costs, because of the elimination of both moving parts and direct contact between the card and the reader; the fact that there is no opening in the reader unit will also prevent the insertion of inappropriate materials. Evaluations of operational tests should shed some light on this issue. The second repair factor pertains to the complexity of the new equipment— does it require more frequent service or monitoring and perhaps more highly trained personnel? Several of those agencies reviewed in this study have indeed experienced—or are expecting—increased maintenance costs with the installation of new electronic fare collection equipment. Presumably, these costs should level off over time, as the agencies complete the necessary retraining or addition of new personnel.

Fare Collection Labor and Cost Savings. The third component of fare collection operating and maintenance cost is those personnel directly responsible for fare collection and processing activities. It is in this area that rail agencies in particular expect to realize significant savings through the introduction of electronic fare collection and the use of AVMs. In fact, reducing the number of fare collection and processing personnel is often cited as one of the key goals in making major technological improvements. Of course, the theoretical reductions must be tempered by the realities of labor agreements that restrict each agency's ability to eliminate positions.

Other Financial Benefits. Transit agencies often expect to generate additional fare revenues through the implementation of new fare technologies. The primary potential sources of these increases are expected to be 1) reduction of fare abuse and fraud and/or 2) increased ridership because of either improved rider convenience or marketing efforts supported by the new technologies. In some cases, though, a key source of increased revenue and ridership may actually be the improvements in revenue and ridership accounting resulting from the new equipment. Although quantifying the actual revenue impact of fare abuse reduction is difficult, an agency will certainly diminish the incidence of such abuse by introducing new equipment that makes it harder to avoid paying the full fare or using an invalid transfer. It is also difficult to identify the impact of fare technology improvements on ridership and revenue—and moreover, to separate the impact of the technology from that of any changes in the fare structure. This particularly applies to stored-value-based systems; new pricing options made possible by the new technology may significantly influence usage of the service. In general, technological improvements should result in at least a small increase in revenue. The more significant financial benefit of a technological improvement, however, will likely occur through the reduction in fare collection operating costs.

With regard to the financial benefits of smart card systems in particular, there are three potential sources (i.e., in addition to the potential maintenance cost reduction): 1) reduction in bus operating costs because of faster boarding times (from contactless cards only); 2) reduction in counterfeiting of fare media; and 3) improvement in the reliability of the technology. The extent to which these impacts will actually result in lower costs or additional revenues has yet to be demonstrated, because of the limited nature of in-service applications. The nature of the actual benefits, as well as an indication of the overall cost-effectiveness of smart cards as general-purpose fare media clearly needs to be determined and documented in a variety of operational tests. Cost-effectiveness will obviously improve as the media cost drops; in the meantime, smart card usage in the United States will likely occur within the following scenarios:

- Cards—and perhaps equipment—are financed by a joint public-private partnership, involving the system integrator or card supplier and the transit agency.
- Cards are provided by a bank or other entity as part of a multiple use system (this is discussed below).

- Cards are provided by the transit agency for specialized uses, such as for riders with disabilities.
- Cards and equipment are tested in limited trials and demonstrations of the technology or specific applications, perhaps funded by the federal government.

Electronic fare media in general offer considerable potential benefit to transit agencies and their riders. Smart cards will play a key role in the continuing evolution of these media; the nature of this role is still being defined.

Emerging Electronic Media Applications

There are several emerging developments in terms of expanded applications of electronic media, including the following:

- Regional fare integration—the ability to use a single farecard on multiple transit operators in a region; each participating agency can still function independently and set its own fares;
- Multiple use card program—an electronic farecard can function as an electronic purse, allowing small purchases for a variety of goods or services, including transit; and
- Post payment/employer billing—the capability to capture and store data on individual transactions for billing of actual trips and post payment.

The first two approaches are generally based on the prepaid stored value capabilities of electronic media, although the third takes advantage of the data storage and processing capabilities of the electronic fare technologies. None of the three are tied to a particular electronic media technology. Although experience is limited in all three applications, each development represents an expansion of the traditional fare payment model, in which a specific fare mechanism can be used only for direct payment for a trip on a particular transit service. Each shows promise for enhancing the efficiency and effectiveness of transit fare collection procedures.

