Title

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Institutional Issues and Arrangements in Interoperable Transit Smart Card Systems: A Review of the Literature on California, United States, and International Systems

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PATH MO-01: Designing a Policy Framework
for a Statewide Transit Smart Card System Task 1 Report

Executive Summary

Many public transit agencies in California have implemented or are in the process of implementing smart card fare collection systems. Smart cards can provide riders with a convenient fare medium that eliminates the need for exact change, and offers riders one fare card that can be used across multiple modes, operators, and even different jurisdictions. For transit operators, smart cards can minimize fare fraud and pilfering, reduce operating and maintenance costs, speed up boarding times, and enhance data collection for planning purposes. One important objective of transportation planning in California is to increase transit ridership, and smart cards are widely viewed as a way to make transit use more convenient and appealing.

To date, transit agencies in California have begun to implement smart card technologies either as stand-alone systems that are incapable of interoperability with other systems, or as "regional" partner schemas where multiple agencies serving contiguous areas agree to develop compatible systems. While there is still room for debate about the appropriate scale and size of interoperable, interregional smart card systems, California may soon have many dozens of non-compatible systems, possibly affecting the ability of riders to seamlessly travel across modes, agencies, and jurisdictions.

The proliferation of many non-compatible systems may also have negative consequences for transit agencies. Unique, custom-designed, and incompatible systems may lock agencies into contract renewals with particular vendors, raising system costs over time. In contrast, common platforms allow agencies to more easily procure through truly competitive bidding, and allow agencies to achieve economies of scale, as well as collect more comprehensive travel data for planning purposes.

Interoperable smart card systems, however, require agencies to agree on two sets of issues: (1) technical specifications, such as card reading protocol, system hardware compatibility, and data management, and (2) institutional and governance issues, such as the identification of lead agencies, parties for data handling, enforcement agencies, performance measures, incentives for participating, and revenue distribution models. Neither of these is trivial, and can significantly inhibit the proliferation of transit smart cards.

This report compares the results of interviews with transit agency leaders and smart card system project managers, and findings from the current research literature on how agencies are coping with the technical and institutional barriers to interoperability. We find that both the research literature findings and transit leaders agree that conflicts over technological specifications are easier to solve than disagreements arising out of institutional differences. However, our interviews suggest that the institutional, managerial, and policy-related problems that transit officials encounter in forming interoperable systems are of three types:

- <u>Local incentives that motivate agencies to act independently</u>: agency staff and officials are hesitant to relinquish control over fares, are bound by different missions or priorities, and serve different markets of users groups.
- <u>Lack of leadership in directing the development of interregional interoperable systems</u>: California's highly decentralized systems of transportation decision-making means ambiguous governance structures for inter-jurisdictional, inter-agency coordination.
- <u>Lack of institutional incentives to comprehensively evaluate the costs and benefits of interoperable, interregional systems for transit agencies</u>: few comprehensive evaluations of demonstration projects have shown adequate costs and benefits, and evaluations have

primarily been undertaken by smart card vendors or industry groups. Small agencies also have less capacity than their larger counterparts for in-house evaluation and analyses.

We find that, while transit leaders and managers struggle with these issues, the research literature is quite limited in identifying potential solutions to these problems. Based on both our interviews with transit managers and our review of the literature, we have identified four sets of basic questions in need of further research:

1. Are there common characteristics and patterns among agencies that adopt smart cards, and those that do not? Are there similarities between operators that are more or less likely to adopt smart card systems in partnership with other agencies?
2. What is the appropriate scale for interoperability? Under what conditions would a statewide or regional system achieve the most benefits at the least cost?
3. For agencies that have not adopted smart cards or formed partnerships, what have been the barriers to implementation?
4. Among agencies that have adopted smart cards – either as stand alone systems or as interoperable partnerships – how are they able to overcome the institutional challenges to adoption and coordination?

These questions will guide the next steps in our work.

Key words: smart cards, interoperability, institutional challenges, fare policy

Table of Contents

1. Introduction

Smart cards are becoming ubiquitous tools used for small financial transactions because of their improved data storage and faster processing capabilities over previous generations of magnetic stripe cards. In recent years, the transportation industry has started to adopt smart cards on turnpikes and bridges to speed toll payments, in public transit to increase ridership by making fare payment easier, and to enhance data collection for accounting and planning purposes. Smart cards present an opportunity to dramatically improve transit services by providing a convenient fare medium for riders, lowering operating and maintenance costs of fare collection, allowing flexible transit fare pricing, minimizing boarding times, reducing fraud, and providing superior user data for transit agencies (Chira-Chavala and Coifman 1996). Many of these potential benefits of smart card systems can be maximized if the technology is operable across modes, agencies, and jurisdictions – effectively creating a seamless system for smart card holders regardless of mode, operator, or jurisdiction.

Increasing transit ridership is an important goal of California's local, regional, and state agencies responsible for transportation planning. Improving the ease and convenience of riding transit is one important step towards achieving this goal. Technological solutions – such as smart cards – can be used effectively to improve service, but can be difficult to consistently implement across agencies in order to achieve economies of scope and scale. Compatible smart card technologies, standards, and protocols for different transit operations may be essential to lowering smart card implementation costs for individual agencies and realizing the potential of the technology for improved operations and data collection for planning. However, while many of California's major transit agencies have implemented or are in the process of adopting smart card technologies, these individual systems have not been compatible and interoperable across the state (Chapman 2001).

To address this potential problem, California Assembly Member Dutra introduced Assembly Bill 684 in 2003, requiring all publicly funded transit operators that purchase smart card technology to follow uniform statewide requirements for implementing intermodal, interoperable systems. In addition, staff in the California Department of Transportation (Caltrans) would like the FasTrak electronic toll collection system[1] to be compatible with a statewide transit smart card system. AB 684 failed in the Assembly Transportation Committee, but its introduction raises important issues and questions for the future of smart card applications and California's ability to form interoperable systems between multiple agencies.

Interoperable smart card systems require multiple agencies to agree on two sets of issues: (1) technical specifications such as card reading protocol, system hardware compatibility, and data management, and (2) institutional and governance issues, such as the identification of lead agencies, parties for data handling, enforcement agencies, performance measures, and revenue distribution models.

1-1. Problem statement and research objectives

As data storage, retrieval, and transfer technologies have become cheaper and more reliable, the obstacles to smart card interoperability are decreasingly technical and increasingly managerial, institutional, and political. Elected officials and senior staff in California, interviewed in a 2002 study, reported that most intelligent transportation systems (ITS)

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[1] FasTrak is an electronic toll program on San Francisco Bay Area bridges, and is operated and managed by the Bay Area Metropolitan Transportation Authority (MTC). By enrolling in FasTrak, drivers receive a small transponder that can be installed on the inside of the car windshield, and can drive through designated lanes at toll plazas without stopping or slowing. FasTrak automatically deducts the toll from the driver's prepaid account, and accounts can be

technologies suffer from institutional problems as well as market weakness. In particular, one interviewee said regarding smart cards:

> 'California has put a lot of money into technology and system development, but we haven't been particularly skilled at handling the institutional issues. We were slow to get automated toll collection, way behind New York and the New England states. Labor issues and contracting problems seem to get in our way. We have spent years on an integrated fare collection system in the Bay Area but have not really faced up to the underlying problem, which is how to allocate costs and revenues, and that is a problem because underlying that is insufficient revenues for transit' (Deakin 2002b).

Accordingly, our research explores the major challenges to coordinating the design of and agreement on interoperable systems, including weak inter-agency decision-making structures (which inhibit reaching and enforcing arrangements for implementing standard electronic fare media), lack of appropriate governing arrangements, and difficulty in forming fair but manageable revenue sharing arrangements. Staff at individual transit agencies are often reluctant to relinquish control over fare policy and revenue collection activities, have a wide range of missions that are difficult to satisfy with a standard technology, and must follow different protocols for equipment procurement. Additionally, agencies have varying abilities to afford the costs of smart card technology, and serve different transit user populations, which may affect the acceptance of smart cards among their respective riders.

This paper presents views of some transit officials who are implementing smart cards in their agencies and coordinating interoperable systems with other agencies. We asked these experts and practitioners about the barriers they face in coordinating interoperable, interregional systems, and compare their views against existing literature on smart card projects in California, the United States, and international transit agencies. Does the literature address the same sets of issues identified by practitioners, or present solutions to reported problems? From both the

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linked to credit cards for automatic or regular reload. The MTC currently is not implementing FasTrak in interview findings and literature review, we synthesize common patterns in forming interoperable systems, and identify critical issues that have not been addressed in recent research.

While we find in the literature abundant discussion and speculation of benefits of interoperability for users and for the partner agencies involved, little information is available about the costs of coordinated systems. Furthermore, we found no comprehensive evaluation of relative costs and benefits of such a system, or any studies comparing the costs and benefits of interoperability at different geographic scales (i.e. regional interoperability versus statewide interoperability). Therefore, our review does not address the relative costs and benefits of interoperable systems, nor do we address the issue of the most appropriate geographic level of coordination (e.g. local, state, national, or international). These issues are left for further exploration in the later stages of our study.

2. Description of Study: Literature Review and Interviews

Cases included in this literature review are based on geographic pertinence[2] to AB 684, Caltrans' objectives for a statewide smart card system, and available published information. Table 1 summarizes the ten smart card projects that we examined either through published research or through informal interviews with agency staff, and includes information on the transit operator and system area, program name, vendor(s) used, governing body, number of cards issued, and start date of each program.

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coordination with transit fare collection, but generally supports the idea of intermodal interoperability.

[2] Smart card programs have been implemented around the world, and this literature review selectively includes some international examples. One concern about drawing inferences from international examples is that political and jurisdictional factors can be quite different among countries. For instance, Hong Kong's Octopus system has integrated general retail payment with transit fare payment, and has matured with strong state support for card distribution. While Hong Kong's political and institutional situation is markedly different than what occurs in California, the Hong Kong study is relevant to understanding the magnitude and importance of government influence in coordination.

Table 1: Overview of Smart Card Programs

	California				United States				International	
Area	**Los Angeles**	**Bay Area**	**San Diego**	**Ventura**	**Washington**	**Chicago**	**Central Florida**	**Puget Sound**	**London**	**Hong Kong**
Name	EZ Pass	Translink	Transit First	Passport	SmarTrip	ChicagoCard	ORANGES	Puget Pass	Presitge	Octopus
Previous System	n/a	n/a	n/a	GoVentura	Magnetic card/GoCard	Magnetic card	E-Pass	n/a	n/a	n/a
Start Date	Sep-02	Feb-02	2004	Sep-00	May-99	Aug-00	Apr-01	Sep-99	Jun-05	1998
Number of Cards	150,000	8,000	n/a	2,500	150,000	120,000	8,000-12,000	500,000	unknown	7,000,000
Partner Agencies	12	6	7	6	1	2	4	5	4	7
Technology	Paper Flash†	Dual Interface‡	Contactless§	Dual Interface‡	Contactless§	Contactless§	Smart card	Paper Flash†	Smart card	Dual Interface‡
Lead Agency	Los Angeles County Metropolitan Transportation Authority (LACMTA)	Metropolitan Transportation Commission (MTC)	Metropolitan Transit Development Board (MTDB)	Ventura County Transportation Commission (VCTC)	Washington Metropolitan Area Transit Authority (WMATA)	Chicago Transit Authority (CTA)	LYNX	Sound Transit	Transys	Creative Star
Governance	LACMTA	MTC	MTDB	VCTC	WMATA	CTA	ORANGES	Regional Transit Integration Group	London	Creative Star
Daily Riders	1,700,000	1,600,000	250,000	16,000	150,000	120,000	2 bus lines	470,000	8,700,000	6,500,000
Card Vendor	Various	ERG	Cubic	ERG	Cubic	Cubic	Ascom	TBA	Transys (EDS/Cubic)	ERG

† Paper flash cards are shown to the driver as payment, similar to showing an identification card; they are not processed through a fare box.

‡ Dual Interface cards, known also as combi-cards, can be used with contact or contactless readers. They have either a single chip (with a dual processor) or two chips that can transfer value between contact-based functions (such as banking) and contactless functions (such as transit).

§ Contactless cards, sometimes referred to as tap or proximity cards, operate with a radio frequency (RF) that has a range of about 10cm or less. These cards are much faster than cash, and are viable alternatives for transit operators.

Much of the literature covering these ten programs has been produced by or for the transit agencies that have adopted smart card programs or by smart card industry groups; this literature has thus often been promotional or technical, rather than evaluative. Most studies, including those by the Transportation Cooperative Research Program (TCRP), also highlight individual smart card systems, rather than synthesize common themes and patterns among agencies as a whole.

