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## **Evaluating the Costs and Benefits of Transit Smart Cards**

**Hiroyuki Iseki, Alexander Demisch,  
Brian D. Taylor, Allison C. Yoh**

**California PATH Research Report  
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# **Evaluating the Costs and Benefits of Transit Smart Cards**

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## **Abstract**

Smart cards are gaining momentum as transit agencies across the country have been implementing them as a fare medium. Smart cards hold the promise of revolutionizing the way riders use transit, and how transit systems operate. But in order to adopt smart cards, transit agencies must purchase new equipment and upgrade their entire fare collection system – a very expensive process. In addition, many of the oft-touted benefits of smart cards are vague, and it is not at all certain if they are worth the high cost of implementation.

This study examines how transportation agencies in three metropolitan areas evaluated smart card systems – the only three major transit smart card cost/benefit analysis studies that we found in the U.S. by the date of data collection. In addition to these three studies, we also reviewed other less extensive analyses that only partially address issues associated with the implementation of smart card technologies as transit fare media. In reviewing documents from these analyses, combined with information collected in the previous steps of the research, we found that the analyses are neither consistent with one another nor definitive to provide any systematic evaluation of costs and benefits of smart card deployment. These shortcomings are mainly due to: (1) difficulty of estimating many of the qualitative benefits, such as convenience for transfers and comprehensive regional travel data, (2) a significant variation in quantitative cost estimates among the analyses for unclear reasons, and (3) difficulty in generalizing costs and benefits among cases with the unique organizational structures and particular political issues in different regions.

Given a lack of solid information available in the literature, we drew on the relevant studies available to identify the cost and benefit items of smart card media and systems and examine the level of reliability and certainty of information for these items. Then we developed a framework on how a proper transit smart card cost/benefit analysis ought to be conducted. With this proposed framework, we found that individual transit operators and multiple agencies bear the majority of the deployment costs, while transit users and individual operators enjoy most of the smart card benefits. The proposed framework sheds light for more comprehensive cost/benefit analysis to evaluate smart card transit fare systems in the current status of knowledge.

**Key Words:** Smart cards; Transit fare media; Costs and benefits



## Executive Summary

Smart cards are gaining momentum as transit agencies across the country have been implementing them as a fare medium. Smart cards hold the promise of revolutionizing the way riders use transit, and how transit systems operate. But in order to adopt smart cards, transit agencies must purchase new equipment and upgrade their entire fare collection system – a very expensive process. In addition, many of the oft-touted benefits of smart cards are vague, and it is not at all certain if they are worth the high cost of implementation.

This study examines how transportation agencies in three metropolitan areas evaluated smart card systems: the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area, the Los Angeles County Metropolitan Transportation Authority (LA Metro) in Los Angeles, and the Southeastern Pennsylvania Transportation Authority (SEPTA) in the greater Philadelphia area – the only three major transit smart card cost/benefit analysis studies that we found in the U.S. by the date of data collection. These three cases represent two regional interoperable systems and one stand alone system. In reviewing documents obtained in these three cases, combined with information collected in the previous steps of the research (the survey of U.S. transit agencies and the interviews with transit agencies officials for the adoption of smart card fare systems), we found that while these public transportation agencies have made their best efforts to estimate smart card costs and benefits, these studies are neither consistent with one another nor definitive. These shortcomings are due to a lack of consensus regarding the costs and benefits of applications of smart card systems.

While they are the best sources of information available, none of the three studies are based on rigorous, complete, or consistent applications of accepted cost/benefit methodologies. We also reviewed other less extensive analyses that only partially address issues associated with the implementation of smart card technologies as transit fare media; these studies tend to focus on technical feasibility, technological capability, and reduction in boarding time, and do not provide complete information to evaluate smart card deployment. While some useful information on smart card deployment can be gleaned from the studies reviewed for this report, we would not characterize any of the studies reviewed as careful, evenhanded cost/benefit analyses of smart cards. Collectively, however, they do offer some insights on the array of costs and benefits to be considered and, to a lesser extent, the general scale of some of the principal costs and benefits.

Given a lack of solid information available in the literature, we draw on the three best cost/benefit studies available to develop a framework on how a proper transit smart card cost/benefit analysis ought to be conducted. That is, lacking sufficient evidence in the research literature on the costs and benefits of smartcard implementation, we use the existing analyses to identify the cost and benefit items of smart card media and systems and to examine the level of reliability and certainty of information for these items.

This proposed evaluation framework is the principal contribution of this work. In it we categorize smart card costs and benefits into three categories: (1) items that have been assessed quantitatively, (2) items frequently identified and likely to be incurred, and (3) items alluded to but with little certainty. We further organize these items in terms of who would likely incur the





costs and enjoy the benefits: (1) transit users, (2) individual transit operators, and/or (3) multiple transit agencies.<sup>1</sup> The proposed framework sheds light for more comprehensive cost/benefit analysis to evaluate smart card transit fare systems in the current status of knowledge.

In our examination of the cost/benefit factors, we determined that individual transit operators and multiple agencies bear the majority of the deployment costs, while transit users and individual operators enjoy most of the smart card benefits. While some items are common across the three analyses, each study estimated different costs and benefits. All three studies estimated the additional cost associated with implementing the smart card, and the LA Metro and SEPTA studies broke these down into capital and operating costs over a lifecycle. Yet these cost estimates were all quite different from one another, due largely to the differences in each region. MTC is the regional funding agency for most of the transit operators in the Bay Area, and operates no service directly. The MTC study estimated costs for four transit operators among six agencies that participated in the pilot program, and those costs varied greatly due to differences in size and mode. LA Metro funds most public transit operators in Los Angeles County, and is in addition the largest operator in the County. Their cost estimates are only for their own operation, but they include some regional inter-operator costs. Finally, SEPTA is the only public transit agency in the Philadelphia region, operating many modes and bearing all of the costs.

All three studies also considered harder-to-quantify smart card costs, mostly related to the risks and uncertainties of adopting a new technology. Unforeseen technical problems were a concern, but in the areas with multiple operators (the Bay Area and Los Angeles), political issues arose as well. In the Bay Area, for example, some smaller operators were unwilling to relinquish control to larger entities, while the many smaller municipal operators in Los Angeles feared a reallocation of their funding by the much larger LA Metro.

The idea of seamless travel and convenience for users was a commonly-touted benefit, as was the centralization of fare and data collection. LA Metro measured time savings as a result of faster, more reliable, fare transactions. The ability of the smart card to store a flexible fare structure, one that changes by mode and time of day, was counted as a benefit in all three areas. Other benefits, though, were not so clear. Each of the three government entities assumed that they could configure smart cards to be used in many non-transit agency applications. While such opportunities surely exist, partnerships must first be negotiated and formed, and the stakeholders in regions like the Bay Area have many political hurdles to overcome. Furthermore, the widely expected operational efficiency benefits to transit operators are directly proportional to the take-up rates of smart cards, which remain far from certain. Finally, it appears that regional agencies, which often lead multi-operator smart card adoption efforts, do not have much to gain from smart card systems beyond the improved travel behavior data they can provide.

How each of the three entities estimated costs and benefits is also quite different from one another. SEPTA and LA Metro compared smart cards to other alternatives using a set of evaluation criteria, while the MTC simply estimated the additional cost of adopting the smart card through a pilot program involving only six operators. SEPTA performed a thorough analysis of financial costs, but did little to evaluate some of the more qualitative benefits. In the

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<sup>1</sup> Some items, such as more accurate travel data, benefit not only individual transit operators but also all transit agencies in a region. We included this category to account for these far-reaching costs and benefits.



end, they recommended a hybrid system of smart cards and magnetic strips. LA Metro evaluated financial costs, but not to the degree of SEPTA. LA Metro did, however, attempt to quantitatively evaluate the qualitative benefits of smart cards using a “0-4” rank-order scheme, but did not clearly identify the criteria used to implement it.

Currently, MTC and LA Metro are gradually implementing smart cards in their regions, and are forming the regional partnerships necessary for inter-operable systems. SEPTA, however, has not followed its evaluation with implementation, largely because of funding shortfalls.

The potential benefits of smart card systems are widely expected to exceed the costs, yet very few public agencies have conducted a cost/benefit analysis of smart card implementation for public transit, and in no cases have such analyses risen to the widely accepted standards for rigorous analysis. In nearly all cases reviewed, smart card implementation has not been based on any systematic evaluation of costs and benefits. While this is partially due to the difficulty of estimating many of the qualitative benefits (such as convenience for transfers and comprehensive regional travel data), even quantitative cost estimates varied significantly among the three entities for unclear reasons. In addition, the organizational structures and political issues in each region are unique, making it difficult to generalize costs and benefits of smart card systems.



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# 1. Introduction

The use of smart cards as transit fare media is growing in many countries in the world, often with large degrees of user acceptance and broad ranges of applications. In Japan, over 20 million “Suica” and “Icoca” smart cards have been sold as fare payment media on regional transit systems in the Tokyo and Kansai metropolitan areas as well as the Sendai and Niigata prefectures. Suica and Icoca cardholders use their smart cards not just to pay for train and bus fares, but to shop at participating private sector stores as well.<sup>2</sup> Similarly, in Hong Kong, the number of daily “Octopus” smart card transactions is over 7 million, exceeding the population of 6.75 million. People use the “Octopus” card to pay for transit, parking, public telephones, and retail purchases, and “Octopus” transactions add about USD \$6.12 million to the economy every day.<sup>3</sup> In London, over 6 million “Oyster” smart cards were in use as of May 2006, and plans are underway to expand the network to include more regional rail systems throughout the country, as well as additional applications such as payment for parking.<sup>4</sup> Within the United States, smart card systems are up and running in Washington D.C., New York, Chicago, Boston, Atlanta, San Francisco, Los Angeles, Ventura County, among others.<sup>5</sup> However, many of these domestic smart card systems are nowhere near as advanced as their international counterparts, and the rates of user acceptance, implementation, and range of applications are limited.

Smart card systems have the potential to implement far more sophisticated and seamless ways to price transit services, and to make it easier to transfer between transit lines, modes, and systems, either as a stand-alone system within one agency or an interoperable system among multiple transit agencies. However, smart card systems are complex and required equipment like card readers and computers are expensive to install on transit vehicles and in stations. Are their potential benefits worth their very real costs? This report attempts to answer this question. Transit agencies in the U.S. must currently be assuming that the benefits outweigh the costs, or else they would not be paying the high cost of implementation. However, our previous review of existing literature revealed that there is a dearth of objective evaluations of smart card systems in the United States. This suggests that agencies are basing their decisions on other information, perhaps the promotional material generated by the smart card industry or successful examples of implementation abroad. This lack of information is a problem, as transit agencies’ lack of analysis may be causing them to make unwise investments in smart card systems.

In this study, we attempt to clarify current information about the costs and benefits of smart card systems, and to offer a framework on how a proper transit smart card cost/benefit analysis ought to be conducted. To do so, we examine three cases of how transportation agencies in three metropolitan areas evaluated smart card systems: the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area, the Los Angeles County Metropolitan Transportation Authority (LA Metro) in Los Angeles, and the Southeastern Pennsylvania Transportation Authority (SEPTA) in the greater Philadelphia area. While these reports are by no means comprehensive or based on accepted cost/benefit methodologies, they do offer insights on the

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<sup>2</sup> <http://www.jreast.co.jp/suica-info/index.html>

<sup>3</sup> <http://www.geocities.com/hal9000report/hal56.html>

<sup>4</sup> <http://news.independent.co.uk/uk/transport/article363627.ece>

<sup>5</sup> <http://www.smartcardalliance.org/pages/smart-cards-applications-transportation>



array of costs and benefits to be considered and, to a lesser extent, the general scale of some of the principal costs and benefits.

From these studies, we identify costs, benefits, problems, concerns, and issues that will have an effect on designing a smart card system. To do so, we examined available information and synthesized the information from the three cases (MTC, LA Metro, and SEPTA—two interoperable systems and one stand-alone system), which were identified in the previous steps of the research: the survey of U.S. transit agencies (Iseki, Yoh, and Taylor 2006, 2007) and the interviews with transit agencies officials for the adoption of smart card fare systems (Yoh, Iseki, and Taylor 2008). To organize the information, we categorized program stakeholders (parties that receive benefits or incur costs) into three groups: 1) existing and potential transit users, 2) individual transit operators, and 3) groups of transit agencies, regional planning organizations, and state agencies. For example, if the smart card program contributes to an increase in ridership and transit service, it can help reduce traffic congestion, improve air quality and improve accessibility. We also classified the information by the degree of clarity of each cost or benefit item in the study reviewed.

Wherever we could collect sufficient information from existing sources, we attempted to *quantitatively* estimate costs. However, our efforts in this regard were considerably hampered because of the early stage of implementation of many systems in the United States, which greatly limits available evaluation data. The costs considered include 1) capital costs associated with the hardware & software necessary for an electronic fare system, 2) operating & maintenance costs for upkeep, 3) staff training costs, and 4) political, institutional, and social costs that have not typically been considered in other research. To gather information for the last item, we carefully examined information obtained through interviews of managers and planners at affected transit operators and regional transportation authorities.

