WHITE PAPER

A Comparison of Smart Tokens and Smart Cards for Limited Use Ticketing and Automatic Fare Collection in Mass Transit

PART I

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BACKGROUND

INTRODUCTION
China Elite Technology Co. Ltd. (CET), a major supplier of smart card products to the transportation industry, has conducted extensive research and development in limited-use smart cards. As a result of research conducted between 2003 and 2005 with partners and clients, CET developed Limited-Use (LU) smart tokens. CET's smart tokens have gained widespread acceptance in China and are currently expanding in Asia and Russia.

This white paper compares the smart token and thin card ticket formats for limited (usually single) use in mass transit. Part I examines smart token and thin card limited-use ticket formats in automatic fare collection (AFC), and explores their impact on transit operators and riders. Part II of the white paper, which will be released later in 2006, discusses how the manufacturing processes varies between the two LU formats, and can impact physical and electronic performance. It will also examine in detail how the bonding techniques for the IC-antenna joint and encapsulation materials affect ticket lifespan and environmental resistance.

TECHNOLOGY SUMMARY

Public transportation systems around the world are gradually shifting to stored-value smart cards for transportation. These smart cards utilize IC chips to store and process information, and radio frequency identification technology (RFID) to communicate with the readers, making them contactless. For the purpose of this paper, the term ‘smart card’ will refer to contactless smart cards, not contact IC cards.

Smart cards minimize cash handling costs and fraud, reduce ticket vending machine downtime, and provide more comprehensive ridership data – benefits for transit operators and riders alike. In a recent white paper, the America Public Transportation Association says that balance protection, quick transaction times and lower operating costs are reasons that smart cards are growing in popularity.

The “Octopus Card” network in Hong Kong is a successful case for the widespread adoption of smart cards, offering not only multi-modal mass transit ticketing functions, but also electronic purse functions at stores such as 7-Eleven and Starbucks, loyalty programs with local retailers, and access control functions for buildings and carparks.

All smart cards are have a RF electronic inlet, which is composed of an IC chip connected to an antenna, embedded into the card. They draw energy to operate from the RF signal emitted from a smart card reader. Once a communication channel has been established between the reader and card, data can be read from or written to the card. The most popular standard used in public transportation is ISO14443, however other standards co-exist and there are often minor variations within a standard between transit systems.

LIMITED USE SMART CARDS

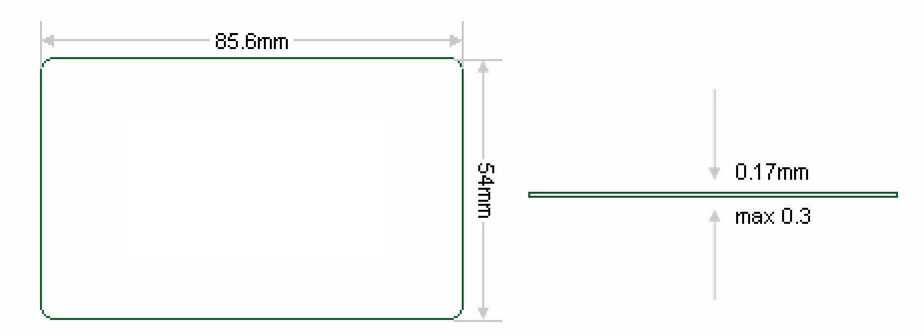
Limited-Use (LU) tickets, such as single journey, day or week passes are usually issued on a different type of media from stored value smart cards. The low face value of a LU ticket has prevented transit operators from using full featured smart cards; instead, many still use magnetic cards. However, in the interest of bring down maintenance costs and streamlining operations, many transit operators are phasing out this dual-media solution in favor of smart card only transit systems.

Many transit operators and transportation groups believe that the adoption of smart cards for LU ticketing will yield positive returns in the long run. Yet the selection of the LU ticket is very cost sensitive, and full featured smart cards are too expensive. So two alternatives have emerged for LU tickets: smart tokens and thin cards.

