

Massachusetts Institute of Technology
Engineering Systems Division

Working Paper Series

ESD-WP-2007-06

POLICY ISSUES IN IMPLEMENTING SMART CARDS IN
URBAN PUBLIC TRANSIT SYSTEMS

Final Report – ESD.10 Introduction to Technology and Policy

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January 2007

“Policy Issues in Implementing Smart Cards in Urban Public Transit Systems”

Final Report

December 8, 2006

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Assignment for Course ESD.10: Introduction to Technology & Policy

1 Table of Contents

<u>1</u>	<u>Table of Contents</u>	3
<u>2</u>	<u>Executive Summary</u>	4
<u>3</u>	<u>Background</u>	7
3.1	<u>What are Smart Cards?</u>	7
3.2	<u>History of Smart Cards</u>	7
3.3	<u>Smart Card Application for Urban Transportation</u>	8
3.4	<u>Characteristics and Components of a Transit Smart Card System</u>	9
<u>4</u>	<u>Analysis of Existing Implementation</u>	10
4.1	<u>Existing Smart Card Systems</u>	10
4.1.1	<u>Table Summary of Smart Card Systems</u>	10
4.1.2	<u>Sample Case Studies</u>	10
4.2	<u>Improvement/Benefits</u>	24
4.2.1	<u>Efficiency</u>	24
4.2.2	<u>Financial Benefits for Transportation Providers</u>	25
4.2.3	<u>Marketing Benefits for Transportation Providers</u>	26
4.3	<u>Concerns</u>	26
4.3.1	<u>Standardization / Technical Considerations</u>	26
4.3.2	<u>Security and Privacy</u>	27
4.3.3	<u>Equity</u>	27
4.3.4	<u>System Failures</u>	28
4.4	<u>Trade-offs</u>	28
4.4.1	<u>Efficiency – Equity Trade-off</u>	30
4.4.2	<u>Efficiency – Security Trade-off</u>	31
4.4.3	<u>Efficiency – Privacy Trade-off</u>	32
<u>5</u>	<u>Analysis of Future Development of Smart Card Systems</u>	34
5.1	<u>Expanded Application</u>	34
5.1.1	<u>Potential Issues</u>	35
5.2	<u>Advancement of Card Technology</u>	36
5.2.1	<u>Smart “Card” No More</u>	36
5.2.2	<u>Biometric Identification Technology</u>	37
5.3	<u>Standardization Efforts to Increase Interoperability</u>	37
<u>Conclusion</u>		39
5.4	<u>Recommendations</u>	39
5.5	<u>Summary</u>	42
<u>6</u>	<u>Acknowledgements</u>	43
<u>7</u>	<u>List of Figures</u>	44
<u>8</u>	<u>List of Tables</u>	Error! Bookmark not defined.
<u>9</u>	<u>Bibliography</u>	46

2 Executive Summary

Many public transportation institutions have been discarding their magnetic strip payment cards or traditional cash-based fee collection systems in favor of automated fare collection systems with smart card technology. Smart cards look like traditional credit cards or ID cards; however, using RFID technology, they allow for contactless payment and identification. Smart cards are becoming increasingly popular among transit agencies primarily because they are convenient for customers, reduce administrative costs for transit agencies, and have the potential of improving the performance of complex transit systems overall.¹ The increased availability and affordability of contactless cards has also contributed to this trend in adoption.²

This report examines six principal smart card transit systems of the world - those of Chicago, Hong Kong, London, Singapore, Tokyo, and Washington DC. Using these case studies, this report determines the principal benefits and concerns resulting from using smart cards for transit payment. The primary benefits were determined to be efficiencies for both the transit riders and transit authority. Therefore, this report also includes a formal discussion of the efficiency-equity, efficiency-security and efficiency-privacy tradeoffs which result from various implementations of smart cards in urban transit. The formal treatment of these tradeoffs differentiates this report from other similar studies. Using the knowledge gained from evaluating these tradeoffs, recommendations are given for the implementation and development of future smart card systems.

The benefits of introducing smart cards into a city's transit system include:

- Increased punctuality of buses as boarding time is reduced.
- Reduced operational costs as the number of cash-based transactions is reduced and the printing of tickets is eliminated.
- Easy recording of transit usage data that can be used to improve the system.
- Easier implementation of complex fare structures.^{3,4,5}

The primary concerns of introducing smart cards into a city's transit system include:

- Cost of substituting a traditional fare collection system with a smart card system.
- Selection of a smart technology standard that is compatible with other existing smart card and transit systems.
- Privacy of user information on personalized smart cards (both in terms of tracking an individual's movements and gaining access to financial and identification data).
- Equitable access to smart cards and their benefits among different social groups such as low-income riders, tourists, and children. (For example, some smart cards require users to have a bank account or credit card.)
- Response to smart card system failures.

This report also takes a look at some of the major future trends associated with urban transit smart cards in Chapter 5. These trends include the expanding of the number of applications for each card, the consolidation of devices, and increased technical standardization along international, regional, and local levels.

¹ Hong 2006

² Hendry 2001: 219

³ Hong 2006

⁴ Hendry 2001: 220

⁵ Attoh-Okine, N.O. & Shen, L. David 1995: 523

Finally, the following steps are recommended to ensure an effective, equitable, and secure implementation of smart cards in urban transportation.

- **Choose a technology standard that allows for integration with other smart card systems.**
By choosing a standard system, these smart cards may also be used with other transportation, retail, and identification smart card systems, among others. Such an open and flexible system can more easily incorporate changes in future technology, respond to new demands from society, and meet future regulatory requirements. Furthermore, transit agencies may prefer to act as clients of another organization's smart card system rather than being responsible for issuing the cards themselves.
- **Offer two types of cards – one with embedded personal identification data, and one without.**
Two types of smart cards are recommended for each transit system - one with more features, but less privacy, than the other. This gives users the option to not link personal identification or financial information with their transit card.
- **Consider a distance-based fare structure.**
Where possible, we recommend transit administrators consider the implementation of complex fare structures as a way to make ridership charges more equitable while at the same time increasing the agency's revenue through price discrimination. If the characteristics of the city and its population are favorable for the implementation of such fare structure, we suggest distance-based fees be calculated according to the radial distance between the start and end of the trip, rather than on the distance traveled between the two locations. However, due to the specific transit routes available and socioeconomic distribution of people with respect to transit lines, some cities have found that flat fare structures remain more equitable.
- **Continue to respect different pricing structures for different social groups**
Cities should continue to allow students, children, and seniors to obtain the same reduced fares as before the implementation of smart cards.
- **Provide financial incentives to encourage adoption**
If trying to get a large number of riders to adopt a new smart card system early in its implementation, incentivize the switch by making it the cheapest option available.
- **Provide backup functionality in case of central system failure**
If the smart card system fails, there should be some alternative way for riders to continue to pay for travel. Transit agencies need to consider the different options for providing backup functionality. Among these options is the continued acceptance of cash and/or magnetic strip cards, as well as equipping local computers to communicate with smart cards even if the central server is down.
- **Routinely screen system for software failures**
The system needs to be designed so that software checkups are routinely carried out to prevent over or under-charging of customers, and mishandling of personal data.
- **Provide parental controls in cases where smart card functionality expands**

beyond transportation

If smart cards can be used for the purchase of goods and services other than public transportation, such as food and retail, parental controls can prevent children from misusing their cards.

3 Background

3.1 What are Smart Cards?

Smart cards are microprocessor cards⁶, made of a chip and an integral operating system. As described by Attoh-Okine and Shen, “the chip contains a processor, arithmetic processing registers, random access memory (RAM) used during program execution, read only memory (ROM) to house the operating systems, and EEPROM (Electrically Erasable Programmable Read-Only Memory) for data storage, [while the] operating system provides the ISO-complaint command, data access, security controls and security algorithms.”⁷ The chip is constructed into the credit card sized card, which must be introduced into a reader/writer machine that powers the chip and enables communication between the card and the other parts of the system. If the card is contactless, communication with the card reader is enabled through radio frequency identification (RFID) technology.

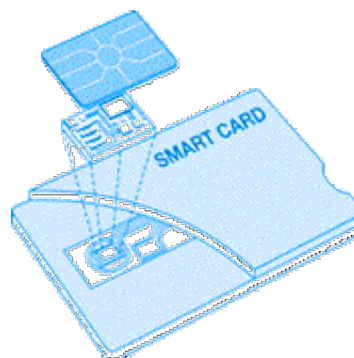


Figure 3-1: Smart Card and Microprocessor⁸

3.2 History of Smart Cards

The direct predecessors of smart cards are magnetic cards that store digital data in a form that is easily read by a machine. Smart card use is typically tied to a physical real-time method of personal identification by the cardholder, such as signing or providing a personal identification number (PIN). Magnetic cards are unsuitable for storing confidential information, however, because anyone with access to the adequate equipment can read, alter, and even delete the information stored in the card. The development of the smart card was, in a way, a response to the need for solving this security problem in a way that would not burden card transactions.⁹

There is some disagreement regarding when smart cards were originally introduced and patented, with dates ranging between 1968 and 1974. According to Rankl & Effing, the idea of using an integrated data storage and logic processing circuit as part of an identification card was originally patented in Germany in 1968, with a similar patent being processed in Japan in 1970. By 1974, Roland Moreno had filed for a patent of an Integrated Chip (IC) card, which shortly thereafter was referred to as a smart card.¹⁰ It was not until 1984, however, after the French Postal and Telecommunications Services Agency carried out a successful telephone cards field trial that smart cards usage increased and widened. After a

⁶ Hendry 2001: 4

⁷ Attoh-Okine, N.O. & Shen, L. David 1995: 523

⁸ <http://www.tiresias.org/guidelines/pats.htm>

⁹ Rankl & Effing, 2001: 3

¹⁰ Atooh-Okine & Shen, 1995: 523; Hendry, 2001: 6; Rankl & Effing, 2001: 3

different pilot project was carried out in Germany in 1984-85 to compare different technologies for telephone cards, it was agreed that smart card technology was superior to magnetic-stripe cards and optical-storage cards, not only because they offered greater reliability and were more difficult to manipulate, but also because they promised greater flexibility for future implementations.

Microprocessor chips were first deployed on a large scale in the telecommunications sector of France and Germany, mostly for mobile applications. Advances in cryptography and semiconductor technology enabled the use of smart cards for banking purposes – Rankl & Effing suggest that these advances, along with other hardware and software improvements, “made it possible to implement complex, sophisticated mathematical algorithms that allowed previously unparalleled levels of security to be achieved.”¹¹ An additional important characteristic of the improved smart cards was that they were easily available to everyone to carry and use everywhere.

Current usage of smart cards can be found in the healthcare sector, transportation services (both for urban transit and interstate highway tolls), as well as corporate and educational identification and security access controls. Smart cards are expected to play an important role in the future of secured monetary transactions and identification practices over the Internet.¹²

3.3 Smart Card Application for Urban Transportation

The components of a city’s transit system – the buses, trams, metro trains, etcetera – are usually the responsibility of a single private or public authority, and are run as “profit centers and must account for their income and volume of passengers as well as their costs.”¹³ Either way, an effective transit system must allow for seamless journeys, so that a ticket is sufficient for a passenger’s trip regardless of how many different types of transit components he or she utilizes. There is an obvious need for charging different fees based on the passenger’s choice of transit mode and the distance traveled. Fees also vary due to the social service nature of public transportation, as some of the services provided to certain passengers, such as children or the elderly, may be subsidized. The complexity of the system makes it difficult to control, with fare evasion a common problem.

Public transportation institutions have begun to shift their traditional cash-based fee collection systems to automated fare collection systems that use smart card technology. Smart cards are becoming increasingly popular among transit agencies because they are convenient for customers and have the potential of improving the performance of the transit system overall.¹⁴ The increased availability and affordability of contactless cards has also contributed to this trend.¹⁵

There are several benefits to introducing the use of smart cards in the transit system, for they “combine the secure, cashless transactions and personalized applications that encourage people to use mass transit.”¹⁶ The performance of transit systems improves by using smart cards because the reliability of service increases as a result of a reduced board-waiting time,

¹¹ Rankl & Effing: 4

¹² Rankl & Effing: 7

¹³ Hendry 2001: 220

¹⁴ Hong 2006

¹⁵ Hendry 2001: 219

¹⁶ Attoh-Okine, N.O. & Shen, L. David 1995: 523

which leads to increased punctuality and possible reduction in journey time. The operational costs of the system also decrease because cash-transactions are eliminated, as is the need to continuously print boarding tickets. The use of smart cards enables transit agencies to identify and record usage and demographic information and patterns that can help them to enhance their operation management and meet government reporting requirements. Finally, the use of smart cards increases the flexibility of the system by enabling the implementation and administration of various fare policies.^{17,18,19}

An automated fare collection system that uses smart card technology is initially expensive, though it is estimated that the system, in the long run, “may eventually cost only one-third of the old system due to improved efficiency and lower maintenance costs.”²⁰ This relatively young technology is yet to be standardized and continues to change rapidly. Therefore, its implementation needs to be highly flexible to allow the system to develop with future smart card improvements. This lack of standards has led to a lack of compatibility between transit systems in different cities, which can be bothersome and impractical for transit users.