We found studies of these agencies and programs in a wide variety of publications, grouped into two broad categories: advocacy and research. The advocacy materials come from private for-profit and not-for-profit groups that have an interest in transit, transportation or smart cards; and they consist of trade magazines such as *ITS International*, transportation and transit industry publications such as *Railway Age*, and smart card industry literature from the Smart Card Alliance. This category also includes any news stories used for anecdotal evidence of how smart cards are being used. While advocates provide much valuable information, their materials tend to exhibit a bias towards the growth of smart cards. Research materials, on the other hand, provided more evaluation and original research and were drawn from transit or transportation-related research organizations like the Transit Cooperative Research Partnership, from government agencies including the U.S. Department of Transportation, and from academic sources. Government agencies presented the most materials reviewing projects, and this was in part due to the role of governmental financing for the pilot programs involving innovative materials. Table 2 below summarizes the advocacy and research publications we examined and their sources.

Table 2: Summary of Literature Sources

Advocacy			Research			N
Transit Industry	Transport Industry	Private Firms	Transit Industry	Govt. Agency	Academic	Total
8	12	9	11	19	13	72
11%	17%	13%	15%	26%	18%	100%

Publications also tended to be either overview, programmatic, comparative, or technical in scope (see Table 3). Articles presenting overviews of systems provided very general, descriptive information without original data or research; these articles merely summarized the use of smart cards in transit applications, and formed the bulk (50% of the total number of studies in the sample) of the works we examined. Programmatic articles (25%) focused on particular smart card programs in transit agencies, including chronology and implementation of a program, while comparative studies (19%) looked at multiple issues or programs, often with a more analytical approach than most other materials. Finally, technical articles (6%) addressed the technical specifications and engineering issues that accompany smart card adoption.

The literature also ranged in topic, including publications specifically about smart cards (63%), to those about fare cards in general (13%), institutions (13%), intelligent transportation systems (6%), technological standards (4%), and interoperability (3%).

The studies reviewed also represented a range of methods and approaches. Thirty-two percent of the studies we examined were case studies of place-specific projects, including intelligent transportation systems, electronic fare media, or smart cards in particular. Descriptive studies (26%) included literature that provided general information about smart card projects, but used secondary sources of data and had little original contribution. Other studies used quantitative methods of analysis (18% of the studies), qualitative methods (11%) drawing from interviews and focus groups, or some combination of both (13%).

Most literature we examined was research oriented rather than advocacy in nature. The majority of these writings presented overviews, covered the topic of smart card applications, or looked at programs on a case-by-case basis. The literature reviewed in this paper is not necessarily representative of all literature available on smart cards in transportation. Appendix A provides the classification scheme for individual publications, and Appendix B provides an annotated bibliography of all studies included in this review.

Table 3: Summary of Literature Orientation

Scope (N=72)	
Overview	50%
Programmatic	25%
Comparative	19%
Technical	6%
	100%
Topic (N=72)	
Smart Card	63%
Fare Card	13%
Institutional	13%
Intelligent Transportation Systems	6%
Standards	4%
Interoperability	3%
	100%
Method (N=72)	
Case Study	32%
Descriptive	26%
Quantitative Analysis	18%
Quantitative & Qualitative Analysis	13%
Qualitative Analysis	11%
	100%

Interviews were conducted by telephone with six transit agency officials who are actively implementing interoperable systems, and in person with five members of the American Public

Transit Association (APTA) Universal Transit Farecard Standards and Revenue Management Committees at the March 20-23, 2005, Fare Collection Workshop meetings held in Oakland, California. Telephone interviews ranged from 30 minutes to two hours, and committee member interviews averaged 15 minutes. Interviewee names and identifying information (such as agencies and cities) have been removed to ensure anonymity.

3. Technological issues in interoperability

Smart cards have been in development and use since the mid-1970s. While there are many types of cards that can store value and that share some characteristics with smart cards, smart cards specifically refer to a card that is the size of a credit card ('ISO–card') and contains a microprocessor (Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003).[3] These cards are machine readable like magnetic stripe cards, but are capable of multiple applications and data storage. These smart cards can handle payment transactions quickly (Maxey and Benjamin; Fleishman et al. 1998; McDonald 2000), have applications in health records and data management (Blobel et al. 2001), and are commonly used for employee records, identification, and access (Messmer 2004; Holcombe 2005). Since these cards have processors, they can also be easily and quickly reprogrammed and function as mini-computers (Christian 1997, 2003; Zandbergen 1994).

3-1. Card options

Smart cards are available in three basic styles: (1) contact-based, (2) contactless, and (3) hybrid. Contact-based cards are slid through a reader, similar to swiping a credit card. These cards have limited value for transit as the action of swiping slows down the transaction so that there is no speed advantage over cash transactions (Zandbergen 1994; Chapman 2001).[4] Contactless cards – sometimes referred to as tap or proximity cards – operate with a radio frequency (RF) that has a range of about 10cm or less (Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003). These cards are much faster than cash, and are viable alternatives for transit operators. Hybrid or combination cards have two embedded chips, but true hybrids cannot transfer value between one chip and another. Combi-cards, or dual interface cards, can be used with contact or contactless readers. They have either a single chip (with a dual processor) or two chips, each with a microprocessor that can transfer value between contact-based functions (such as banking) and contactless functions (such as transit).

Bank of America first introduced a hybrid card for use in their offices in San Francisco, but the transit industry has since become the biggest advocate of hybrid cards (Fleishman et al. 1998). In California, the Bay Area Metropolitan Transportation Commission (MTC) and Ventura County smart card systems use dual interface cards (Zandbergen 1994; Chapman 2001; Giuliano, Moore, and Golob 2000; Smart Card Alliance 2005; Johnson and Thomas 2001). San Diego officials considered dual interface cards for transit, but the additional costs associated with this technology diminished the attractiveness of contracting for them (Dreisbach-Towle; Irwin 2002).

3-2. Open vs. Closed Systems

An *open system* is one where the stored value card can be used for more applications than just transit. Examples of this include the extension of a transit card to also handle electronic toll

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[3] For the purposes of this research project, however, we do not exclude older generation smart cards that use microchip storage devices.

[4] While the speed of the transactions may not increase with contact cards, there may be advantages over cash by reducing fare fraud. Unfortunately, fare fraud is not easily estimated, and the effects are not well understood. This is further explained in the fare policy section.

collections (Libbrecht and Oy 1999), parking fees (Shoup 2005; McDonald 2000; Smart Card Alliance 2003), retail transactions (Smart Card Alliance 2003; McDonald 2000; Michael 2005), or employer and university services (Shoup 2005; Giuliano, Moore, and Golob 2000; Johnson and Thomas 2001; Foote and Stuart 2000). In a *closed system*, cards can only be used for transit fares (McDonald 2000; Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003). Obviously, open systems allow many more partners in the system, greatly enhancing the potential usefulness of the cards, especially for occasional transit users (Smart Card Alliance 2003).

The system design (closed or open) has implications for the selection of card technology. While contact cards are often the lowest common platform for multiple agencies and uses (Smart Card Alliance 2003; Balducci 2003; Field and Agnew 1996; Fleishman et al. 1998), they may not be suitable when handling transactions for multiple modes that demand different operating parameters. For example, highway toll collection may require cards that can operate over a longer distance between transponder and receiver so that drivers may pass under a gantry without slowing down (Chapman 2001), but transit fare collection may require that cards be read within close proximity of the fare box to prevent inadvertent charges when a cardholder passes near a fare box.

Solutions, however, do exist for operational compatibility. High-tech, and more expensive, solutions include adapting in-car transponders to accept contact smart cards as a plug-in. This technology is currently used for in-car parking meters in some areas as well as electronic toll collections (Gordon and Trombly 2000; General Services Administration 2001).

3-3. Smart Card and Reader Performance and Reliability

In general, smart card technology has been advanced enough to implement advanced fare payment systems (Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003; McDonald 2000; Lovering and Ashmore 2000). Moore and Giuliano (1998) evaluated a 1994 demonstration project in Los Angeles of an advanced fare payment system using either radio frequency cards or smart cards; they found that the electromechanical performance of the equipment consisting of low cost commercial components (not customized products) is high enough for use on transit buses, though the lifecycle performance had not yet been evaluated.

The transit programs that have initiated smart card systems generally have not reported major problems with their technological infrastructure (Hashimoto 2002; Goto, Matsubara, and Sasaki 1994; Ennis 2004; Foote and Stuart 2000). One study found that rates of smart card system failures are as low as credit card failures (Di Giorgio 1997). However, when failures do occur, their consequences can be more severe than breakdowns in older generation systems, simply because of the highly centralized nature of smart card refill stations and transactions. For example, one month after implementation, London's Oyster system experienced a glitch on the morning of March 10, 2005, that prevented card readers from recognizing cards for a few hours. The cost of the free rides and repairs was estimated to be around $3.8 million (BBC News 2005). This type of fare collection failure is certainly not limited to smart cards, but it shows that with centralization of smart card reading, writing, and refilling functions, consequences of a systemic problem can be more severe than cash farebox malfunctions.

Interoperability performance has also become less of a technical problem. Card readers must be compatible with the card technology and the administrative systems, and because of international standards, card readers do not need to be manufactured by the same companies that produce smart cards (Zandbergen 1994; Torode 1998; Michael 2005). Cubic Transportation Systems of San Diego produces a "Tri-Reader," which is a proprietary system that can read multiple types of contactless cards (Maxey and Benjamin).[5] The "unbundling" of cards from their readers allows transit agencies to enter contracts for cards and readers separately, and large transit agencies have taken advantage of contracting with multiple vendors. For example, Washington Metropolitan Area Transportation Authority used Cubic and ERG to implement a regional farecard (Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003).

Transit systems throughout the country and world using smart cards across modes and agencies offer compelling evidence that smart cards are a viable technology (U.S. DOT ITS Joint Program Office 2004; Smart Card Alliance 2003; McDonald 2000; Libbrecht and Oy 1999). As discussed, operational problems can be fixed with technological "patches" such as in-car card readers that allow contact cards to be read across longer distances for highway toll gantries, and manufacturers such as Cubic Transportation Systems have produced readers capable of reading multiple types of cards. These technological fixes, however, add additional costs to the systems.

While smart card systems generally receive high marks for reliability in the industry literature, some transit operators, however, have not required such advanced technology to realize efficiencies in fare collection. The Puget Sound Regional Fare Program, for example, found that magnetic stripe cards were sufficient for achieving their multi-agency, coordinated

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[5] The Tri-Reader can process ISO 14443 Type A and B cards and Cubic's GO CARD. The reader can also be upgraded through smart card overlays to stay current with communication standards.

fare policy at much lower costs without the installation of smart card equipment (Balducci 2003). Between 2000 and 2002, ridership increased by 56 percent, and the transit agency, Sound Transit, gives credit to the regional pass program as well as to improved service and route expansion (Stanley and Hyman 2005).

The Los Angeles County Metropolitan Transportation Authority (LACMTA) also used magnetic stripe cards in conjunction with smart cards for a coordinated fare policy demonstration project (Moore and Giuliano 1998). The Los Angeles project showed that card reliability was quite high, but the card distribution was heavily subsidized and the cards' effect on transit demand is uncertain. Overall evaluation of the project was therefore limited (Moore and Giuliano 1998). While many agencies are interested in achieving broader objectives possible with smart cards, such as improved data collection, few are actually using smart card systems for this purpose (Moore and Giuliano 1998; Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003), partially due to the increased personnel costs for training and outreach or uncertainty about whether the costs justify the expanded objectives (Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003).

In summary, the literature has offered technological solutions for interoperability issues, but has been silent on questions about the relative costs and advantages of smart cards in comparison to older generation technology that is currently in use or to no-tech options. And where there is technological incompatibility, little is said about the status or role of software vendors that can "bridge" together competing systems.

4. Institutional Issues Hindering Interoperability

Transit agencies perceive some important benefits from smart card fare collection systems when multiple agencies – possibly with other transportation-related agencies or public and private entities – implement interoperable smart card systems (Smart Card Alliance 2003; Plouffe, Vandenbosch, and Holland 2001; Lovering and Ashmore 2000; Johnson and Thomas 2001; Foote and Stuart 2000; Fleishman et al. 1998). These benefits include seamless travel for transit users (Balducci 2003), the collection of more comprehensive transit travel data (Foote and Stuart 2000), and the ability for transit operators to act as a group, rather than as individual separate entities when negotiating contracts with technology vendors and manufacturers (American Public Transportation Association Fare Collection Workshop 2005).