SMART TOKENS AND THIN CARDS

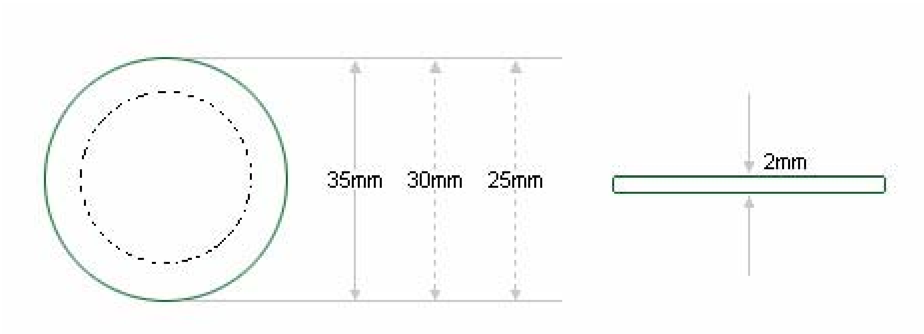
Smart LU tickets are similar to full featured smart cards; they also contain an IC and antenna. However the IC is usually specifically designed for limited use and cost significantly less. These ICs contain less memory and processing power.

Thin cards are the same size as a stored-value smart cards, but they are thinner because they are made of paper or plastic films such as PET or PVC. The inlets used for thin cards can be very similar to those in full function smart cards.



Dimensions:	86mm x 54mm
Thickness:	0.04mm(Paper), 0.6mm(PVC)
Materials:	Paper or PVC
Operating Temperature:	-10°C to +50°C

Smart tokens are shaped like coins. The inlets in a smart token are very different from those used in full-function smart cards and thin cards. The antenna is formed and connected to the IC using a manufacturing process derived from printed electronics, and is different from that of smart cards and thin cards. They are injection molded into hard plastics such as ABS so they share the physical characteristics of plastic chips.



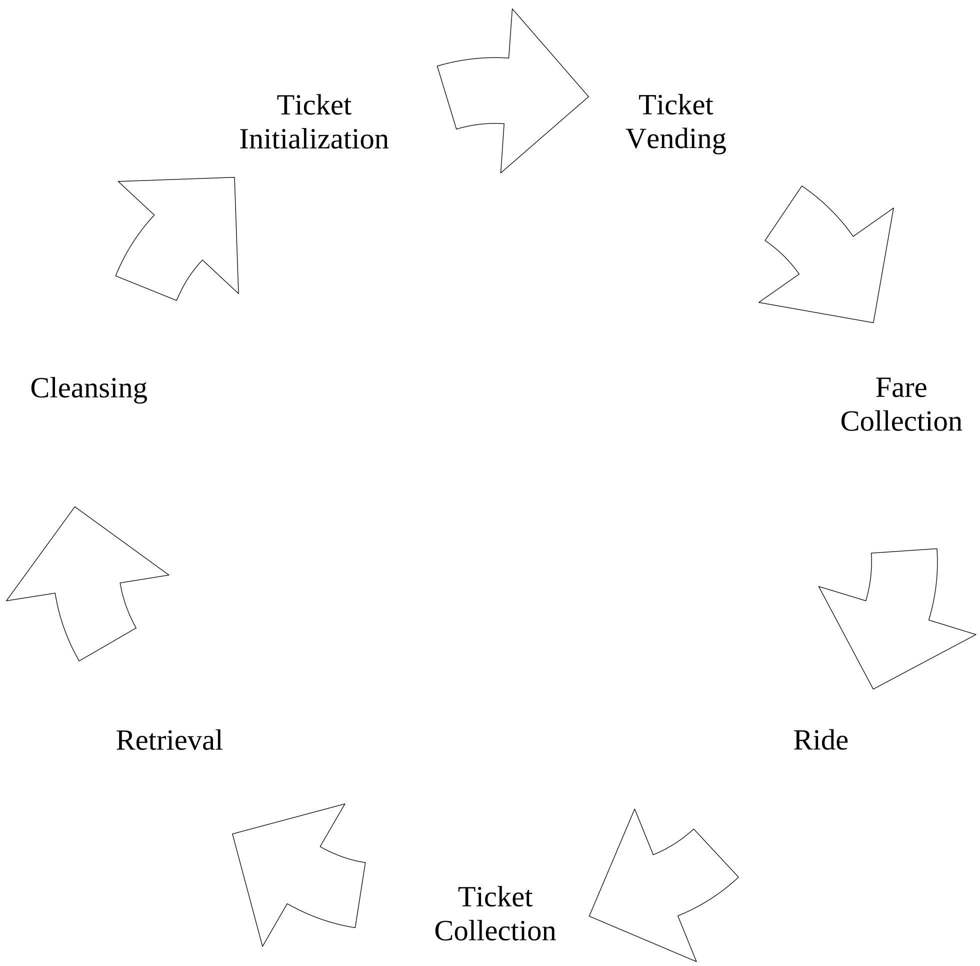
Dimensions:	Diameter: 25mm or 30mm or 35mm
Thickness:	2mm(ABS), 1mm(PVC)
Materials:	ABS or PVC
Operating Temperature:	-10°C to +50°C
Max Temperature and Relative Humidity:	+130°C and 100%RH