An additional concern towards the use of smart cards in urban transit is its potential to infringe on individuals’ privacy through the tracking of users’ travel and movement patterns. If smart cards are used for additional services other than transit, then other personal information can equally be monitored.

Various cities have adopted a smart card-based automated fare collection system, and many others are planning to also do so in the future. Cities that currently use smart cards in their transit systems include Hong Kong, Washington D.C., Tokyo, Singapore, London, and Chicago.

3.4 Characteristics and Components of a Transit Smart Card System

A smart card used for transit purposes is ideally one with a microprocessor chip that allows for contactless payment. Smart cards with microprocessor chips are useful to transit purposes because one can add and change data on the processor, whereas with memory cards one can only use pre-programmed data and make no changes. While memory smart cards can only be used once, smart cards with microprocessors can be reprogrammed when necessary and thus continuously reused. The contactless feature of the smart card helps to expedite the process of boarding, because transit users do not need to even take the card out of their wallet or purse.

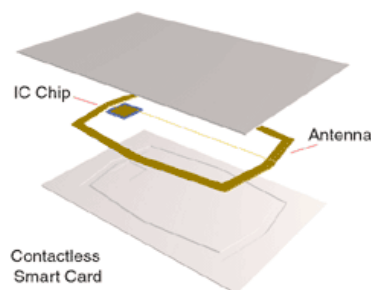


Figure 3-2: Contactless Smart Card Structure²¹

¹⁷ Hong 2006

¹⁸ Hendry 2001: 220

¹⁹ Attoh-Okine, N.O. & Shen, L. David 1995: 523

²⁰ Poon & Chau in Hong 2006

²¹ <http://www.alphacard.com/id-cards/smart-cards.shtml>

4 Analysis of Existing Implementation

4.1 Existing Smart Card Systems

4.1.1 Table Summary of Smart Card Systems

Year of Implementation	Transportation (Issuing) Authority	City(Country)	Name of card
1997	Octopus Card Limited	Hong Kong (China)	Octopus
1997	Tampere City Transport	Tampere (Finland)	Tampere Travel Card
1999	Washington Metropolitan Area Transit Authority (WMATA)	Washington D.C. (US)	SmarTrip
2000	Taipei Smart Card Corporation	Taipei (Taiwan)	EasyCard
2001	Warsaw Transport Authority	Warsaw (Poland)	Warsaw City Card
2001	East Japan Railway Company (JR East)	Tokyo (Japan)	Suica
2002	Ventura Country Transportation Commission (VCTC)	Ventura Country (US)	Go Ventura
2002	EZ-Link Private Limited	Singapore (Singapore)	EZ-link
2002	Chicago Transit Authority (CTA)	Chicago (US)	Chicago Card (Plus)
2003	Transport for London (TfL)	London (UK)	Oyster
2004	Korea Smart Card Co., Ltd	Seoul (Korea)	T-Money
2006	Beijing Municipal Administration & Communications Card Company Ltd	Beijing (China)	Beijing Municipal Administration and Communication Card (Yikatong)
2006	Transperth	Perth (Australia)	SmartRider
2006	Metropolitan Atlanta Rapid Transit Authority (MARTA)	Atlanta (US)	Breeze
2007(Planned)	Massachusetts Bay Transportation Authority (MBTA)	Boston (US)	CharlieCard
Pilot Trial	Metropolitan Transportation Commission	San Francisco (US)	Translink
Pilot Trial	New York City Transit	New York City (US)	MasterCard PayPass (Citi credit or Citibank Debit)

Table 4-1: Summary of Smart Card Usage for Transit²²

4.1.2 Sample Case Studies

In this section, six of the world's premier urban transit smart card systems are examined – those of Chicago, Hong Kong, London, Singapore, Tokyo, and Washington DC. Of these programs, Hong Kong's Octopus Card and Singapore's EZ-Link are considered the most successful because they have achieved penetration rates greater than 90%, as is shown in Figure 4.1. These two smart cards are multi-module and multi-purpose, meaning that they can be accepted as standard payment in services across industries, including transportation, retail, food, education, security, and healthcare. The Octopus and EZ-Link are truly commercialized due to their high level of personalization, artistic themes, and souvenir values. Tokyo's Suica

²² Hong 2006: 29

card can also be used in many retail services, but the extent of its reach is less due to standardization issues between Tokyo’s railway companies. In contrast, smart cards in the cities of Chicago, London, and Washington DC, are restricted to transportation use. The table and chart below summarize the key characteristics of the six smart cards systems studied.

City	Uses	Available Options
Chicago (Chicago Card & Card Plus)	Transit	Pay-Per-Use (CC&CCP) 30-Day Pass (CCP)
Hong Kong (Octopus)	Transit Parking Retail Identification Building Access etc	Pay-Per-Use
London (Oyster)	Transit	Pay-Per-Use Period and Concession Passes
Singapore (ez-link)	Transit Retail Identification Building Access etc	Pay-Per-Use Concession Passes
Tokyo (Suica)	Transit Retail	Pay-Per-Use Period and Concession Pass
Washington D.C. (SmarTrip)	Transit Parking	Pay-Per-Use

Table 4-2: Usage and Options of the Six Major Smart Card Programs²³

City	Magnetic Card	Cash	Paper/Token
Chicago	X	X	
Hong Kong	X	X	
London	X	X	X
Singapore		X	
Tokyo	X	X	
Washington D.C.	X	X	X

Table 4-3: Alternative Fare Media of the Six Major Smart Card Programs²⁴

All of the cities have maintained some form of traditional payment, but the majority is phasing out the use of paper tickets and tokens.

²³ Hong 2006: 30. IT Media, November 2005

²⁴ Hong 2006: 30. IT Media, November 2005

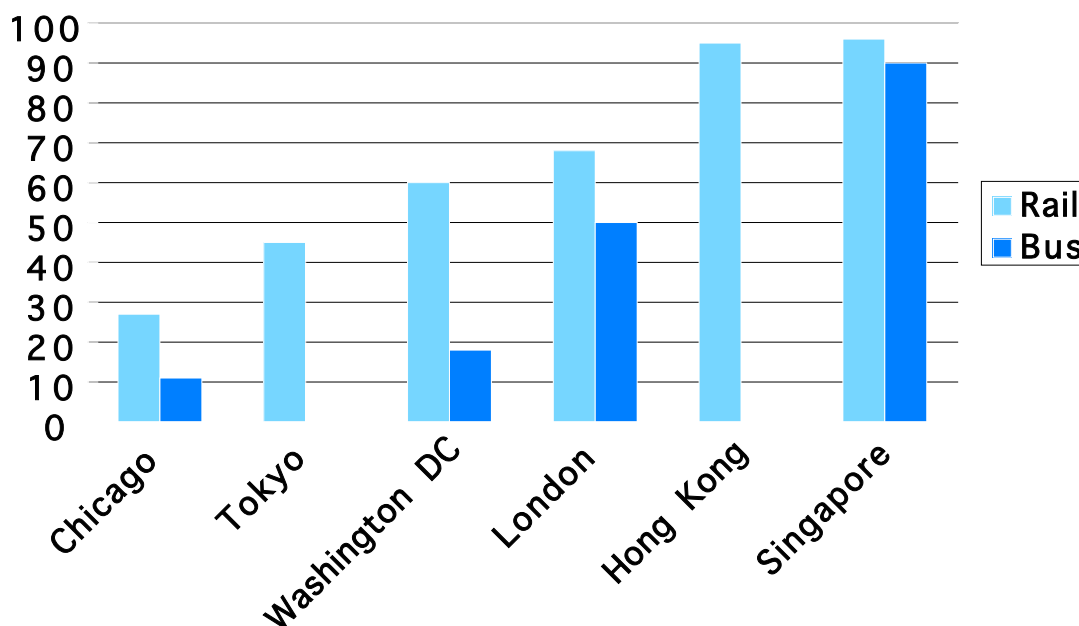


Figure 4-1: Comparison of Smart Cards Penetration Rate of the Six Major Smart Card Programs²⁵

4.1.2.1 Chicago

Background

Chicago, a major transportation hub, has a city area of 606.2 sq km, and a population of 2.8 million.²⁶ The Chicago Transit Authority (CTA) controls the second largest public transportation system in the US. It operates a network of buses, a rapid transit system, a commuter rail service, and interstate highways. Weekly ridership can reach 1.5 million.²⁷

Chicago Card Basics

Chicago introduced two types of smart cards to its transportation system in 2002: the Chicago Card and the Chicago Card Plus. Both of these cards provide faster payment by eliminating the need to remove the card from a wallet in order for it to be read. The Chicago Card Plus offers more features than the Chicago Card and, as such, is marketed differently. The Chicago Card offers pay-per-use proximity payment. In addition to this feature the Chicago Card Plus provides a monthly payment option, online account management, and automatic reloading of the card from the card owner's bank account. Therefore, the additional conveniences of the Chicago Card Plus require that additional personal information be tied to the card. Whereas Chicago Card Plus users are required to register a valid email address and credit card, Chicago Card users do not have to meet such requirements. However, pass-back privileges²⁸ still allow one card to be used to pay for up to 7 people entering a transit vehicle together.

²⁵ Hong 2006: 30. IT Media, November 2005

²⁶ The City of Chicago.

²⁷ Hong, Yi. Thesis 167

²⁸ Pass-back privileges refers to the ability of one person to pass their transit card back over the fare gate for a companion to use. In other words, one card can be used multiple times sequentially to allow a each member group to charge their travel to this same card.



Figure 4-2: Chicago Card, Card Plus²⁹

Feature	Chicago Card	Chicago Card Plus
Online Viewing of Transactions	Not Available	Available
Auto-reloading	Not Available	Available
Requirements	N.A.	Email address and credit card
Options Available	Pay-Per-Use	Pay-Per-Use and 30-Day Pass
Transit Benefit Program	Not Available	Available

Table 4-4: Difference between the Chicago Card and the Chicago Card Plus³⁰

Usage

Chicago Cards are read by the front of rail station turnstiles and bus fare-boxes on all but one available transit route.³¹ These cards are sold for \$5 both online and at more than 700 locations throughout the Chicago land area, including several major retailers.³² Recently, to encourage adoption, the CTA waived the \$5 purchase fee until June 2006.³³

Currently, Chicago Cards are only available for paying full adult fares. Student, senior, weekly and other reduced fare structures are available via magnetic strip cards, called Transit Cards. Nevertheless, all users of Chicago Cards are given a US\$0.25 discount on the full fare price of each single ride, equivalent to savings of 12.5%. Chicago Card holders are also provided a 10% bonus for each \$20 of value added to their cards. As of May 2006, the CTA estimated that the penetration rates of Chicago Card (Pay-Per-Use) were 22.2% for rail and 8.4% for bus, and 5.2% for rail and 2.2% for bus with the Chicago Card Plus (30-Day Pass)³⁴.

Chicago is currently running an express lane pilot program, the Go Lane, for Chicago Card and Chicago Card Plus owners. The Go Lane allows these smart card holders to form a separate line from the transit users that choose to pay with cash or by using a magnetic strip card. The smart card holders are able to enter the bus to the left of these other riders and thereby board the bus much faster. Similarly, the Go Lane program has designated lanes for smart card holders to use when going through subway turnstiles. The Go Lane program is depicted in the advertisement shown in Figure 4.3.

²⁹ Chicago Transit Authority. "Chicago Card Frequently Asked Questions."

³⁰ Hong 2006: 33

³¹ Chicago Transit Authority. "Chicago Card Frequently Asked Questions."

³² Chicago Transit Authority. "CTA Fares."

³³ Monifa Thomas, The Chicago Sun-Times "No-fee Chicago Cards extended to May 31"

³⁴ CTA Fare Media Summary in Hong 2006: 34

Get in the *Go Lane* today!

Board buses more quickly with the CTA's new *Go Lane* boarding process.

Chicago Card and Chicago Card Plus customers simply board the bus on the left side of the entrance and proceed to the touchpad located immediately to your left along the aisle.

Transit Card and cash-paying customers board on the right side of the bus entrance.

Try CTA's new *Go Lane* turnstiles

Chicago Card and Chicago Card Plus customers can use dedicated *Go Lane* turnstiles at eight rail stations to help speed boarding.