The following sections detail specific examples from the literature and from interviews of (1) how variation among transit agencies and the strength of local incentives hinder coordination among multiple partners, (2) how external forces and uncertainties in markets and the direction of technology prevent agencies from reaching consensus, and (3) how ambiguous governance structures stymie the collective identification of goals and objectives of interoperable systems.

We also highlight some smart card programs that have been successful and present evidence from interviews with transit officials who have found some solutions to institutional problems.

4-1. Variation among agencies and local incentives

Agency authority, missions, structures, and protocols

In California, many different types and sizes of public agencies administer, plan, manage, and/or operate transit systems. Small municipal (city or county) transit agencies mainly serve their own jurisdictions, but function under the auspices of regional transportation authorities that coordinate region-wide transit service. In addition to distributing funding to local transit agencies, some regional authorities also provide and operate their own transit services. In addition to transportation agencies, metropolitan planning agencies are involved in long-range regional transportation planning in conjunction with housing, employment, and other planning arenas. State transportation departments may or may not directly provide any transit service, but carry an important role in facilitating statewide planning for transit services.

Thus, each type of agency has different functions and missions – some exclusive, others overlapping. Even among transit service providers, the diversity of agency missions and priorities partly depend on their respective local, financial, operational, and political conditions. Not all transit agencies have the same priorities, and an agency's propensity to adopt smart card systems are likely to be influenced by organizational structure, interest in objectives that require collaborative action (such as improved data collection), and ability to overcome costs. One transit official observed that, "in an agency, if the technology group is separated from the planning groups, you will get silo thinking," and therefore weak interest in adopting smart cards and joint decision-making with other agencies over interoperable systems. Another interviewee reported that locally determined procurement protocols, such as low-bid regulations, prohibit individual agencies from procuring compatible equipment as a group. Members of the APTA Fare Collection Workshop reported that agencies also have varying timelines for equipment replacement, which make it difficult to organize and implement multi-agency systems.

Several studies found that interest in smart card applications also varies by mode: bus-only transit agencies were interested in coordinating a smart card program with their other in-vehicle technologies, while light-rail agencies placed a higher priority on reducing farebox fraud (Foote and Stuart 2000; Field and Agnew 1996; Maxey and Benjamin; Libbrecht and Oy 1999). This implies that coordinating bus operators and light rail agencies may require the incorporation of multiple features to handle the many objectives in partnered systems – often raising the cost and increasing the complexity of the technology. For transit officials, the complexity of smart card technology can be an obstacle in garnering political and public support from their CEOs, board members, and riders, many of who do not understand the highly technical intricacies of negotiating equipment compatibility and who may be particularly risk-adverse as a result (American Public Transportation Association Fare Collection Workshop 2005).

Transit representatives of the APTA Fare Collection Workshop agreed that one benefit of smart cards for agencies is the ability to increase revenues through the floats collected on pre-paid cards and reductions in operating budgets. However, the strength of these incentives may differ from agency to agency. Transit officials from smaller agencies serving non-discretionary dependent riders may need to install both cash boxes and fare card readers, and with disproportionately fewer card users, these agencies collect less float. Smaller agencies also have fewer staff members able to administer the technical details of a smart card program, thus raising the administrative and human resource costs associated with implementing smart card systems. Additionally, the costs of processing smart card transactions (whether through a regional clearinghouse or through the agency itself) approach the costs of counting cash, and while large agencies may have floats to offset these costs, smaller agencies may not.

These differences between agency priorities, missions, and conditions highlight challenges faced by all transit agencies in prioritizing the collective goals of a coordinated smart card system.

Differences in agency patronage and markets

Agencies' incentives to adopt smart cards may also vary by their patronage and markets of users. Acceptance of fare media may differ between income groups and lower income groups may be particularly resistant if they are less likely to have bank accounts used to reload value on cards (Giuliano, Moore, and Golob 2000). The poorest of these groups may also be unable to afford lump-sum pre-payment, and prefer to use cash on a per-ride basis (Foote and Stuart 2000; Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003). Additionally, certain groups such as immigrants may be concerned about privacy and reluctant to provide identification to buy or re-fill a transit card (Giuliano, Moore, and Golob 2000).

One transit official we interviewed speculated that smaller agencies serving very dependent riders or those serving rural areas may have more riders who are unwilling to transition to smart cards. These agencies would therefore be bound to provide both smart card readers and traditional cash fareboxes, adding expense to their systems and only minimal speed advantages of electronic payment (Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003). In contrast, larger agencies may have relatively more discretionary riders who are able (and willing) to transition to smart cards, giving the agency a critical mass of users to realize benefits system wide. Existing literature, however, has not directly assessed the role of agency size, operating environment, or markets of users in the ability to coordinate smart card adoption and multi-agency agreements on interoperable systems.

Market segmentation – the practice of identifying groups of users with similar characteristics who are likely to exhibit similar responses to changes in services (Elmore-Yalch 1998) – may offer opportunities for smart card acceptance, however. Smart card programs that partnered with universities to supply students, faculty and staff with transit cards saw sharp increases in adoption and transit ridership in Chicago and Ventura (Foote and Stuart 2000; Giuliano, Moore, and Golob 2000). Other successful programs included those that coupled transit passes with employee identification passes. The largest of these is the federal government and Washington Metropolitan Area Transit Authority (WMATA) in Washington, D.C. (U.S. DOT ITS Joint Program Office 2004; Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003). These findings suggest that while public acceptance of smart cards may vary from agency to agency depending on ridership markets and demographics, successful smart card programs depend on an agency's ability to identify markets, target these subpopulations, and partner with non-transportation agencies to capture these markets.

Agency reluctance to relinquish control over fare collection and policies

Interoperable smart card systems require some centralized control over revenue distribution among the various partner agencies. As one interviewee stated, "the problem is that if a rider loads his smart card at a bank, or at another transit operator's fare box, and then rides on *our* system, how will that fare be transferred to *us*?" The two common solutions reported by transit officials are the use of a distributed third-party clearinghouse, where a third-party agency acts as a centralized "pool' for all partners involved; or a centralized clearinghouse, where one transit operator acts as the lead in distributing revenues to other partners.

A few studies have documented local government and transit agencies' concern over the use of technology to centralize revenue collection, especially when this centralization removes fare processing out of direct oversight and control of individual agencies (Deakin 2002a; Public Technology Inc.). Agency officials whom we interviewed also reported a culture of mistrust between agencies, but they also raised concerns over the difficulty in forming unified regional fare policies to improve the feasibility of implementing interoperable systems. Interoperable systems become increasingly difficult and complicated to implement when dealing with multiple fare policies among the various partners because of the need to form multiple purses on the cards. One interviewee we spoke with described an example in which every operator had a different age qualification for senior citizen fare discounts, which proliferated into extremely complicated programming needs. This seemingly minor policy difference made an interoperable card surprisingly difficult to implement; however, no agency was willing to change its senior citizen discount policy.

Agencies are resistant to change fare policies and structures for a number of reasons. Some agencies are legally constrained from changing fare policies – such as the Los Angeles County Metropolitan Transportation Authority (LACMTA) under a consent decree.[6] Other agencies are politically bound by public resistance to fare increases or structural changes. And even though smart cards offer potential for innovative policies such as regionally unified fares or distance-based fares, agencies may be limited to their current flat-fare policies because they lack gated entries and exits from the vehicles (Fleishman et al. 1996), and installation may be prohibitively expensive or may require unproven contactless technology (Christian 2003, 1997).

4-2. External factors hindering coordination

Uncertainty over the future of technology

Several transit agencies have recognized the value of interoperable smart cards and have been working towards generally accepted standards (U.S. Department of Transportation 2002) to

[6] The LACMTA was sued by the Bus Riders Union (BRU) in 1994. The BRU charged the LACMTA with discriminatory practices by raising bus fares and eliminating monthly passes. In addition, the LACMTA was accused to be spending a disproportionate amount of its resources on rail projects even though 94 percent of its

facilitate interoperability. In the United States, APTA has been working on developing guidelines and standards for its member agencies in the hopes of lowering the costs of entry for both transit agencies as well as for smaller technology vendors. One member of the APTA Universal Transit Farecard Standards Committee speculated that smaller transit agencies have not been committed to interoperable systems, but could be “brought onboard” if one communication platform is developed, reducing the risks of adopting outmoded technology. Another member speculated that if transit operators could collectively agree on an architecture for interoperability, agencies could save money by outsourcing the clearinghouse functions rather than contracting proprietary systems.

In parallel with these efforts, however, the private sector continues to gain markets of smart card users for credit card transactions, security and access cards, and other data management applications (Blobel et al. 2001; Carter 2001; Dalbert 2001, 2002; Ennis 2004; Goto, Matsubara, and Sasaki 1994; International Railway Journal 1995; Rat 2001; Smart Card Alliance 2003, 2005). Financial institutions that also develop and supply smart card systems tend to develop stored-value cards and are most interested in open system architecture (Quisquater 1997). Major financial institutions that are actively pursuing smart card transit programs include VISA/MasterCard, Mondex, Banksys, and Europoay (Chambers 1998; Libbrecht and Oy 1999).[7]

APTA’s standing committee on Public Transportation Marketing and Fare Policy foresees that, “a contactless smart card for use in the bank, the supermarket, the mall, and the transit vehicle is coming soon…Smart cards will be an early development in the new millennium, but

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riders used the bus. As a result of this lawsuit, the LACMTA entered into a consent decree that limited their ability to raise fares.

[7] These groups, however, have been more influential in European and Asian smart card projects than they have in the United States, because European and Asian markets have relied on smart card technology to reduce credit card fraud and telecommunications expenses. In the U.S., fraud is reduced by online authorizations and other highly sophisticated prevention and detection systems not found in other parts of the world. In comparison to Europe and Asia, the U.S. also has lower telecommunication costs (Smart Card Alliance 2003).

they will soon be outstripped by continuing technological developments (Boyle, Foote, and Karash 2000)."

The future direction of smart card applications will likely be determined by the multitude of players outside of the transportation sector, making it difficult for the transit industry to settle upon the best technology for public transit or to predict with any certainty the future direction of the technology. Members of APTA's Universal Transit Fare System committee commented at the recent annual Fare Collection Workshop that,

> …the major transit agencies [in the U.S.] have adopted smart cards now. Are we fighting the last war? We as an industry are already so invested in this technology, and…as we debate whether to use contact or contactless cards, [another member of our committee] just mentioned new developments in nano-technology. Should banks enter this fray and lead [on the technology]? Or should a third party merge the institutions and sectors? To [stay] involved, we need to invest. Do we do open systems? We need to make a choice. Should we use debit/credit cards right at the turnstile? We don't know.

This comment raises at least two issues that have yet to be resolved: (1) the appropriate choice in technology, and (2) the role of banks and other private sector initiatives in smart card proliferation.

Uncertainty over strategies for public-private partnerships

Successful smart card systems have involved partnerships among multiple stakeholders. These partnerships, however, are difficult to create in part because they are public-private partnerships promoting technology that is largely untested in the United States (Fleishman et al. 1998). Deakin (1998) conducted surveys and interviews of public officials who emphasized the importance of private sector involvement, but it is not clear how important private sector involvement is to overall success of ITS projects, nor is it apparent the appropriate strategies for public and private roles in partnerships. Indeed, some transit agency staff members acknowledge the contentious nature of public and private interests, especially in the transit industry's need to gain leverage over private vendors. One member of the UTFS committee commented that,

> We're here as transit agencies, and vendors are here to make money. If we [transit agencies] want to change the industry, we have to come together… Is anyone here from Cubic? No surprise, they don't have to be here. That's why we're here to decide on a standard, because we're taken up by proprietary vendors.

These discussions raise issues over whether the problem of interoperability will be resolved by market forces – either by market-savvy vendors or financial institutions that eventually dominate the market, or by third-party private vendors that will specialize in technology "patches" or bridges that can easily translate between systems.

4-3. Leadership and Governance Structures

Partnerships among public agencies are notoriously difficult to incubate and may be more challenging at the state (as opposed to regional) level, especially in California. California law, in addition to Federal legislation (such as ISTEA and TEA-21), gives metropolitan planning organizations (MPOs), county transportation agencies, and the district offices of Caltrans significant responsibility and authority in selecting and developing projects (Deakin 2002a, 2002b). Since authority is decentralized among various agencies at different levels in California, Caltrans may face greater difficulty in directing ITS implementation than in other states where state DOTs have more centralized control over transportation decision-making. The California context also means that a "top down" implementation is less likely to work (Deakin 2002a, 2002b).