Regional Fare Integration

Although many areas provide for some limited interoperator transfer mechanisms or other coordination, few have sought to develop seamless transit travel through a universal ticket or other type of regional fare integration. Developments in electronic media and equipment and the push for improved transit access prompted by clean air legislation requirements, however, have combined to promote recent integration efforts in several areas. The use of stored-value electronic fare methods, in a system supported by ridership and revenue allocation software and interagency agreements, has facilitated the creation of universal tickets that can be used on any participating system. Of course, such an arrangement requires installation of the necessary equipment by the individual agencies. These universal tickets enhance passenger convenience and increase travel opportunities, presumably leading to higher ridership on each system.

There are, however, several major barriers to implementing technology-based integration efforts effectively; the most serious of these is the cost of the new equipment, which must typically be borne by the individual agencies. There are also, however, institutional barriers associated with getting a diverse group of transit agencies to agree to particular technologies and equipment and a particular revenue distribution method. Existing integration efforts, such as those in San Francisco and Los Angeles, were reasonably successful at achieving the initial institutional elements. Cost and selection of common technology have, however, become key barriers to expansion in these efforts.

The concept of regional fare integration certainly has merit, as a means of making transit travel more attractive—both to people who have to use more than one operator's service and to those who would make greater use of transit in the region if it were more convenient. Although such integration can also conceivably be achieved through the establishment of uniform regional fare structure agreements, as in San Diego, this requires considerable authority on the part of a regional agency in being able to institute a single fare structure for all operators. This approach also suffers from the lack of a technologically based revenue apportionment methodology. Beyond the latter benefit, a key advantage of a universal stored-value ticket system is the ability of each agency in the region to retain its own fare structure and still offer seamless travel to the rider. The current projects, still in the early stages of development, indicate significant potential for the concept but also clearly point up the significant barriers and issues that must be addressed.

Multiple Use Card Program

As with the push for increased convenience in regional transit trip-making, the transit industry is beginning to consider the potential benefits associated with integrating fare payment with other types of purchases—in a single medium. Transit fare payment now occurs in a closed payment environment—fare media can be used only for transit travel. There is, however, a growing push for including transit usage in a more open environment such as that in which credit cards are used. There has been an increase in interest in prepayment in general in the financial and various retail and service sectors, as banks and other entities increasingly recognize the advantages of replacing cash payments for small purchases with prepaid stored-value mechanisms. (Ironically, this practice essentially started in the transit industry, with the introduction of stored value magnetic fare media at BART and WMATA.) This interest has led to the development of the electronic purse or multiple use media concept—i.e., prepaid cards that can be used to conduct transactions related to several different functions.

Application of this approach has taken hold around the world, although efforts in the United States have been slower to develop. Several transit-related projects (those being developed in New York City, Atlanta, and Wilmington, Delaware, are the most comprehensive) are planned for implementation in this country, and the results of these efforts will shed considerable light on the potential for—and barriers to—such arrangements. The two basic scenarios in which a transit agency might take part in a multiple use arrangement are as follows:

- The transit agency establishes and administers the program (directly or through a contractor or joint venture partner); the farecard is made available for use in parking lots, pay telephones, vending machines, and/or other functions. Where a joint venture or consortium is involved, there is likely to be some private financing, and the consortium might receive a fee for each transaction (i.e., each fare or other payment). This basic model has been demonstrated in Dublin, Ireland, and Manchester, England, and represents the basic approach being pursued in the NYMTA MetroCard program, as well as in Hong Kong and Sydney, Australia.
- Alternatively, a bank or other private entity might initiate and administer the program; in other words, the bank ATM/credit card or telephone prepaid card can be used for fare payment, as well as other functions. This is the approach in several existing projects in Europe (e.g., Biel, Switzerland, and throughout Denmark) and is under development in Atlanta and Wilmington. The acceptance of credit cards for fare payment in Phoenix represents a variation on this approach.