***Go Lane* turnstiles** are located at Howard, Chicago, Washington/State, 79th and 95th on the Red Line, Jefferson Park and Washington/Dearborn on the Blue Line, and Clark/Lake on the Loop elevated.

Figure 4-3: Go Lane Promotion³⁵

Evaluation

In a 2005 CTA survey, almost 45 % of the participants cited convenience as the principal advantage of the Chicago Card and the main reason for using it. Additional reasons include saving money by using the card, automatic reloading of the card, and a reduced boarding time.³⁶ An important motivation for riders to adopt the smart card system is the savings it provides. In the case of the Chicago Card, there was no difference in price between this smart card and a 7-Day Pass, which was a magnetic card; if there was a difference, it was that the latter allowed for a greater number of trips during the week. In this case, users preferred the magnetic card to the smart card.³⁷

One of the challenges the Chicago Card system has faced is being able to integrate the three regional transit systems, Metra, Pace and the CTA. While smart cards seemed to provide the best option, regional officials argued they were too “expensive and untested to now pursue.”³⁸ Instead, they chose to introduce a regional transit card with one side being a zoned

³⁵ Chicago Transit Authority. “Go Lane Pilot Program”

³⁶ Hong 2006: 23

³⁷ Hong 2006: 86 - 92

³⁸ Herguth 2003

monthly Metra pass, and the other a magnetic strip Pace and CTA pass – a consequence of the failure to meet the challenges of how to “get three systems to talk to each other.”³⁹ At the beginning of 2006, a software problem in the system led to over billing Chicago Card and Chicago Card Plus holders for using the bus system. While various users identified the overcharge (which, in at least one case, was of US\$70), the CTA was uncertain about how many other customers had been affected.⁴⁰ This problem highlights the increased intensity of the consequences that glitches in the automated system may cause.

4.1.2.2 Hong Kong

Background

Hong Kong, a highly developed modern city with an area of 1092 sq km, and a population of 7 million, has a sophisticated and advanced transportation system.⁴¹ Hong Kong’s major modes of urban transport are metro systems including the Mass Transit Railway (MTR) and the Kowloon-Canton Railway (KCR) (consisting of both rapid transit and light rail system), a tramway that exclusively operates double-decker trams, public bus services, and ferries.⁴² Public transportation is heavily used by local residents and tourists, summing up to over 11 million daily passenger journeys on all modes of transportation.⁴³

Smart Card technology was first introduced to Hong Kong in 1997. The card carries the brand name Octopus (___), and is operated by Octopus Holdings Limited, which was launched by several public transportation companies comprised of MTR, KCR, Kowloon Motor Bus, Citybus, and New World First Bus. Octopus’s popularity and acceptance is unmatched in any other city with similar smart card programs. It is deemed the most successful and well-developed contactless smart card system for mass transit in the world.



Figure 4-4: Octopus cards design⁴⁴

Octopus Basics

MTR collaborated with ERG Transit Systems, an Australian transit system vendor, to build Octopus’s back-end structures and design the overall system. The card uses Sony’s FeliCa radio frequency identification (RFID) chip running on 13.56 MHz.⁴⁵ The card is contactless, allowing users to either touch the card on the Fare Deducting Processor at the entrance or exit gate while traveling, or simply hold out a wallet or bags containing the card, thus significantly increasing uploading efficiency.⁴⁶ All wireless communication through the card is encrypted using two-way authentication.

There are two types of Octopus smart cards: Sold and On-Loan. Both can be purchased

³⁹ Herguth 2003

⁴⁰ Groark 2006

⁴¹ CIA—The World Factbook, Hong Kong.

⁴² Wikipedia, Hong Kong.





⁴³ Hong, Yi. Thesis 137

⁴⁴ Octopus Website. <<http://www.octopuscards.com/>>

⁴⁵ Smart Card Alliance “Hong Kong Octopus Card.”




⁴⁶ The World Bank Group “Hong Kong Smart Card System,”

online or from any MTR customer service center, Airport Express Line service center, KCR ticket office, and 7-Eleven and Circle K convenience stores, among others. The Sold Octopus cards have special designs, and are regularly promoted as souvenirs. The On-Loan cards are for daily use and require a refundable HK\$50 deposit, though they can be personalized for HK\$20 with the user’s name and photograph on the card.⁴⁷ The differences are shown in the following figures.

				
	Child	Adult	Elder	Personalised
Age	3-11	All Ages	*	Applied to All Ages
Deposit (HKD)	\$50	\$50	\$50	\$50
Stored Value (HKD)	\$20	\$100	\$20	\$30
Handling Charge (HKD)	—	—	—	\$20
Total Amount (HKD)	\$70	\$150	\$70	\$100

* Refer to the transport companies for eligibility

Figure 4-5: On-loan Octopus Card⁴⁸

			
	Adult	Child	Elder
Card Type			
Age	All Ages	3-11	*
Deposit (HKD)	—	—	—
Stored Value (HKD)	\$0	\$0	\$0
Selling Price (HKD)	\$70	\$70	\$70

* Please refer to the transport companies for eligibility

Figure 4-6: Sold Octopus cards design and pricing⁴⁹

⁴⁷ Octopus Cards Limited

⁴⁸ Octopus Cards Limited

⁴⁹ Octopus Cards Limited

Usage

Soon after the Octopus system launched in 1997, 2.5 million smart card transactions daily took place. This number increased to 7 million by 2003, translating into a daily monetary value equivalent to US\$6.5 million.⁵⁰ In 2005, Octopus reached 90% penetration on the MTR system.⁵¹ With Octopus's success as an electronic payment for mass transit, other businesses and services soon started to accept Octopus payment. Now, 25% of Octopus transactions are related to non-transit businesses. These businesses include Hong Kong's main supermarkets, Starbucks, McDonald's, many convenience stores, more than 3,000 vending machines, pay phones, and public recreational centers charging for admission.⁵² Octopus is available at over 410 service providers, across markets in transportation, apparel, food, parking, cinemas, stores, and restaurants. Even schools are using Octopus as students' identification cards for library loans and payment for food and tuition. Private estates and offices also use Octopus as an access control ID. In total, the company has issued more than 9 million Octopus cards and 150,000 smart watches.⁵³

After the initial purchase of an Octopus card, customers can reload values onto the same card by signing up for the Automatic Add Value Service (AAVS), using cash at any outlet that accepts Octopus for payment, or using electronic funds transfer at Add Value Machines or ATMs. The AAVS automatically charges the card owner's credit card account with either HK\$250 or HK\$500, as specified by the customer. The Octopus card service not only provides convenience and standardization in payment method across platforms, it also offers various fare discounts, bonuses, and rebates in public transportation. All money retained on the On-Loan cards is fully refundable, unless the card is returned within 3 months of purchasing because a small fee is charged to discourage such practice.

Evaluation

One of the key factors contributing to the success of Octopus cards is that it received complete support from all transport operators in a particular area, facilitating widespread acceptance. Nevertheless, not everyone agreed with the new system, which in turn was not flawless. The card also gained wide acceptance in micro-payment markets, such as small retail shops. Some merchants did not want to introduce smart card payments, however, because they would be subject to an interchange charge. To do this, the transport authority in effect had to become a money issuer. Transit operators enjoyed considerable savings in maintenance using smart card versus magnetic systems, and there is far less cash handling especially for bus operators. Passenger throughput is much faster at gates or when boarding buses, though bottlenecks at stations can be transferred from the gates to the escalators. Smart cards give operators more information than older systems, and enable operators to introduce more sophisticated fare policies and marketing initiatives.⁵⁴

4.1.2.3 London

Background

Metropolitan London covers a land area of 1,584 sq km, and has a population greater than 7 million.⁵⁵ The city has the world's oldest transportation network, which is administered and

⁵⁰ Octopus Cards Limited

⁵¹ Hong, Yi. Thesis 137

⁵² Octopus Cards Limited

⁵³ Octopus Cards Limited

⁵⁴ International Railway Journal

⁵⁵ National Statistics

regulated by Transport for London (TfL). The capital's transport system includes London's buses, underground subways (the Tube), Docklands Light Railway (DLR), Croydon Tramlink, and London River services.⁵⁶ Daily passenger volume is large in the greater London area, totaling up to 6.3 million bus journeys and up to 3 million Underground trips.⁵⁷

London launched a 1.2 billion pound smart card program called Oyster in 2002. The trial period lasted approximately a year, and large-scale implementation started in the fall of 2003. The use of the Oyster card is currently restricted to TfL and National Rail services, but the TfL has plans to add financial functionality to the card, modeled after the Octopus card in Hong Kong.

Oyster Basics

The Oyster card is a contactless smart card using RFID technology with a 10 cm range. It is designed by Transys based on Philips' MIFARE standard 1k chip. In 2006, approximately 5 million people are using Oyster.⁵⁸ There are a variety of passes an Oyster card can hold, including Pay-As-You-Go, 7-Day, monthly Travel Cards, monthly or season bus passes, and Freedom passes for elderly and disabled Londoners.⁵⁹ Card registration is required for monthly or annual season tickets.



Figure 4-7: Oyster card, front and back⁶⁰

Usage

Oyster owners make the smart card touch a card reader at the start and end of a trip. The TfL promises a lowest fare policy on Oyster to encourage adoption, and a daily price capping for frequent travelers. Various discounts on Oyster are offered to people in the following categories: 16 years old and younger, 16 to 17, and students older than 18. Passengers can purchase or add value to the cards at numerous Underground and DLR stations, National Rail ticket offices, tram stops, online, or by phone. Adults and students cardholders can also sign up for an Auto top-up account online which money is automatically added when balance falls below 5 pound. Lost and stolen cards are reported online. After November 19th, 2006, passengers will be penalized for forgetting to touch in and out at the right stations, by applying a maximum cash fare for the particular Tube or DLR trip.

⁵⁶ Transport for London

⁵⁷ Hong, Yi. Thesis 174

⁵⁸ RFID News.

⁵⁹ Transport for London

⁶⁰ Transport for London

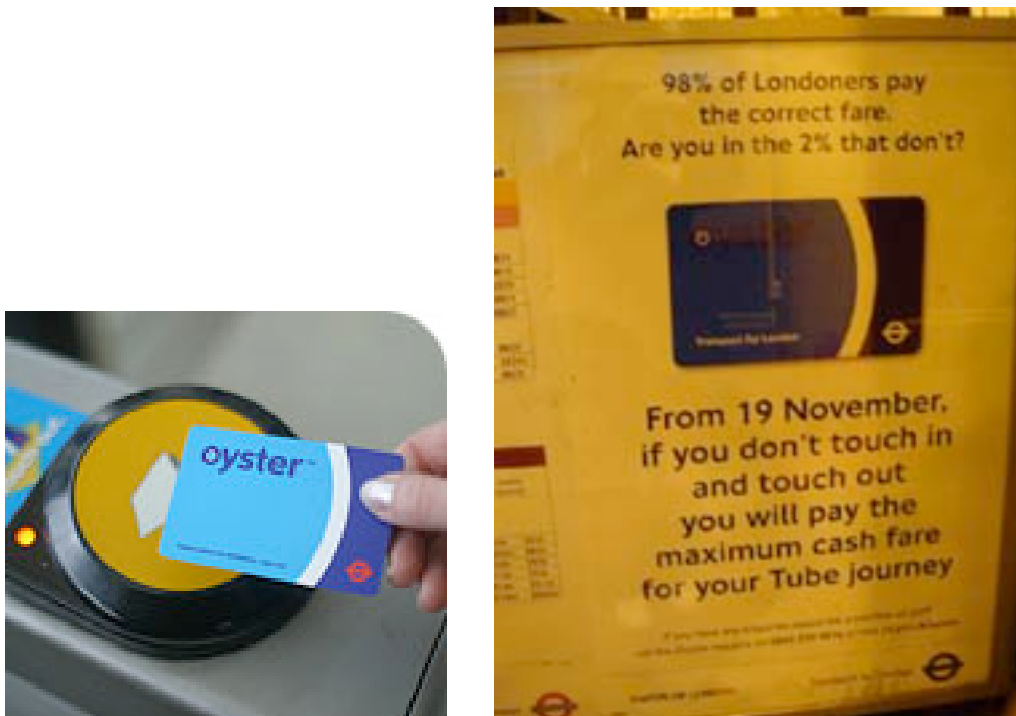


Figure 4-8: a) An Oyster card reader⁶¹ b) Poster warning

Evaluation

London commuters generally support the Oyster card because it offers really good discount compares to buying paper ticket (magnetic strips). A ticket for a single underground trip costs 3 pound, but the same trip only costs 1 to 1.8 pound on Oyster. Public transportation is not cheap in London. Therefore Oyster can reduce the financial burden for frequent travellers. Besides trip savings, Oyster card also eliminates problems with cash transaction, and waste associated with printing paper tickets.