The process of setting and adopting a platform is uncertain; seats of authority over the decision are unclear; and institutional barriers, including legal issues, limit agencies' authority and power (Lovering and Ashmore 2000; Gordon and Trombly 2000; Giuliano, Moore, and

Golob 2000; General Services Administration 2001). While individual agencies have clear procedures and rules for decision making, the process of joint decision-making between multiple agencies has been more difficult. These issues, combined with the lack of precedence in many cases, weaken the political feasibility of crafting an interoperable, interregional smart card system that local agencies and operators can agree upon.

"Stronger partnerships with local government and other state agencies, developing mutually beneficial, multi-purpose applications (Deakin 2002a)" are considered very important by elected officials and planning staff. However, a lack of partnership and coordination among agencies and local government, other metropolitan agencies, county agencies, and state agencies has been one of the most difficult barriers to overcome when trying to realize mutual benefits and fulfill multiple goals through technology (Deakin 2002a 2002b; Public Technology Inc.).

In contrast, some international cases such as the Hong Kong Octopus card exemplify how centralized government control over transportation investments has been effective in deploying open system smart cards (Wildermuth 1994). However, it is difficult to transfer these institutional arrangements from one place to another due to differences in institutional and legal settings (Deakin 2002a, 2002b).

Through our interviews, however, we found California examples of regionally interoperable smart card systems, implemented in part either because regional systems of funding and decision making have been established, or because of informal networks established between operators. For example, one transit official working in a regional partnership reported that smart cards and equipment for all partner operators were paid for "off the top" of the regional funds so that no individual agency was required to pay for equipment from their own funds. Because the program was paid for from a mutual pot before regional funds were allocated to agency- or area-specific projects, it provided incentives for all agencies to participate. Another transit official at a smaller agency reported that informal networks and a very simple process aided the formation of partnerships among several operators.

> There were no signed agreements – only a handshake. It was done without huge political battles as in other areas. Why? Our program kept very simple operating rules. Operators who wanted to participate just called me and didn't have to go through their boards for approval. In our area, we have smaller ridership and a higher percentage of dependent riders who are less likely to voice opposition. But, we are also developing a rapid white collar commuter force taking transit, and they want easy technology. Since we're small, all it takes is one single person to respond and to carry the project forward.

While transit professionals have accrued some lessons from their program implementation, and while the literature has addressed potential shortfalls in state governing structures, existing research has not examined the issue of the most appropriate scale for interoperability. One interviewee reported that "coordination probably is the best at the broadest scale possible, but often this is impossible because of institutional arrangements."

4-4. Lack of institutional capacity to evaluate costs and benefits

A central premise of this work is that interoperable, interregional smart card systems will benefit both transit operators and transit users, but there has been little analysis evaluating and documenting those benefits (Volpe National Transportation Systems Center. 2004; U.S. DOT ITS Joint Program Office 2004; U.S. Department of Transportation 2002; Torode 1998; Smart Card Alliance 2005, 2003; Quisquater 1997; Plouffe, Vandenbosch, and Holland 2001; Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003; Moore and Giuliano 1998; Michael 2005; McDonald 2000; Lovering and Ashmore 2000; Rat 2001; Battelle Memorial Institute and Charles River Associates 2003; Casey 2000; Chira-Chavala and Coifman 1996). Agencies that have conducted demonstration projects of smart card systems have yet to provide thorough evaluations, either due to lack of institutional capacity, or to avoid political fallout (Giuliano, Moore, and Golob 2000; International Railway Journal 1995; Johnson and Thomas 2001; Lovering and Ashmore 2000; McDonald 2000; Moore and Giuliano 1998; Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003; Plouffe, Vandenbosch, and Holland 2001; Quisquater 1997; Smart Card Alliance 2003). No studies have examined the costs of interregional, interoperable systems, and how these costs compare with expected and documented benefits. The result is a body of literature that has largely been promotional and descriptive, rather than comparative and evaluative, lacking in detailed data collection and methodology, and absent of rigorous analysis.

One study claimed that Ventura County increased revenues by saving $9.5 million annually in reduced fare evasion (Dinning 1995), but in our view the reduction in costs seem to be much too large given the ridership. And, in contrast to the good news often reported for revenue savings and increases, some agencies actually lost revenue (Foote and Stuart 2000; Giuliano, Moore, and Golob 2000). Chicago Transit Authority (CTA) installed a smart card system in 1998, which began as an automated fare collection (AFC) system using magnetic stripe tickets, and eventually changed into a smart card-based ChicagoCard. During the first year of implementation, ridership increased by 4.3 percent overall and most noticeably during off-peak hours, but revenue decreased overall by 3.1 percent, as per-trip revenues declined (Foote and Stuart 2000). The ridership increase was largely due to three factors only tangentially related to automated fare collection. First, new passes were introduced that lowered the price for unlimited monthly passes and included a student U-PASS. Second, the minimum farecard purchase was reduced by 10 percent to encourage switching from coins and tokens. Third, tokens were eliminated and replaced with farecards. All of these actions were specifically targeted to increase ridership. In addition, fare structures were changed dramatically, where calendar-based monthly passes were discounted and converted into a "rolling pass" that was good for 30 days and pre-paid farecards were discounted by 10 percent or more.

London's transit systems experienced a drop in revenue, as well, in part because they instituted a fare-cap program, where all rides after the first three boardings on any given day were free (Transport for London 2005). The drop in revenue for London transit was limited to a per-rider drop, however, rather than overall revenues as was the case in Chicago. In Chicago, the drop in revenue was directly related to incentive programs to get people to ride transit, particularly with the new fare cards. It is unclear what the long-term effects will be on fare revenues for these agencies.

The most burdensome cost associated with broad adoption of smart card systems is the requisite investment in cards, readers and processing equipment. Many transit operators throughout the country are already moving towards a smart card system of some sort as their traditional fareboxes or legacy systems need replacing (Smart Card Alliance 2003). Part of this investment is driven by agencies recognizing that increasing ridership through improved services can improve their operational performance, which is necessary as federal and state subsidies have become less predictable.

Agencies may also face additional costs of data collection, payment collection, and administration computers and software for interoperable smart card systems, which alone can be hundreds of thousands of dollars depending on the size of the system and mode. Ventura County's GoVentura contractors, for example, provide computers capable of processing up to 10,000 daily transactions. Above this threshold, the processing is turned over to the contracting vendor (Multisystems Inc., Mundle and Associates Inc., and Simon and Simon Research and Associates Inc. 2003).

Despite the importance of evaluation of costs and benefits resulting from implementation of smart card technologies, information and objective evaluations of smart card technologies are significantly limited. Policy makers and practitioners have expressed that most literature on intelligent transportation systems is heavily promotional and riddled with jargon, and national ITS experts have indicated a serious concern that there are few rigorous evaluations of demonstration projects in the past, as most are unsupported by reliable evidence or are meaningless without comparison to no-tech options (Deakin 2002a 2002b; Public Technology Inc.). Additionally, most studies in the past have focused on benefits for transit operators without an examination of benefits and costs for travelers, and few studies compare the benefits derived from smart card implementation against benefits derived from policy measures that require no major overhaul of existing equipment (Deakin 2002b).

Much of smart cards' promise lies with the ability of transit agencies to vary and innovate fare policies and improve revenues through flexible pricing, loyalty programs, fare fraud reduction, and floats received from pre-paid fares. And, improved convenience and service quality *should* lead to greater ridership, but there is scant evidence of this so far. The equipment used in the demonstration project in Los Angeles showed the technical feasibility of collecting market data, processing highly differentiated fares (zone and area based fare, route and time of day pricing, special event and special user fares), issuing intermodal transfers, providing automatic verification of card status and updates of fare accounts (which might include negative balances), processing electronic benefit transfers (EBT), and integrating fares with corporate transit, rideshare, and parking plans (Moore and Giuliano 1998). However, the project had insufficient read/write activities to evaluate the effectiveness of these functions in increasing ridership (Moore and Giuliano 1998).

5. Concluding Remarks

Existing literature on smart card applications for transit is comprised mostly of descriptive works documenting technical specifications and obstacles for individual agencies, with only brief or cursory exploration of institutional barriers. Far less research has addressed issues such as the advantages and disadvantages of interoperability at local, regional, statewide, national, or international scales – or even if interoperability should be undertaken at all. The answers to such policy questions are dependent on the purpose and objectives for interoperability, which can be as difficult to agree upon as standards for interoperability. If, for example, interoperability is seen to primarily benefit users, strong arguments can be made for regional interoperability since most transit use is in major urban areas, and travel patterns have become more and more regional in nature. In contrast, if interoperability is pursued to benefit transit agencies or private vendors by mandating a common platform to stimulate competition, or to allow agencies to qualify for federal dollars for equipment upgrades, interoperability might be most beneficial at the national level.

No literature has explored the role of the state in interoperable smart cards nor whether interoperability should be mandated through formal mechanisms (e.g., state legislation such as AB 684) or managed vis-à-vis informal and loosely-coordinated agencies as is currently the case among some agencies. And, if interoperability does improve the ease of using transit, to what extent can it actually *increase* ridership? How effective are interoperable smart card systems when compared with other options such as no-tech alternatives or policy measures?

Evaluations of benefits and costs of smart card interoperability have not been rigorously conducted nor have findings been reliable. Benefits have been overemphasized, while the costs of implementing smart card systems and interoperable partnerships have received short shrift. Additionally, studies have overlooked the evaluation of costs and benefits to users.

While most literature focuses on benefits, little has been conducted on evaluating the institutional barriers that transit officials report nor have studies attempted to document potential solutions to these challenges.

5-1. Next Steps

Despite the abundance of descriptive work on agencies that have adopted smart cards, no research to date has been conducted on agencies that have *not* chosen to use smart cards. Next steps of this research project will address this shortcoming by surveying transit agencies to assess the degree of smart card support and implementation and to address more specific institutional barriers to coordination among multiple agencies. Among agencies that have not adopted (or have decided not to implement) interoperable systems, we will explore the types of issues that prevented them from doing so. Among agencies that have successfully acquired smart card systems and are involved in interoperable systems, we will ask what factors have facilitated their projects.

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Appendix A: Classification of Publications

	Advocacy			Research			Orientation		
Citation	Transit Industry	Transport Industry	Private Firms	Transit Industry	Govt. Agency	Academic	Scope	Topic	Method
Christian 1997	x						Overview	Smart Card	Descriptive
Hashimoto 2002	x						Overview	Smart Card	Case
Johnson et. al. 2001	x						Overview	Smart Card	Descriptive
Maxey et. al.	x						Programmatic	Smart Card	Case
Torode 1996	x						Overview	Smart Card	Case
Torode 1998	x						Overview	Smart Card	Descriptive
Transit Australia 1994	x						Overview	Smart Card	Descriptive
Transp. for London 2005b	x						Overview	Smart Card	Case
Christian 2003		x					Overview	Smart Card	Descriptive
Crawford 1996		x					Overview	Smart Card	Case
Crawford 2001a		x					Overview	Smart Card	Case
Crawford 2001b		x					Overview	Smart Card	Case
Dalbert 2001		x					Overview	Smart Card	Case
Dalbert 2002		x					Overview	Smart Card	Case
Ennis 2004		x					Overview	Smart Card	Case
Int’l Railway Jrnl 1995		x					Overview	Smart Card	Descriptive
Int’l Railway Jrnl 1998		x					Programmatic	Institutional	Case
Lovering et. al. 2000a		x					Comparative	Smart Card	Quantitative
Railway Age 2003		x					Overview	Smart Card	Case
Woldermuth 1994		x					Overview	Smart Card	Case
BBC News 2005			x				Overview	Smart Card	Case
Carter 2001			x				Overview	Smart Card	Descriptive
Dreisbach-Towle 2005			x				Overview	Smart Card	Case
Messmer 2004			x				Overview	Standards	Descriptive
Michael 2005			x				Overview	Smart Card	Qualitative
Oulds 2001			x				Overview	Smart Card	Descriptive
Rat 2001			x				Comparative	Smart Card	Quantitative
Smart Card Alliance 2003			x				Comparative	Smart Card	Descriptive
Smart Card Alliance 2005			x				Overview	Smart Card	Case
Boldt 2000				x			Technical	ITS	Qual./Quant.

