IC CARDS

# The Evolution of e-payments in Public Transport—Singapore's Experience

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## Background

Singapore's commuters pay an average fare of S$0.81 (S$1 = US$0.74), but more importantly, the lowest 10% of income earners—earning less than S$700 a month—spend less than 8% of their income on commuting, which compares favourably with fares in both developing and developed countries. However, although Singapore's public transport system (PTS) is not government subsidized and is operated by for-profit public companies, the government bears the development cost of Singapore's transit systems. The operators have no rights or land concessions near stations but the government Land Transport Authority (LTA) works with the operators to improve the PTS efficiency and service level with fare collection as a key area.

The introduction of contactless smartcards (CSC) for fare payments in April 2002 was a major public-transport initiative for Singapore and the number of cards now in circulation has grown exponentially in the last 5 years to reach about 8 million. The use of CSC in fare collection has not only proven cost effective, but has also increased the reliability, security and convenience for consumers. For example, the life-cycle cost, including capital, operation, and maintenance, has been reduced to less than 5% by extensive use of e-payments and by removing all ticket capturing mechanisms of mechanical gates, and the resultant 7% saving for stored-value cards has been passed on to commuters.

## Business Model

Because the Singapore PTS has an integrated fare structure, the business and technical model was designed to meet the following eight objectives:

- Use a shared stored-value ticket allowing different rates for different services and modes. Bus fares on trunk and express services are distance related (based on the number of fare stages), while town and feeder services complementing trunk services have flat-rate fares. Rail fares are also distance based but differ between operators.
- Give transfer rebates between services and modes so network rationalization does not penalize commuters travelling in the same direction within one journey. For example, if bus routes are changed or removed because of a new subway, the transfer rebate ensures the commuter pays the same between any two points in the zone affected despite the changes.
- Use a post-payment fare system with fair adjustment after completing the journey if the card credit at the journey end is insufficient.
- Offer concession and season tickets for special groups, such as students, senior citizens, and military personnel, incorporating season-ticket functions into the same stored-value card for convenience and cost reduction.
- Provide full security by ensuring all CSC are recorded and tracked by a backend system so all transactions are fully accounted and fraudulent use is easily detected. Disable stolen or lost cards within 24 hours so a commuter's card investment is fully assured.
- Allow cash payment of fares but at higher rates, stimulating a drop in single fares from 10% to 4% of total trips, the lowest in the world. The successful switch to smart cards decreases cash transactions, lowering the high cost of handling cash (3% in Singapore) and minimizing the traditionally disproportionate impact on tickets costs.
- Allow commuters to transfer between networks without exiting to buy separate tickets.
- Settle accounts for collected fares between operators based on agreed algorithms within 24 hours.

## Improved Efficiency

Use of CSC systems greatly improves the PTS overall speed and efficiency. For example, commuters using CSC do not need to know the exact fare in advance. They just present a CSC at entrance and exit and the system calculates the fare using the service number, direction, boarding and exit fare stages on buses, or entry and exit rail stations on trains, to deduct payment from the card.

The buses use an odometer-based system backed-up by GPS to update fare stages and make deductions. Generally, the system is reliable but the technical limits of GPS-based systems such as accuracy, road diversions, etc., must be resolved by operational procedures.

This arrangement simplifies fare payment, especially for children, tourists, etc., as shown by the low number of card retries (0.24%) at bus and rail gates. It also enhances safety for bus passengers and pedestrians because one-man bus drivers can concentrate on driving, instead of issuing and checking tickets. Another major benefit has been a significant reduction in fare evasion for bus operators who have recovered the capital cost in less than 18 months. The conventional and tedious manual counting of commuters by surveys has given way to automatic extraction of data from the backend system, eliminating the need for additional manpower to collect data.

## Extensive Card Top-Up Facilities

The availability of top-up points has been a key factor in the success of CSC; self-service top-up machines using either cash or bank card are provided at numerous locations in stations and card dispensers throughout the network are online 18 hours a day. The card dispensers support card sales, top-up, processing of problem cards, and card refunds. Auto top-up is also supported by direct debit from bank account or credit card. A unique feature is the ability to link the CSC to the holder's bank account electronically and instantaneously, eliminating the lengthy manual application process.

A trial using mobile phones to top-up cards had some limited success.