In addition, we identified to the extent possible, the benefits to be realized when smart cards are deployed either as a stand-alone system or through multiple agencies as an intermodal and interoperable program. The task of clearly identifying and quantifying costs and benefits associated with smart card programs is important since the expected benefits for smart card fare systems are expected to exceed the costs of implementation.

While we expected to find that regional transit smart card systems increase revenues, reduce fare collection costs and establish a strong institutionalized precedence for other inter-agency, inter-governmental transit collaborations, we could neither confirm nor reject this hypothesis. This was primarily because: 1) the level of costs and benefits were found to vary significantly depending on transit systems operating characteristics, and 2) some often-touted benefits such as customer convenience are very difficult to quantify, particularly in early stages of implementation. This implies that decisions to employ the smart card technology in transit service in the cases examined here were not based on a careful balancing of expected benefits and costs. Rather, the decision to implement smart card systems is due more to a rush to modernize transit service and not on a firm business return on investment basis. Regional agencies have been making collaborative efforts with individual operators to coordinate operations and fares, often providing operators with financial incentives to join regional partnerships, based on the expectation of significant net benefits resulting from the

implementation of smart card technology. However, it is still unclear whether the benefits of smart card systems outweigh the costs.

## 2. Costs and Benefits of Smart Card Transit Fare Media

Our analysis of three case study areas – the San Francisco Bay Area, Los Angeles, and Southeastern Pennsylvania – shows that there is a wide variety of perceived costs and benefits for smart card payment systems. To further assist our understanding of the issues of smart card system deployments, we organized these costs and benefits in the following way:

- First, the information is grouped into three different categories of stakeholders (beneficiaries or parties that receive costs) of the program—namely:
  - Existing and potential transit users,
  - Individual transit operators, and
  - Multiple transit operators and regional agencies (in the case of inter-agency smart card systems)
- Second, the information is also organized in three different categories in terms of the level of information available for each cost and benefit item:
  - Items that can be quantified or monetized based on some studies,
  - Items that are frequently mentioned and have credibility, but cannot be quantified due to a lack of information, and
  - Items that are mentioned by the literature, reports, or people, but lack credibility.

Tables 1 and 2 are a model of our organizational methodology, and show the types of items we expect in each category (not necessarily what was found):

**Table 1 Costs of Smart Cards (Conceptual)**

	<b>A. Costs that have been assessed quantitatively</b>	<b>B. Costs frequently mentioned, likely incurred, but which have not been carefully quantified</b>	<b>C. Costs sometimes mentioned, but which are speculative or treated with considerable uncertainty</b>
<b>Existing and Potential Transit Users</b>	Cost of the smart card	Time needed to learn new system	Uncertainty regarding adopting a new technology
<b>Individual Transit Operators</b>	Capital & operating costs incurred by transit operators	Qualitative costs	Uncertainty regarding implementing a new technology
<b>Multiple Transit Operators and Regional Agencies</b>	Costs incurred due to inter-agency coordination and management, and clearing house efforts	Qualitative costs & political issues arising due to inter-agency coordination	Uncertain issues arising due to inter-agency coordination

**Table 2 Benefits of Smart Cards (Conceptual)**

	<b>A. Benefits that have been assessed quantitatively</b>	<b>B. Benefits frequently mentioned, likely incurred, but which have not been carefully quantified</b>	<b>C. Benefits sometimes mentioned, but which are speculative or treated with considerable uncertainty</b>
<b>Existing and Potential Transit Users</b>	Time savings	Convenience	Convenience in the use of smart cards for other purposes
<b>Individual Transit Operators</b>	Operational cost savings	More reliable fare media	Spillover benefits to individual transit system
<b>Multiple Transit Operators and Regional Agencies</b>	Increase in regional mobility	Better data collection	Operational and policy issues improved by the employment of smart cards

Responsible parties in each region have taken different approaches to analyze the costs and benefits of the use of smart cards as transit fare media. None of these cases appear to suggest that a thorough cost-benefit analysis has driven their decision in choosing to adopt smart card systems. In the San Francisco Bay Area (Bay Area) study, the Metropolitan Transportation Commission (MTC) mainly focuses on cost savings from the implementation of smart card systems. In the Los Angeles case, the Los Angeles Metropolitan Transportation Authority (LA Metro) compares smart card systems against four other alternatives and shows why smart card systems will bring about the most benefits for its costs. The LA Metro case evaluates costs quantitatively, while it treats benefits only qualitatively. Finally, Southeastern Pennsylvania Transportation Authority (SEPTA) also compares the smart-card-only option against four alternatives, but does not conclude that the smart-card-only option is the best option. The SEPTA study only considers the costs of implementation and operation as evaluation criteria, and chooses a smart card/magnetic strip hybrid as the best choice.

## 2-1. Costs

Tables 3 and 4 show the costs of Smart Cards we gathered from the three case study areas.<sup>6</sup>

The Bay Area’s TransLink program is the only system of the three reviewed here that was anticipated to charge users for the smart card. Although the cost of the smart card is only \$5.00,<sup>7</sup> it is still perceived as a barrier given the relatively low average incomes of transit users, and was expected to discourage some people from adopting the new fare media.

In addition, replacing current fare media with smart cards would create an extra burden to users by forcing them to use a new fare medium. The smart card was expected to provide added benefits (i.e. discounts) to frequent transit riders, though casual users could be hurt if a cash fare

<sup>6</sup> In this section, capital & operating cost estimates are normalized to 2006 dollars for the purpose of comparison.

<sup>7</sup> <http://www.translink.org>

option is not kept. Also, if purchasing a smart card requires the user to divulge personal information, such as an address and credit card number, it is likely such a policy will prevent undocumented immigrants from using the smart cards (Yoh et al. 2006). Although these social costs are difficult to quantify, they should at the very least be considered transit agencies develop policies associated with the smart card, since these policies affect not only transit operators but also people who use transit service.

**Table 3 Costs of Smart Cards (Part I)**

	<b>A. Costs that have been assessed quantitatively</b>	<b>B. Costs frequently mentioned, likely incurred, but which have not been carefully quantified</b>	<b>C. Costs sometimes mentioned, but which are speculative or treated with considerable uncertainty</b>
<b>Existing and Potential Transit Users</b>	<ul style="list-style-type: none"> <li>• Users must purchase cards for \$5 (BA)</li> </ul>	<ul style="list-style-type: none"> <li>• Existing fare media may be cancelled, and users must learn to use a new system (BA, LA, S)</li> <li>• Users may have to provide identification and personal information to use smart cards</li> </ul>	
<b>Individual Transit Operators</b>	<ul style="list-style-type: none"> <li>• Capital Costs – Buy/Upgrade equipment and infrastructure                LA: \$35.5 million per 1,000 peak vehicles                S: \$47.8 million per 1,000 peak vehicles</li> <li>• Lifetime Operations &amp; Maintenance                LA: \$99.4 million per 1,000 peak vehicles                S: \$492 million per 1,000 peak vehicles</li> <li>• Training staff to use new technology                BA: \$629,000<sup>8</sup> per 1,000 peak vehicles</li> <li>• Additional operating costs to be borne by agencies:                BA: \$4.3 million per 1,000 peak vehicles</li> </ul>	<ul style="list-style-type: none"> <li>• Relinquishing control of fare structures, policies, and collection to a regional organization<sup>9</sup> (BA)</li> </ul>	<ul style="list-style-type: none"> <li>• Uncertainty of how smart card readers will hold up in more unprotected environments, e.g. parking lots (S)</li> <li>• More accurate ridership data may change allocation of regional funds – individual operators could receive less funds (LA)</li> </ul>

[LA: LAMTA or LA Metro, S: SEPTA, BA: The San Francisco Bay Area]

<sup>8</sup> All figures for the San Francisco Bay Area case study are derived from a pilot program only including four agencies: San Francisco Municipal Transportation Agency, Golden Gate Bridge Highway & Transportation District, CalTrain, and the Santa Clara Valley Transportation Authority.

<sup>9</sup> In the LA Metro case, individual operators decided not to cede control of their fare structures.

**Table 4 Costs of Smart Cards (Part II)**

	<b>A. Costs that have been assessed quantitatively</b>	<b>B. Costs frequently mentioned, likely incurred, but which have not been carefully quantified</b>	<b>C. Costs sometimes mentioned, but which are speculative or treated with considerable uncertainty</b>
<b>Multiple Transit Operators and Regional Agencies</b>	<ul style="list-style-type: none"> <li>• Outsourced clearinghouse functions - \$8 million annually in MTA case (LA)</li> </ul>	<ul style="list-style-type: none"> <li>• Shared operating costs - clearinghouse, marketing &amp; distribution (BA, LA)</li> <li>• Unforeseen technical problems may delay system implementation, increasing capital costs (BA)</li> <li>• Opportunity cost of adopting other technologies (BA, LA)</li> <li>• Path dependence; being “held hostage” to future change orders and contract renewals (BA)</li> <li>• Institutional barriers may delay system implementation, increasing capital costs (BA)</li> </ul>	

[LA: LAMTA or LA Metro, S: SEPTA, BA: The San Francisco Bay Area]

In all three studies, agencies estimated some additional expenses and costs incurred by individual transit operators. These can be broken down into capital, operating, and additional costs.

*Capital Costs:* Because the Bay Area information is derived from a pilot program involving only four of the 23 operators in the region, the results may not be necessarily representative of what would occur in a region-wide implementation. The MTC estimates an additional \$2.0 million (in 2006 dollars) cost incurred by the four agencies in several areas to implement smart card systems, including preventative maintenance, replacement due to vandalism, and marketing (Nancy Whelan Consulting 2002).<sup>10</sup>

Since the LA Metro and SEPTA analyses were for implementing new systems, they both estimate capital and operating costs. LA Metro estimates a capital cost of \$35.5 million per one thousand peak vehicles (Booz Allen & Hamilton 2001), and SEPTA estimates a capital cost of \$47.8 million per one thousand peak vehicles (PB Team & LTK Engineering Services 2000). All approximated costs for LA Metro (capital or otherwise) are only for those vehicles operated by LA Metro itself, and does *not* include any of the other transit operators that serve Los Angeles County such as the Culver City Bus or Santa Monica's Big Blue Bus. SEPTA, on the other hand, operates all transit vehicles in the region. Despite this, LA Metro's capital costs are still lower than SEPTA's costs.

*Operating Costs:* LA Metro's estimated operating cost is \$99.4 million per one thousand peak vehicles (Booz Allen & Hamilton 2001), whereas SEPTA estimates a cost of \$492 million per one thousand peak vehicles (PB Team & LTK Engineering Services 2000). The difference in operating costs is substantial, but may be due to the ways they each calculated operating costs. LA Metro's report is unclear on what timeframe constitutes a "lifetime," nor does it explain what items are included in the operating cost estimate. On the other hand, SEPTA's report is explicit in stating an operation lifetime of 15 years, although it does not explain how this particular lifecycle was selected. The SEPTA report also outlines the various items that comprise its operating cost estimates (see the SEPTA case study for more details).

*Additional Costs:* The MTC estimates the cost for individual operators to train their staff to use the new equipment. The total cost is about \$629,000 per 1,000 peak vehicles for all four of the agencies. Neither LA Metro nor SEPTA included this item in their cost calculations.

One serious concern for transit operators in the Bay Area and Los Angeles is ceding control of their fare structures and policies. In Los Angeles, the movement towards a universal fare structure failed, and each operator has retained its individual fare structures. In the Bay Area, this issue has not been resolved. Since SEPTA is the only operator in the Southeastern Pennsylvania region, its managers maintain control over fares for each of their modes.

Since there are many operators in the Bay Area and Los Angeles, the question of shared operating expenses of smart card systems arises. A new electronic fare and data collection system requires one regional clearinghouse to manage the funds and data. LA Metro recently agreed to outsource these clearinghouse functions for \$8 million annually (Yoh, Iseki, and

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<sup>10</sup> See Appendix A: The San Francisco Bay Area Case Study for more details.

Taylor 2008). Smart card marketing costs are an additional cost of conversion to this new fare media, but the scale and duration of such costs are unknown at this point.

Adopting a new technology (smart card systems) in a new application (transit fare payment) also carries a certain amount of risk for transit operators and their regional coordinators. The MTC and LA Metro studies both note that by adopting a particular smart card system today, the opportunity to adopt newer, and presumably superior, systems in the years ahead are, if not foreclosed, delayed. Additionally, MTC officials are worried that by implementing a new system, they will be “held hostage” to future change orders and contract renewals (Yoh, Iseki, and Taylor 2008). Finally, unforeseen technical problems and institutional barriers may lengthen the implementation time of smart card systems.

## **2-2. Benefits**

Tables 5 and 6 show the benefits of Smart Cards we gathered from the three case study areas.