Challenges to the system are both technical and societal. Many travelers complain about the robustness of Oyster card. The card is easily damaged from flexing and rubbing with loose changes. The replacement procedure can be a hassle although individual experience varies. Sometimes the card readers would error out and force the traveler to seek assistance from a London Underground staff in order to gain access through the gate. The helpfulness of the staff again varies in individual situations. Another major concern of Oyster system is privacy. TfL can track commuters' movement every time their cards are read. The card's unique ID number is linked to the owner's name. Information such as the location and time at which the card made the contact are recorded. Civil right groups, such as Liberty, are concerned about the types of organizations that can access these data and potentially misuse the information.⁶²

4.1.2.4 Singapore

Background

Singapore, a city-state with a total area of 692.7 sq km, and a population of 4.5 million, is one of the world's major trading links and Asia's major transportation hub.⁶³ Domestic transport modes include a network of expressways, a heavy rail Mass Rapid Transit (MRT) metro system, and a Light Rapid Transit (LRT) light rail system. Public transportation is heavily

⁶¹ Transport for London

⁶² Aaron Scullion.

⁶³ CIA—The World Factbook, Hong Kong.

used, adding to more than 2.8 million daily bus passengers and up to 1.3 million rail passengers.⁶⁴

EZ-Link Basics

The EZ-Link card is a contactless smart card that uses RFID technology at 13.56 MHz, conforming to ISO/IEC 7816 card dimensions. The card can communicate with the reader within a 10 cm radius. Secure encryption is implemented to preserve information integrity. Customers can use these cards as forms of identification or request special themes and personalized designs for the cards.



Figure 4-9: EZ-Link Cards⁶⁵

Usage

As of May 2006, the penetration rate for EZ-Link cards has been estimated as high as 90% for bus travel, and 96% for rail. Over 8 million cards have been issued, and there is an average of 4 million transit-related smart card transactions in Singapore each day.⁶⁶ Singapore introduced the EZ-Link smart card in 2002 and by January 2003, phased out the use of all magnetic stripe cards. Transit riders without EZ-Link cards must therefore pay cash or purchase a one-time use Standard Ticket, which requires a deposit that is refunded upon return of the card. The EZ-Link system covers all buses and rail transit systems in the city.⁶⁷

The EZ-Link fare system for transit is distance-based. Riders must tap their card upon entering and exiting a vehicle. The maximum distance fare is charged if the user fails to tap out.

Unlike some cities' transportation smart cards, Singapore's EZ-Link cards serve multiple purposes. For all students, and many others in Singapore, the cards are a form of identification. All students are required to have ID cards, and given that most also need to use public transit these two purposes have been combined onto this one card.⁶⁸ The EZ-Link cards can be personalized with your photo and other identification information, or simply with a photograph or image of your choice. The cards are now an accepted form of payment at several fast food restaurants, supermarkets, and select government services.

As of September 2006, users may use these cards with their home computers to make purchases online or add value to their cards if they purchase a home card reader. The anonymous EZ-Link cards are treated as cash payments online. Nicholas Lee, Senior Vice-President of Business and Technology at EZ Link Private Limited promises that even with

⁶⁴ Singapore Land Transport: Statistics In Brief 2005. Land Transport Authority.

⁶⁵ EZ-Link. "The Card:: Products:: ez-link card:: Card Types"

⁶⁶ Hong, Yi. Thesis 34

⁶⁷ Hong, Yi. Thesis 34

⁶⁸ Hong, Yi. Thesis 34

the personalized cards, no identification data contained on the cards will be passed along to online merchants during these transactions.⁶⁹

Some people question the need for a children's concession card to be an identity card as well. Smart cards are more expensive for parents to replace when lost by their children than traditional student ID cards. Also, several parents criticized the expansion of the EZ-Link service to include fast food restaurants and vending machines. They are concerned that they have limited ability to ration how their children use the money stored on their cards, and yet they must provide the cards to their children in order for transportation to and from school each day.⁷⁰

Evaluation

Transition to use of the EZ-link system was not without problems. It took 6 months of fine-tuning the EZ-Link software after its introduction onto buses before the software error rate dropped below the 1% target.⁷¹ Three years later, in 2005, software glitches resulted in overcharging customers on 0.053% of rides.⁷² In 2006, the EZ-Link ticketing system was given an average score of 7.4 out of 10, indicating overall satisfaction with the service, on a survey conducted by the Public Transport Council.⁷³ Another either unadvertised or unexpected result of the EZ-Link system occurred with single-trip rail tickets. The required deposit fee for single-trip rail tickets resulted in increased lines and slower travel time per person. The problem was that it forced single-use riders to wait in a line to obtain the card, and then again to return the card upon disembarking.⁷⁴ This problem has a great impact on infrequent users including tourists.

Comparing smart cards with magnetic strip cards, "[it] was found that while the use of magnetic strip cards has an average throughput of 40 passengers per minute at fare gates and 35 passengers per minute at bus entry, the average throughput for smart cards was 50 passengers per minute at both fare gates and bus entry."⁷⁵ In Singapore, the EZ-Link cards cost S\$5.20 (≈ US\$3.30) a piece to produce compared to S\$0.40 (≈ US\$0.25) a piece for the old magnetic stripe cards.⁷⁶

TransitLink estimates that bus fare evasion occurs in 1.8% of bus trips, or an average of 42,000 cases per day. With an average amount of S\$0.60 evaded, this amounts to S\$9 million of daily lost revenue. Seventy percent of this fare evasion is the result of underpayment. Most often this means that passengers "tap-out" of a bus at a stop earlier than the one at which they actually leave the bus, or less than a full fare of cash is inserted into the register. Twenty-four percent of fare evasion cases are the result of non-payment when passengers intentionally choose not to tap their smart cards upon entering the bus. The final 6% of fare evasion comes from people using someone else's reduced fare card.⁷⁷

⁶⁹ Nicholas Lee, Senior Vice-President of Business and Technology

⁷⁰ Wikipedia "EZ-Link"

⁷¹ Lian, Gon Chin. "Fewer ez-link errors on buses; Less than 1 per cent of transactions last month went wrong, which is within the target set"

⁷² Lian, Gon Chin. "Bugs still plague ez-link on buses; TransitLink says system errors accounted for about a quarter of all refunds last month"

⁷³ The Straits Times (Singapore). "Bus service better but there's room to improve: poll; Long waiting times and journeys, overcrowding top list of complaints" November 2, 2006

⁷⁴ Lian, Gon Chin.

⁷⁵ Sim, Seow and Prakasam, 2003 in Hong thesis, 24

⁷⁶ Segaran and Sim, 2004 in Hong thesis, 25. and EZ-Link.

⁷⁷ TransitLink. "Fare Evasion Affects Public Transport Commuters"

4.1.2.5 Tokyo

Background

The capital city of Tokyo, with a land area of 2,187 sq km and a population of near 12.7 million, is Japan's largest transportation hub. The major domestic forms of transportation include trains, subways, buses, monorails, and trams. Rail is the primary mode of transport, and is operated by JR East. Tokyo Metro and Tokyo Metropolitan Bureau of Transportation are responsible for the subways. Other government agencies and private companies operate the bus network.

Suica Basics

JR East launched the Suica IC card ticketing system in November 2001. Suica, which stands for "Super Urban Intelligent Card," is a rechargeable contactless smart card. The Suica card uses contactless RFID technology called "FeliCa", developed by Sony. The same technology is also used in the Octopus card in Hong Kong, and the EZ-Link card in Singapore.



Figure 4-10: The Suica Card⁷⁸

There are two types of Suica cards. One type is a standard prepaid Suica card. Another type is a Suica commuter pass, which can be used unlimitedly between any two designated stations during a certain period, such as one month, three months, or six months. The Suica commuter pass is used at other stations in the same way the prepaid Suica is used.⁷⁹

Since January 2006, the Suica card has been incorporated into mobile phone technology. Mobile phones can be used as prepaid Suica or Suica commuter pass cards. Passengers can charge their Suica to the mobile or purchase the commuter pass through the network of the user's mobile phone, without having to go to the stations.



Figure 4-11: Suica Mobile Phone Reader⁸⁰

⁷⁸ JR East Company

⁷⁹ JR East Company

⁸⁰ JR East Company

Usage

As of May 2006, 16.6 million Suica cards had been issued. The Suica is currently usable not only in the Tokyo area (528 stations), but also in the regions of Niigata and Sendai (36 and 66 stations respectively). The Suica card is also usable in the ICOCA network, another rechargeable contactless smart card system in the Osaka region in Japan. By March 2007, other transportation companies in the Tokyo area will be able to share the use of the Suica. This will enable Suica holders to use their card at almost any railway station in Tokyo.⁸¹

The Suica can also be used outside of the railway sector, such as in grocery stores, restaurants, bookstores, and other businesses in the city. Approximately 1,000 stores accept the payment of Suica nowadays. In addition, the mileage of Japan Airlines (JAL) can be transferred to the Suica's electric money. Overall, Suica had been used for 100,000 electronic money transactions a day as of May 2005. JR East aims to drive daily transactions up to 2 million in the near-term and to 4 million by fiscal 2009.⁸²

Evaluation

The mobile Suica, which was introduced in January 2006, has generated synergy effects. The user of mobile Suica reached 20,000 people in two weeks after introduction, and 60,000 people in one month. The mobile Suica increases both the use of Suica and the number of cell phone users, and brings benefits to both JR East and cell phone companies. However, there are still concerns about mobile Suica. For example, only credit card holders can use the mobile Suica.⁸³

4.1.2.6 Washington DC

Background

Washington DC is the capital of the US, with a city area of 177 sq km, and a population of 582,049 people. Washington DC is considered to have the 2nd largest rail system and 5th largest bus network in the US.⁸⁴ The Washington Metropolitan Area Transit Authority (WMATA) operates both the Metrobus and the Metrorail.

SmarTrip Basics

The SmarTrip Card is a plastic contactless stored-value smart card used for payment within the WMATA of Washington DC. It can be reloaded and used permanently. The SmarTrip Card was first introduced in the Metrorail system in 1999 and was implemented in the Metrobus system in 2004. Since June 2004, the Metro parking system can also be paid for with the SmarTrip Card. The SmarTrip Card can also be used in the transit systems of Maryland and Virginia.⁸⁵

By the fiscal year of 2005, 700,000 SmarTrip Cards had been sold. The percentage of Metrorail rides made using the SmarTrip Card was 35% between 1999 and 2005, and by early 2006 the number had increased to more than 60%.⁸⁶

⁸¹ JR East Company

⁸² JR East Annual Report 2005

⁸³ IT media, February 2006

⁸⁴ Hong 2006: 151

⁸⁵ Hong 2006: 31

⁸⁶ Hong 2006: 32



Figure 4-12: SmarTrip Card⁸⁷

Usage

A microchip in the SmarTrip Card stores its value, most recent entry and exit points, and a unique identifier. However, the unique identifier is not linked to a person's name or identity, unless one registers the card online. If riders register SmarTrip cards, they can recover the card balance value (minus the \$5 cost for a new card) when the card is lost, stolen, or damaged. The unique identifier also allows workers to enrol in the Smart Benefits program to receive their monthly benefit automatically to their SmarTrip card.⁸⁸

Riders with insufficient value to pay their fare are allowed to exit the system with a negative balance. This negative balance must, however, be paid before the card may be used again to enter the system.

In addition, WMATA and Citi have teamed up to consolidate a Citi Platinum Select SmarTrip MasterCard, a Metro SmarTrip Card and a Citi credit card into one plastic card.⁸⁹

Evaluation

In 2004, WMATA decided to introduce a smart card-only payment system at all WMATA parking lots. As a result, station dispensers sold as many cards in a single year as were sold in the previous five years. However, tourists also have no option to pay by cash. During the summer season, for example, up to 50% of the cards obtained from the dispensers are used by one-time users.⁹⁰

4.2 Improvement/Benefits

4.2.1 Efficiency

Smart cards provide many efficiency improvements to both customers and transportation providers.

The most obvious benefit is that smart card fare collection systems are an easier payment method and allow faster boarding. Passengers no longer have to prepare cash or a token, or wait in line to get tickets. Therefore, the boarding process can become smoother and faster. There is also a major cost saving opportunity for transportation providers since they can decrease cash transactions, which are more labor intensive and prone to errors.

⁸⁷ Washington Metropolitan Area Transit Authority

⁸⁸ Wikipedia, "SmarTrip"

⁸⁹ Washington Metropolitan Area Transit Authority

⁹⁰ Joshi, "Innovations at Work: Fare Collection - WMATA's SmarTrip, Cashless Parking"

These efficiency benefits can be enhanced with contactless smart cards. Passengers can go through automatic ticket gate without having to remove the card from their wallets or purses. This will further decrease congestion at checkpoints, and the convenience resulted may induce a higher adoption rate.