Chambers 1996	x			Programmatic	Smart Card	Case
Chambers 1998	x			Programmatic	Smart Card	Case
Field et. al. 1996	x			Overview	Fare Card	Case
Fleishman et. al. 1996	x			Comparative	Fare Card	Qual./Quant.
Fleishman et. al. 1998	x			Comparative	Fare Card	Qual./Quant.
Lovering et. al. 2000b	x			Comparative	Smart Card	Quantitative
McCollum et. al. 2004	x			Comparative	Fare Card	Qual./Quant.
Multisystems et. al. 2003	x			Comparative	Fare Card	Qual./Quant.
Stanley et. al. 2005	x			Programmatic	Fare Card	Qual./Quant.
Zandbergen 1994	x			Technical	Standards	Descriptive
Balducci 2003		x		Programmatic	Fare Card	Descriptive
Batelle et. al. 2003		x		Programmatic	Fare Card	Case
Caltrans 2005		x		Overview	Smart Card	Descriptive
Chapman 2001		x		Technical	Interoperability	Descriptive
Dahlgren et. al. 1994		x		Programmatic	Institutional	Qualitative
Gordon et. al. 2000		x		Comparative	ITS	Qualitative
Holcombe 2005		x		Overview	Institutional	Descriptive
Irwin 2002		x		Programmatic	Fare Card	Case
Libbrecht et. al. 1999		x		Programmatic	Fare Card	Qualitative
USDOT 2004		x		Overview	Fare Card	Case
Public Techn. Inc.		x		Overview	Institutional	Qualitative
USDOT 2005		x		Overview	Standards	Descriptive
Volpe Nat'l Trans. 2004		x		Programmatic	Fare Card	Qual./Quant.
Casey 2000		x		Overview	ITS	Descriptive
Dinning 1995		x		Comparative	Smart Card	Quantitative
FHWA 1996		x		Overview	Smart Card	Case
General Services 2001		x		Comparative	Smart Card	Quantitative
Transp. for London 2005a		x		Overview	Institutional	Qual./Quant.
USDOT 2002		x		Programmatic	ITS	Quantitative
Blobel et. al. 2001			x	Programmatic	Interoperability	Quantitative
Chira-Chivala et al 1996			x	Programmatic	Smart Card	Quantitative
Deakin 2002a			x	Comparative	Institutional	Qualitative
Deakin 2002b			x	Comparative	Institutional	Qualitative
Foote et. al. 2000			x	Programmatic	Fare Card	Quantitative
Giuliano et. al. 2000			x	Programmatic	Smart Card	Quantitative
Goto et. al. 1994			x	Technical	Fare Card	Quantitative

McDonald 2000						x	Overview	Smart Card	Qual./Quant.
Miller et. al. 2001						x	Programmatic	Institutional	Qualitative
Moore et. al. 1998						x	Programmatic	Smart Card	Quantitative
Plouffe et. al. 2001						x	Comparative	Institutional	Quantitative
Quisquater 1997						x	Overview	Smart Card	Descriptive
Shoup 2005						x	Overview	Smart Card	Descriptive
Count	**8**	**12**	**9**	**11**	**19**	**13**			

Appendix B: Annotated Bibliography

Balducci, P. J. (2003). Central Puget Sound Regional Fare Coordination Project. U.S. Department of Transportation ITS Joint Program Office. Washington, D.C., U.S. Department of Transportation.

The Central Puget Sound Regional Fare Coordination (RFC) project features smart card technology that will support and link the fare collection systems of the major transit agencies operating in the Central Puget Sound region of Washington State (King County Metro, Community Transit, Everett Transit, Kitsap Transit, Pierce Transit, Sound Transit and Washington State Ferries). The RFC Project will consolidate hundreds of existing fare media in an effort to streamline the management of fare transactions and facilitate cross-jurisdictional and multi-modal trip making in the Puget Sound region.

The RFC Project will allow customers to purchase or revalue regional fare cards (smart cards) from several outlets (e.g., customer service offices, phone, retail outlets, internet), and will enable them to use the smart card on an estimated 2,379 fare transaction processors (2,207 on-board fare transaction processors, 91 stand-alone fare transaction processors, 81 portable fare transaction processors). The fare will be automatically debited from the smart card electronic purse and/or the card will be acknowledged as a fixed period unlimited ride pass. Each time a card is used, data relating to the date and time the card are used, the amount of fare paid, any incentives applied, the agency providing the service, the route, and if applicable, the institutional account, will be captured and stored electronically. The fare transaction processors have the capacity to access information on the smart card and transfer data to a data acquisition computer. The regional revenue clearinghouse will perform transaction processing, revenue reconciliation, and financial reporting functions for the RFC system. The RFC project is presently in the Preliminary Design Review Phase. The costs shown below reflect the amounts included in the vendor contract and the Inter-local Agreement signed by the participating transit agencies.

The total capital cost of the RFC project is estimated at $42.1 million (nominal), paid out during the 2003-2007 timeframe. This estimate includes all vendor contract cost components, including equipment, equipment installation, fare cards, integration and project management as well as other RFC project administration costs, including sales tax, contingency fund, and project management team costs. This estimate includes only regionally shared items in the RFC Project capital budget and does not include an estimated $6.4 million in individual agency implementation costs. Cost shares are allocated among the seven participating agencies based on the proportional share of total RFC project equipment purchased by each agency. Total operations and maintenance costs over a 10-year time horizon are estimated at $32.8 million (nominal). These costs include depot maintenance, software maintenance, customer service, card procurement and distribution, and fare card management. Preliminary operations and maintenance cost shares are distributed among the participating agencies per a formula based on ridership projections for 2005. For example, King County Metro accounts for an estimated 72 percent of total transit ridership in the region. Thus, King County Metro will initially pay 72 percent of the total RFC system operations and maintenance costs. The operations and maintenance cost-sharing formula will be revised annually based on actual transaction data.

Battelle Memorial Institute and Charles River Associates (2003). Evaluation Strategy Puget Sound Regional Fare card: FY01 Earmark Evaluation. U.S. Department of Transportation ITS Joint Program Office. Washington, D.C., U.S. Department of Transportation ITS Joint Program Office.

This research outlines a strategy for evaluating a regional fare card (RFC) in the Puget Sound region in Washington state. The Battelle Memorial Institute, along with Charles River Associates, organized the goals and approach for evaluating the program.

The program requires the cooperation of many different agencies. It is organized as follows. King County Metro Transit is the lead agency responsible for implementing the Central Puget Sound Regional Fare Coordination Project (RFC Project). The project features a smart card technology that will support and link the fare collection systems of the major transit agencies operating in the Puget Sound region. The RFC Project will consolidate hundreds of existing fare media in an effort to streamline the management of fare transactions and facilitate the cross-jurisdictional and multi-modal trip making of travelers in the Puget Sound region. All seven public transit agencies in the Central Puget Sound area are participating in the project, and on April 29, 2003, each of these agencies signed agreements to participate. These are:

- King County Metro Transit, lead agency
- Community Transit
- Everett Transit
- Kitsap Transit
- Pierce Transit
- Sound Transit
- Washington State Ferries.

Integrating a regional fare card system across the large number of transit users and land area constitutes a challenge both for the project partners, who must successfully implement the program, and for the evaluation team, who must capture the institutional and organizational processes undertaken and the issues and challenges faced. This evaluation of the project was not included in the document nor were any early findings.

BBC News (2005). '£50,000 lost' in Oyster failure. BBC News UK Edition. London.

This news story covered a failure of the new Oyster system shortly after it was implemented in London for transit.

Blobel, B., Peter Pharow, Volker Spiegel, Kjeld Engel and Rolf Engelbrecht (2001). "Securing interoperability between chip card medical information systems and health networks." International Journal of Medical Informatics 64: 401-415.

Health information systems supporting shared care are going to be distributed and interoperable. Dealing with sensitive personal medical information, such information systems have to provide appropriate security services, allowing only authorized users restricted access rights to the patients' data according to the 'need to know' principle.

Especially in healthcare, chip card based information systems occur in the shape of patient data cards providing informational self determination and mobility of the users as well as quality, integrity, accountability, and availability of the data stored on the card, thus improving the shared care of patients. This paper presents a feasibility study of the DIABCARD project for health care providers and looks at issues of interoperability, security and legal issues. The project is found to be feasible and much of it can be widely used within the health care industry.

Carter, A. (2001). Smart Card Technology Just Got Smarter. Metro Exchange.

This commentary piece discusses how rail and bus transit electronic fare collection developed from magnetic stripe cards to smart cards. In part, the author argues, transit agencies switched from magnetic stripe cards because of the increased potential of smart cards to customize their fare systems for their customers. The article provides an overview of how transit agencies might use the capacity of smart cards to improve their electronic fare collection, but it fails to provide any evidence that transit agencies are using improved data collection to target potential riders. It uses manufacturer representatives to argue that smart cards are a superior type of electronic media.

Casey, R. F. (2000). What Have We Learned About Intelligent Transportation Systems? John A. Volpe National Transportation Center. Washington, D.C., Federal Highway Administration: 87-106.

Chapter five of this publication describes the Advanced Public Transportation Systems of the U.S. DOT's ITS program. The report summarizes the deployment of many ITS innovations for transit agencies across the country, and suggests that most ITS technologies have limited deployment at this time. Additionally, cost concerns are likely to hinder widespread adoption of ITS technologies for the foreseeable future.

Chambers, B. (1998). "The Octopus Hong Kong's Contactless Smartcard Project." Public Transport International 47(1998/3): 14-19.

This piece described the Hong Kong experience with their Octopus contactless smart card system. Introduced in 1997, the system took three years to develop and test and was quickly adopted by 50 percent of the city's population and handled over 2.5 million transactions daily. The public enjoyed the use of one card for all transit trips. Transit operators were enticed into the program by the promise of reduced equipment maintenance, reduced cash transactions, and the possibility of better incentive fare programs. The system infrastructure is shared among the participating operators, and they realized economies of scale cost reductions in its implementation and maintenance. In addition, the shared commitment of operators allowed for multi-agency promotions designed to increase ridership.

This paper identifies four layers of the Hong Kong system, as well, and briefly describes each one. The first layer is the central clearinghouse. This layer consolidates all transactions, facilitates settlements and maintains the master records of the smart card transactions. Second, the service provider's central computer data processing system layer collects, processes and distributes data from and to each of its primary locations. The third layer is the service provider's local data processors. These are workstations that provide communications between the locally collected data, including transactions, and the service providers central computers. The fourth layer is the contactless smart cards processing equipment. This equipment is the interface between the card and the fare collection equipment, including kiosks and readers. To implement all of these layers requires a tremendous amount of planning and coordination. Consistent design standards were used in Hong Kong to minimize customer confusion.

Chapman, B. (2001). White Paper on Establishing Interoperability of the Caltrans FasTrak Electronic Toll Collection System with Regional and Local SmartCard Transit payment Systems now being Deployed within the State of California. Caltrans. Sacramento.

This internal document outlines the opportunities and challenges that face creating interoperability between FasTrak electronic toll collection and local smart card transit operations. The goal of interoperability is to increase the traveler friendliness of transit, especially between providers. It also recognizes that many highway toll customers use public transit during portions of their commutes. One basis for pursuing this idea is to explore how technology can be used to better manage the transportation system. This paper introduces two basic questions about interoperability. First, what barriers exist to establishing interoperability? Second, what actions should be recommended to achieve interoperability? The authors suggest that there are no prohibitive barriers to interoperability, and that Caltrans should strongly advocate for interoperability to achieve it across the state.

Chira-Chavala, T. and B. Coifman (1996). "Impacts of Smart cards on Transit Operators: Evaluation of I-110 Corridor Smart Card Demonstration Project."

This report presents the evaluation results of the first transit smart card demonstration in California. The transit smart card system was deployed on one bus line each from the Los Angeles DOT, Torrance Transit, and Gardena Transit. The study then assesses the cost and benefit implications of the smart card system to other transit agencies. The authors support their work with interviews of transit personnel, onboard observations and communications with Echelon, the company contracted to configure the system.

The authors found that the smart card system worked smoothly and reliably during the six-month demonstration project. The fare cards were popular with passengers, who liked the convenience, and transit personnel, who liked the faster transaction times, especially compared with cash fares. The cards did reduce transaction times, vehicle down times, driver workloads and driver stress. Smart cards also hold promise of collecting improved ridership data for planning purposes.

The cards used in the demonstration were radio frequency proximity cards in LA and Torrance and contact cards in Gardena. Overall, about 600 cards were issued and were used for pre-purchased trips. The key findings of the study are as follows. The cost of fare collection with smart cards ranged from being about equal to previous collection technologies to about one-third less expensive than conventional fare boxes. However, capital costs for installation are substantially higher. Vehicle dwell times remained unchanged because cash fares were still present, negating any speed advantages from smart cards. The data collected were not used by the transit agencies for planning, but the managers were optimistic about using them. Drivers liked the increased ease of smart cards to cash fares and thought they had positive impacts on their work performance.

Christian, F. (1997). What makes the smartcard smart? Mass Transit. 22.