A key question to be answered in the coming years is, to what extent will transit agencies lead the way in introducing and administering multiple use programs? Very large agencies may realize benefits—through attracting new riders and collecting fees from participating vendors—from directly administering a multiple use card program. Furthermore, multiple use transportation applications (i.e., covering transit and parking) represent natural extensions for farecards and are already being tested by transit agencies in Washington, DC, and Ventura County, California; if successful, these and other efforts could conceivably be expanded to a broader multiple use focus. It would appear at this time, however, that most agencies that might take part in a multiple use arrangement are most likely to follow the latter model. This strategy offers the benefit of significantly reducing an agency's fare collection costs. If an agency is considering the use of smart cards in particular, this may be the best way it can be accomplished in a cost-effective manner.

Besides the administrative issues cited above, there are a number of regulatory, institutional, and operational issues that must be considered in establishing or deciding to participate in a multiple use program. The potential legal issues pertain to compliance with the requirements associated with open payment systems in general, including refunds and reimbursement of unused stored value, theft or loss of the card, or card and hardware failures; these have not yet been resolved with regard to prepaid and stored value cards in general. One of the principal operational issues to be addressed relates to the ability to offer purchase or use bonuses on farecards for transit use only (i.e., without passing the bonus on to other participating vendors who may have no interest in offering such a bonus). A second, related issue pertains to the use of transit vouchers to buy multiple use cards; because the farecard does not necessarily have to be used for transit, the employer could effectively be subsidizing retail purchases or telephone calls for some employees. Thus, some type of restriction would have to be introduced (e.g., vouchers could only be used to buy transit-only fare instruments). Although the multiple use concept certainly offers potential, the development and success of the current and planned efforts will be carefully watched by the transit, financial, and card technology industries.

Post Payment/Employer Billing System

The development of transactional data base capabilities, in conjunction with electronic fare collection equipment, has made it possible to introduce post payment or employer billing systems; in other words, payment is made after the trips have been taken. This is a very different approach for the transit industry. Unlike other types of purchases, which are routinely made with credit cards, transit trips have traditionally been paid for either at or before the time of use. However, the use of post payment was developed (in Phoenix) as a means for helping employers provide evidence of their employee trip reduction programs. The Phoenix BusCard Plus is a monthly pass, issued by employers to their employees; the employer is billed at the end of each month on the basis of the number of trips actually taken.

In Phoenix, there is a cap on the maximum amount that is billed for each employee; this is equal to the price of a regular prepaid monthly pass. A post payment arrangement, however, allows an agency to bill (an employer or an individual) for all trips taken, thereby avoiding loss of the revenue associated with trips above the pass breakeven level. Of course, there is a cost involved in generating and sending out invoices to employers or individuals, and the agency also forfeits the float normally gained from selling prepaid fare instruments.

Although Valley Metro in Phoenix developed its own post payment software, a transactional data base is now available commercially, as noted above. Several agencies have acquired—or plan to purchase—this system and have expressed interest in implementing a post payment program. As the push for implementation of documented trip reduction measures intensifies, more and more agencies are likely to pursue this approach as well.

Besides using its own medium for post payment, Valley Metro also recently became the first transit agency to accept commercially provided credit cards (MasterCard, VISA, American Express, and Discover) for direct fare payment. The agency adapted its data base software to allow for the processing of these cards, which are swiped through the same card readers used for the BusCard Plus and other magnetic stripe passes. The agency negotiated an arrangement with the local credit card clearinghouse that allows the "batching" of a week's worth of trips for each card; a lower than usual transaction fee was also negotiated, making the arrangement quite cost-effective for the transit agency. The program has apparently been well received by users, and the transit agency reports no problems to date. Although the program is still very new—and has received limited use to date—the basic approach appears to be feasible for the transit industry; as transit moves toward a more open payment system, the acceptance of credit cards would appear to represent an important concept.

Emerging Fare Media Purchase and Processing Methods

The major technology-related developments in fare media purchasing and back-end processing procedures relate to the use of the following two types of EFT methods:

- The use of credit and debit cards in AVMs and
- The use of ATMs for sale of fare media.