According to a survey of Chicago Transit Authority in 2005, almost half of the 232 respondents who own a Chicago Card cited convenience as the main reason for using it.⁹¹ In 2002, one year after the introduction of Suica, JR East carried out the questionnaire survey. Of the respondents who use Suica, approximately 45% said that JR East's service had become easier to use, 10% replied that they use JR East more often than before, and 5% stated that when they had a choice of lines to the same destination they had started using JR East. That is to say, the result of this survey confirmed that Suica is creating new demands.⁹²

Secondly, some smart cards can be used for non-transportation purposes. Suica in Tokyo, Octopus in Hong Kong, and EZ-Link smart card in Singapore can be used as electric money for the payment at convenience stores, restaurant, etc. EZ-Link smart card in Singapore is also used as identification for students and other people. They do not have to carry multiple cards or cash. These non-transportation functions help to increase the usage of smart cards.

Furthermore, in contrast to conventional magnetic card or paper ticket, smart cards can be reissued with their value reinstated when lost, stolen or damaged if individual identification information is connected to the card.

4.2.2 Financial Benefits for Transportation Providers

Smart cards provide financial benefits for transportation providers. First, smart cards can reduce various operational costs. According to the statement of JR East president, the maintenance cost for contactless smart card systems is lower than that for magnetic card systems because the automatic fare collecting gates for contactless smart card systems have fewer mechanical parts. Also, if Suica cards became more common, it could be possible to reduce the number of ticket vending machines, ticket offices, other facilities and station staff.⁹³ This allows the freed space and staff to be used for other purposes.

Second, smart card systems can reduce fare evasion because fares are automatically calculated and collected. When bus operators do not have to collect cash and distribute paper tickets, they can instead concentrate on preventing fare evasion.⁹⁴

Finally, smart card systems enable transportation providers to set flexible fare policies. Flexible fares enhance competitiveness between transportation options. As a result, they can attract more passengers and increase the mass transportation agency's revenue.⁹⁵

⁹¹ Hong, Yi. Thesis 23

⁹² JR East Annual Report 2004

⁹³ JR East Annual Report 2002

⁹⁴ Hong, Yi. Thesis 24

⁹⁵ Hong, Yi. Thesis 25

4.2.3 Marketing Benefits for Transportation Providers

With smart cards, passenger behavior can easily be tracked and recorded into a database. This information about passenger behavior, such as common origins and destinations, frequency of travel, length of standard trip, etc, is very valuable for transportation providers. Providers can use this information to enhance their business plans⁹⁶ by better evaluating the traffic demand and assessing future investment.

4.3 Concerns

Along with the convenience of urban transit smart cards come several concerns. From a technical standpoint, there are several different technologies available, each with their own strengths and weaknesses, which are not necessarily compatible with each other. From a policy perspective, some of the key concerns are privacy of data, and equity in both access to and use of these cards. The following subsections will outline the primary concerns about smart card implementation in urban transit.

4.3.1 Standardization / Technical Considerations

The term smart card encompasses several different data storage and transmission technologies. Therefore, the type of smart card technology chosen for use in any particular city affects the ultimate range of locations where the card can be used. For example, neighboring cities may choose to use the same technology such that riders can use the same card in both locations. Similarly, within a city, the technology platform chosen determines whether or not different smart card applications including building access, library borrowing, and transit, can all be combined onto one card. Japan's Suica card, Hong Kong's Octopus Card, and Singapore's EZ-Link card all use the same RFID technology. The other cities examined in Section 4.1 use other platforms.

An example of similar smart card standardization in the United States is found in electronic toll systems. E-ZPass transponders are sold separately by each of the following states: Maine, New Hampshire, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, West Virginia and Illinois.⁹⁷ Instead of the E-ZPass, Massachusetts offers the FAST LANE, a distinct system which is fully compatible with the E-ZPass system.⁹⁸ E-ZPass holders may use their transponders to pay Massachusetts FAST LANE tolls and likewise FAST LANE transponders will pay E-ZPass tolls. A similar interoperability between urban transit cards might encourage more cities to adopt the technology. With technology standards that allow interoperability, a city is able to transport more riders without having to pay the administrative costs of creating new cards and accounts for each visitor.

At this time, several different standards are used in urban transit smart cards. Standardization efforts are ongoing at international and national levels. Wary of selecting a technology different from what becomes the future standard, some cities are hesitant to adopt any smart

⁹⁶ Hong, Yi. Thesis 25

⁹⁷ E-ZPass. "Summary of Facilities Accepting E-ZPass."

⁹⁸ Massachusetts Turnpike Authority. "FAST LANE Program"

card technology at this time. In Chapter 5, the future development of standards is discussed in more detail.

4.3.2 Security and Privacy

As smart cards are used in more locations, and have increasing amounts of personal data stored on them, this personal data is spread to more people and organizations. In cities where customers must both swipe or tap in and out of the transit systems, the card-administering agency can now track between where and when individuals are traveling. As previously mentioned, this information can be used to improve transit routes and schedules; however, if any personal identification is contained within the card, this transit data can also be used to track the whereabouts of individuals. If a card is lost or stolen, users have to worry about how much personal data could be stolen by reading the data on their card. Does the card contain customers' full names and addresses, phone numbers, email addresses, or bank account information? The card-administering agency's choice of where to store data, either in a centralized database, or on individual cards, as well as how to use it in conjunction with usage data, are important with regard to privacy.

Most cities using smart cards offer multiple types of cards, some with more privacy than others. For example Chicago offers two card options, the Chicago Card and the Chicago Card Plus. No bank account or email address is required to obtain Chicago Card; however for those people willing to provide this information, they may obtain a Chicago Card Plus and obtain additional conveniences including the ability to manage their card online. An additional interesting contrast between these two cards is where the data is stored. Transaction and balance data for the Chicago Card is stored directly on the card, whereas to enable online account management of the Chicago Card Plus, this data is stored on a centralized server.⁹⁹ London and Washington DC issue just one card but both provide the option for users to register their card online in order to obtain online access, and the ability to recover the card balance in case the card is stolen.

Singapore requires photo IDs for all students. Given the prevalence of EZ-Link use in the country, student identification is printed on their EZ-Link smart cards, thus eliminating the need for two cards issued to each student. Many adults in Singapore have EZ-Link cards which double as photo identification as well. However, this is not required. The issuance of smart cards to all Singapore school children has raised concerns among parents. Some parents are unhappy that their children can use these cards to buy fast food and other goods as well as transportation. Schools in Hong Kong similarly use Octopus cards as students' identification for library loans and payment for food and tuition.¹⁰⁰ Additionally, a smart card costs more for a parent to replace than a standard ID each time a child loses one.

Similar privacy concerns affect the use of retail store loyalty cards. However, despite infringements on personal privacy, a 2004 survey by Boston University's College of Communication found that most cardholders agree that the benefits of using the card outweigh the privacy concerns.¹⁰¹

4.3.3 Equity

⁹⁹ Hong 169

¹⁰⁰ "Hong Kong Octopus Card."

¹⁰¹ About.com "Grocery Store Loyalty Card use is Strong Despite Privacy Concerns"

While smart cards provide additional conveniences for the majority of urban transit riders, they are not necessarily accessible to all transit riders. Low-income riders, tourists, and children are examples of groups that may not benefit from smart card implementation. For these groups, and others who simply do not wish to use smart cards, all cities using smart cards currently offer an alternative form of payment. Cash payments are still an option in all cities. Magnetic strip cards are available in most smart card locations including Chicago, Washington DC, Tokyo, and London. However, these cards are being phased out as smart cards become more common. In Hong Kong, the use of magnetic cards is now limited to specific trains. Singapore, however, has phased out the use of all magnetic cards and now requires the payment in cash if not using a smart card.

Many lower income transit riders do not have bank accounts and therefore the requirement that a smart card holder must tie their card to a bank account prevents this group of people from participating in the program. In cities where fares are discounted for smart card users, a bank account requirement makes this policy particularly inequitable. In most cities using smart cards, it is possible to obtain and reload a smart card without a bank account.

In Singapore, children below 0.9m in height are currently allowed to ride for free. Once they reach that height they are required to obtain a child EZ-Link pass. Some parents do not believe that basing a child's status on height is fair. They state that families with taller children should not have to pay more for transportation than shorter families. Transit administrators cite the additional work it would take to check children's birth certificates instead of height as a reason for the current policy. A young child (under 8 years) EZ-Link card, where no fares would be charged, has been proposed as a more equitable solution.¹⁰²

4.3.4 System Failures

Another concern for users and administrators of smart card systems is how to deal with system failure. What happens when the smart card system stops working? In Singapore, riders were frustrated to find they were asked to pay cash fares in such a situation. They found this to be an unfair solution given that cash payments are more expensive than EZ-Link payments in Singapore. Consumers felt unfairly penalized for a lack of service.¹⁰³

Software glitches have also resulted in many cases of over-charging customers for their travel in Singapore. When this occurs, it requires both additional software development to fix the problems, and additional administration to refund affected customers.

4.4 Trade-offs

The increased efficiency in public transit resulting from the introduction of smart cards is considered to be one of the most, if not the most, important benefit of the implementation of an automated fare collection system. Securing higher efficiency, however, jeopardizes certain equity, security, and privacy characteristics of transit systems operating traditional fare collection systems.

¹⁰² Huang, Ms. Catherine Ngiam Sok The Straits Times (Singapore).

¹⁰³ Ling, Law Sin. The Straits Times (Singapore).

The benefits of smart cards mentioned in previous sections can be divided into those affecting the individual user and those affecting the transit agency. For the user, smart cards are convenient because they can have multiple uses, they can be managed online, and, if contactless, they allow for faster boarding and thus have a potential to reduce travel time. In addition, users may be able to store personal information on their cards. The benefits of smart cards for transit agencies include the ability to store and record user's personal information, track user's mobility patterns, and phase out traditional payment systems such as those based on cash transactions. The following sections portray the tradeoffs each of these benefits entails, while Figure 4-13 illustrates the principal idea of trade-offs, where a card like the Chicago Card Plus, with multiple functionalities and features to store personal data and be used contactlessly is much more efficient than the standard Chicago Card. Nonetheless, the latter is a better safeguard of equity, security, and privacy concerns. At the other end of the spectrum one finds cash, which while being the least efficient payment method for transit purposes, does not invade commuter's privacy, nor inflict equity or security issues among society.



Figure 4-13: Trade-off between Efficiency vs. Equity/Security/Privacy

As mentioned earlier, one of the major marketing appeals for smart cards is the convenience they provide transit users. Depending on the design of the smart card system in a particular city, users may enjoy benefits such as a discounted fare, an automatic loyalty program, faster pass-through time at checkpoints, and an online payment program. These benefits, however, are not equally shared among the various stakeholders utilizing the transit system. While a smart card program can bring efficiency benefits to most users of the public transit system, there are some groups that would be disadvantaged, including infrequent travelers, tourists, and lower-income populations.

4.4.1 Efficiency – Equity Trade-off

Efficiency vs Equity

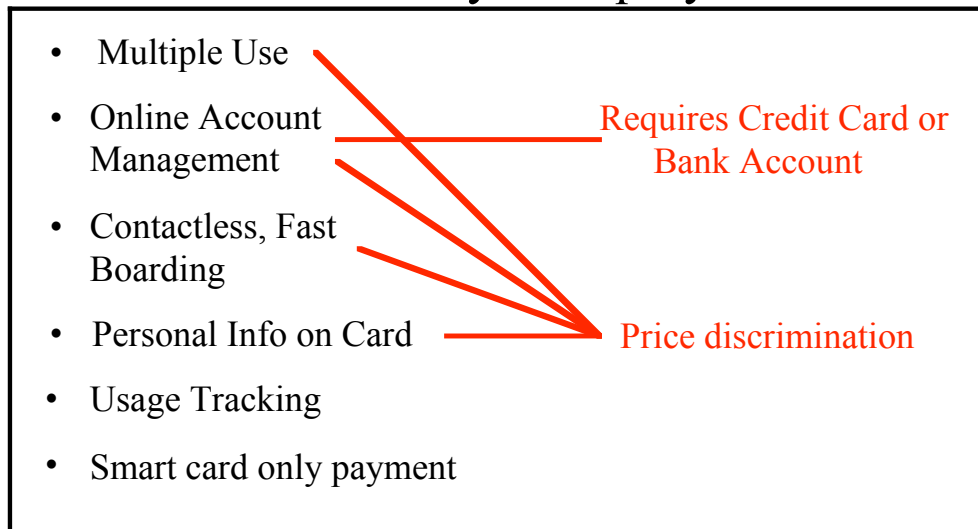


Figure 4-14: Efficiency vs. Equity Trade-off

4.4.1.1 Frequent vs. Infrequent Riders

Since there is often a higher cost associated with joining the smart card program, infrequent travelers may find it is not cost efficient to participate in the program. Therefore, they pay higher cash fares when using public transportation and/or enduring longer wait times to purchase a single-ride pass at the booth. Even when they do use smart cards, they can not enjoy the full benefit of the program because the benefits are designed for frequent usage. Tourists also face similar issues. Tourists have to pay a deposit for only short-term use of a smart card. Moreover, many tourists are often confused about navigating the public transportation in new cities while struggling with language and cultural barriers. Joining a smart card program can be more complicated than simply using cash to purchase single-ride passes. On the other hand, one can argue that frequent users and local residents do bare more financial burden in maintaining and developing the transit system and should logically enjoy more of its benefits.