Christian, F. (2003). Introduction. The Parking Professional: 43-47.

These two articles discuss the potential for smart cards and the technological issues that present challenges to commercial success of smart cards. The author explains that smart cards are part of the chip card family, specifically the microcontroller circuit cards (MCU). These cards can be programmed to interact with card readers and are very effective for banking and financial applications. They hold great promise for transportation. Contactless cards are MCU cards and are either passive cards or active cards. Passive cards have no internal power source. Active cards carry their own battery and are substantially more expensive and thus are expected to be used far less than passive cards.

Contactless smart cards are powered by radio frequency energy. This energy is converted into DC voltage so that the cards can carry out its functions. MCU cards require 5-10 times more DC power than the more simple memory cards. The ability to convert radio frequencies into energy necessitates the close proximity of contactless smart cards to readers, as the energy decreases with distance rapidly. This means that contactless smart cards need to be within about 10cm of the reader to be in range.

The International Standards Organization (ISO) has developed the standards for smart cards. They are ISO 14443, which govern proximity cards, and ISO 15693, which applies to vicinity cards. There is more interest in ISO 14443 than the other standard because it is further developed. In addition to these standards, there are efforts in many countries to standardize their transit cards with retail payment media.

Dahlgren, J. and D. B. Lee, Jr. (1994). Integrating ITS Alternatives into Investment Decisions in California. California Centre for Innovative Transportation. Berkeley, University of California, Berkeley.

The purpose of this study was to document the process by which decisions are made in California about implementing intelligent transportation systems (ITS) projects. It also considers how to bring ITS into the mainstream by evaluating ITS projects alongside non-ITS projects. The paper presents a review of the transportation planning process and how this process influences the adoption of ITS projects. Overall, the authors find that though there are many agencies at many levels of government involved in transport planning, the process is workable, but decision makers often lacked critical information at relevant periods of the process.

Specifically, decision makers tended to not have information about the expected impacts and benefits of proposed ITS projects. Often, government agencies relied on generic claims about the efficacy of projects. However, the costs associated with ITS projects often were quite specific.

The authors suggest that providing better information should not take major effort because, in part, precise answers are not essential. Since no information is currently available, even estimates represent an improved situation. The examples of the Freeway-Arterial Diversion in Silicon Valley and the SR-17 HOT Lane project in Santa Cruz are provided as examples of how information dissemination can be improved.

Dalbert, T. (2001). Number One is Beijing. ITS International.

Dalbert, T. (2002). ORANGES for Picking. ITS International: 54-55.

These two articles are short descriptions of how Beijing chose Philips Semiconductors MIFARE smart card technology for their new 'Beijing One' card, and ORANGES in central Florida developed their multi-agency collaborative partnerships for electronic payment in transport.

Deakin, E. (2002a). Mainstreaming Intelligent Transportation Systems: I. Findings from a Survey of California Leaders. Berkeley, California, University of California Transportation Research Center.

Deakin, E. (2002b). Mainstreaming Intelligent Transportation Systems: III. Interviews with National Experts. Berkeley, California, University of California Transportation Research Center.

These reports investigate issues that affect the implementation of ITS in transportation planning. The first report is based on interviews with elected officials and senior planning staff of jurisdictions and agencies in California. The second report is based on interviews of national ITS experts. Since findings are similar in these reports, the results are summarized below.

Many interviewees expressed a concern that information and evaluation of ITS technologies and the implications are generally limited. Policy makers and practitioner stated that ITS literature is heavily promotional and full of jargon. Many national ITS experts expressed a serious concern that there are no good evaluations of demonstration projects. In particular, a lack of good information on ITS benefits and costs is a serious problem. In addition, most studies in the past focused on benefits and costs for transit operators and have not examined benefits and costs for travelers.

This lack of information causes a problem that agencies, which are considered to participate in ITS planning, have no consensus for advantages of implementing ITS technologies: what only smart cards can do and achieve or for what smart cards have much more advantage than other technologies or policy measures. The evaluation of an alternative is particularly important if legislators allocate earmarked funds for implementation of ITS technologies, since ITS programs will deprive funds for other projects.

In addition to a lack of consensus of costs and benefits regarding ITS implementation among transportation agencies, there are several institutional issues identified to prevent ITS from making as much progress as people expected. Most respondents expressed institutional and political concerns about potential central control through ITS technologies over facilities and services that are currently managed by individual agencies. These concerns are particularly relevant to issues of revenue sharing and technology standards for smart card equipment.

There is also a lack of partnership and coordination among various agencies, local government, metropolitan agencies, county agencies, and state agencies to search ways to realize mutual benefits and fulfill multiple goals by deploying ITS technologies. Local agencies can hardly see benefits of ITS technologies for them.

Another institutional issue is a lack of leadership. Federal legislation, such as ISTEA and TEA-21, and California law give metropolitan planning organizations (MPOs), county transportation agencies, and Caltrans' district offices significant responsibility and authority for selecting and developing projects. This autonomy for regional and local agencies makes it difficult for state DOT to take leadership. In particular, in the California context in which authority is decentralized among various agencies in various levels, Caltrans has more difficulty in directing ITS implementation than in other states where state DOTs have more central control. In other words, a "top down" implementation will hardly work in California. Caltrans need to largely rely on policy directives backed up with incentives and rewards to overcome this difficulty. Another suggestion made is that the state DOT should take leadership on implementing ITS technologies by example, ready-to-go technologies on its own facilities and within its own agency.

Di Giorgio, R. (1997). Smart Cards: A primer. *JAVA Developer*. *New York City, JAVA World. 2005.*

This article briefs JAVA programmers about the use and viability of smart cards. Most of the article contains a discussion of programming code for smart card applications, but the author provides a concise overview of the expected impact of smart cards on small retail payments and other personal issues.

Dinning, M. (1995). Benefits of Smart Cards in Transit. John A. Volpe National Transportation Center. Washington, D.C., Federal Transit Administration.

This paper presents a general overview of expected benefits from using smart cards for fare collection by transit agencies. The benefits include improved ridership data, fare flexibility, faster boardings and alightings, partnership opportunities and improved service.

Dreisbach-Towle, J. San Diego Smart Card Project. San Diego, Urbanicity. 2005.

This article is a short piece that provides a brief overview of the proposed San Diego smart card program. It is useful as background information but does not contain specific information about the program.

Ennis, M. (2004). "The Oyster Smart card is a Pearl of a Solution." Traffic Engineering and Control 45(1): 2.

This article describes the experience of London during deployment of the Oyster smart card for transit. The program began in spring of 2003. It included over three million smart cards, 16,000 remote ticketing devices, new gates at 150 stations, training of 3,500 ticket sellers and new fare programs for riders. The managed rollout introduced different levels of fare cards at different times until eventually all ticket types will be offered through Oyster.

Field, D. L. and N.P. Agnew (1996). London Underground's Ticketing, Past, Present and Future. Public Transport Electronic Systems.

This is a short article that traces the development of ticketing on London transport from the early 1900s to the introduction of the Prestige system in the 1990s. The London Underground vends over 180 million tickets annually and processes over 926 million gate transactions. This huge volume presents a challenge for any fare system and highlights the advantages of using a magnetically encoded ticket (the precursor to smart cards). The benefits realized included labor savings, reduced fraud, improved data collection and eased the introduction of innovative fare policies.

The magnetic card is not the most convenient media for intermodal transit, however, especially for travelers carrying luggage and those with physical handicaps. In addition, magnetic stripes are corruptible, and customers are reluctant to store a lot of value on a card when they have to put it into a machine because of the fear they may not get it back. These concerns suggest improvements to the system should include contactless smart cards.

Fleishman, D., C. Schweiger, D. Lott and G. Pierlott (1998). Multipurpose Transit Payment Media Report 32. Transit Cooperative Research Program. Washington, D.C., Transportation Research Board.

This report contextualizes advances in payment technology, especially smart cards and other stored value cards, as part of a broader set of opportunities for transit. Interoperability among transit agencies can be supported, plus non-transit uses can be added to the fare card. Closed environments are those that are limited to transit, while open environments are those that include other non-transit entities, such as banks or universities. This report addresses many different issues relating to electronic fare media, including institutional, legal, technological, financial, and acceptance.

This report suggest that transit agency interest in pursuing multipurpose fare programs is shaped by their interest in regional transit cooperation, reduction of fare collection costs, increasing revenues, improving customer convenience, improving ridership data collection and use, and expanding the market base for transit. To fulfill these points of interest, agencies may consider partnering with financial institutions that are already administering smart cards. In this way, open systems can flourish as the financial institutions pursue non-transit uses.

The relative scarcity of smart cards used in the United States presents a challenge to transit operators as customers are not as comfortable using the technology and standards have not been fully developed. This also makes the potential market for smart cards difficult to predict. However, research supports the notion that potential smart card users are interested in using the technology when it becomes available.

Foote, P. and D. G. Stuart (2000). "Impacts of Transit Fare Policy Initiatives Under an Automated Fare System." Transportation Quarterly 54(3): 15.

The Chicago Transit Authority inaugurated several fare policy and pricing initiatives two years after beginning its automated fare collection system. The AFC system was helpful in carrying forth the initiatives, monitoring the revenue and ridership impacts, and generally facilitating their implementation. The CTA reports that over 1.2 million riders daily are part of the AFC. This represents 82 percent of their total ridership. The remaining 18 percent continue to pay cash for their trips. The AFC system includes stored value automated farecards, as well as monthly passes. The usage of passes has increased substantially due to related discounting and previously unavailable passes. One of the new passes was a U-Pass, issued in conjunction with 14 schools, which made 30,000 students eligible for discounted travel.

The CTA saw substantial ridership growth after the passes were introduced. The 4.3 percent increase in ridership was partially offset by a decline in revenue per passenger due to the discounts available with the passes. However, the fare structure was also simplified, which may have accounted for some of the decrease. Overall, the AFC program was very adept at handling multiple fare options and data collection. The U-Pass program was the most successful aspect, as it greatly increased ridership at off-peak hours, making better use of existing capacity.

General Services Administration (2001). CIO PKI/Smart Card Project Approach for Business Case Analysis of Using PKI on Smart Cards for Government wide Applications. Washington, D.C., GSA.

Booz·Allen & Hamilton, under contract to the General Services Administration, was tasked to document a business case approach that can be utilized by Federal agencies considering an investment in Public Key Infrastructure (PKI) on smart cards for government-wide applications. The Chief Information Officer (CIO) of the Enterprise Interoperability Emerging IT Committee plans to use the methodology presented herein to help these agencies build business cases that examine using smart cards in concert with the emerging Federal PKI to provide government employees with a standard identification card to be used for authentication, access control, and electronic commerce (e-commerce). The intended audience of this report is investment decision makers of Federal agencies that are seeking information assurance solutions for their agencies and those practitioners charged with developing business cases.

This report was prepared as a means of helping Federal agencies understand the components for building a sound business case for using PKI/smart cards (cryptographic smart cards) within Federal agencies. By following the business case methodology presented in this document, decision makers will be able to determine for themselves whether the investment costs for PKI/smart cards are justified and whether investment benefits outweigh the risks. Decision makers are also given guidance on evaluating the economic impact of alternatives, comparing alternatives, and ultimately monitoring the investment.

Technological advances and recent legislation like the Government Paperwork Elimination Act have pushed Federal agencies into making e-commerce a reality.

Technology and infrastructure are in place to support initiatives such as paperless contracting, wide-area workflow, and the expansion of the government-wide commercial purchase card program. E-commerce represents a radical change to the way business has been conducted within the Federal government. To support this radical change, Federal agencies are being required to increase overall network security including providing information assurance. Electronic authentication issues are leading many agencies to consider PKI/smart cards as a probable solution to the security challenges presented by e-commerce. While it is possible to use PKI without smart cards or vice versa, this report focuses on the joint use of PKI and smart cards.

A business case analysis is simply an extended form of cost-benefit analysis that considers factors beyond financial metrics. Other factors to be considered might include security needs, business needs, associated risks, and qualitative benefits resulting from the investment. At its core, however, any business case analysis is founded on a comprehensive economic analysis; thus, the business case methodology will examine PKI/smart cards in the context of its investment worthiness as well as its technical and programmatic feasibility.

Giuliano, G., J. E. Moore II and J. Golob (2000). "Integrated Smart-Card fare System: Results from Field Operational Test." Transportation Research Record 1735(1735): 138-146.