**Table 5 Benefits of Smart Cards (Part I)**

	<b>A. Benefits that have been assessed quantitatively</b>	<b>B. Benefits frequently mentioned, likely incurred, but which have not been carefully quantified</b>	<b>C. Benefits sometimes mentioned, but which are speculative or treated with considerable uncertainty</b>
<b>Existing and Potential Transit Users</b>	<ul style="list-style-type: none"> <li>Fare processing time significantly decreased: 2.27 seconds for smart card vs. current 3.07 seconds (LA)</li> </ul>	<ul style="list-style-type: none"> <li>Seamless travel for riders (BA, LA, S)                             <ul style="list-style-type: none"> <li>Smart card can be modified to interact with multiple transit operators, eliminating need to buy multiple fare media</li> </ul> </li> <li>Convenient &amp; practical for users                             <ul style="list-style-type: none"> <li>Ease of transfers (LA, S)</li> <li>No need to remove card from wallet</li> <li>Can add value/buy passes online (LA, S)</li> <li>Smart card loading machines can provide exact change (S)</li> </ul> </li> <li>Durable fare medium (LA)</li> <li>Balance protection – if card is lost or stolen, value of card is still preserved (BA, LA)</li> <li>Reduced need for cash (LA)</li> <li>Loyalty programs reward frequent users (LA)</li> </ul>	<ul style="list-style-type: none"> <li>Station staff will spend less time handling cash transactions and more time helping customers (S)</li> <li>Card can be configured to be used in many non-transit applications, e.g. parking meters, retail purchases, and university campus purchases (S)</li> </ul>
<b>Individual Transit Operators</b>	<ul style="list-style-type: none"> <li>Less cashiers needed (BA, S)</li> <li>Reduced need for paper media (BA)</li> <li>Fare processing time significantly decreased: 2.27 seconds for smart card vs. current 3.07 seconds (LA)</li> </ul>	<ul style="list-style-type: none"> <li>Replaces aging fare equipment (LA)</li> <li>Can accommodate different pricing structures (S)</li> <li>Greater memory – many fare options (LA)                             <ul style="list-style-type: none"> <li>Smart card capacity: 256 kilobytes</li> <li>Magnetic capacity: 100 bytes<sup>11</sup></li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Handheld Ticketing Terminal devices allow quicker processing of tickets onboard regional rail and revenue collection throughout commuter rail system (S)</li> <li>Station computer centralizes data collection, and also performs credit card authorization (S)</li> </ul>

[LA: LAMTA or LA Metro, S: SEPTA, BA: The San Francisco Bay Area]

<sup>11</sup> <http://www.uctc.net/mainstream/papers/compendium/Compendium%205.pdf>

**Table 6 Benefits of Smart Cards (Part II)**

	<b>A. Benefits that have been assessed quantitatively</b>	<b>B. Benefits frequently mentioned, likely incurred, but which have not been carefully quantified</b>	<b>C. Benefits sometimes mentioned, but which are speculative or treated with considerable uncertainty</b>
<b>Individual Transit Operators (cont'd)</b>	<ul style="list-style-type: none"> <li>Significantly fewer failures than magnetic strip readers: 6.7/day for smart cards vs. 200/day for magnetic strips (LA)</li> <li>Cost significantly cheaper than other options<sup>12</sup> (LA)</li> </ul>	<ul style="list-style-type: none"> <li>Greater fare media flexibility (S)</li> <li>Greater reliability (S)</li> <li>Capacity to track and audit trips (S)</li> <li>Fraud prevention<sup>13</sup> (LA, S)</li> <li>Improved data collection (S)</li> </ul>	<ul style="list-style-type: none"> <li>Farebox activation by smart cards eliminates need for staff to activate them with keypads, also minimizes data entry errors and enhances data reliability (S)</li> <li>Fare system security and enforcement (S)</li> <li>Multi-application potential (S)</li> <li>Savings from cash handling dependant on smart card take-up rates (BA)</li> </ul>
<b>Multiple Transit Operators and Regional Agencies</b>		<ul style="list-style-type: none"> <li>Improved data collection – ridership &amp; travel behavior information can aid regional planning (BA, LA)</li> </ul>	<ul style="list-style-type: none"> <li>Regional integration of transfer transactions (BA, LA, S)</li> </ul>

[LA: LAMTA or LA Metro, S: SEPTA, BA: The San Francisco Bay Area]

<sup>12</sup> This was not the case for SEPTA.

<sup>13</sup> LA Metro estimates they lose anywhere from \$5.5–11 million annually to fraud

One of the major benefits of smart cards system to both users and operators is a reduction in fare processing time. The average smart card fare processing time estimated in the LA Metro study is 2.27 seconds (Booz Allen & Hamilton 2001). Compared to the current 3.07 seconds, this represents a savings of almost 1 second per boarding. Furthermore, LA Metro noted that smart cards fail to interface with smart card readers less often than magnetic strip technology (6.7 failures per day for smart cards, compared to 200 per day for magnetic strips) (Booz Allen & Hamilton 2001). Overall, this time savings will most significantly affect modes where boarding and fare payment occur at the same place, namely on buses. If enough people use smart cards, there will be a significant reduction in boarding time and thus total vehicle dwelling time. This will increase the ability for vehicles to maintain their schedule, and improve on-time performance and reliability. Since users value the quality of transit service very highly, this benefit could help increase ridership.

Another major benefit to users is the simple convenience of the smart card. Riders do not have to worry about having enough money or exact change, they can add money and buy passes online, and pay their fare without having to take the card out of their wallet. If the card is integrated to operators region-wide, riders will enjoy seamless travel all over the metropolitan area.

In addition, the card itself is durable, and usually offers balance protection. In other words, if the card is lost or stolen, the money stored on the card can be electronically preserved for the user if it is reported to the issuing agency. The LA Metro report stated that they would offer their customers loyalty programs, although further details were not provided (Booz Allen & Hamilton 2001).

The card has tremendous potential for use in many non-transit applications as well. SEPTA's plan was to integrate the smart card with parking meters at their commuter rail stations (PB Team & LTK Engineering Services 2000). Furthermore, the card has the capacity to be linked with many other electronic cash uses, from integrating them with cell phones to retail purchases, as examples in other countries has shown. However, this depends on the ability of regional transit agencies to partner with private sector companies, and the costs and benefits for such applications are unknown at this point.

Both the MTC and SEPTA quantified the savings based on the reduction in cash handling cost, and found this to be one of the biggest financial benefits of smart card systems. However, as the MTC reports noted, these savings are dependant upon the take-up rate of smart cards. If a cash fare is kept and few users adopt the smart card, operators will still have to process a significant amount of currency.

A major benefit of the smart card to individual operators is its memory features. It is the first fare medium that can store the unique pricing structures of many operators as well as a more flexible fare structure that can vary by distance and/or by time of day. This is needed to facilitate regional integration. The new electronic infrastructure also provides an unparalleled means of data collection, which will aid regional planning efforts. However, interviews with LA Metro officials revealed that individual operators in Los Angeles are worried about what this more accurate data will bring (Yoh, Iseki, and Taylor 2008). Since the programming of regional funds

is based partially on each operator's share of riders, new data could significantly alter how much money each operator receives, be it more or less than they currently receive. There is little disagreement about how helpful this new data will be, though.

Finally, the adoption of new technology will, as LA Metro notes, modernize the current generation of fare equipment. SEPTA and LA Metro also believe that smart card systems will reduce fraud. LA Metro estimates that it loses anywhere from \$5 million to \$11 million annually to rider fraud (Booz Allen & Hamilton 2001), while it should be noted that the estimate of revenue loss due to fraud is not very accurate due to limited data available.

In summary, smart card systems provide substantial benefits to users, and at little cost to the average users. Individual transit operators also have much to gain in terms of operational efficiency. But transit agencies must make significant financial investments to garner these gains, and while these numerical costs are clear, many benefits are difficult to quantify. Furthermore, multiple operators and regional agencies as a whole do not stand to gain very much except for new ridership and travel behavior information. There is little doubt that the smart card systems provide certain benefits, but all participating stakeholders do not enjoy these benefits evenly. In addition, by adopting smart card systems, individual operators and transit agencies as a whole must assume a certain amount of risk, and it is still uncertain if the benefits are worth their costs.

The risks, costs, and uncertainty of benefits have led to reluctance (or perhaps prudence) on the part of some transit operators toward immediately participating in an interoperable smart card system. This is particularly true for small operators that have other immediate needs for their available funds, such as replacement of vehicles (Iseki, Yoh, and Taylor 2007). Because of this situation, there has to be a mechanism to provide incentives to individual operators for their participation. Furthermore, many costs and benefits (except clear expenses) are difficult to quantify, and currently make any cost-benefit analysis less complete than hoped. Therefore, our analysis of costs and benefits only provides partial information, not the decisive guidance we had hoped for in the decision making process related to the implementation of smart card systems.

### **3. Conclusion**

Transit smart cards have been implemented in the U.S. mostly as stand-alone systems and to a lesser degree as interoperable regional systems. None have been implemented at the state level. Despite the growing adoption of transit smart card systems, there are precious few rigorous evaluations of their costs and benefits. In this research, we first developed a framework for categorizing the costs and benefits of transit smart cards systems. This framework organizes costs and benefits by both stakeholder (which we define as the bearer of costs or beneficiary) and the quantitative clarity of the cost or benefit. We then applied this framework to the three most comprehensive analyses of transit smart card costs and benefits we could find: by the MTC in the San Francisco Bay Area, LA Metro in Los Angeles, and SEPTA in Philadelphia.

We used these three studies to help quantify the additional capital and operating costs of adopting transit smart card systems. However, the methodologies used by each agency to calculate these additional costs varied greatly, and in some cases, it is unclear how they arrived at their added costs. Aside from having to adopt a new fare media, transit users do not bear much cost. Rather, individual transit operators must pay to implement smart card systems, although

regional agencies may subsidize this cost, or offer other incentives (which, of course, entail costs of some sort). Given the substantial change smart card systems entail, there are difficult-to-quantify costs associated with the uncertainty of adopting a new fare collection technology, including those associated with unforeseen technical and political issues that may arise. Put simply, we do not yet have reliable implementation cost estimates for smart card systems.

The benefits of smart cards accrue to both transit users and individual transit operators, and are difficult to quantify. While users can certainly enjoy seamless travel throughout a region, and operators will likely benefit from a more automated passenger processing and fare collection system, these are inherently qualitative items. Furthermore, the degree to which users and operators will benefit is dependant upon many other unknown factors. For example, transit operators will only reduce their expenditures on cash processing if enough users decide to use the smart card. Lastly, regional agencies only indirectly benefit from smart card systems, mostly in the form of more accurate data collection and more inter-agency transfers.

Among the three studies examined here, the Bay Area and Los Angeles have been gradually implementing regional transit smart card systems, forming regional partnerships along the way. SEPTA, in contrast, concluded their comprehensive study of the capital and operating costs of various fare collection technology options by recommending a move to a system that incorporates smart cards, but fiscal shortfalls have to date prevented adoption.

Through a careful examination of these reports and other documents, we found that transit agencies typically analyze expenses related to capital equipment and operation of the smart card system, which are relatively easy to estimate. Despite the many claims of smart card benefits touted in the literature, most of it appears promotional and descriptive in nature (Yoh et al. 2006; Yoh et al. 2006). This includes benefits such as flexible pricing, loyalty programs, fare fraud reduction, increased card balances from pre-paid fares, improved convenience and service quality. None of the three cases examined in this research quantified such benefits with anything approaching clear evidence. Therefore, the best possible way to evaluate transit smart card benefits at the present time is to qualitatively compare the smart card technology to other options. This conclusion is consistent with the findings of earlier phases of this research—the survey of U.S. transit agencies (Iseki, Yoh, and Taylor 2006, 2007) and the interviews with transit agencies officials for the adoption of smart card fare systems (Yoh, Iseki, and Taylor 2008); namely, that transit agencies are uncertain about the benefits and the costs of *interoperable* systems. Nonetheless, there is a certain level of consensus among agency officials and planners about the benefits of smart card systems, in particular the benefits for transit users (Iseki, Yoh, and Taylor 2007).

The estimation of costs was conducted at a highly aggregated level in the Los Angeles study, and at the individual agency level in the Bay Area and SEPTA cases. In these latter two studies, we found it difficult to infer the costs of large-scale implementation. The specific difficult-to-forecast costs from the Bay Area study are related to fare collection, solving customer disputes, the administrative, management, and customer service functions of the MTC, and developing a system for solving accounting system problems by the clearing house.

We also found that estimates of capital and operating costs of smart card systems varied significantly depending on the transit operating characteristics (modes operated, service areas, and patronage patterns) in the Bay Area and SEPTA studies. In addition, coordinating different modes in different transit systems that will likely require advanced features on the fare media to handle the multiple objectives of the system partners is another factor adding uncertainty to the technology cost estimates. Given such uncertainties in estimating costs for individual transit systems, the difficulty of accurately estimating the implementation costs of an interoperable smart card system is even less certain. To produce reliable cost estimates for an inter-operator system, we suggest a pilot study that includes a sufficiently diverse array of transit systems that takes into account various operating factors.