Transit agencies are increasingly purchasing AVMs that accept credit and debit cards. This capability has been available at several agencies for the last few years. Some agencies have decided that the transaction fees charged for credit card use do not make this option cost-effective; thus, these agencies accept debit cards but not credit cards. One of the key benefits of EFT is reduced cash handling costs; other potential benefits include quicker access to AVM revenues and improved revenue security for the agency, as well as enhanced convenience for the rider. Despite the increase in operating costs (i.e., transaction fees), the use of both credit and debit cards has been on the rise. It is felt that this trend will continue, especially as the number of POP fare systems grows and agencies increase their use of AVMs in general.

The other type of transit EFT application is the use of ATMs for sale of prepaid fare media. This approach serves to expand the availability of an agency's fare media. Several agencies have implemented ATM programs, although at the present time the research team knows of only one such arrangement: at Seattle Metro, with the Seafirst Bank. Seattle Metro's ATM program has been quite successful, and roughly 3,000 monthly passes are purchased in this fashion each month. Other ATM programs were at WMATA and Portland TRI-MET. Although the WMATA operational test was deemed a success, the program was shelved because of changes in bank ownership. The TRI-MET effort was discontinued for the same basic reason.

It is thus difficult to predict the potential for this concept. Although the approach has been found to work reasonably well, the potential is highly dependent on the specific attitudes and policies of particular banks and thus varies from place to place. The interest of a bank in such an arrangement may also reflect the nature of the fare media to be dispensed. For instance, the Cash Station ATM network in Chicago has expressed considerable interest in selling CTA's new stored value farecard. Finally, it is also possible that the ultimate expansion of this general strategy—i.e., making fare media available through an open system—will be tied to a large extent to the interest shown by banks in multiple use arrangements. In general, as transit fare payment and media purchase technologies become more sophisticated, they will likely become increasingly linked to open payment systems—through the efforts of both the transit and banking industries.

OVERALL CONCLUSIONS

Impacts of Technology on Operations and Development of Fare Policy and Structure

Whereas decisions regarding fare policy and structure have traditionally been made independent of technology decisions, advances in the capabilities of the technologies have increased the interrelationships among these areas. Electronic fare media significantly improve a transit agency's ability to target different market segments; these technologies also offer benefits in terms of improvements in operations and planning, as well as the potential for increasing revenues and reducing fare collection costs. Although experience with these technologies is limited to date, a range of potential impacts can be identified; these are discussed below.

Greater Flexibility in Fare Policy and Structure Development and Improved Operations Planning

Electronic fare payment provides the ability to offer a wide range of fare options and to easily modify the fare structure; for instance, electronic stored-value media permit differentiation of fares by payment option (e.g., time-based, trip-based, and/or value-based), time of day, mode, nature of minimum purchase price, and discount or bonus offered. A key benefit is the ability to offer a range of fare options with a single fare medium.

Electronic fare payment allows the collection of more accurate and comprehensive ridership data (by fare category); this can permit better analysis and forecasting of fare changes, as well as improved understanding of ridership patterns by route and time period—and thus better service planning.

Improved Transit Operations

The use of electronic fare payment can considerably reduce bus operators' fare collection responsibilities, thereby minimizing potential operator-rider conflicts (i.e., regarding pass or transfer validity). The reduction in the need for operators to handle and inspect transfers or flash passes can have the effect of reducing dwell time and thus improving service reliability.

Electronic fare options provide the convenience of prepaid passes for riders who may not be able to afford a monthly pass; besides removing the need to carry exact change, stored value options effectively eliminate the need to know the specific fare for every trip.

Increased Revenue and Reduced Operating and Maintenance Costs

The use of electronic media facilitate the generation of increased revenues through reduction in fare evasion and abuse; as well as through better revenue control.

Agencies can receive considerable revenue from unused value on stored-value cards; the agency benefits from the "float" associated with prepayment in general, as well as the remaining value on cards never actually used for purchasing trips.