This research examined the experience of Ventura County when demonstrating phase III of their smart card program. The program successfully showed that smart cards are feasible, but it highlighted some trouble areas in technical performance, user response and institutional issues. Technical performance was hampered by institutional issues, which caused problems with the installation of equipment, failure of equipment and poor communications. The user response was generally satisfactory with the program, but the cards were not embraced by the low-income, non-English speakers who are the majority of Ventura County's transit riders. Institutionally, there were no clear roles defined and responsibilities were mishandled, and the technology was misunderstood and thought to be much simpler than it proved.

Gordon, S. and J. Trombly (2000). Tracking the Deployment of the Integrated Metropolitan Intelligent Transportation Systems Infrastructure in the USA: FY99 Results. U.S. Department of Transportation ITS Joint Program Office. Washington, D.C., Department of Transportation: 66.

This report presents the results of an update of a major nationwide data gathering effort to track the deployment of the metropolitan ITS infrastructure in the largest U.S. metropolitan areas. There are nine components that are tracked as part of the ITS infrastructure: Freeway Management, Incident Management, Arterial Management, Transit Management, Electronic Fare Payment, Electronic Toll Collection, Highway-Rail Intersections, Emergency Management, and Regional Management. These components were measured with various indicators that reflected their level of implementation of ITS.

The results show that 83 percent of all fixed-route buses accept electronic fare payment, and 56 percent of rail stations accept electronic fare payment. There were three metropolitan areas using smart cards in 2000, and this was expected to increase to 24 in 2005. It is unclear if this prediction was met. Magnetic stripe cards were the most popular electronic fare media for transit agencies.

Goto, K., H. Matsubara and K. Sasaki (1994). "New Railway Ticket System Using Contactless IC Cards." Transportation Systems: Theory and Application of Advanced Technology 2: 6.

The article is about contactless IC cards used in Japan, and it describes that new contactless IC cards were developed for new railway ticket systems. There were two types of cards, one with medium wave radio and a microprocessor, and one that uses microwaves and ASIC chips. These cards were tested, and this article states that the new systems provided enough ability to accomplish more user services than the previous system, including improved performance and fraud reduction.

Hashimoto, S. (2002). Japan Touch and Go with SUICA. Public Transport International-Special Edition: 20-22.

This is a short descriptive article about the IC card system used for Tokyo metropolitan railways.

Holcombe, B. (2005). Government Smart Card Handbook. U.S. General Services Administration. Washington, D.C., U.S. General Services Administration: 262.

This handbook is intended to serve as a reference document providing government agencies with guidance for implementing an interoperable smart card program within their organization. This handbook was originally conceived and published in 2000. As a result of significant advances in smart card technology, an effort was initiated in 2003 to bring the information in the handbook current. In addition, many government agencies have significantly increased their internal knowledge of smart card technologies and related systems. This information is reflected in the current version of the guide. The implementation of smart cards can be complex. The intent of this guide is to provide the high-level reasons for why to implement a program as well as provide practical guidance for who should be involved and how to begin.

Reforms in electronic business, travel re-engineering, and expanded use of government-wide commercial purchase cards have presented new opportunities to use smart card technology as an enabling tool. Smart card technology offers an additional layer of electronic security and information assurance for user authentication, confidentiality, non-repudiation, information integrity, physical access control to facilities, and logical access control to an agency's computer systems. To facilitate this effort, the Smart Card Program was established and composed of representatives from the Federal civilian, defense, and intelligence communities as a co-operative effort under the leadership of the General Services Administration (GSA) and the Smart Card Project Managers Group. The President's Management Agenda (PMA) released in fiscal year 2002, also called for the following:

- Expand and improve the FirstGov web site (www.FirstGov.gov) to offer citizens a convenient entry to government services;
- Establish a Federal Public Key Infrastructure (PKI) to be adopted by agencies to promote digital signatures for transactions within the Federal government, between government and businesses, and between government and citizens; and

- By the end of 2002, use a single e-procurement portal, www.FedBizOpps.gov, by all agencies to provide access to notices of solicitations over $25,000.

This Government Smart Card Handbook was developed to assist agencies in the development of a smart card program to harness the technologies currently available to:

- Obtain a secure identity management solution.
- Accomplish the objectives of government initiatives.
- Remain consistent with government regulations, directives, and applicable standards.

International Railway Journal (1995). "Smartcards Benefits Look Attractive." International Railway Journal and Rapid Transit Review (June 1995): 30-34.

This short article appeared in the "Rapid Transit Review" section of the magazine, and it describes the benefits commonly associated with the cards. Of note, however, the article admits there is little evidence supporting all of the claims generally associated with smart card fare collection.

Irwin, N. (2002). MTDB Awards $35.6 Million in Contracts for Smart Card Automated Fare Collection System. Metropolitan Transit Development Board, Metropolitan Transit Development Board.

This press release announces the contract to Cubic Transportation, Inc. for supplying San Diego Metropolitan Transit Development Board's smart card fare collection system.

Johnson, C. M. and E. L. Thomas (2001). Ventura County fare Integration: A Case Study. U.S. Department of Transportation ITS Joint Program Office. Washington, D.C., U.S. DOT ITS Joint Program Office: 24.

An automated transit fare collection system using smart card technology was field tested during the multi-agency "Smart Passport" demonstration project in Ventura County, California, between January 1996 and October 1999. The fare collection system integrated several ITS technologies – automatic passenger counters, automatic vehicle location systems based on Global Positioning System technology and contactless smart card technology – and was applied to seven bus transit systems. Transit patrons had the option to use the Smart Passport fare card as a prepaid pass or as a "stored value" debit card that deducted the fare of each trip from a prepaid amount. When using the prepaid pass, passengers were able to ride on any of the seven systems and transfer between systems at no extra charge.

The fare collection system, called the Fare Transaction and Vehicle Monitoring System, was developed by Echelon Industries using Small Business Innovation Research (SBIR) program grants funded by the U.S. Department of Transportation Federal Transit Administration (FTA) and the California Department of Transportation (Caltrans), beginning in 1992. Echelon also used SBIR funds to finance the Smart Passport demonstration project and served as the systems integrator. The intent of the project was to examine the interoperability of smart card technology among multiple transit operators using ITS technologies. FTA and Caltrans hoped to assess the feasibility of implementing a coordinated multi-agency fare collection system and to gain insight into the functional requirements for implementing and operating such a system.

The Smart Passport project was coordinated by the Ventura County Transportation Commission (VCTC), a commission that operates two transit properties and is responsible for the allocation of transportation resources in Ventura County. VCTCs primary goal for the project was to create a seamless "universal ticket" for transit patrons to use on all of the county's transit systems. This goal relates to using the advanced fare payment system to encourage, accommodate, manage, and assess travel patterns of passengers between transit systems. Additionally, the participating transit agencies wanted to improve data collection and reporting processes. The reports generated from the improved data collection process could be used to analyze ridership demographics, fixed route schedule adherence, service route planning, and to identify new market segments.

The demonstration project ended in 1999 without Ventura County transit operators experiencing many of the programs anticipated benefits. The fare collection system was plagued by numerous operational and data processing problems, resulting in inconsistent data and infrequent reports. While the system performed well for some of the smaller transit operators, the system was never fully operational for the largest transit operator in the county, South Coast Area Transit, due to system reliability problems.

Libbrecht, R. and T. Oy (1999). Area Report 1998-Fare Collection and Integrated Payment. E. C. DGXIII.

The European Commission requested this report on the activities of the Telematics Applications Programme (TAP), which ran from 1994 to 1998. The purpose of the program was to promote synergy among integrated fare collection and payment projects. The area within the TAP that was specific to transportation broadly covered many categories of interest, including fare collection for public transport, integrated payment services, multi-modal payment systems, chained mobility products, loyalty schemes, smart cards, e-purse and pan-European operability. This report is a status report on the area progress, and it synthesizes the information found in other reports to the commission.

The authors conclude that much progress was made institutionally towards the stated goals of this area. The e-purse aspect was successfully managed by the banking sector, and this reflects current trends in integrated payment schemes. The banks enjoy this because of the increased client base, and the transit operators appreciate the banks handling the burden of clearinghouse activities. Technologically, all solutions in this area are based on smart cards. Contactless cards are preferred because of ease of use. Hybrid cards are emerging, and these hold promise for increased reliability and decreased device costs. Occasionally users are still problematic, as the cards are too expensive for them to purchase for a single ride. The future research in this area will address the challenges of integrating these payment schemes with the Euro currency, as well.

Lovering, M. W. and D. P. Ashmore (2000). When Do Smartcards Make Commercial Sense? European Transport Conference 2000, Homerton College, Cambridge, Association for European Transport.

This paper asks the question of when it is prudent for a transit operator to invest in a new smart card ticketing system. It explores the size of the technological and financial hurdles that impede a new system. There is a tendency to answer these business-driven questions with technological answers. However, evidence to date supports the notion that the viability of smart card systems depends more on financial considerations than technological issues.

In the United Kingdom, the UK Transport Card Forum was formed to explore these issues. They were charged with developing a common set of guidelines that organizations could follow when considering smart card schemes. These guidelines were not prescriptive, but rather they were designed to be flexible enough so that groups from different operating environments would find them useful. The Forum developed four business case studies to understand the components of adopting smart card systems.

The cases included single operators, multi-group operators, a comprehensive one with concessionary fares, and a comprehensive multi-modal case. From their estimates, the authors caution that there is substantial risk for smart cards to be costly to agencies in each of their four cases. Careful planning and operations can minimize the risk factors. They conclude that it is impossible to generalize when and if smart cards make sound business sense for transit operators.

Maxey, C. L. and P. Benjamin "Seamless Fare Collection: Using Smart Cards For Multiple Mode Transit Trips."

This article highlights the features and applications of the WMATA SmarTrip contactless stored value smart cards. It describes the current magnetic stripe card applications, fare structure, and payment methods. It compares this current system with the implementation of SmarTrip card, contracted with Cubic Transportation Systems (fare boxes). A joint procurement allows the Maryland Mass Transit Administration and twelve other area transportation providers to separately purchase compatible fare boxes and SmarTrip capability from the same vendor.

The article highlights the advantages, as well as the setup of a Regional Bus Fare Collection System and a Regional Customer Service Center.

The article does not address the disadvantages of such a system, nor does it describe any of the difficulties of forming collaboration on a joint procurement among the various operators in the DC area.

McDonald, N. (2000). "Multipurpose Smart Cards in Transportation: Benefits and Barriers to Use." UCTC Research Papers: 27.

This paper looks at whether smart cards can become the next fare payment media for transit, supplanting cash fares, tokens and passes. While many transit agencies are considering smart cards, few have adopted them, which makes evaluation difficult. In addition to the difficulty of evaluation, the relative scarcity of programs leave unanswered questions about how to structure programs, an ill-defined lexicon of smart institutional language, and undetermined scope of smart card projects.

This paper looks at the examples of Hong Kong and Paris to attempt to address some of these issues. The author then looks at the implications of her findings on the San Francisco Bay Area program. The four main reasons the author found for implementing smart cards are cost reduction, service improvement, fare policy flexibility, and increased revenues. The success in achieving these goals depends on the conditions faced by individual agencies, making it difficult to recommend a single policy or program that would apply to all agencies. Smart card programs should only be implemented when a strong business case can be made in favor of them, not because they are they ‘new’ thing.

If a business case can be made for smart cards, implementation issues are dominated by institutional arrangements, including user requirements and system equity that must be addressed. These issues further complicate making a single program recommendation for all potential smart card agencies. To conclude, the author suggests that smart cards should only be implemented when a strong case for them has been made, and it is clear what benefits are expected from them. Otherwise, it is hard to justify the program and its costs.

Messmer, E. (2004). Feds eyeing one access model for all. Network World. 21.

This short piece explains that President Bush signed legislation requiring all federal employee identification cards to be designed to use common technology. The government requires this as an enhancement to homeland security.

Michael, S. (2005). Experts say culture hinders single smart card. Federal Computer Week: 2.

This short article explains that technological issues do not prevent interoperability of government issued smart cards, but rather that corporate cultural issues coupled with a lack of management support prevent realizing the full benefits of smart cards.

Moore, J. E. and G. Giuliano (1998). "Functional evaluation of the Los Angeles smart card field operational test." Transportation Research Part C 6: [247]-270.

Moore and Giuliano evaluate technical aspects of an Advance Fare Payment System deployed in Los Angeles in the summer of 1994. This demonstration project of a new fare payment system evaluated two types of advanced fare cards – Radio Frequency (RF) Cards and Smart Cards with IC – incorporating very different technologies on three transit systems, using a relatively low-cost system constructed from components manufactured to commercial specifications.