Unfortunately, the dearth of information on the costs and benefits of interoperable transit smart card systems makes even informed speculation on the potential costs, benefits, and risks of the statewide interoperable system impossible (Yoh et al. 2006). While a rigorously constructed and reliable cost/benefit study is certainly possible, the very small amount of previous work on the subject means that such a study would require substantial original data collection and analysis that are well beyond the scope of this current research. Further, given that the two largest metropolitan areas in California—Los Angeles and the San Francisco Bay Area—are currently moving forward on implementing smart card technologies compatible among operators in their region, but incompatible between regions, the statewide coordination of smart cards as transit fare media presents enormous logistical challenges.

To sum, transit smart card systems hold tremendous promise to bring speed, flexibility, and greater information to fare payment, but at substantial time, effort, and monetary costs. Whether the purported benefits are worth the costs remains an open and important question. Carefully constructed and executed cost/benefit analyses are an important way to answer this question, but only a handful of government agencies have attempted such analyses, and they are by no means comprehensive. This report summarized the findings of three such cost/benefit analyses and while each is informative, none are comprehensive or generalizable. Indeed, the methods and findings of these studies differ substantially in some cases. Given the inherent risk of moving to a new, advanced system of fare collection, the dearth of cost/benefit analyses is to us surprising. More are clearly needed.

## **Acknowledgment**

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## Appendix A: The San Francisco Bay Area Case Study<sup>14</sup>

“TransLink® is an Automated Fare Collection (“AFC”) program cooperatively developed and implemented by the transit operators (“operators”) in the nine-county San Francisco Bay Area and the Metropolitan Transportation Commission (“MTC”). The TransLink® card is a fare instrument that can operate in all of the different transit modes in the Bay Area (“the Region”) and can be used to pay fares for both inter-operator and intra-operator services.” (TransLink 2005)

TransLink is a program developed in the Bay Area that uses smart cards for transit fare media. TransLink is the third major undertaking of coordinated fares in the Bay Area. In the early 1980s, a program was once launched to improve customer convenience but was plagued by mechanical and technological problems. In the early 1990s, another precursor to TransLink was attempted but was also unsuccessful.<sup>15</sup> TransLink has built off of these previous attempts (TransLink 2005). The Transportation 2030 Plan adopted in February 2005 included the TransLink program with an emphasis on the importance of regional cooperation among the Bay Area transit agencies.

In June, 1999, the MTC, as the TransLink Contract Manager, made a contract with Motorola, Inc.<sup>16</sup> to design, build, operate and maintain TransLink, which is to be implemented in two phases: a six-operator demonstration (Phase I) and full roll-out (Phase II). The interagency participation agreement specifies:

“Agencies intend to create a forum for joint Agency decision-making (the “TransLink® Consortium” or “Consortium”) to work towards the successful implementation of TransLink®. The TransLink® Consortium will be governed by a TransLink® Management Group (“TMG”) comprised of the general managers or equivalent (or their designees) of designated Operators and the Executive Director of the MTC (or designee).”

In this Phase I project, the TransLink Interagency Participation Agreement (the “Participation Agreement” or “Agreement”) was made among the MTC and the six largest fixed-route transit operators of the 23 in the Bay Area region:

- 1) the Alameda-Contra Costa Transit District (AC Transit)
- 2) Golden Gate Bridge Highway and Transportation District (GGBHTD or Golden Gate Transit)
- 3) the San Francisco Bay Area Rapid Transit District (BART)
- 4) San Francisco Municipal Transportation Agency (San Francisco Muni or MTA)
- 5) the San Mateo County Transit District (Caltrain or SamTrans)

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<sup>14</sup> In this section, we describe the details of the SF Bay Area. Since we do not intend to make a comparison across the three cases, we do not adjust dollars to one in a specific year; the dollar amounts specified are the estimates included in the original reports.

<sup>15</sup> The previous attempts at regional fare policy have not been fully researched

<sup>16</sup> MTC has signed a contract with Motorola, Inc., and ERG Transit Systems to design, build, operate and maintain the TransLink system (TransLink 2005).



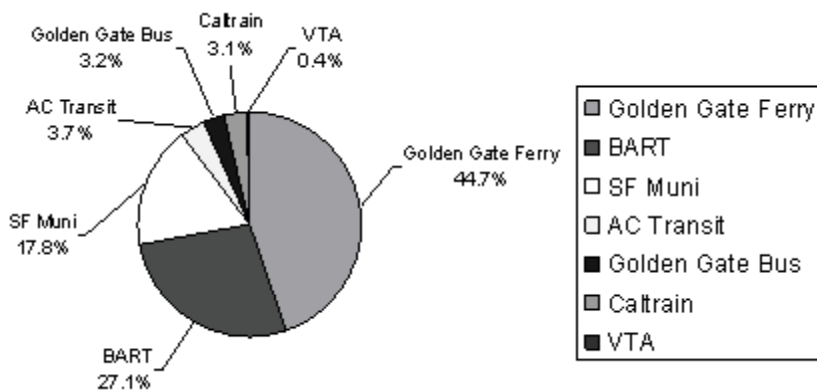
6) the Santa Clara Valley Transportation Authority (VTA)  
 (The TransLink Consortium 2003)

These six transit operators comprise the TransLink Consortium, based on the agreement that provides the framework for interagency decision making roles and responsibilities. This agreement also provided flexibility to allow other transit operators to join the interagency implementation of smart card system in future. One important condition in this agreement is that all operators were required to procure fare collection equipment compatible with TransLink (TransLink 2005).

TransLink was installed on the vehicles and stations of Consortium agencies as a pilot project during Phase I. Translink used hybrid smart card technology that operated as tap cards with the in-vehicle readers and were inserted into ATM-type machines to add value. There were over 4,000 cards issued in January 2002, and these cards were used on large portions of the six participating agencies' routes. Overall, just over 3,000 cards were used during the demonstration. Although the cards were distributed in a way to ensure that a representative sample of all transit riders would receive the cards, this was not as successful as originally hoped. Since many of the targeted transit users did not volunteer to use the cards, the program made additional efforts to recruit more users. Value could be added to the cards only at certain machines located in stations and nearby retail stores. In general, the transit stations were used more often than the nearby retail stores.

Figure A-1 shows the distribution of trips taken among different transit systems in the Bay Area. It reveals that Golden Gate Ferry shared the largest percentage of the trips made by TransLink demonstration participants during the study period. This can be attributed to the 20 percent fare discount that Golden Gate Ferry provided through the TransLink e-cash system (as is provided for the paper ticket book), in addition to the advantages of adding value of any denomination to the card.

**Figure A-1 Distribution of Trips by Agency**



It should also be noted that Golden Gate Ferry, SF Muni and BART combined shared almost 90% of all TransLink trips. Each of these three operators had more than 1,000 card holders who used their system during the course of demonstration, while barely 400 card holders used the transit system operated by AC Transit, Golden Gate Bus, Caltrain, and VTA.

After the successful demonstration, Phase II will include the remaining 17 agencies. Smaller agencies on the fringe of the metro area may be included as part of Phase III. There is currently no firm expected date for completion of either Phase II or Phase III, but the reports indicate substantial deployment in 2006.

The MTC commissioned a series of studies to evaluate the TransLink pilot program, hiring Charles River Associates (CRA) and Nancy Whelan Consulting. These studies discuss the outcomes and impacts of the TransLink pilot program, and estimate the costs of the implementation for separate multiple stand-alone systems of the following five transit operators (Charles River Associates Incorporated and Systan Inc. 2002; Nancy Whelan Consulting 2002):

- *Muni*: San Francisco Municipal Railway
- *GGBHTD*: Golden Gate Bridge Highway & Transportation District
- *CalTrain*: CalTrain Joint Powers Board
- *BART*: Bay Area Rapid Transit
- *VTA*: Santa Clara Valley Transportation Authority

We identified many costs and benefits items that could reasonably be attributed to the TransLink program in this report. As is often with other cases of similar studies, however, all the benefits are not translated into equivalent dollars to estimate the societal benefits over the costs incurred in the TransLink program.

#### **A-1. Funding and Overall Costs**

TransLink has been funded by federal and state funds. The first five years of the project are budgeted for \$115 million, about 52 percent of which will be paid from federal Surface Transportation Program (STP) and Congestion Mitigation and Air Quality Improvement program (CMAQ) funds. The balance will be paid through State Transit Assistance (STA) and Regional Discretionary funds (Regional Measure 2—RM2—funds) programmed by the MTC (TransLink 2005).

The financial support for the TransLink program was provided from the regional discretionary transportation funds. The MTC provided 100 percent of the capital and equipment costs and 50 percent of the operating costs for the first ten years of the project; the MTC covers all fixed costs of the clearinghouse and variable operating costs, as specified in Table A-1. The other 50 percent of the operating costs was borne by the participating agencies. In addition, the operating costs in the agreement included administrative expenses and legal expenses (e.g. payment of claims, costs of litigation, and attorney's fees) that will be incurred by the MTC and contractors in the system implementation.

In the Phase II total capital funding budget of \$79 million, the MTC also provides the total of \$10 million to participating operators to cover the capital operating costs associated with the deployment of the TransLink system.

Operators can use this incentive funding to pay capital and operating costs associated with Phase II, which include contracting for design enhancements and contingency to contractor for

transaction assurances in the case that the minimum transaction volumes are not achieved. However, it is not possible how much administrative, labor and miscellaneous costs are involved in determining conditions in this agreement and continuing interagency efforts from both the MTC and operators' perspective.

**Table A-1 Capital Costs and Operating Costs of TransLink Covered by the MTC**

Capital Costs	Operating costs
Program Management – Operations, and Maintenance TransLink <sup>®</sup> Testbed Operations & Maintenance Marketing Allowance Operator Help Desk Reporting Asset Management Cardholder Help Desk Location Acquisition Support Phase II Network Management Phase II TransLink <sup>®</sup> Central System Services	Card Distribution Services Cardholder Help Desk

**A-2. Costs for Individual Participating Agencies**

The studies commissioned by the MTC do not include cost estimates for implementing the inter-agency smart card system.<sup>17</sup> The principal categories of costs that are potentially incurred by the participating agencies are (Charles River Associates Incorporated and Systan Inc. 2002; Nancy Whelan Consulting 2002):

- revenue collection and financial services
- administration,
- customer service,
- equipment servicing, and
- staff training,

each of which is elaborated upon below.

Revenue collection and financial services

Revenue collection includes: 1) collecting cash from the ticket counters or *Add Value* machines, 2) the security used to transport the cash to the vault department, 3) counting the cash at the vault department, and 4) reconciliation (Charles River Associates Incorporated and Systan Inc. 2002). In the case of Muni and VTA, the decline of costs of collecting revenue was reported over the course of the demonstration, and is considered to be due to the startup costs. It is not clear whether the inter-agency operation will increase or decrease aggregate revenue collection costs. The concern was regarding the more costs for agencies with the locations of more value-loading points and more convenience to users, compared to their share of revenue.

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<sup>17</sup> It should be noted that transit managers were concerned about future problems that would involve the governance and financial issues that were not well defined at the time of study. However, these issues were left to the responsibility of the nine-county regional committee that oversees the TransLink institutional issues (Nancy Whelan Consulting 2002).

The cost associated with financial accounting for the TransLink program among Golden Gate Transit, Muni, and VTA fluctuated over the pilot project. This indicates the fixed nature of this cost, while it generally increases as ridership or the number of transactions increases.

In the pilot program, individual agencies needed to download TransLink financial reports from the clearinghouse for their own financial accounting purpose. This is done for the purpose of “reconciling the backend reports with cash counts and other sources and resolving customer disputes (p.123).” However, the agencies did not have access to an independently-generated source of information which can be used to audit the TransLink transaction records (Charles River Associates Incorporated and Systan Inc. 2002). This implies potential fraud. In addition, there are some occasions that transactions of smart cards were not reported to the clearinghouse. It is also expected that the cost of resolving disputes, which will increase as the number of transaction increases, will increase over time. This also means that the time spent to respond to customer disputes will increase as well.

#### Administration

Administration costs include the costs of general oversight of the TransLink program. No clear pattern of the administration costs among BART, GGBHTD, and VTA were identified during the course of the pilot project (Charles River Associates Incorporated and Systan Inc. 2002).

#### Customer Service

The MTC made the Design, Build, Operate, Maintain (DBOM) contract with Motorola, and paid the full costs of the services provided from the contractor, which includes: 1) system equipment, equipment servicing, 2) customer service support, and 3) financial clearinghouse services (including the production of financial reports) (Charles River Associates Incorporated and Systan Inc. 2002). Since the DBOM contract specifies the contractor’s responsibility of customer service support, no costs were reported from individual participating agencies.

#### Equipment

The implementation of the TransLink program in the Bay Area will require operators to install and upgrade various types of equipment in the fare collection system. Table A-2 shows the costs associated with the anticipated hardware deployment and the percentage share of each cost category in the total cost for each agency (Nancy Whelan Consulting 2002). Each operator has adopted different modes to tune the present facilities with the smart card system. The hardware that was anticipated to be deployed includes: Station Card Interface Devices (CID), Vehicle CIDs, Hand-held Card Readers (HCR), Ticket Office Terminals (TOT), Add Value Machines (AVM), Ticket Vending Machines (TVM) Retrofit, and Driver Display Units (DDU).