Electronic payment also offers opportunities related to expanding the existing capabilities of the fare media themselves (e.g., through regional fare integration, multiple use cards, and post payment/employer billing applications).

The use of electronic payment—and distribution—technologies may result in net fare collection cost savings. Although the maintenance and repair costs for new equipment can be expected to rise (at least initially), because of the need for more highly trained personnel, agencies generally expect to realize a net decrease in fare collection costs through introducing such systems—because of reductions in the numbers of overall fare collection staff (particularly ticket agents and clerks and revenue processing personnel) needed.

Thus, electronic fare payment technologies offer considerable promise in furthering many policy goals.

General Trends in Fare Policy, Structure, and Technology

Transit agencies have, over the years, employed a broad range of fare structure and payment options; on the basis of the review of the policy development patterns of recent years, several general industrywide trends can be noted as the world moves toward the next millennium. Although the changes in the policy and structure area have been relatively subtle, however, the technology area has seen major changes during the same period. There has been considerable advancement in the design and capabilities of fare payment media and equipment in recent years, and advancements are continuing at a rapid pace. Many transit agencies are evaluating the available options, although others are taking a wait-and-see attitude—until the emerging technologies have been thoroughly tested and their benefits documented. Given the pace of technological change, coupled with the questions concerning future public funding, it is difficult to predict with any certainty what will happen in the coming years in this area. On the basis of the research conducted in this study, however, certain likely trends can be identified. The key trends in the United States in the coming years related to the development and selection and adoption of fare policy, structure, and technology options are summarized below.

Continued Focus on Ease of Use and Market-Based Pricing

Concerns over keeping fare structures simple and easy to use are largely driving the selection of fare strategies, maintaining the predominance of flat fare structures over fares differentiated by distance, time of day, or type of service. This trend is expected to continue in the coming years.

At the same time, agencies are paying increasing attention to the potential to effectively target different market segments through prepaid market-based pricing strategies; many agencies are thus increasing the numbers of fare option choices for riders; in this vein, pricing is increasingly being viewed as an important aspect of an overall marketing program.

The expanded adoption of electronic stored-value fare payment technologies will increase the use of prepaid market-based options as growing numbers of agencies recognize the benefits of offering a range of fare options with a single payment medium.

Expanded Use of Electronic Fare Collection Equipment and Stored-Value Options

The use of electronic fare collection equipment in general has grown significantly over the past several years and should expand at an even greater rate in the next few years (as budgets allow). For bus operators, the desire for improved data collection and revenue security will lead many agencies to install ERFs, and many agencies will also acquire magnetic swipe readers, to read passes, or TPUs, in order to automate transfer issuance and acceptance and accept stored-value cards.

Many agencies will also likely take advantage of the transactional data base capabilities of the new fareboxes and implement billing/post payment programs in order to allow employers to document trip reduction efforts.

Most, if not all, heavy rail systems will eventually introduce electronic stored-value media, on both rail and bus. The use of stored-value media will increase at bus-only agencies as well, particularly those agencies participating in regional integrated fare programs. Regional fare integration efforts will increase, because of the growing emphasis on seamless transportation coupled with recognition of the capabilities of electronic payment systems to facilitate such integration on a single ticket.

Influence of Developments in the Banking Industry and Development of Public-Private Partnerships

Transit fare payment developments will increasingly intersect with developments in the banking industry, as there will be increasing use of 1) EFT methods for purchase of fare media (e.g., credit and debit card payments in AVMs, as well as sale of fare media through ATMs) and 2) use of credit cards for direct payment of fares.

Developments in the banking industry—and other sectors, such as communications and retail—will also influence the selection of particular fare payment technologies by transit agencies. As these industries begin to adopt the prepaid stored value (or electronic purse) concept as a replacement for use of cash in small purchases, there will be an increase in opportunities for transit agencies to participate in multiple use arrangements. Such arrangements can take various institutional forms, one of which is for the transit agency to accept the multiple use card issued by the bank (or other private entity) as a fare medium. The medium in such programs, at least within the foreseeable future, will likely be the contact smart card, for which the commercial banking industry is developing international standards.