4.4.1.2 Disadvantaged Groups

There is also an equity issue related to disadvantaged groups. First, low-income social groups and immigrant workers, among others, may not have the required credit card or bank account necessary for joining the smart card program. Second, the elderly population, which is not necessarily technically savvy, may have difficulty performing online transactions (for example, adding value to card or checking balance, among others). These groups do not enjoy the maximum benefits and conveniences that an urban transit smart card offers. Since public transit is a public service, the system should be designed so that all users can enjoy equal benefits.

4.4.2 Efficiency – Security Trade-off

Efficiency vs Security

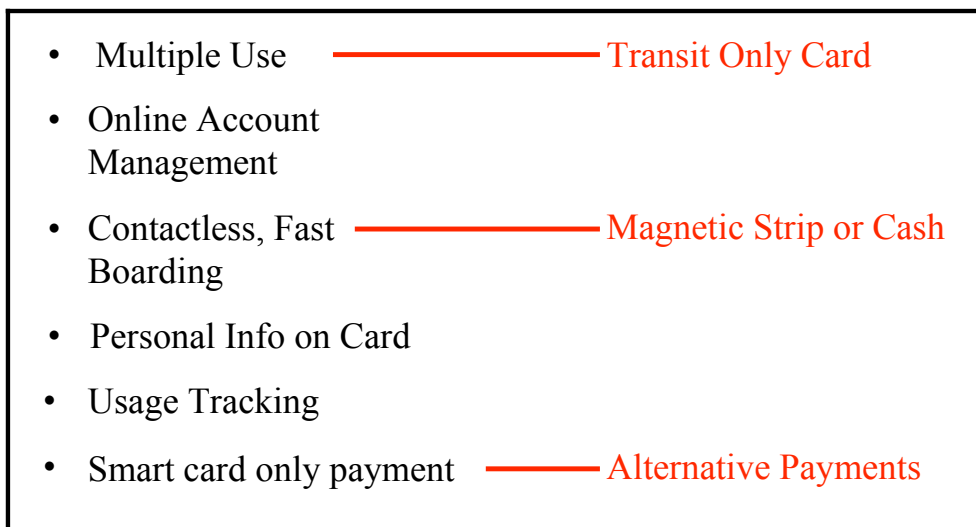


Figure 4-15: Efficiency vs. Security Trade-off

The same features that enable smart cards to have such a positive efficiency effect in the transit system and allow it to incorporate new functionalities to become integrated in different service systems, also introduce users to certain risks they might not be comfortable assuming. Furthermore, the smart card sponsoring agency might not know how to control and respond to these new risks.

4.4.2.1 Multiple Uses

The ability of smart cards to have multiple functionalities and thus be used as debit cards, ID cards, access cards, etcetera, makes them both more convenient and insecure. While such multi-functionality allows users to carry one card only, the potential consequences of losing the smart card are more severe. A solution to this could be to secure user's private data in a central database and be able to access such information solely by use of the smart card, rather than storing all data on the card itself.

4.4.2.2 Contactless Feature

Smart cards' ability to communicate contactlessly with the card readers at stations or buses jeopardizes the security of user's information. This contactless feature of smart cards enables smooth payments, and has the potential to reduce boarding times, particularly in buses. The security concern regarding this feature lies in the fact that not all RFID transmissions use proper encryption, thus making contactless smart cards less secure than those designed for communicating through direct contact only. Depending on how far the smart card signal travels, sniffing on this transmission is easily done by standing close to someone with the right electronics. Some people argue that spying and eavesdropping on smart card transmission is unlikely to happen, disregarding this as a major security concern. If, however, smart cards store unencrypted personal identification and transaction details, this information is subject to illegal retrieval and identity theft.

4.4.2.3 Smart card only payment system

The introduction of smart cards as the sole form of transit payment, while economically viable and reasonable in that it reduces the transit agency's operational costs, could be risky if

no backup payment system is established to respond to the potential failure of the automated fare collection system. If the card has multiple functionalities, the increased dependence of citizens on one small plastic card also augments their vulnerability to system failures and manipulations, such as is the case with identity theft.

4.4.3 Efficiency – Privacy Trade-off

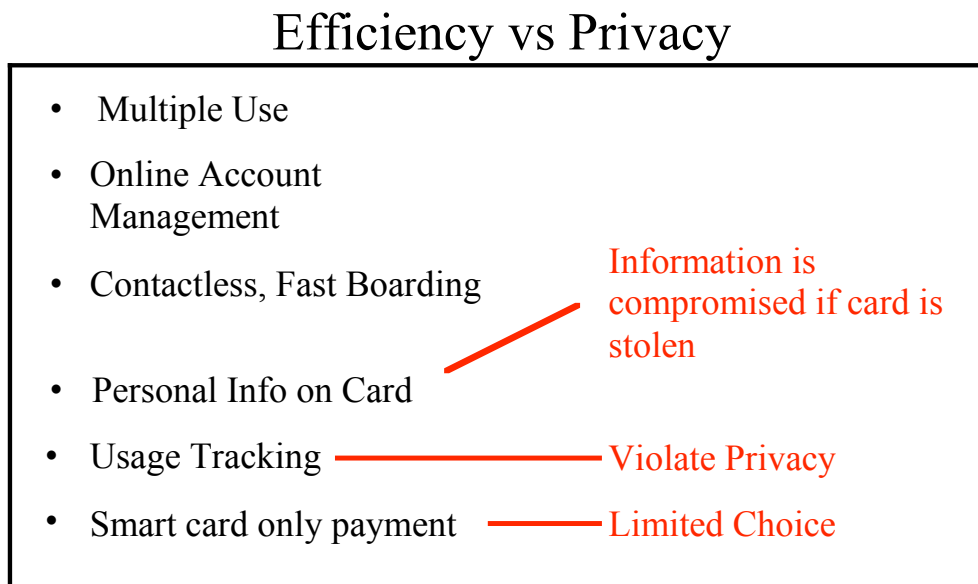


Figure 4-16: Efficiency vs. Privacy Trade-off

Many of the efficiency benefits of using smart cards in urban transportation come at the cost of the personal liberty or privacy of transit riders. The main privacy concerns with smart cards are tracking riders' usage of the cards, and the storage of information on each card. Each of these concerns is explained in more detail below. Many current smart card users are also unaware of the liberties they forego by participating in existing smart card systems. They do not know how the information they provide the transit agencies is being used. Therefore, the Transit Cooperative Research Board has been recommended that transit agencies create and advertise a customer bill of rights detailing how their data is being used and what steps have been taken to protect individuals' privacy.¹⁰⁴

4.4.3.1 Information on the card

When smart cards are tied to personal identification, the value stored on the cards can be reissued when it is lost or stolen. However, in case of lost and stolen cards, this information may be subject to identity theft. The more information stored on the card, the more significant its loss may be. However, in the multi-purpose card case, having to only replace one card instead of several credit cards and forms of ID may be more efficient for the person who otherwise loses their whole wallet.

4.4.3.2 Tracking user behavior

Smart cards enable easy, detailed, and relatively cost free, tracking of passenger behavior. Both individual and aggregated data on statistics such as frequently used routes, passenger volume, and peak travel times is extremely valuable to transit agencies. These agencies can

¹⁰⁴ TCRP Report 32 page 73

use this information to improve transit routes and other forms of customer service. If personal identification is tied to the cards, the movement of specific individuals can also be tracked. Individual tracking may be helpful in criminal cases and make some riders feel more secure; however, tracking is also worrisome to those concerned with personal privacy. With tap-in, tap-out transit systems, smart cards can increase equality as fare evaders are more easily caught. With multi-purpose cards, providers can track people's shopping habits in addition to their movement, as well as other linked activities. All of the data being collected through smart card use can be used to improve transit, retail, and other services; however the collection of this data constitutes a form of loss of privacy.

5 Analysis of Future Development of Smart Card Systems

There are three major development trends of the smart card system. Firstly, the traditional smart card used for public transportation fee payment will start to pack more and more applications onto the same card, such as payment at retail and food stores. Secondly, there are major efforts at different levels to integrate different smart card systems (within and across applications). Thirdly, we can expect to see continual advancement of the smart card technology.

5.1 Expanded Application

In general, smart cards usage can be grouped into seven main areas: transportation, banking and loyalty, telecommunication, healthcare, electronic payment, personal identification, and physical access control. In developed countries, it is not uncommon that people are carrying more and more smart cards for different purposes. The variety of these cards not only creates inconveniences for the public but also causes confusion. In the future, we expect to see more multi-purpose cards with increasing number of applications packed in a single card.

Even within a single application, we expect to see the card to gain wider access. For example, in the transportation area, there are national efforts to make a transportation smart card be applicable for all public transport, such as car toll, bus, rail, and subways. Hong Kong has pioneered the effort to introduce card reader in taxis. In June 2006, the first trial of taxis equipped with Octopus was launched in the New Territories with the Yellow Taxi Group, an effort widely welcomed by the public and the local press. There are also substantial opportunities for implementing more sophisticated and targeted marketing strategies to encourage more people to use public transport, and for introducing passenger loyalty and frequent-user schemes for bus and rail users. For example, more and more financial institutions are considering issuing smart cards because banks are seeking to bring new-value added services to customers, such as cash bonus points or other customer loyalty program, in a fast, secure, and efficient way.

Perhaps the most common feature that will be packed into a transportation smart card is the electronic payment (i.e. an e-purse) function. This not only increases user convenience but the decrease use in cash can actually result in gain in thin-margin industry. Sony, the Japanese electronics giant, is the main proponent in this application. They envision a “global currency”¹⁰⁵ where purchases will mainly be made on these smart cards, and currency conversion is done automatically. However, this may have a significantly negative impact on national lending and financial institutions. Therefore, the e-purse movement is tracked very closely by these organizations.

¹⁰⁵ Leander, T. “The Future of Money” CFO Asia. October 2001.



Figure 5-1: An Octopus card reader at a McDonald's restaurant in Hong Kong¹⁰⁶

Many countries have started to experiment multi-purpose smart cards. For example, the Reserve Bank of India (RBI), along with the Institute for Development and Research in Banking Technology (IDRBT), is working on such a system. Their multi-purpose cards can operate as a bank account, store electronic cash, contain security features such as biometric identification, and double up as an entitlement identifier or as a social security card. The Malaysian government launched a multi-purpose card in 2001. The card serves as a national ID card, driving license, passport, store-value card for public transport and road tolling, e-cash (maximum limit is \$500), ATM card for 8 banks, health card that includes allergies and medical history, and contains public key infrastructure for secure e-commerce.



Figure 5-2: Malaysian Government Multi-Purpose Smart Card, MyKad¹⁰⁷

5.1.1 Potential Issues

The movement towards increasing functionalities in a single card is somewhat constrained by the fact that different issuers may have different transaction security and time requirements, which require different card technologies. For example, a contact card offers greater security but slows down the transaction speed. Therefore, banks would prefer customers to use a contact smart card but the public transit authority, which is more concerned with speed of passenger moving through checkpoints, would oppose to this format. More importantly, packing more and more functions into one card raises serious privacy concerns since the card can then provide powerful linkage to consumer behavior. Critics also question whether the security features on the card can really protect consumers from fraud and impersonation. Once the security measurement is breached, criminals will have access to data of all applications at once. Privacy International, a London-based human-rights group formed in 1990 as a watchdog on surveillance and privacy invasions by governments and corporations, warns that no smart card technology is secure enough to escape fakes issued by terrorist and

¹⁰⁶ Wikipedia. "Octopus Card"

¹⁰⁷ Clarke, Roger: MyKad – The Malaysian ID Card;
<<http://www.anu.edu.au/people/Roger.Clarke/DV/MyKad.html>>

criminal gangs. There could also be accidental data leakage. In 2002, personal data was leaked from Japan's new nationwide identification system only two days after the controversial program was launched. Personal information of over 2,500 people was sent to the wrong hands.¹⁰⁸

5.2 Advancement of Card Technology

5.2.1 Smart “Card” No More

Just like the trend to pack more and more function into one electronic device, such as a cell phone that is also a digital camera, a video recorder, an MP3 player, and a planner, in the future, a transportation smart card may no longer be in the form of a card. Hong Kong, for example, has already made headway into this direction by introducing the Octopus Watch and Octo-phone. Sony’s FeliCa, a contactless, 13.56MHz card technology, is the major enabler of Hong Kong’s Octopus card advancement. One major characteristic of FeliCa is that it can be applied onto devices regardless of shape, as long as the application comes with the IC chip and antenna.