Costs are incurred for preventive maintenance and repair, revenue collection, financial reporting, replacement due to failures and vandalism, and marketing. The vandalism replacement cost accounts for the failure of the CID units and their immediate replacement. Therefore, the cost is higher for those operators who deploy the large number of CIDs in location with minimum staff supervision.

**Table A-2 Costs Associated with Hardware Deployment by Agency**

<i>Costs</i>	<b>Muni</b>	<b>GGBHTD</b>	<b>Caltrain</b>	<b>VTA</b>	<b>Total</b>
Preventive Maintenance / Repair (AVM/TVM)	\$ 47,615 5.2%	\$ 15,815 7.1%	\$ 18,919 15.6%	\$ 63,226 12.2%	<b>\$ 145,575</b> <b>8.2%</b>
Revenue Collection (AVM / TOT)	\$ 7,776 0.9%	\$ 41,337 18.6%	-	-	<b>\$ 49,113</b> <b>2.8%</b>
Financial Reporting	\$ 358,510 39.4%	\$ 136,722 61.4%	\$ 83,520 69.9%	\$ 211,042 40.7%	<b>\$ 789,794</b> <b>44.6%</b>
CID / DDU / CHR Replacement (due to failure)	\$ 454,807 50.0%	\$ 8,797 3.9%	\$ 3,169 2.6%	\$ 106,974 20.6%	<b>\$ 573,747</b> <b>32.4%</b>
Vandalism Replacement	\$ 40,976 4.5%	\$ 139 0.1%	\$ 563 0.5%	\$ 1,866 0.4%	<b>\$ 43,544</b> <b>2.5%</b>
Marketing	- -	\$ 20,000 9.0%	\$ 15,000 12.4%	\$ 136,000 26.2%	<b>\$ 171,000</b> <b>9.6%</b>
<b>TOTAL COST</b> Total	<b>\$ 909,684</b> 51.3%	<b>\$ 222,810</b> 12.6%	<b>\$ 121,171</b> 6.8%	<b>\$ 519,108</b> 29.3%	<b>\$ 1,772,773</b> 100%

In addition to the total cost of hardware deployment, Table A-3 shows the total costs associated with production, distribution, collection, and processing of existing fare media (passes, tickets/books, transfers, tokens, Eco Pass, bus day pass, cash, and other) and monthly total operating cost. In comparison with the total cost of fare media, the hardware deployment costs are relatively more costly for Caltrain and GGBHTD. Due to the present high costs of fare media, it has relatively a small impact on Muni. In terms of the ratio of deployment cost to the total operating cost (acquired from the National Transit Database), the deployment cost is 3.5% of GGBHTD's monthly operating cost, the largest proportion for all of the operators. The ratio is lower for Muni, CalTrain, and VTA (and similar among the three).

**Table A-3 Costs Associated with the Anticipated Hardware Deployment for Each Agency**

	<b>Muni</b>	<b>GGBHTD</b>	<b>Caltrain</b>	<b>VTA</b>	<b>Total</b>
Deployment Costs	\$ 909,684 (51.3%)	\$ 222,810 (12.6%)	\$ 121,171 (6.8%)	\$ 519,108 (29.3%)	\$ 1,772,773 (100%)
Cost of Fare Media	\$4,452,406	\$ 234,324	\$121,500	\$750,381	\$5,558,611
Ratio of Deployment Costs to the Cost of Fare Media	20.4%	95.1%	99.7%	69.2%	31.9%
Monthly Operating Cost	\$36,873,170	\$6,282,944	\$5,113,655	\$22,745,163	\$71,014,932
Ratio of Deployment Cost to Monthly Operating Cost	2.5%	3.5%	2.4%	2.3%	10.7%

Table A-4 summarizes the operating costs of equipment in the Phase I pilot program, the number of units of equipment, and the mean cost per unit. While Muni shows substantially lower mean cost per unit with the large number of units, it is still not clear if there is an economies of scale because of the problems associated with the data: 1) the large variance of reported costs among agencies, and 2) the variance of types of equipment among agencies.

**Table A-4 Equipment-related Operating Costs by Agency**

	Mean monthly equipment related costs	Number of units of TransLink equipment***	Mean cost per unit of equipment
BART*	\$3,012	82	\$36.73
Golden Gate Transit Bus	\$1,134	56	\$20.26
Muni**	\$3,493	355	\$12.32
VTA	\$1,375	54	\$25.45

Source: Charles River Associates Incorporated and Systan Inc. 2002.

\* The mean for BART is averaged over April through July as earlier months had much higher costs suggesting some startup issues. BART costs are fully loaded.

\*\* At Muni, 253 units of equipment were installed initially. The expansion of the program in May to all Muni Metro lines added another 102 units.

\*\*\* Equipment includes ADU, AVM, CID1, CID2, CID3, HCR, and TOT.

### Training

The implementation of the smart card system incurs the cost of training agency staff. The staff positions are broken into operators, inspectors, maintenance, station agents / ticket office, customer service representative, supervisors, and other (Table A-5). The quality of training is related to the quality of customer service. Users of TransLink were unsatisfied with high rates of out-of-service equipment on vehicles, which was attributed to drivers' disinterest in the program (Charles River Associates Incorporated and Systan Inc. 2002). Customer services was mentioned as one of difficulties in the pilot program (Nancy Whelan Consulting 2004). With a lack of understanding of the new equipment, the front line staff at each transit agency may not be able to provide adequate service to customers. While better training and backline support will likely correct these problems, these measures will require more investment.

**Table A-5 One Time Training Costs**

Staff Position	Muni	GGBHTD	Caltrain	VTA	TOTAL
Operators	\$ 120,306	\$ 20,324	-	\$ 67,729	\$ 20,8359
Inspectors	\$ 1,026	-	\$ 6,750	\$ 2,180	\$ 9,956
Maintenance	-	-	-	\$ 11,791	\$ 11,791
Station Agents / Ticket Office	\$ 2,644	\$ 2,834	\$ 875		\$ 6,353
Customer Service Rep.	-	\$ 5,006	-	\$ 30,778	\$ 35,784
Supervisors	-	\$ 2,398	-	\$ 2,192	\$ 4,590
Other	-	-	-	\$ 12,659	\$ 12,659
<b>Total</b>	<b>\$ 123,976</b>	<b>\$ 30,562</b>	<b>\$ 7,625</b>	<b>\$ 127,329</b>	<b>\$ 289,492</b>

Although Muni is largest among all the four operators, Muni spends relatively less in training program than the other operators, comparing to the total costs of production, distribution, collection, and processing of fare media (Table A-6). When comparing the ratio of training costs to monthly operating cost (from the National Transit Database) for each of the transit operators, VTA and GGBHTD again spend the largest shares, 0.56% and 0.49%, respectively. Muni spends 0.34% and Caltrain spend the smallest share, 0.15%. Looking at monthly operating costs as a proxy for operation size shows that Caltrain and GGBHTD are similarly sized in comparison

to Muni and VTA. Yet Caltrain's ratio is much less than GGBHTD's, and thus they spend less on training in comparison to their total monthly expenditures.

**Table A-6 Percentage share of Training Cost over Operating Cost**

	<b>Muni</b>	<b>GGBHTD</b>	<b>Caltrain</b>	<b>VTA</b>	<b>Total</b>
One Time Training Costs	\$123,976	\$ 30,562	\$7,625	\$127,329	\$ 289,492
Monthly Operating Cost	\$36,873,170	\$6,282,944	\$5,113,655	\$22,745,163	\$71,014,932
Ratio of Training Cost to Monthly Operating Cost	0.34%	0.49%	0.15%	0.56%	1.53%

VTA and Muni assumed that all the staff will be trained beyond the normal working hours and thus will be paid for the extra working hours. They both estimated that initial training will be required for all front-line personnel dealing with the new TransLink medium. This basic assumption has made the one time training cost almost equal for both Muni and VTA. However, because of the relatively lower scale of operation of VTA, the share of this expenditure has shot up to a high percentage.

Savings

Smart card take-up rate is the percentage of customers that would switch from the existing fare payment methods to the new smart card technology. In the cost analysis model, these take-up rates were one of the key assumptions that the operators made.<sup>18</sup> Table A-7 shows the take-up rate of smart cards in two different scenarios: 1) with changes in policy to eliminate the production of paper fare media and offer incentives for patrons to move from cash to smart card, and 2) without it. The largest cost driver in the revenue collection and processing is the handling of cash fare payments. It makes up approximately 71%, 68% and 46% for Muni, GGBHTD and VTA, respectively. This implies that significant savings will unlikely be realized until the number of cash fare payment transactions is considerably reduced. Therefore, high shift rates from cash fare to smart card was assumed by each operator to estimate the optimum net savings.

**Table A-7 Comparison of Smart Card Take-up Rates**

<b>Fare Payment Method</b>	<b>Muni</b>		<b>GGBHTD</b>		<b>Caltrain</b>		<b>VTA</b>	
	Without policy change	With policy change	Without policy change	With policy change	Without policy change	With policy change	Without policy change	With policy change
Pass Users	40%	100%	-	-	73%	100%	80%	100%
Stored Ride Users	-	-	61%	100%	73%	100%	-	-
Cash Users	40%	60%	61%	90%	10%	75%	20%	25%

Using take-up rates shown in Table A-7, cost savings that will be accrued by the implementation of smart cards were estimated for each operator. Table A-8 presents first the cost for production, distribution, collection and processing of the existing fare media fare payment media (which is

<sup>18</sup> The basis of the assumptions was not mentioned in the report.

used as a proxy for the scale of operation), total savings in each scenario, and the net savings<sup>19</sup> that will be accrued with or without policy change—the difference of the savings accrued through the reduction in the production, distribution, collection and processing of the existing fare media and the cost incurred due to additional hardware deployment.

The percentages of savings compared to the cost for production, distribution, collection and processing of the existing fare media fare payment media are calculated for each case. Table A-8 reveals that Muni, GGBHTD and VTA will save 48%, 23% and 2%, respectively, of the amount they spend in fare media in the case of policy change, while only Muni will achieve cost savings without it. But for Caltrain, additional 6% of the cost of fare media will be incurred due to the TransLink program. The last row shows an increase in cost savings from a no policy-change scenario to a policy-change scenario. It signifies the importance of a policy change to increase a usage of smart cards and net cost savings.

**Table A-8 Comparison of Savings as in Baseline Scenario (in terms of Dollars)**

Costs (\$)	Muni	GGBHTD	Caltrain	VTA	Total
<b>Cost of fare media production, distribution, collection, processing (1)</b>	\$ 4,452,406	\$ 234,324	\$ 121,500	\$ 750,381	\$5,558,611
<b>Without Policy Changes</b>					
<b>Total Savings</b>	\$2,067,417	\$ 107,766	\$ 68,838	\$ 421,685	\$2,665,711
<b>Net Savings (2)</b>	\$1,157,733	-\$ 115,044	-\$ 52,333	- \$ 97,423	\$ 892,938
<b>Percentage of savings, compared to (1)</b>	26%	-49%	-43%	-13%	16%
<b>With Policy Changes</b>					
<b>Total Savings</b>	\$3,046,004	\$ 276,066	\$ 113,750	\$ 530,609	\$3,966,439
<b>Net Savings (3)</b>	\$2,136,320	\$ 53,256	- \$ 7,421	\$ 11,501	\$2,193,666
<b>Percentage of savings, compared to (1)</b>	48%	23%	-6%	2%	39%
<b>Savings Difference (3) – (2)</b>	\$ 978,587	\$ 168,300	\$ 44,912	\$ 108,924	\$1,300,728

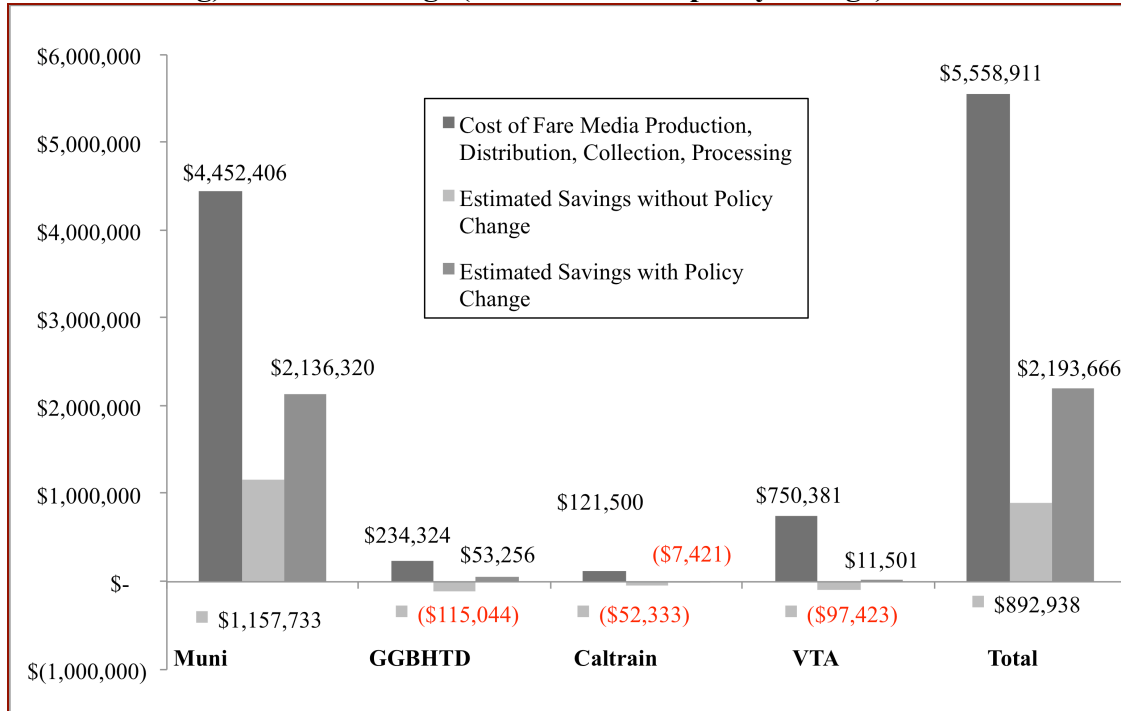
Note: The negative numbers indicate cost increase.