FINDINGS

As Chinese cities have developed in the last 20 years, many built underground subway systems as a major means of public transport. The single journey ticket has played a large role in facilitating travel for riders as they required time and experience before adopting stored value tickets. Therefore, it is important to understand the life of an LU ticket.

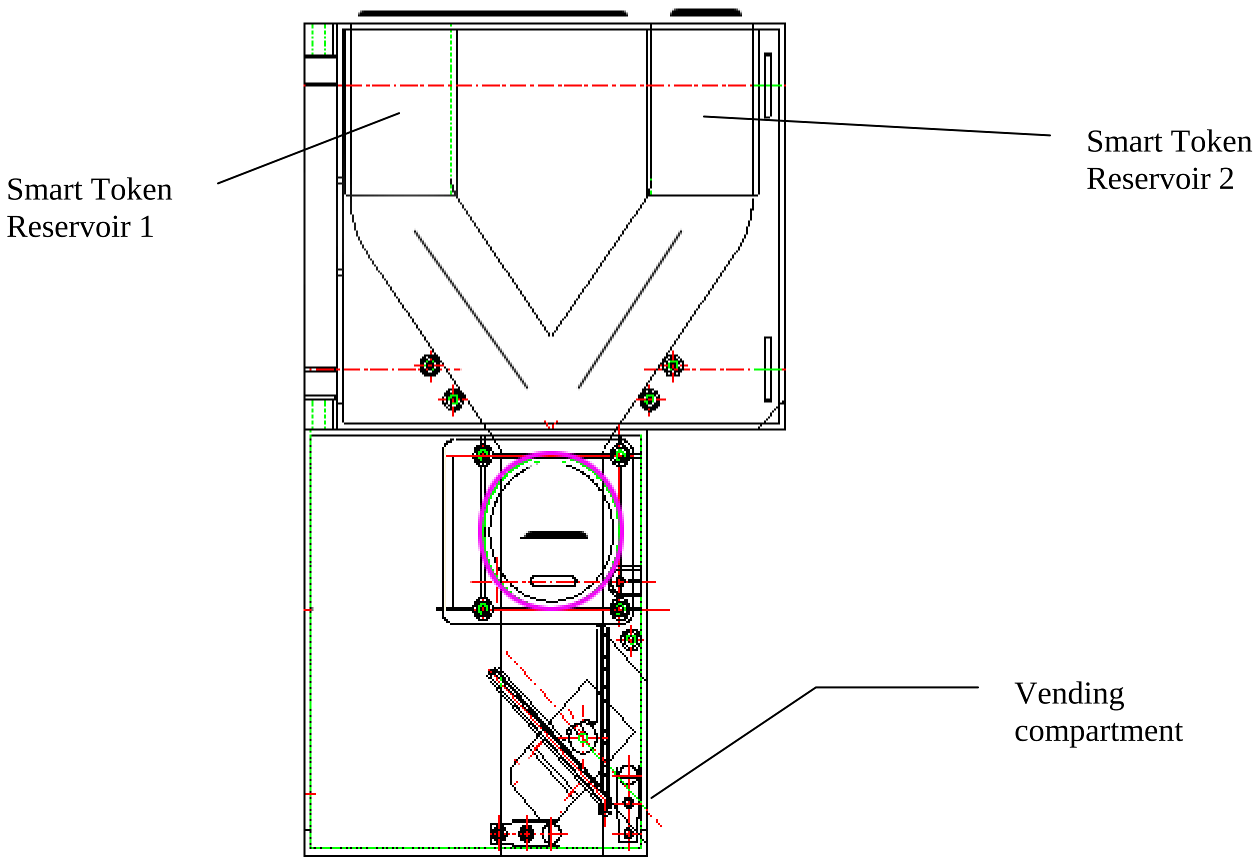
TICKET INITIALIZATION AND RECYCLING SYSTEMS

The lifecycle of a LU ticket is represented in the following flow chart.



The testing simulated the lifecycle of a smart token using standard initialization and recycling equipment from a transit operator. The tests involved ticket initialization, ticket vending, and ticket collection, repeated until the smart token reached failure.

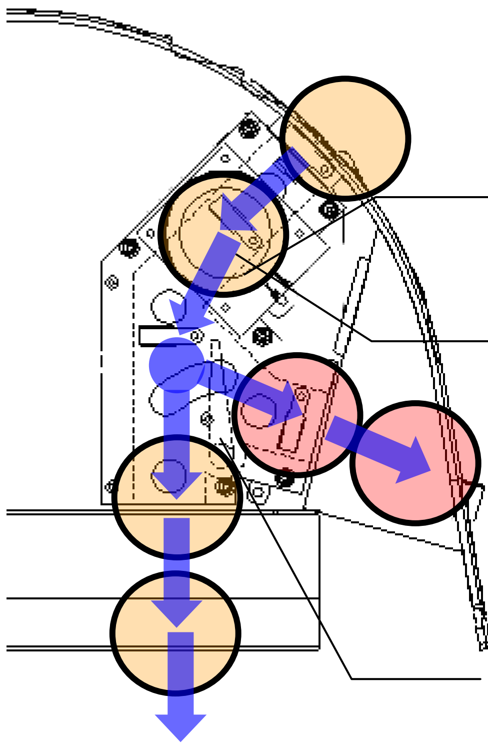
The smart token vending machine is made up of a series of compartments, which are fed tokens from reservoirs on the top. The tokens' round shape and weight carry them down the chutes, through each of these compartments. After they are initialized, they are dispensed to the rider.



There are very few moving parts inside the smart token vending machine. Instead, the machine relies primarily on gravity move the tokens through the machine. The machine must be top-loaded and vertically oriented, but this generally does not pose a problem for machines installed in station walls where there is ample room.

Perhaps the most important factor to selecting a LU ticketing system is hov with in the automatic fare collection (AFC) system. AFC systems typically access control gates which collect the fare, validate the tickets, and grant or restrict passage through the barriers. The AFC system has a tremendous impact on riders' perceptions of the user-friendliness of the entire transit operation.

The smart token collection machine is built into the access control gate. When the smart token is deposited into the collection slot, it triggers a series of sensors which activate a reader. The reader validates the token against prescribed criteria and credentials before releasing the shutter to drop the token. If the token is invalid, a sorting lever directs the token back out. If the token is valid, then it drops into a retrieval compartment for recollection, and the barriers are raised to allow the rider to pass through. .



Once again, this system involves a minimal number of moving parts because the smart token collection machine also relies on gravity to carry the token. Ordinary coins inadvertently dropped into the slot will be returned to the user. If chewing gum or fluid is put into the slot, there are no motorized parts that will get jammed above the shutter -- and the machine can be opened and cleaned.

For comparison, a Chinese transit operator provided test data on a thin card system. Thin cards are issued using standard ticket issuing machines (TIM) that are commonly used to dispense magnetic tickets.