Figure 5-3: Sony FeliCa chip technology emphasizes its ability to enable multi-application on a single smart card.¹⁰⁹

¹⁰⁸ Raja M., “Smart cards make inroads into Asia”

¹⁰⁹ Sony Corporation.

Hong Kong introduced the Octopus Watch in limited edition by MTR in December 1999 to commemorate the new Millennium. It is a plastic wristwatch with a Sony FeliCa IC chip embedded inside that can be used exactly in the same way as a normal Octopus card. In Hong Kong, for example, a youngster would buy a colorful Octopus watch which lets him buy drinks at 7-11 stores, jump on the MTR, buy a hamburger at McDonald's, enter local stadiums, or make a payphone call all with a simple wave of his arm over the card reader. Over 11,000 transponder watches were delivered to Octopus Cards Limited for the year ending 31 May 2003.



Figure 5-4: Octopus Watch¹¹⁰

The Octo-phone, produced by Nokia, is another example. The phone has the smartcard embedded in the "Xpress-on" covers used in the Nokia 33nn series of mobile phones, such as the popular Nokia 3310 model.

5.2.2 Biometric Identification Technology

As the functionalities increase in a smart card, there is more emphasis on enhancing the security measure. Two important technologies in consideration are incorporating biometric information or PKI into the smart card.

Biometric identification techniques, such as fingerprint and iris pattern identification, are used to replace the conventional PIN method because PIN is just a series of digits that cannot truly represent the personal identity. In the near future, we can expect to see more use of biometric identification in the smart card operating systems. For example, the Malaysian MyKad smart card mentioned above already contains fingerprint data. But biometrics is not without problems. Critics point out that once a fingerprint or other biometric source has been compromised, it is compromised for life, because users can never change their fingerprints.

5.3 Standardization Efforts to Increase Interoperability

It is now widely accepted that standardization, from smart card software to hardware, will be the critical success factor for the future of smart card systems. There are organizations at the international, European, and national levels that seek to drive standardization. Most progress in standardization that addresses the physical, electrical, and physical properties of cards has been produced by international organizations. European standards focus on addressing issues

¹¹⁰ Vision Engineer, Octopus Watch; <http://www.visionengineer.com/tech/octopus_watch.php>

in transport industry and enhancing interoperability with other standards. National initiatives usually seek to develop standards that will cover business rules and supporting systems (back office systems, financial transaction clearing systems, etc). There are also collaborative efforts made among different national standardization organizations, such as UK and France.

Up until recently, different smart card vendors have developed their own proprietary smart card operating systems, APIs and even card readers and device drivers. This wide range of technologies developed by vendors lead to interoperability problems between systems at many levels. There are three emerging multi-function smart card operating systems – Java Card, MULTOS (Multi-applications Operating System), and Microsoft's Smart Card for Windows – which may help standardize smart card systems up to the application programming level. If these OSs can prevail, smart cards would be taken as a commodity item much like PC components. No standard for contactless cards' communication protocol has been established. This poses a serious barrier for the development of transit smart cards. In the future, we expect to see one of the following three protocols become more prevalent: type “A” technology which involves pulsing radio waves, type “B” technology which involves a constant radio wave with reduced intensity, and type “C” technology which uses the same radio signal as B but transmits data differently.¹¹¹

¹¹¹ McDonald, N. “Multipurpose Smart Cards in Transportation: Benefits and Barriers to Use”, 8 Dec 2000

Conclusion

5.4 Recommendations

Smart card technology offers many advantages to urban transportation systems over traditional payment forms. This technology, however, should not be implemented without considering the various issues previously mentioned. To address the various tradeoffs previously presented, the following recommendations are made for the implementation of smart cards in urban transit.

Choose a technology standard that allows for integration with other smart card systems.

Cities should be particularly aware of the scalability of the chosen software and hardware. Therefore, they should pay attention to and support the development of standards in smart card technology. By choosing a standard system, these smart cards may also be used with other transportation, retail, and identification smart card systems, among others. Such a flexible system will be better able to incorporate changes in future technology, respond to new demands from society, and meet future regulatory requirements.

Given that there are multiple smart card systems being used currently, it is hard to determine which will become the standard of the future. The implementing organization will need to strike a balance between the costs of including additional flexibility to respond to future uncertainties and the unexpected costs that may result from a more rigid system.

Offer two types of cards – one with embedded personal identification data, and one without.

To address equity and privacy concerns, a cash-only version of smart cards should be made available in all locations. This option would enable those who either do not have, or do not wish to share, bank accounts, email accounts, or other personal information, to use the smart card-based transit system. Two types of smart cards are therefore recommended for each transit system - one with more features, but less privacy, than the other. A great example of this is the Chicago Card system. Offering more types of smart cards is generally not recommended.

On the other hand, more card options usually lead to greater confusion and would incur additional administrative costs. This recommendation might be resisted by the transit agencies since providing such a choice to the public may prevent a city from reaping the maximum efficiency benefits from implementing a smart card system as the benefit increases exponentially with adoption rate. To overcome this dilemma, transportation agencies will need to invest in marketing efforts and incentive programs to encourage people to voluntarily opt into the multi-purpose smart card program.

Consider a distance-based fare structure.

Smart cards allow transit administrators to implement distance-based complex fare structures, which have the potential to make ridership charges more equitable and at the same time increase the transit agency's revenue through price discrimination. If such a complex fare structure is considered, however, the transit agency needs to recognize that the transit system itself largely shapes and limits users' trips and chosen routes, directly influencing the distance

they travel. Whereas traveling by private transportation allows a person to go from one place to the next via the most direct route, traveling by public transit might force the user into a route that could be much longer than necessary. We therefore suggest distance-based fees be calculated according to the radial distance between the start and end of the trip, rather than on the distance traveled between the two locations. If different socio-economic groups live in distinct areas of the city in a way that makes poorer communities commute for longer distances, this might not be the best method for increasing equity in transit charges and a flat fare structure may be the most equitable option.

In cities that do not already price transportation differently based on zones or distances covered, however, this transition can be difficult to implement and to explain to residents. Setting aside this possible confusion during the transition period, this distance-based fare policy is easy to enforce on rail systems, but not so on buses, where riders can easily engage in partial fare evasion. In Singapore, for example, bus riders have been observed to “tap-out” earlier than they actually leave the bus in order to reduce the fare charged to their card. Japan solved this by requiring bus users to enter at the back of the bus but exit at the front, tapping out in front of the driver.¹¹² Another possible solution to this problem would be to have riders tap out at the bus stop on the sidewalk after exiting the bus, instead of on the bus while leaving. These options, however, make the implementation of a distance-based fare structure for buses considerably expensive, particularly when compared to the cost incurred for rail systems. The viability of this suggestion depends on the percentage of riders evading fares by tapping out early. An alternative option would be to combine a distance-based fare structure for transit rail systems with a flat-fare structure for public buses.

Continue to respect different pricing structures for different social groups

Cities should continue to allow students, children, and seniors to obtain the same reduced fares as before the implementation of smart cards. Some people have been observed to fraudulently use the smart cards of another group in order to obtain a cheaper fare, but this is generally uncommon.

The implementation difficulty here is once you have extended preferential pricing for one group, what is to prevent another social group from claiming the same benefit? For example, should lower income teachers and nurses be able to enjoy the pricing benefit as well? What is the method and standards in determining the bigger equity question? And of course, there is the practical concern that the more groups that can enjoy preferential treatments, the higher the administrative costs and the lower the overall system benefits there would be. Controversy is minimized by only providing lower prices to groups that have been traditionally receiving benefits (such as elders, veterans, and children).

Provide financial incentives to encourage adoption

If trying to get a large number of riders to adopt a new smart card system early in its implementation, encourage the switch by making it the cheapest option. Do not continue to provide lower travel rates via older payment options. Many cities have also had success in quickly increasing adoption by providing subsidized or free smart cards during the initial

¹¹² E-mail conversation with Matthew Dorfman, M.Sc. Candidate in MIT’s Technology & Policy Program, November 27, 2006.

stages of implementation.

Although this is an effective approach in fomenting adoption, transportation agencies also need to, at the same time, invest in educating the public about the full implication (i.e. privacy concern) of opting into a smart card program. Some privacy activists have critiqued that the government uses fare discounts as "bait" to lure unaware public into giving up their valuable personal information.

Provide backup functionality in case of central system failure

If the smart card system fails, there should be some alternative way for riders to continue to pay for travel. Transit agencies need to consider the different options for providing backup functionality. Among these options is the continued acceptance of cash and/or magnetic strip cards, as well as equipping local computers to communicate with smart cards even if the central server is down.

This increased system flexibility is likely to be initially more expensive, but in addition to allowing for an effective response to system failure, it provides riders a greater range of choice in how to pay for transit. On the other hand, such a wide range of payment options might discourage users to switch from the cash-based system to the automated fare collection system, thus jeopardizing the success of the later.

Routinely screen system for software failures

Glitches in the software, which could have serious economic and security consequences, may emerge from time to time. The system needs to be designed so that software checkups are routinely carried out to prevent any over or under-charging of customers, or any mishandling of personal data to occur. If the problem is identified after it affects customers, then the transportation authority must be equipped to minimize and, if possible, reverse the effect of its mistake.

However, there are practical questions, such as how often the screening should be done, what methods and how in depth each screening should be. The implementation agency has to juggle cost concerns with the scope and depth of system screening. Benchmarking against successful cities is suggested in this case.

Provide parental controls in cases where smart card functionality expands beyond transportation

If smart cards can be used for purchase of goods and services other than public transportation, such as food, parents should be able to control which non-transportation outlets at which their child's card will be accepted. It is a legitimate concern that, with smart cards, children will gain access to products and services that were previously out of their reach, such as junk food, for example. By introducing parental controls, children-owned smart cards will function less like debit cards.

Incorporating parental controls will likely increase the technical requirements of the system as well as the administrative costs. Furthermore, to what extent can parents control the functionality? Is it by category or by specific merchant? For a transit system that includes a

large proportion of underage users, would this significantly decrease the desirability of the system? Would such measure decrease merchants' willingness to participate in the program? These are all potential implementation difficulties that must be addressed.

5.5 Summary

Smart cards offer great promise in the field of urban transportation. They offer benefits to both passengers and the administering companies. For passengers, these benefits include faster boarding times, cashless transactions, and contactless payment. Smart card transit payment also offers reduced administrative costs. With less cash handling required, transit agencies are able to save substantial money on labor costs. The expanded use of smart cards to local retailers helps thin-margin businesses reduce costs in the same way. The semiautomatic fare charging of contactless payment reduces fare evasion. Transit agencies can also better track passengers' travel behavior, and use this information to both improve transit schedules and to sell more targeted marketing opportunities. Tap in/tap out smart card systems allow for more complex fare structures where the amount charged can now be a function of how far someone travels. This form of price discrimination allows transit agencies to capture more of the economic consumer surplus and thereby increase revenue.

These benefits, however, do not come without drawbacks. From an equity perspective, it is important to consider which sections of the population are able to obtain and use smart cards. Is a bank account, email address, or ID required? Children and the poor are two groups who typically may not have these common requirements. Furthermore, as more personal data is incorporated, users become increasingly concerned with privacy. The liberty to travel without being tracked is lost by many smart cards users. The future trend is packing even more information and applications into each card. A single smart card can be used as someone's identification card, passport, driver's license, building key and an electronic purse. The future also will likely include the consolidation of devices. For example, some countries have already incorporated smart cards into cell phones. But again, as more is integrated into one device, concerns of security and privacy increase. If someone with a smart card in their cell phone loses their cell phone, they've now lost more than just a phone. Additionally more information encrypted onto a card takes longer to be read. If someone's passport information needs to be decrypted each time the person leaves a subway, this will substantially slow down the speed of transit lines. Finally, standardization of smart card systems remains a major challenge. Consolidation is difficult if each card uses a different technology standard.

In order to implement smart cards in urban transit successfully, the following recommendations are made.