The electromechanical performance of the equipment consisting of low-cost commercial components (not customized products) is high enough for use on transit buses, while the lifecycle performance was not yet evaluated. While the rate of errors not to collect fares by Smart Cards was too high (0.1 percent) for revenue collection in transit service, RF cards performed extremely well with the rate of errors lower than less than 0.01 percent. The equipment used in the demonstration project showed flexibility for “collection of market data, highly differentiated fares (zone and area based fare, route and time of day pricing, special event and special user fares); intermodal transfers; automatic verification of card status and updates of fare accounts (which might include negative balances); electronic benefit transfers (EBT); and integration with corporate transit, rideshare, and parking plans, (p. 247)" while these were not fully tested due to insufficient read/write activities.

Although transit agencies and smart card users may experience problems with fare collection in the beginning of deployment of new technologies, these problems were quickly solved by learning by the technology vendor, management of the participating transit properties, bus drivers, and card users.

In addition to revenue sharing, the interoperable smart card system will require extensive database searches, updates, and transactions for a great number of cards in the large size of combined transit systems, including checking against lost and stolen cards. While technology may advance to overcome technical problems, transit operators might have a problem about who will pay the cost for lost and stolen cards and transactions made with these cards.

Multisystems Inc., Mundle and Associates Inc. and Simon and Simon Research and Associates, Inc. (2003). Fare Policies, Structures and Technologies: Update Report 94. Transit Cooperative Research Program. Washington, D.C., Transportation Research Board: 184.

This report summarizes the work of Transit Cooperative Research Program Project A-25. The intent of this project was to provide guidelines for transit operators to pursue decisions of fare policy, structures and technology. This particular report updates TCRP Report #10, of the same name, that was published in 1996.

This report contains key findings, including:

- Transit agency fare levels are increasing.
- The transit industry favors simplified fare structures.
- Low and free fares have been minimized along with 1-day passes.
- Agencies offer many ways to pay, including increased options for pre-paying fares.
- Electronic fare payment is increasingly popular.
- Multiple agency integration is difficult and requires agencies to fundamentally change how they collect fares.
- Transit fares are seen as a key application of smart cards.

Some of the benefits for customers from smart cards listed in the report include:

- Balance protection features for prepayment.
- One card works with multiple agencies.
- Contactless cards are convenient.

Other possible benefits from smart cards include opportunities for collaboration with employers and universities. There are also possibilities for non-transit use of smart cards.

This report uses case studies to explain how smart cards are used, but it offers little evidence that smart cards are being used in a way that realizes widespread benefits. The cost effectiveness of smart card programs in not discussed in detail, and there are many claims of possible benefits rather than statements of actual use.

Plouffe, C., Vandenbosch and John Holland (2001). "Intermediating technologies and multi-group adoption: A comparison of consumer and merchant adoption intentions toward a new electronic payment system." Product Innovation Management 18: 65-81.

This article describes how electronic payment systems are adopted by multiple groups simultaneously. This approach recognizes that traditional technological adoption has focused on one group adopting the new technology. This paper contends that there are many instances where a technological advance must be adopted by many groups to succeed. To support their hypothesis, the authors evaluate an in-market trial of a smart card-based electronic payment system for retail systems. The data used in the analysis were from a mail survey of consumers and businesses in the city where the trial was undertaken.

The primary findings of the authors are that new payment technologies must provide an obvious and clear advantage for consumers or merchants to consider adoption. They also suggest that consumers prefer to consider adoption as being under their control, and merchants are concerned with their bottom line. Also, later adopters of the technology may have concerns that are substantively different than early adopters.

Public Technology Inc. Survey and Focus Group Report: Local Governments and the National ITS Architecture. Information gathering forum in conjunction with PTI's Urban Consortium Transportation Task Force meeting.

This summary report is based on information collected in a forum that was designed to encourage local elected and appointed officials to share their concerns about ITS and related outreach and technology transfer endeavours – in particular regarding National ITS Architecture.

According to the survey, the majority of local government officials knows about the National ITS Architecture, state that their agencies are preparing for it, think that its development should include opinions from local governments, and expect higher involvement of the federal government in developing strategies for ITS implementation on the local level.

While local decision makers expressed a concern that they do not understand benefits of developing integrated and interoperable ITS, U.S. DOT officials are confident that local government officials will be amenable to allocate resources to comply with the National ITS Architecture, once they understand the concept of the national standard.

DOT assumes that region is an appropriate geographic level to tailor the system design of the National Architecture, and that the system should be modified for use in metropolitan, statewide, multi-state, or interurban corridor levels.

The first five obstacles for the deployment of ITS are: 1) funding availability, 2) training of personnel, 3) staffing, 4) lack of cost/benefit information, and 5) coordination with other agencies. Respondents also mentioned as ITS operations and maintenance issues: 1) institutional resistance against procurement and 2) inter-agency coordination. To encourage coordination among stakeholders, participants mentioned the role of Metropolitan Planning Organizations (MPOs) and Councils of Governments (COGs)in facilitation and coordination to promote ITS activities in the regional level, and funding as an incentive to bring stakeholders together on the regional level.

Quisquater, J.-J. (1997). "The adolescence of smart cards." Future Generation Computer Systems 13: 3-7.

This short history of smart cards states that the technology is interesting in that it was not invented to solve broad problems in commercial applications. Rather, they were created to solve a few specific problems, which are not mentioned, and this has created many problems for large-scale adoption. The card technology has largely outpaced the interests of possible commercial applications.

Rat, H. (2001). A Love Affair with Plastic? ITS International: 37-38.

This short article questions conventional wisdom that transit applications are a natural fit for smart cards. There are many possible advantages, including reduced fraud, faster boarding, and effective communications. But these advantages come with high costs, and transit agencies need to be careful about why and how they adopt smart cards to realize these benefits and improve service for customers.

Shoup, D. (2005). The High Cost of Free Parking. Chicago, Planners Press.

While this book is about parking, the chapter referenced explains how new technologies are used in parking applications and what the expected benefits are.

Smart Card Alliance (2003). Transit and Retail Payment: Opportunities for Collaboration and Convergence. S. C. Alliance. Princeton Junction, New Jersey: 30.

This report was developed by the Smart Card Alliance to describe the current market opportunities for combined transit and retail payment cards. The Alliance sees the expansion of ridership on transit and the current investment in modernization of fare technologies as a prime time to stimulate further ridership through increased presence of contactless payments systems. This report answers the following questions:

- What investment is being made in transit contactless smart card fare collections systems in the United States? *Answer: Numerous urban areas are going through a "once in a generation" infrastructure modernization.*
- How do automatic fare collection systems use smart cards now? *Answer: Most transit systems operate their fare policy autonomously. Those that use smart cards can do more to integrate their programs with other operators.*
- What retail payment methods are commonly used in the United States, and how are smart cards being used? *Answer: Smart cards must replace both cash and credit/debit cards transactions.*

This report provides an overview of the abilities and opportunities for smart cards in transit and retail, but it provides few details about the challenges that face such integration.

Smart Card Alliance (2005). San Francisco Bay Area TransLink: 2.

This news release provides some details about the size of the TransLink program in the San Francisco Bay Area. For this program, the Metropolitan Transportation Commission awarded a contract for a single-card regional fare collection system. This system will be rolled out in phases, the first phase having 7,000 contactless smart cards distributed. Overall, this program will affect over 1.5 million rides daily in the 100 cities in the Bay Area.

Stanley, R. G. and R. Hyman (2005). Research Results Digest 69. Quick Response for Special Needs. T. C. R. Program. Washington, D.C., Transportation Research Board: 57.

This report assesses why transit agencies realized ridership increases in the 1990s. The relevant findings to smart cards research are that fare pricing initiatives played a major role. Especially important were pass programs with universities and employers. Ventura County saw an increase of 24.6 percent in ridership mostly accountable to a university pass program.

Torode, R. (1998). "Smartcards-Transport Ticketing for the 21st Century." Public Transport International 47(1998/6): 32-33.

This paper describes London Transport's Harrow Bus Smartcard Trial and the development of the "Prestige" program, which was initiated by London Transport to 'progress the procurement of a new revenue collection service for London's buses and Underground.' The Harrow project demonstrated the feasibility of contactless smart cards for transit fare collection. In addition, the industry has not identified an alternative to smart cards for a new system of fare collection, and the business case has been made that new methods for revenue collection are necessary (details of this are not provided). The Prestige system, it is agreed, should be built according to European Commission standards. This paper is a very short overview that explains the program, but it fails to provide many details or any evaluation.

Transport for London (2005). Transport for London 2004 Annual Report. Mayor of London. London, Transport for London.

This is an annual report that provides a summary of the state of transport in London, including transit operations. It also provides previous data for the categories. It provides little analysis, rather it supplies a snapshot of overall transport in London.

U.S. Department of Transportation (2002). ITS Deployment Tracking 2002 Results. U.S. Department of Transportation. Washington, D.C., U.S. Department of Transportation. 2005.

This brief report summarizes current federally-supported ITS deployment projects. The projects involve all types of ITS and are not specific to transit or smart cards.

U.S. Department of Transportation (2005). ITS Standards Acquire a New Mission: Transitioning the ITS Standards Program to Align with the US DOT's New ITS Research Initiatives. US Department of Transportation. Washington, D.C., U.S. Department of Transportation: 6.

This document provides a quick discussion of the history and importance of ITS standards. It builds on twelve years of research within the transportation community that supports ITS as solutions to the nation's transportation problems. The report promotes standards-based integration to help facilitate the exchange of transportation data, equipment upgrades and system expansion. To support such integration, the U.S. Department of Transportation adopted a list of criteria used to evaluate new initiatives.

The U.S.DOT is interested in interface standards that apply within and across transportation modes. Most of their interest has not been focused on smart cards, but this report points to their interest in corridor management, emergency operations, freight manifests and other issues that do not apply to transit. Smart cards are not specifically addressed.

U.S. Department of Transportation ITS Joint Program Office (2004). Washington Metropolitan Area Transit Authority's (WMATA) SmarTrip Regional Customer Service Center. US DOT ITS Joint Program Office. Washington, D.C., US DOT ITS Joint Program Office.

This webpage provides a summary of the federal funding that the Washington Metropolitan Area Transit Authority received for development of a regional customer service center to accompany its SmarTrip regional fare program. This center provides multiple management, distribution and reconciliation tasks for the participating transit operators, and it has an annual operating budget of $25.5 million. The regional fare system requires this type of central processing center.

Volpe National Transportation Systems Center. (2004). ORANGES Evaluation Phase 1 Risk Assessment Report. Evaluation of the ORANGES Electronic Payment Systems Fields Operational Test. U. DOT, US DOT: 46.

This report provides an evaluation of phase 1 of the ORANGES program in Central Florida. The program involves many public sectors partners and private sector partners that developed a smart card program that applies to transit, toll and parking. The system is built around smart cards, and uses smart card transponders for toll collection. A central clearinghouse was developed to process the transactions. The program is limited to less the 1,200 cards in this evaluation.

Each facility in the program accepts cash, check or credit cards for revaluing the cards. These payments are processed by the clearinghouse and credited and distributed to the agencies where they are bought or spent. This report proposes an evaluation strategy for the program as it has not been fully implemented at the time of publication. Future research will evaluate performance of the clearinghouse, customer satisfaction, and other issues. The key finding of the evaluation thus far is that it is impossible to underestimate the complexity of interagency, interoperable electronic payment systems because of the institutional issues. Vendors were only willing to provide limited support without getting

paid for their efforts. It is unclear if contracting with the vendors for payment would solve this problem.

Wildermuth, B. (1994). "Hong Kong Adopts The Contactless Smart Card." International Railway Journal and Rapid Transit Review (September 1994): 36-37.

This is another article that provides a description of the Hong Kong system. It was written before the adoption of the Octopus system, so it provides some insight into the early effort undertaken by Hong Kong.

Zandbergen, A. (1994). IC Cards in Transport: Applications and Standards. Towards and Intelligent Transport System, Paris.

This paper provides brief summaries of the types of cards and their standards as they apply to transport applications. It makes a connection between performance of smart cards in transportation and in other sectors. This paper is not limited to transit, however, and discusses person-cards, vehicle-cards, and freight-cards. Person-cards are what are typically thought of as smart cards, as credit card-sized cards that have processors of some sort.

Standardization of smart cards is performed by the International Standards Organization on a world-wide level. The European Commission has its own set of standards, but the United States does not. The ISO standards are focused on technical aspects, unlike EU specifications, which deal with usability. Size and performance of the cards are covered by all sets of standards, and the EU generally defers to ISO as they are commonly accepted by manufacturers.

Appendix C: Contact Information for U.S. Vendors Included in Literature Review

Cubic Transportation Systems

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