Most commonly, TIMs store the thin cards in two magazines, and use motorized transport mechanisms to move the cards in and out of the machines. Different machines vary in complexity, but all rely on a transport module to process cards. The thin card collection machines use a similar transport module. (Although other mechanisms exist, they are not commonly used in subway systems.)

Transport modules are vulnerable to the problems associated with all motorized systems, and require relatively extensive maintenance. Also. TIMs generally hold fewer thin cards than a smart token vending machine, requiring staff to make more frequent ticket retrievals.

In addition to lower AFC maintenance costs, the mechanics of smart token systems also help the tickets live longer. Tokens rely mainly on their own weight to fall into the ticket boxes, so there is very little attrition or pressure. Thin cards rely on friction from a mechanism for transport. In the course of the AFC profess dispensing and collecting the thin cards, they will be more quickly damaged beyond repair -- shortening their mean time to failure.

PASSENGER THROUGHPUT

The speed with which passengers can pass through the AFC system is critical. Areas with a high concentration of passengers must disperse them them quickly.

The biggest impact that a LU ticket has on passenger throughput rates is how much time the access control gate must spend processing the ticket at both entry and exit of the station. The speed depends on how quickly the content of the ticket can be read – giving RF contactless card technology a major advantage over other systems such as magntic tickets

To enter, riders tap either thin cards or smart tokens on a reader located on top of the access control gate. The RF data exchange rate for fare collection is similar for tokens and thin cards, although thin cards are slightly faster. Riders are not likely to notice a difference.

However, the process of collecting the LU ticket as a passenger exits reveals a significant performance advantage for smart tokens. Thin cards are collected through a sequence of motorized conveyor belts, during which the card reader must recognize and confirm the data on the card before instructing the gate to raise the barriers.

Smart tokens do not have a motorized transport module – they rely on gravity to complete their passage through the collection machine, which speeds up the process. The reader completes the data verification during the token’s decent into a collection bucket, after which the gates raises the barriers, or returns the token.

Thus, the smart token collection process has one less step than the thin card process – making smart token collection quicker.

LOST TICKETS AND FARE EVASION

Several subway operators have reported that up to 10% of single journey tickets get lost. In China, the majority of lost tickets were related to fare evasion, and a small percentage was due to non-riding patrons purchasing the tickets as souvenirs.

Incidences of lost tickets due to fare evasion occurs equally with both smart tokens and thin cards. Riders enter the transit system using the LU ticket, but do not return the ticket upon exit. Fare evading riders who do not pay for a LU ticket at all, do not contribute to ticket loss.

The ease with which a rider can exit without returning their ticket is dependant on the sensitivity and reflex speed of the access control gates. Access control gates are designed to comply with safety requirements such as opening to allow unobstructed passage in event of an emergency, and automatic back-off in event of obstruction. Sensors in the barriers detect when there is an obstruction, and automatically raise the barriers to allow passage. Transit operators also often set the access control gates to their softest close force, and reflex speed to a minimum, in order to minimizing queues the during rush hours.

These considerations protect riders, but also enable come riders with a way to escape paying for their trip. Whether intentionally or not, some riders are able to slip through behind another paying passenger when the gate is slow. Some riders intentionally raise their knees as the barrier is descending to obstruct the barrier, and trigger the automatic back-off reaction. Riders have been observed forcing their way through closing gates because they know the soft close force will not injure them.

The competing needs of maximizing rider throughput and minimizing fare evasion are hard to balance. The onus of this challenge is on the access control gate manufacturers to design systems to handle very high throughput while ensuring passenger safety.

ADVERTISING

Transit tickets serve a critical role in the relationship between the transit operator and its riders. Stored value smart cards generate immediate loyalty to modes of transportation that accept the card, and advertising on the tickets bring in revenue for the transit operator, as well as providing marketers with a highly targeted advertising media that travels with the rider.

Typical a LU ticket will have one side available for printing advertising, and the other side is reserved for the transit operator’s branding. Currently the advertising has be limited to printed images, however in the future near field communications (NFC) equipped devices such as mobile phones may enable marketers to explore even more interactive modes of advertising.