- **Choose a technology standard that allows for integration with other smart card systems.**
- **Offer two types of cards – one with embedded personal identification data, and one without.**
- **Consider a distance-based fare structure.**
- **Continue to respect different pricing structures for different social groups**
- **Provide financial incentives to encourage adoption**
- **Provide backup functionality in case of central system failure**
- **Routinely screen system for software failures**
- **Provide parental controls in cases where smart card functionality expands beyond transportation**

6 Acknowledgements

Our team would like to thank Professors Annalisa Wiegel and Daniel Roos for advising our team over the course of this research project. We would also like to thank Matthew Dorfman and Professor Nigel Wilson for their expert advice on the topic of smart card usage in urban transportation.

7 List of Figures

Figure 3-1: Smart Card and Microprocessor	7
Figure 3-2: Contactless Smart Card Structure	9
Figure 4-1: Comparison of Smart Cards Penetration Rate of the Six Major Smart Card Programs	12
Figure 4-2: Chicago Card, Card Plus	13
Figure 4-3: Go Lane Promotion	14
Figure 4-4: Octopus cards design	15
Figure 4-5: On-loan Octopus Card	16
Figure 4-6: Sold Octopus cards design and pricing	16
Figure 4-7: Oyster card, front and back	18
Figure 4-8: a) An Oyster card reader b) Poster warning	19
Figure 4-9: EZ-Link Cards	20
Figure 4-10: The Suica Card	22
Figure 4-11: Suica Mobile Phone Reader	22
Figure 4-12: SmarTrip Card	24
Figure 4-13: Trade-off between Efficiency vs. Equity/Security/Privacy	29
Figure 4-14: Efficiency vs. Equity Trade-off	30
Figure 4-15: Efficiency vs. Security Trade-off	31
Figure 4-16: Efficiency vs. Privacy Trade-off	32
Figure 5-1: An Octopus card reader at a McDonald's restaurant in Hong Kong	35
Figure 5-2: Malaysian Government Multi-Purpose Smart Card, MyKad	35
Figure 5-3: Sony FeliCa chip technology emphasizes its ability to enable multi-application on a single smart card.	36
Figure 5-4: Octopus Watch	37

8 List of Tables

Table 4-1: Summary of Smart Card Usage for Transit	10
Table 4-2: Usage and Options of the Six Major Smart Card Programs	11
Table 4-3: Alternative Fare Media of the Six Major Smart Card Programs	11
Table 4-4: Difference between the Chicago Card and the Chicago Card Plus	13

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IT Media BIZ Mobile, 24 February 2006, Available at
<<http://www.itmedia.co.jp/enterprise/mobile/articles/0602/24/news027.html>> 17 Nov 2006.

This article analyzes the effects and concerns of the mobile Suica after one month of the introduction of the mobile Suica.

Joshi, Ashok. "Innovations at Work: Fare Collection - WMATA's SmarTrip, Cashless Parking", Mass Transit Dec 2005/Jan 2006, p. 44

This article describes the effects of smart card-only payment policy at WMATA parking. This policy provided a significant increase of card issuance. However, there were still some concerns to be solved.

JR East Company. Available at <<http://www.jreast.co.jp/suica-info/index.html>> 17 Nov 2006.

This the official website of the East Japan Railway Company (JR East). It describes the types of Suica cards available and their basic usage. This website also includes information about the retail stores which are able to accept Suica card payment.

JR East Annual Report 2005

This report describes the summary of company activities in 2005, including statistical data and pictures. This also mentions the future plan of JR East.

JR East Annual Report 2004

This report describes the summary of company activities in 2004, including statistical data and pictures. This also mentions the future plan of JR East.

JR East Annual Report 2002

This report describes the summary of company activities in 2002, including statistical data and pictures. This also mentions the future plan of JR East.

Leander, Tom. "The Future of Money" CFO Asia. October 2001.

This article addresses the future trend, benefits, and possible issues in use of electronic cash in Asia. Asia has been quite advance in leveraging smart card technology to roll out e-purse in combination with other applications, such as urban transit. The author suggests that the decrease use in cash will help thin-margin industry and cites the Octopus card system in Hong Kong and illustrates the system benefits.

Lee, Nicholas. Interview by Loretta Foo on Radio Singapore International. "EZ-Link Launches Online Service. 1 September 2006. Available at

<<http://www.rsi.sg/english/businessideas/view/20060901144312/1/.html>> 3 Nov 2006

This is an interview transcript of Nicholas Lee, Senior Vice-President of Business and Technology at EZ Link Private Limited, by Loretta Foo of Radio Sinapore International. The topic of discussion is the launch of EZ Online, what it will entail, and how it will benefit both consumers and merchants.

Lian, Gon Chin. The Straits Times (Singapore). "Fewer ez-link errors on buses; Less than 1 per cent of transactions last month went wrong, which is within the target set" October 15, 2002

This news article published in Singapore's leading newspaper, The Straits Times, announces a reduction in error rates for ez-link charges on bus transit. It also describes problems with the deposit fee required for ez-link usage for rail travel.

Lian, Gon Chin. The Straits Times (Singapore). "Bugs still plague ez-link on buses; TransitLink says system errors accounted for about a quarter of all refunds last month" September 21, 2005

This news article published in Singapore's leading newspaper, The Straits Times, describes the continuation of software glitches which result in riders being overcharged for their fares. It describes the refunds being offered by TransitLink to those affected and provides statistics for the percent of glitches observed in both April and July 2005.

Ling, Law Sin. The Straits Times (Singapore). "Take bus off the road when card system fails. Otherwise it's unfair to commuters" ONLINE STORY 14 October 2000

This is an online post to the Singapore Newspaper webpage, The Straits Times, by a Singapore resident. In this post, the resident expresses concern that smart card system failures are not being handled in a just manner by the transit authority.

Massachusetts Turnpike Authority. "FAST LANE Program" Available at <<http://www.massturnpike.com/travel/fastlane/index.html>> 10 Nov 2006.

This webpage introduces the FAST LANE Program for paying roadway tolls in the state of Massachusetts. It briefly introduces how the system works and how to join by obtaining a transponder. It also includes many links to more information about the FASTLANE system.

McDonald, Noreen. "Multipurpose Smart Cards in Transportation: Benefits and Barriers to Use" The University of California Transportation Center. December 2000.

This paper focuses on discussing different case studies of multipurpose smart cards, lessons learned in each case, technical and practical concerns in creating more multipurpose cards in the future as well as packing more applications into the same card.

National Statistics. Available at <<http://www.statistics.gov.uk/census/default.asp>> 2 Nov 2006.

A British government site gives accurate data on London's population.

Octopus Cards Limited. The official Hong Kong smart card website. Language is in Chinese. Available at <<http://www.octopuscards.com/>> 4 Nov 2006.

This site provides comprehensive support to the Octopus card. Product information, customer service, online shopping, employment, and reporting for lost cards are all on this website.

Raja M., "Smart cards make inroads into Asia" Asia Times. Available at <http://www.atimes.com/atimes/South_Asia/FJ02Df03.html> 12 Nov 2006.

The article describes the recent trend of more and more use of multipurpose cards in Asia. It specifically talks about India's initiative in implementing national ID card

scheme in combination with using the card for urban transit. The author estimates the cost, benefits, and policy issues, such as security and privacy in the implementation.

RFID News. <<http://www.rfidnews.org/library/2002/12/01/a-tube-full-of-oysters-london-goes-contactless>> 12 Nov 2006.

A site briefly talks about the Oyster card technology and the number of users bought the cards.

Rankl, Wolfgang and Effing, Wolfgang. Smart Card Handbook. The Netherlands: John Wiley & Sons, Ltd, 3rd ed. 2001. (Translated by Kenneth Cox)

This book includes a thorough discussion of smart card technology and its applications. It compares the advantages and disadvantages of smart cards vis-à-vis other technologies, and includes information on standards.

Scullion, Aaron. "Smart cards track commuters." BBC News. 25 September 2003. Available at <<http://news.bbc.co.uk/2/hi/technology/3121652.stm>> 15 Nov 2006.

This article on the BBC News addresses privacy issues relating to London's smart card. Civil rights group showed concerns about the new Oyster system would track commuters' movement and violate personal privacy. The article provides a brief overview of the system, benefit of collecting traveling pattern for journey planning purpose, and warns about "function creep." (Unlawful use of personal data harmful to citizens)

Smart Card Alliance, Inc "Hong Kong Octopus Card." Available at <http://www.smartcardalliance.org/pdf/about_alliance/user_profiles/Hong_Kong_Octopus_Card.pdf> 1 Nov 2006.

A document provides statistics on HK Octopus card usage. We obtained penetration, annual sale figure and volume of the card, and other basic features of Octopus from this site.

Sony Corporation. Available at <http://www.sony.net/Products/felica/abt/index.html>. 12 Nov 2006.

This website explains this contactless IC card technology and provides the Sony FeliCa product and system information. It also provides instances where FeliCa is currently in use, such as the Octopus card in Hong Kong, the ez-Link card in Singapore, and the Suica in Japan.

The Straits Times (Singapore). "Bus service better but there's room to improve: poll; Long waiting times and journeys, overcrowding top list of complaints" November 2, 2006

This news article published in Singapore's leading newspaper, The Straits Times, presents results from an annual survey of customer satisfaction on bus service. The survey was conducted by the Public Transport Council (PTC).

Thomas, Monifa. The Chicago Sun-Times "No-fee Chicago Cards extended to May 31" NEWS; Pg. 14. March 31, 2006

This short news article announced the extension of the Chicago Transit Authority's fee <http://www.ezlink.com.sg/ezlinkCardTypes.htm#P> waiver on electronic fare cards.

Transit Cooperative Research Program. "TCRP Report 32- Multipurpose Transit Payment Media" National Research Council Transportation Research Board. National Academy Press: Washington DC 1998. Available at

<http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_32.pdf> 28 Oct 2006

This report examines the potential for introducing multipurpose payment smart cards that can be used to purchase transit services from multiple operators, and, potentially, other goods and services (e.g., parking and retail products). This report examines smart card technology, legal and institutional issues associated with introducing multipurpose card programs, cost and revenue impacts, and customer attitudes. On the basis of experiences around the world, guidelines are provided for development of multipurpose fare payment programs." It has been written in such a way to interest transit managers, transit operations personnel involved with fare collection, parking professionals, and the financial services community.

The Transit Cooperative Research Program (TCRP) is run by the Transportation Research Board, part of the United States National Research Council. The TCRP brings industry leaders together to develop innovative near-term solutions.

TransitLink. "Fare Evasion Affects Public Transport Commuters" - 17 October 2005

Singapore. Available at <http://www.transitlink.com.sg/news_171005.html> 16 Nov 2006

This short news article estimates the daily cases of fare evasion on Singapore busses. It describes various ways in which commuters evade fares, some, but not all, of which involve the use of smart cards.

TransitLink is a service company set up by SBS Transit Ltd, SMRT Trains Ltd and SMRT Buses Ltd to provide an integrated public transport system by bringing the MRT, LRT and buses together as one single, comprehensive network.

TransitLink is also EZ-Link's partner in managing existing and new public transport operators to accept the ez-link card as a means of payment for bus and train fares. TransitLink is the master load agent of EZ-Link to manage all top up channels within the transport environment.

Transport for London. Transport for London Website. Available at

<<http://www.tfl.gov.uk/tfl/Default.asp>> 1 Nov 2006.

Official site for London's public transportation. It has detailed information on Oyster card to help commuters navigate the underground smoothly, including fare policy updates. It also provides pictures of the card and card readers.

Washington Metropolitan Area Transit Authority. "WMATA SmarTrip". Available at

<<http://www.wmata.com/riding/smartrip.cfm>> 17 Nov 2006.

This website is a official website of WMATA. This website provides users with necessary information of SmarTrip such as how to use the SmarTrip. This also contains the latest news.

Wikipedia, Hong Kong. Available at <http://en.wikipedia.org/wiki/Hong_Kong> 3 Nov 2006.

This site has a useful background section on Hong Kong's transportation system. Information includes the city's major transport modes, government transit agencies, Octopus card, bus service, and access to the airport.

Wikipedia, Octopus Card. Available at <http://en.wikipedia.org/wiki/Octopus_card> 12 Nov 2006.

This website provides a general overview of the Octopus Card system in Hong Kong, including its usage, history, backend technology, comparison with other similar systems, and future developments. Readers can also find pictures of the card, card readers, and fare structure.

Wikipedia, SmarTrip. Available at <<http://en.wikipedia.org/wiki/SmarTrip>> 17 Nov 2006.

This website describes general information, background, history, etc. about SmarTrip. This also contains some pictures and useful external links.

The World Bank Group. "Hong Kong Smart Card System," Available at <<http://lnweb18.worldbank.org/External/lac/lac.nsf/Sectors/Transport/D5A576A039A802C0852568B2007988AD?OpenDocument>> 3 Nov 2006.

This site provides detailed background on Octopus. Information includes partnerships, range of automated fare collection equipment, and service and fare.