In addition, the percentages shown in Table A-8 also manifest the scenario: how big the operator is and how much it is going to save. This is also depicted in Fig A-1 as shown below:

<sup>19</sup> Cost categories examined here are: faregate / farebox maintenance, pass production / distribution (all passes), transfer production / distribution, token production / distribution, ticket / ticket book production / distribution, other Savings, and cash processing.



**Figure A-2 Scale of Operation (Cost of Fare Media Production, Distribution, Collection and Processing) and Net Savings (with or without policy change)**



**A-3. Comparison of Personnel Costs of the TransLink Program to Operating Costs**

In order to gauge the relative extent of additional personnel costs due to the TransLink program among agencies, we compared them to total operating expenses obtained from the 2002 National Transit Database (Table A-9). All costs and expenses were converted to monthly costs or expenses. Monthly general administration expense and total monthly operating expense are the highest for Muni, followed by BART ((1) and (2)). Total monthly personnel cost for administration and total monthly personnel cost in the TransLink Program are the highest for BART, followed by VTA. The ratio of personnel cost for administration relative to the general administration cost (4) significantly varies by agency, and is much higher for BART than for the three other agencies. Muni has the lowest ratio. The relative ratio of personnel cost to the operating cost (6) varies by agency, but the range is smaller. BART has the highest ratio also on this account while Muni has the lowest ratio. The variance in the ratios calculated here implies that the personnel costs vary quite significantly by agency and that it is not an easy task to estimate the cost for an agency based on the cost for another agency.

**Table A-9 Cost Comparison**

	<b>Cost / Expense / Ratio</b>	<b>Muni</b>	<b>GGBHTD</b>	<b>VTA</b>	<b>BART</b>
(1)	Monthly General Administration Expense (in \$1000's)*	\$7,892	\$2,244	\$4,339	\$5,424
(2)	Total Monthly Operating Expense (in \$1000's)*	\$36,873	\$6,283	\$22,745	\$27,579
(3)	Total Monthly Personnel Cost for Administration in TransLink Program (in \$) **	\$618	\$1,211	\$7,027	\$16,932
(4)	=(3)/(1)	0.08	0.54	1.62	3.12
(5)	Total Monthly Personnel Cost in TransLink Program (in \$) **	\$4,110	\$1,796	\$10,724	\$19,944
(6)	=(5)/(2)	0.11	0.29	0.47	0.72

Source: \*: National Transit Database 2002; \*\*: Charles River Associates Incorporated and Systan Inc. 2002.

#### **A-4. Benefits**

In “Phase II Operating Rules: Version 1.2 by TransLink (TransLink 2005)”, the Partnership Transit Coordination Committee (“PTCC”) specified the goals for the TransLink Program some of which can be interpreted as benefits. The main benefits that the TransLink program was planned to achieve are: 1) convenience for users (in particular for “inter-operator trips”), 2) improvement in efficiency and security of the fare collection system, 3) increase in fare revenue, reduction in operating costs, and 4) coordination in service among the Bay Area operators (TransLink 2005).<sup>20</sup> In contrast, as was specifically stated in this document, the fare policy continues to be determined by each transit operator (TransLink 2005). In most cases, transit operators keep current fare policies, which are often flat fare policies.

Operators are not required to replace existing non-cash fare media with TransLink smart cards. After the implantation of smart cards, reduction in the quantities of current fare media can be expected (Charles River Associates Incorporated and Systan Inc. 2002). In the case of TransLink, the quantities of paper media that need to be purchased from suppliers is expected to be reduced. A level of saving from it depends on the combination of present expenses associated with the existing paper media and the demand for TransLink. Furthermore, additional savings from the reduction in costs of labor to “handle the purchasing, handling, and destroying of media could be reduced or eliminated” if the percent media is completely replaced. In addition, it is also possible to significantly reduce commissions paid to third-party vendors (Benton International 1995).

One of main benefits often mentioned by the literature is the cost savings from replacing cash fare by smart cards. The costs associated with cash payment amount to \$3,674,229 (66.10% of the total cost). However, because of low-income transit users and non-frequent users, it is unlikely that agencies will be able to get rid of cash fare. Taking into account other fare types are already in place, it is unlikely that transit users currently paying fares in cash will move from

<sup>20</sup> It also included the implementation of MTC’s *Transit Coordination Implementation Plan*, which is a long-range planning document that seeks to guide regional coordination among transit agencies and has not yet been reviewed.

cash fare to smart cards, unless agencies provide very strong incentives, such as frequent-ride-discounts and ability to use them in multiple systems, to do so.

In terms of revenue effects, the interviews with staff at the pilot program participating agencies found that there is almost no good quantitative estimate of fare evasion loss, while most managers have some expectation that TransLink would help them (Charles River Associates Incorporated and Systan Inc. 2002). Two potential ways to reduce fare evasion loss by the use of TransLink are: 1) enforcing existing policies without an observant staff member confronting with a passenger, and 2) validating the right to concessionary fares or free travel more strictly.

Certainly, smart cards help agencies track the movement of riders between the services of the participating agencies (Charles River Associates Incorporated and Systan Inc. 2002). This information from this tracking further helps agencies revise agreements on interagency transfer fare revenue sharing. Based on the information provided for the TransLink pilot project among the four operators (Muni, GGBHTA, Caltrain, and VTA), the costs associated with transfers amount to the total of \$441,478 (Nancy Whelan Consulting 2002). This figure translates to 0.10% of the monthly total operating costs for the four agencies combined. This is also equivalent to 7.9% of the total costs of fare media production, distribution, collection, and processing by operator. At the same time, this is a sensitive issue since there will be winners and losers in this agreement revision and the revenue allocation based on more accurate data, assuming aggregate fare revenue remains constant.

In summary, this Bay Area case indicates some costs associated with implementing the interoperable smart card system. First, while the study could examine fare collection costs for individual agencies, there is no information to predict whether aggregate revenue collection costs increase or decrease for the interoperable system as a whole. Second, the accounting system for the clearinghouse exhibited the problem of individual agencies' audit of the TransLink transaction records due to the system limitation. In addition, there is evidence of unreported transactions, which may result in customer disputes. It would incur additional costs to address these problems. Third, the administrative, management, and customer service functions taken by the MTC incur costs in the interoperable system, which are currently covered by the MTC. Capital and operating costs of hardware of the smart card system vary depending on operating characteristics of individual transit systems, such as modes, service areas, and patronage. In contrast to a detailed analysis of expenses—costs—in this case, benefits were not examined. This indicates the difficulty to examine the benefits of the smart card transit fare system. In addition, the clause in the agreement to state that all participating agencies keep their own fare policies shows that technology does not necessarily lead to policy change, which is consistent to our finding in the earlier report in this research.

## **Appendix B: The Los Angeles Case Study<sup>21</sup>**

According to LA Metro, the purpose of smart cards is to provide the most beneficial fare collection technology for the Universal Fare System (UFS). The UFS is not a technology itself, but rather a set of fare collection specifications and requirements that will facilitate the goal of seamless travel among Los Angeles County's many transit modes and operators. Rather than using the standard bid process, the UFS adoption process allows LA Metro to evaluate all available options and procure, through negotiations, the technology that best fits their criteria. These factors include price, performance, reliability, standards, lifecycle costs, delivery timetables, and support logistics (Los Angeles Metropolitan Transportation Authority 1998). In addition, LA Metro seeks to replace their aging bus and rail fare equipment, establish policies and procedures to coordinate fare collection through a regional clearinghouse, and maximize transit customer convenience throughout the county (Booz Allen & Hamilton 2001).

On August 23, 2001, Metro decided to implement a smart card system after considering five alternatives. These alternatives were: "(1) a magnetic system; (2) smart card with magnetic transfers; (3) smart card with "on-board electronically printed" transfers; (4) smart card with manual transfers; and (5) smart card system. All options included the collection of cash fares" (Booz Allen & Hamilton 2001). LA Metro evaluated these five options on a 0-4 scale for the benefits accrued to both itself and its customers. The total benefits to Metro and its customers are shown in tables B-1 and B-2, respectively.

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<sup>21</sup> In this section, we describe the details of the Los Angeles case study. Since we do not intend to make a comparison across the three cases, we do not adjust dollars to one in a specific year; the dollar amounts specified are the estimates included in the original reports.

**Table B-1 Total Benefits to Metro**

<b><u>Benefits to Metro</u></b>	<i>Magnetic</i>	<i>Smart Card With Magnetic Transfers</i>	<i>Smart Card with Printed Transfers</i>	<i>Smart Card With Manual Transfers</i>	<i>Smart Cards Only</i>
Reliability	0	2	2	4	4
Dwell Time Impacts	0	2	2	3	4
Driver Impacts	3	3	2	1	4
Data Collection	2	3	1	1	4
Fare System Security/Enforcement	2	3	1	0	4
Administrative Requirements	2	3	3	1	4
Auditability	3	3	2	2	4
Regional Integration	2	4	4	4	4
Multi-application Potential	2	4	4	4	4
Sub Total	16	27	21	20	36
<b><u>Regional Integration</u></b>	<i>Magnetic</i>	<i>Smart Card With Magnetic Transfers</i>	<i>Smart Card with Printed Transfers</i>	<i>Smart Card With Manual Transfers</i>	<i>Smart Cards Only</i>
Ability to accommodate fare structures	2	4	4	4	4
Ability to differentiate between riders	2	4	4	4	4
Auditability	2	4	4	4	4
Ease of card distribution	2	4	4	4	4
Ability to hold multiple fare types	0	4	4	4	4
Fare flexibility	0	4	4	4	4
Sub Total	8	24	24	24	24
<b>Grand Total</b>	<b>24</b>	<b>51</b>	<b>45</b>	<b>44</b>	<b>60</b>

Source: Booz Allen & Hamilton, 2001

**Table B-2 Total Benefits to Metro's Customers**

<b><u>Customer Benefits</u></b>	<i>Magnetic</i>	<i>Smart Card With Magnetic Transfers</i>	<i>Smart Card with Printed Transfers</i>	<i>Smart Card With Manual Transfers</i>	<i>Smart Cards Only</i>
Convenience: purchasing	4	3	3	3	3
Convenience: use to pay	2	3	1	1	4
Convenience: transfers	3	3	2	2	4
Fare system reliability	2	3	2	3	4
Fare type choice	2	4	4	4	3
Fare media durability	2	3	2	2	4
Fare value security	2	4	3	3	4
Additional applications	2	4	4	4	4
Sub Total	19	27	21	22	30
<b><u>Fare Policy by Technology</u></b>	<i>Magnetic</i>	<i>Smart Card With Magnetic Transfers</i>	<i>Smart Card with Printed Transfers</i>	<i>Smart Card With Manual Transfers</i>	<i>Smart Cards Only</i>
More Convenient than cash	4	4	4	4	4
Rolling Period Passes	4	4	4	4	4
Supports new discount programs	4	4	4	4	4
Seamless transfers	4	4	4	4	4
Balance protection	2	4	4	4	4
Customer loyalty	2	4	4	4	4
Supports employer and social service agency programs	2	4	4	4	4
Autoload	0	4	4	4	4
Guaranteed lowest fare program	0	4	4	4	4
Act as Pass and Cash	0	4	4	4	4
Sub Total	22	40	40	40	40
<b>Grand Total</b>	<b>41</b>	<b>67</b>	<b>61</b>	<b>62</b>	<b>70</b>

Source: Booz Allen & Hamilton, 2001

The “all smart card option” (the fifth) scored as “best” in all categories except convenience of purchasing and fare type choice. LA Metro also concluded that smart cards, when compared with magnetic fare media, offered the most benefit to LA Metro. Smart cards will provide Metro’s customers with a durable fare medium, balance protection, reduced need for cash, and loyalty programs (Metro determined this by citing a focus group in Washington D.C.) (Booz Allen & Hamilton 2001). The smart cards also provide the most policy options, such as loyalty, and guaranteed lowest fare programs, as well as increased flexibility for partnership programs that will broaden the appeal of the smart card fare media. In addition, smart cards were found to have greater capability to track and audit trips (Booz Allen & Hamilton 2001). Again, LA Metro used a numerical scale to quantify these benefits.