The most likely alternative multiple use arrangement is for the transit agency to initiate and administer the program (most likely in partnership with a private company as part of a public-private joint venture) and enlist other entities (e.g., retail outlets, vending machine operators, and parking lots) to accept the farecard for payment. This represents a means of potentially reducing the transit agency's fare collection costs, as system vendors are, in several current programs, helping to finance the fare equipment and media in return for collecting transaction fees (on fares and other payments using the card). Because such programs are not directly tied to the banking system, the medium could conceivably be any technology, although indications are that it will be some type of smart card.

Expanded Testing and Use of Electronic Fare Media

Regarding the trends for specific fare media technology, magnetic stripe cards and tickets are seeing increasing use, both as passes used in a read-only mode and as stored-value media; the two largest rail systems in the United States are installing magnetic AFC systems, and a growing number of bus operators are installing magnetic readers and processing units, as mentioned above. As more agencies acquire such equipment, the use of magnetic cards will expand considerably, especially on buses.

The data and logic capabilities of smart cards have made them the general technology of choice in both multiple use programs and regional fare integration efforts. Smart cards are also receiving increasing consideration by the transit industry in general. Cards are now being tested by agencies throughout the world, including several in the United States. At this point, the transit industry is generally more interested in contactless smart cards than in contact cards. This has produced dual paths for transit smart card use: contactless cards are more often the medium of choice in programs initiated by the transit agency (and perhaps restricted to transportation applications), while contact cards are typically employed in multiple use arrangements that include banking networks. Until one technology is demonstrated to be clearly superior for use in transit—from a technical and/or an economic viewpoint—it appears likely that this trend will continue; eventually, a combined contact-contactless card may well become prevalent in multiple use programs.

Regardless of the specific smart card technology adopted, the economics of providing the cards will be a key concern to transit agencies until such time that the price of the cards drops considerably and/or the cards are clearly demonstrated (through large-scale testing and independent evaluation) to represent a cost-effective alternative to the currently lower-priced magnetic stripe cards. Smart card prices will come down as usage spreads and the cards are produced in much greater volume. Moreover, serveral feasibility studies have concluded that smart cards are already more cost-effective than other options because of their durability, reliability, security, and data capacity advantages. Nevertheless, at least in the near term, smart card usage by most transit agencies will likely follow one (or a combination) of the following scenarios: 1) the cards are provided at no charge or at a substantial discount by an outside party (i.e., a bank or a card supplier, as part of a multiple use program, or the federal government, perhaps as part of a demonstration); 2) cards are provided only for specialized uses (e.g., the elderly and those with disabilities, or perhaps agency maintenance personnel); or 3) cards are issued only to high-frequency users (i.e., who will keep a single card for a long period of time) or are sold with high minimum purchase prices. Even in the first scenario, it is unlikely that smart cards would be intended to be the sole fare medium; thus, at least for the foreseeable future, smart cards are likely to be offered along with less expensive media (e.g., magnetic stripe cards, tokens, or paper tickets) that remain available for occasional riders or riders unable to afford the smart card purchase price.

CONCLUDING REMARKS

In summary, as transit agencies face ever tighter budgetary constraints, their decisions regarding fare policy, structure, and technology become increasingly important. Most agencies will be required to generate greater revenues from fares while seeking to avoid ridership loss. This will place increasing pressure on fare structure development, including greater attention to the targeting of individual rider markets, and should also be accompanied by renewed efforts to reduce the loss of fare revenues through fare abuse and evasion. Fortunately, technological advances in fare collection and distribution have served to improve agencies' abilities to address both of these areas. On the other hand, the rate of change in the development of these technologies—coupled with a general lack of widespread operational testing—has made the selection of a new technology a difficult task.

This study has sought to compile and present information designed to assist agencies in decision making related to both fare structure development and the choice of an appropriate fare collection approach. It is hoped that the report, if not providing all of the answers, has at least identified the right questions to be considered in making these decisions.

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