Thin cards provide a larger surface area for printing than smart tokens, and allow for high quality color screen printing. Established pre-printing techniques for PVC cards can be employed to produce printed thin cards in large volumes at a reasonable cost. However, thin cards can only be printed once as there is no safe way to remove the image without damaging the card.

Smart tokens have a smaller surface area for advertising, and sometimes the transit operator may choose to emboss both sides with their insignia which would preclude screen printing. However, embossing is more durable than printing and allows for recognition by touch, which can be used to enable identification for the blind and visually impaired.

The screen printing process on ABS usually limits the number of colors available as the circular shape of the token makes it hard to ensure the accuracy of the positioning. However, printed images on smart tokens can be removed using chemical solvents, and new advertising can be reprinted onto them.

This factor is important for transit operators that need to maximize the advertising efficiency of their tickets. Re-printability permit smart token space to be sold on a schedule, like traditional advertising media such as billboards, because their images can be removed after the paid run is over.

In summary, thin card provide a very competitive product for advertising and allow transit operators to charge more per advertisement than smart tokens, but smart tokens can be reprinted, delivering a higher return over its useful lifetime.

PUBLIC HEALTH CONSIDERATIONS

The importance of a transit operator's ability to disinfect their LU tickets was brought into sharp relief when Severe Acute Respiratory Syndrome (SARS) appeared in China in 2003. Millions of LU tickets were in daily circulation and potentially exposed riders to indirect contact with other LU ticket users. Though there has never been a documented case of SARS transmission via LU tickets, the hygiene of the tickets became a public health issue.

Transportation authorities across the country had to consider how to effectively clean their LU tickets. At the time, the Guangzhou Metro had already implemented smart tokens for single journey ticketing. As the smart tokens are injection molded into ABS, the Guangzhou Metro was able to take advantage of the smart tokens' ability to withstand full immersion and agitation in a chemical cleaning solution. The large scale cleansing of LU smart tokens removed any harmful biological organisms from the smart tokens and helped to assure the riders.

Through this episode it became evident that the special attention needed to be paid to how the various LU tickets measured up in terms of disinfection.

While smart tokens can be washed in batches, thin cards had the problem that the paper medium could not be cleansed with liquids, though the PVC medium could. Various technologies such as UV disinfection are available to cleanse paper thin cards, but they would have to be cleansed sequentially. Thus the cleansing process would take longer and require more complex staging areas and equipment. Furthermore, UV can only provide surface disinfection, washing is better at removing dirt and grease on the tickets which could contain biological organisms.

PVC thin cards are better suited for washing, as long as the solvents do not attack the antenna or the IC joints. However this raises the problem of tickets sticking together when wet. The embossing and smaller surface area of smart tokens minimized this effect. However thin cards have a relatively large surface area and are very light, giving them the tendency to stick together. This makes it difficult to singulate each thin card, causing problems with the reliability of the disinfection and drying processes.

Recent public health threats such as avian flu have kept the hygiene of LU tickets a high priority, and in this regard smart tokens are superior to thin cards. In addition, washing can degrade or damage thin cards, but have little effect on smart tokens.

CONCLUSION

Though some of the tests would benefit from further investigation, the comparison of the performance characteristics of smart tokens and thin cards reveals the following results:

Smart tokens facilitate higher throughput through automatic fare collection systems than thin cards. The greater stability of the smart token leads to a greater number of uses than thin cards. Thin cards provide better advertising space than smart tokens, but re-printing smart tokens may be explored to boost advertising revenue. Smart tokens can be more readily disinfected than thin cards to address public health concerns.

Smart tokens have a number of significant advantages over thin cards. Part II of this white paper, which will be released later in 2006, show that the manufacturing processes of smart tokens give them a tenfold greater number of uses over thin cards, leading to an annualized operating cost that is one third that of thin cards.

Global transportation groups may need to pay particular attention to smart tokens in drawing up new guidelines for limited-use ticketing, and further develop this option for the high volume markets that would benefit most from this technology.

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