Partnering with other organizations such as schools, businesses, government, and other transportation providers may increase benefits further. Due to these benefits, Metro expects an eventual market share of 90% for electronic fare media (Booz Allen & Hamilton 2001). Types of partnership include: purchasing fare with credit/debit/ATM cards, combination card with bank credit/debit cards, combination identification/transit card, and auto-loading from credit/debit card or employer benefits. Although these are intrinsically qualitative benefits, Metro used a numerical ranking system of 0-4 to assess the benefits of the five alternatives. Table B-3 shows Metro’s evaluation of partnership benefits among the five alternatives:

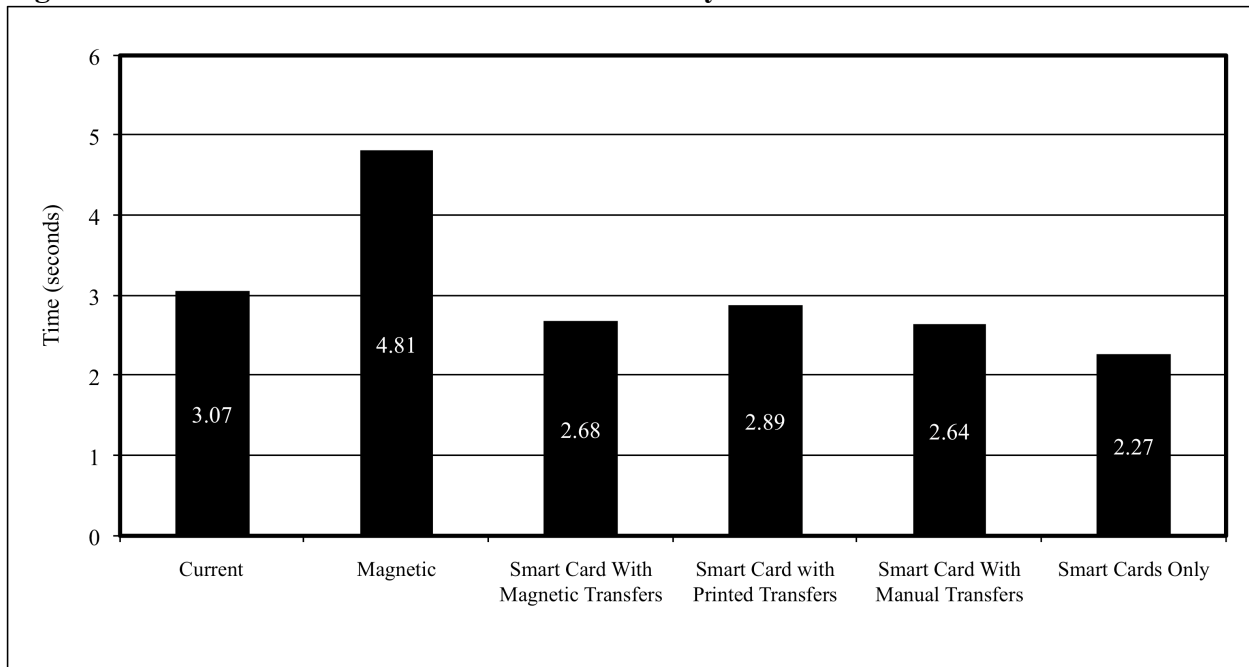
**Table B-3 Partnership Benefits**

<i><u>Activity</u></i>	<i>Magnetic</i>	<i>Smart Card With Magnetic Transfers</i>	<i>Smart Card with Printed Transfers</i>	<i>Smart Card With Manual Transfers</i>	<i>Smart Cards Only</i>
Purchase fare from TVM and POS with credit/debit card	4	4	4	4	4
Post Billing Hotels, Social service agencies, schools, employers	2	4	4	4	4
Combination identification/transit card	2	4	4	4	4
Autoload from credit/debit card or employer benefits	0	4	4	4	4
Combi-card with bank credit/debit cards	0	4	4	4	4
Loading from ATMs	0	4	4	4	4
Total	8	24	24	24	24

Source: Booz Allen & Hamilton, 2001

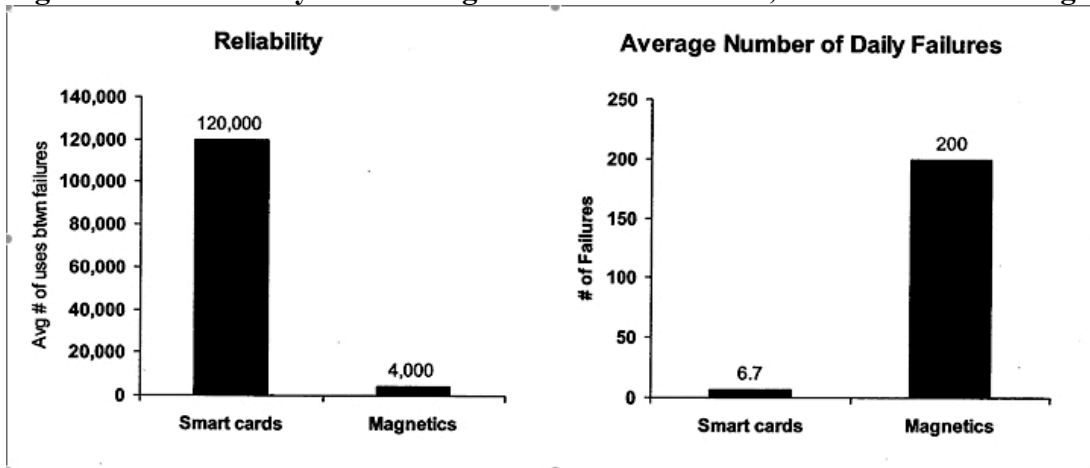
In addition, the smart cards were also found to be best at preventing fraud, which costs Metro between 5.5 million and 11 million dollars per year. The smart cards can also reduce average transaction times from current of 3.07 seconds to 2.27 seconds. Additionally, smart cards were found to have the fastest validation time for any fare media at about one second (Figure B-1). And finally, smart cards were found to be more durable and reliable than magnetics (Booz Allen & Hamilton 2001). Figure B-2 shows the comparison of durability and reliability.

**Figure B-1 Estimated Transaction Times of Fare System**



Source: Booz Allen & Hamilton, 2001

**Figure B-2 Reliability and Average Number of Failures, Smart Cards vs. Magnetics**

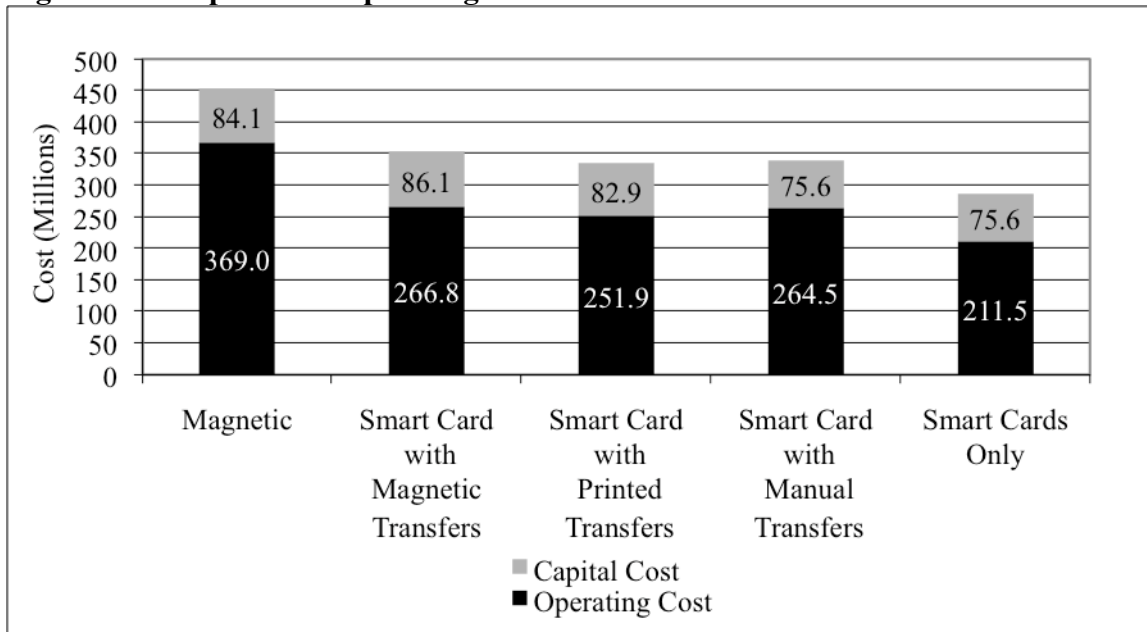


Source: Booz Allen & Hamilton, 2001

The costs of the smart card system were determined to be significantly lower than the other options. Figure B-3 shows the capital and operating costs of the five alternatives. The capital costs for smart cards were estimated to be \$75.6 million, and lifetime operating costs were estimated to be \$211.5 million, totaling \$287.1 million. This is at least \$50 million less than any of the other four options (Booz Allen & Hamilton 2001).



**Figure B-3 Capital and Operating Costs**



Source: Booz Allen & Hamilton, 2001

By adding all the benefit “points” for both LA Metro and its customers (Tables B-1 and B-2) given on a 0-4 scale, we calculated an index to quantify the total benefit of each alternative. We did not include benefits deriving from partnerships in this calculation. We then divided the total cost by total benefit to yield a price for each benefit point. Table B-3 shows this calculation.

**Table B-3 Using Total Benefits and Total Cost to Yield Cost Per Benefit Point**

	<i>Magnetic</i>	<i>Smart Card With Magnetic Transfers</i>	<i>Smart Card with Printed Transfers</i>	<i>Smart Card With Manual Transfers</i>	<i>Smart Cards Only</i>
Total Potential Benefit	73	142	130	130	154
Total Estimated Cost (Capital + Operating, Millions)	\$453.1	\$352.9	\$334.8	\$340.1	\$287.1
Cost Per Benefit Point in Millions	\$6.21	\$2.49	\$2.58	\$2.62	\$1.86

The “Smart Card Only Option” yielded the cheapest cost per benefit point, at \$1.86 million per unit. This effect is also amplified by the smart card’s high amount of benefit points and low total estimated cost. However, since Metro has begun implementing the smart card system, capital costs were reported to have increased to over \$102 million dollars (Los Angeles Metropolitan Transportation Authority 2005). While this about \$30 million dollar capital cost increase would not change a selection among alternatives, this case presents a difficulty to estimate costs accurately before implementing technology.

The LA Metro case provides relatively less information than the other two cases, taking into account the expected size of the smart card operating system. Like SEPTA (as described in

Appendix C), LA Metro considered cost to be a significant factor in evaluating alternatives. Yet while SEPTA is a single operator, LA Metro aims to integrate the smart card with other operators and therefore also evaluated the smart card on “regional integration.” But while a list of benefits considered in an evaluation seems reasonable, points for alternatives were given without a clear explanation for differences among them. The underestimation of costs is also common with capital-intensive transit project such as this. While the minimum cost and the highest benefits points lead, without a surprise, to the lowest cost per benefit point for the smart card only option, the level and quality of cost and benefit analysis in this LA Metro case appear able to provide only partial support for a chosen option. In other words, the cost and benefit analysis is not detailed enough to be a decisive factor.

## Appendix C: The Philadelphia Area Case Study<sup>22</sup>

The Southeastern Pennsylvania Transit Authority (SEPTA) is the major transit agency serving the Philadelphia metropolitan region. SEPTA operates buses, light rail, subway/elevated rail, paratransit, and commuter rail, as well as connector services to New Jersey and Delaware. In 2000, SEPTA commissioned PB Team and LTK Engineering Services to conceive a conceptual design for a new fare collection system that would meet all the needs of SEPTA's many modes.<sup>23</sup> More specifically, SEPTA wanted a system that would facilitate the following goals:

- fare flexibility
- comprehensive information about their riders
- increased convenience to their riders

SEPTA held an initial *Fare Collection Study Workshop* that evaluated three conceptual alternatives: a proof of payment system, an upgrade of the present system, and a new smart card/magnetic system. The workshop used the following evaluation criteria for an alternative fare collection system: simplicity and convenience for users, capability of data collection (e.g. ridership statistics) and discount fare transaction, improved control and communication, banking simplicity, flexibility in technology for future upgrade, accountability, and resources required. The workshop identified the smart card/magnetic system alternative as better than the other two options. The consultant team performed a thorough study comparing various smart card/magnetic systems to other upgrades of the system. The study considered five alternatives:

- 1) Baseline scenario – minor upgrades to improve revenue security only
- 2) System upgrade – using more automation in the processing of cash and tickets, but preserving the basic fare system
- 3) New magnetic/smart card system
- 4) Smart cards only
- 5) Magnetics only

The study identifies Alternative 3, the combination of smart cards and magnetic cards, as the “alternative which provides SEPTA with a system that meets its objectives while providing the best value” (PB Team & LTK Engineering Services 2000).<sup>24</sup> This rationale implies a trade-off between the goals of the universal fare system and the monetary cost of implementing the system. PB Team and LTK Engineering Services calculate the capital, operation, maintenance, and contractual costs over a 15-year period for each of the alternatives. Figure C-1 summarizes these costs.

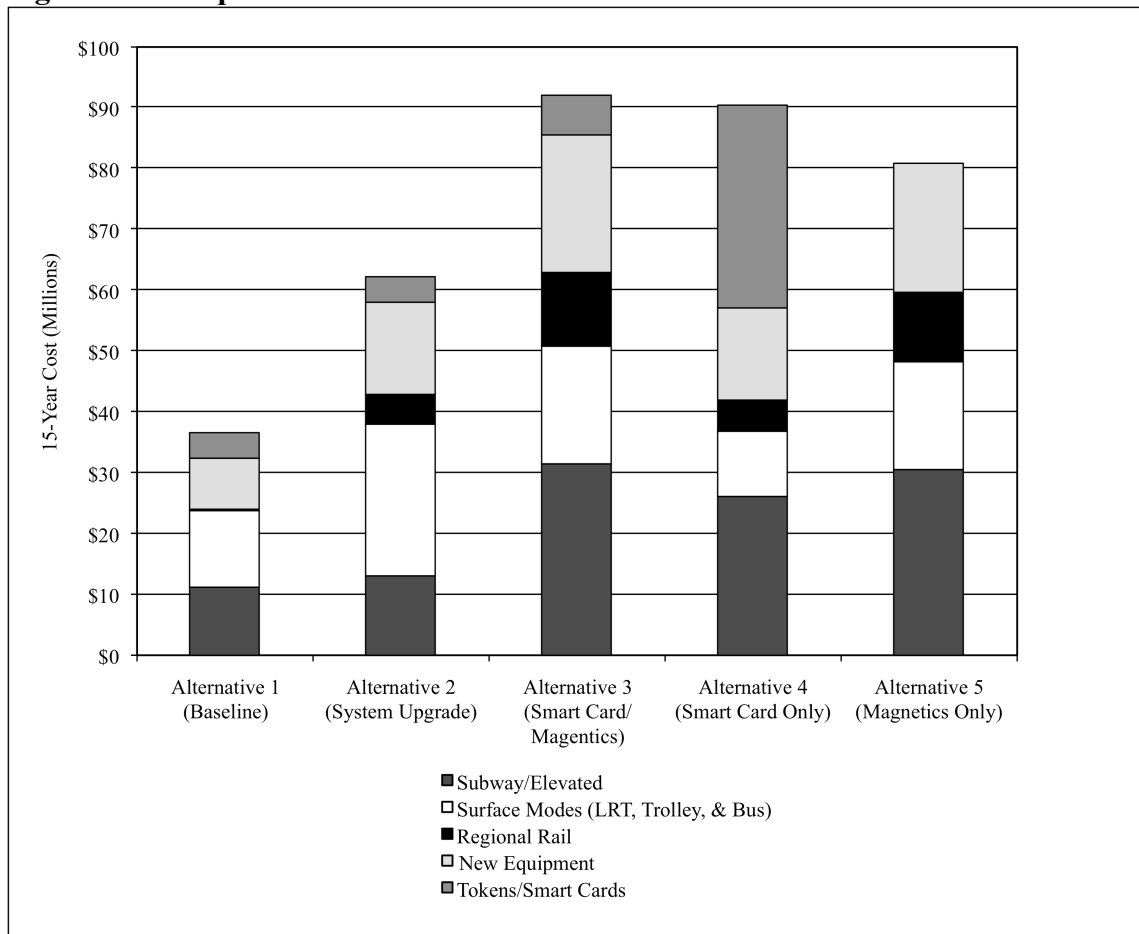
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<sup>22</sup> In this section, we describe the details of the Philadelphia area case study. Since we do not intend to make a comparison across the three cases, we do not adjust dollars to one in a specific year; the dollar amounts specified are the estimates included in the original reports.

<sup>23</sup> This section is based heavily on this report, entitled “SEPTA Fare Collection Analysis and Conceptual Design Study” by PB Team & LTK Engineering Services (PB Team & LTK Engineering Services 2000).

<sup>24</sup> In particular, an integration of “fare collection functionality across all modes, fleets, and business functions” was very important for SEPTA since it operates many different modes (PB Team & LTK Engineering Services 2000).

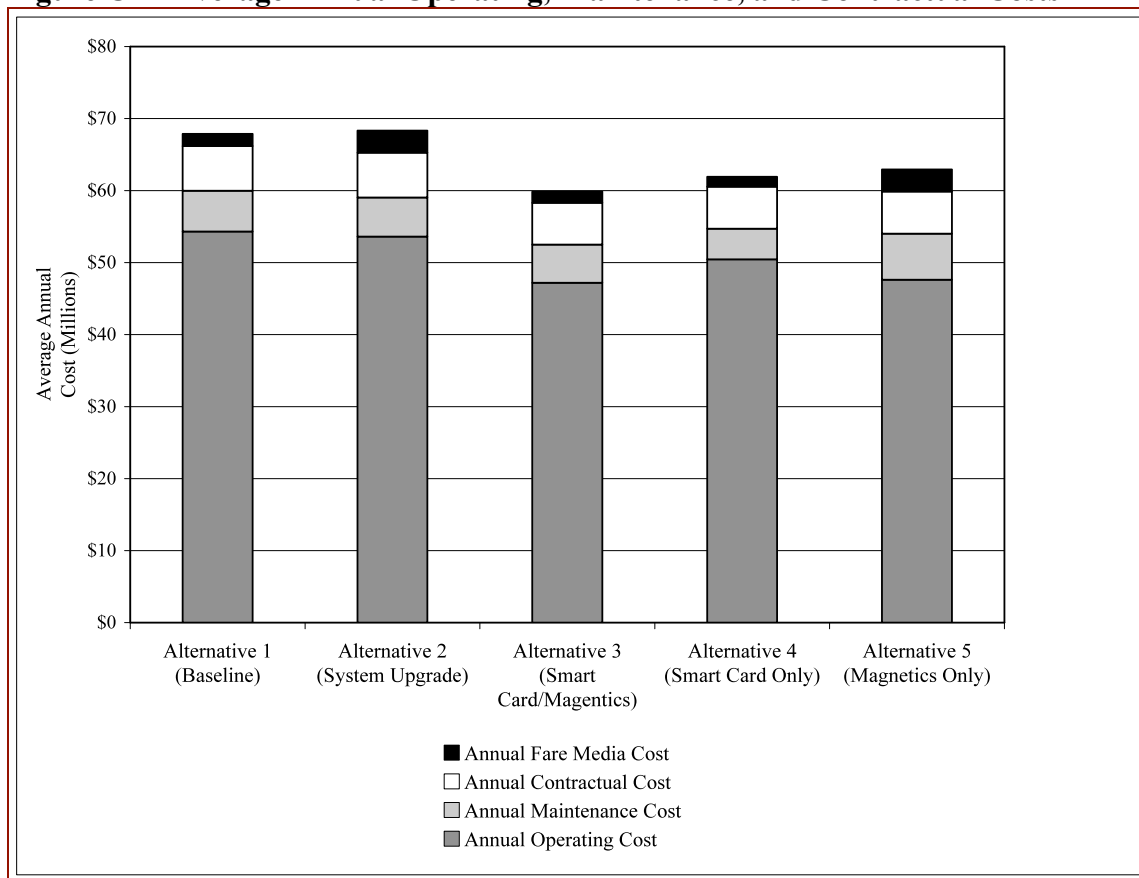
**Figure C- 1 Capital Costs Over a 15-Year Period**



SEPTA operates many different transit modes, and each mode’s share of capital costs is not necessarily the same across the different alternatives. This means that the costs associated with different fare media significantly vary by mode. Also, because each alternative uses differing levels of new technology, the cost of new equipment (hardware not installed on the vehicles themselves e.g. centralized computer) varies across each alternative. Likewise, the cost of fare media is different among the five alternatives. Alternative 3 has the highest cost of new equipment, while Alternative 4 is associated with the highest cost of new fare media.

The smart card/magentic system, the alternative chosen, has the highest capital cost overall, with the smart card only option costing slightly less. However, the alternatives with the highest capital cost have the lowest upkeep costs over time. Figure C-2 shows that Alternative 3 has the lowest average annual operating cost, and Table C-1 shows it has the lowest cost to collect \$1 in both the short and long run.

**Figure C-2 Average Annual Operating, Maintenance, and Contractual Costs**



**Table C-1 Cost to Collect \$1.00, Years 1 and 15 (Using Discount Rate of 6%)**

	Alternative 1 (Baseline)	Alternative 2 (System Upgrade)	Alternative 3 (Smart Card/Magnetics)	Alternative 4 (Smart Card Only)	Alternative 5 (Magnetics Only)
Year 1	\$0.167	\$0.171	\$0.161	\$0.166	\$0.168
Year 15	\$0.196	\$0.194	\$0.157	\$0.175	\$0.165

Source: PB Team & LTK Engineering Services 2000

While this trade-off between capital cost and operating cost signifies the importance of the depreciation period for capitals, the study does not provide a clear explanation for its time period of 15 years. Thus, the smart card/magnetics alternative has the cheapest long-term operating cost, while it is the highest in the up-front capital cost.

Table C-2 shows SEPTA’s total operating cost and Alternative 3’s average annual (over 15 years) capital and average annual operating, maintenance, and contractual costs. We calculated the proportion of Alternative 3’s capital and operating costs to SEPTA’s total cost of maintaining their system. The ratio of the Alternative 3’s capital cost and operating cost to SEPTA’s total operating cost is 0.01 and 0.09, respectively. In other words, the annual implementation costs of the card/magnetic option are 10% of SEPTA’s current annual costs.

**Table C-2 Comparison of Smart Card/Magnetic Option Costs to SEPTA’s Total Annual Operating Cost**

	<b>Cost</b>	<b>Ratio to (1)</b>
<b>SEPTA Total Annual Operating Cost (NTD) (1)</b>	\$695,183,079	1.00
<b>Alternative 3 Average Annual Capital Cost</b>	\$6,134,925	0.01
<b>Alternative 3 Average Annual Operating, Maintenance, and Contractual Costs</b>	\$59,851,987	0.09

The benefits mentioned in this report include the ability to easily expand the system, improved trackability of all fare media, a highly reliable and redundant data communications system, and the ability to provide transactional data for all fare collection system usages and sales (PB Team & LTK Engineering Services 2000). From a revenue collection standpoint, the Smart Card/Magnetics alternative provides highly secure and flexible fare media. The system eliminates insecure cash collections, incorporates electronic payment systems, and can easily and automatically accommodate different pricing structures (PB Team & LTK Engineering Services 2000).

While the report prepared for SEPTA is one of a few that examined the costs and benefits associated with smart card transit fare media, it has some caveats. First, the analysis in this report only measured costs in its quantitative evaluation, whereas LA Metro evaluated their alternatives quantitatively on various levels (e.g. fare collection time, benefits to customers, vehicle dwell time). It is also unknown whether or not the PB/LTK team took into account training of staff members to operate the new technology. Second, except for the difference in cost between all the different alternatives, all benefits are qualitative statements. In many cases, Card/Magnetics and the Smart Card Only systems share the same benefits, such as “increased automation” and “reduction of cash processing”. Because of these rather vague descriptions, it is difficult to tell which system offers a greater marginal benefit. (For example, it is difficult to answer a question, such as “Does one system provide *more* automation, or perhaps a *greater* reduction of cash processing than the other?”) Furthermore, the extra marginal costs in operation and staff expenditures between Alternatives 3 and 4 are quite small (compared to the larger cost differences between Alternatives 1, 2 and 5). In addition, there is no clear explanation for the 15 year period for capital costs. In relation to the selected Smart Card/Magnetics option, it is unknown whether the marginal benefit of the Smart Card Only option is greater than its marginal cost. In other words, the cost differences between Alternative 3 and 4 may be small in the long run, and spending a little extra money on the Smart Card Only option may have been a worthwhile expense.

In spite of all the analyses, however, SEPTA did not upgrade its fare collection system. Despite being the only transit agency in the region and operating many systems, the cost of implementing smart cards proven to be prohibitively high. Since 2000, SEPTA has been continually plagued by budget problems, and has raised fares to cope with them. In 2007, SEPTA attempted to eliminate paper transfers, but a court order mandated that SEPTA keep them. Some advocate a modern electronic fare collection system as a means to get around SEPTA’s fare collection problems, but SEPTA continues to claim a lack of funds to modernize.<sup>25</sup>

<sup>25</sup> “Another Fare Hike Starts.” *The Philadelphia Inquirer*. October 1, 2007. <[http://www.philly.com/inquirer/business/20071001\\_Another\\_SEPTA\\_fare\\_hike\\_starts.html](http://www.philly.com/inquirer/business/20071001_Another_SEPTA_fare_hike_starts.html)>.