## Enhanced Data Mining for Strategic Planning

The ability to capture system transactions offers the LTA a comprehensive database for strategic planning, route planning and target setting to improve public transport services. For example, the LTA can track journey times on public transport by monitoring the percentage of journeys completed in less than 45 minutes, which is a key performance indicator. A separate data warehouse has been developed to make best use of data extracted from the system and is well utilized by LTA planning and regulatory departments, to plan new subways, new bus routes, etc.

## Non-transit Applications

Various non-transit applications have been developed and implemented, including student ID cards, resource booking and school attendance tracking, office access management, hotel room access, corporate ID, and cashless payment (fast food and school canteens, cinema tickets, library fines).

## Current Disadvantages

Despite the phenomenal growth of smart cards for revenue collection, most systems—including those in Singapore—are proprietary and lack adherence to standards. In Singapore, the problems are compounded by separate contact and contactless stored-value card systems. Consequently, lack of competition keeps transaction costs high. Also, with a dedicated payment system, transport providers bear the high cost of installing and supporting the value-added infrastructure. To reduce transaction costs in the future, transport providers need to leverage payment schemes/systems deployed by the banking sector. There is also growing concern about the security of first-generation contactless cards that needs addressing.

## Common Payment Framework

There are significant benefits in bringing the transport and banking sectors together to operate within a common payment scheme where banks can co-brand cards. To this end, a taskforce was formed in 2004 to develop a national standard for a common micropayment scheme. It is composed of card and terminal suppliers, card issuers and service providers, and relevant regulatory bodies. The aim has been to establish the foundation for a multi-application smartcard framework bringing together multiple payment applications on a single card and providing greater synergy between applications with less duplication of effort and infrastructure.

## CEPAS Security

To fulfil the above objectives, the Contactless e-Purse Application Specification (CEPAS) was released in late 2006 as the National e-Purse Standard. In addition to other applications, it incorporates banking e-purse, transit and electronic road pricing requirements.

To meet banking security requirements and allow versatility in key management, the CEPAS e-Purse establishes two cryptographic channels for every transaction compared to one cryptographic channel implemented by most e-payment schemes. The two cryptographic channels are composed of an authentication channel and a non-repudiation channel each using a different key on the card. The authentication channel uses a debit key and is used by the merchant to verify that the card is valid for payment; the non-repudiation channel uses a signature key for signing transactions and is used by the card issuer to verify that the card signature accompanying the transaction is authentic and determines that the transaction is 'good-for-settlement'. A transaction can be verified by the sender and recipient—in this case, the card generates a signature based on the issuer key that can only be recognized by the card issuer.

By using two different keys in two different key files for two different purposes, the liabilities of both parties involved in the

**Figure 1 Different Designs of Ez-Card**


transaction are separated and can be managed separately. This framework permits multiple entities participating in a common e-payment scheme to create their own keys on a card that will be used to protect their own liabilities without affecting the liabilities of other parties.

## CEPAS Features

However, addressing the security needs of an e-Purse alone is insufficient. To increase the e-Purse uptake and usability, several unique features must be incorporated to provide the reliability and performance required for deployment in multiple applications. The required features and attributes built-in to CEPAS include:

- Fast transaction speed (<140 ms)
- Atomicity (no corrupted or partial updates to card in contactless usage)
- AutoLoad
  This automatic credit-while-you-debit facility increases the e-Purse balance by a specified amount when the debit amount is greater than the balance.
- Partial refunds (allows partial refund of the last debit)
  If the previous transaction is a debit, the next debit transaction can refund up to the amount debited.
- Cumulative debits
  A single transaction log is created for consecutive debits within a single card session with the same transaction type, date, time, and user data to perform an integrated debit and credit. The aim is to accumulate several debit operations into a single transaction to minimize transaction processing overhead.
- Multiple applications
  Segmentation of directories accessed by distinct keys allows for multiple applications to reside on one card.

## Interoperability

Interoperability was a key consideration when designing CEPAS—it has to be easily adaptable to various environments and hardware platforms. Consequently, the focus was the logical structure of CEPAS rather than the physical nature. This resulted in development of CEPAS as a set of ISO 7816 commands using an ISO 7816 file structure. Consequently, CEPAS can be deployed over both contact (ISO 7816) and contactless interfaces (ISO 14443 and ISO 18092) as well as a GSM SIM application in NFC-enabled phones. This powerful deployment permits direct top-up to the e-Purse from a bank account, while the ISO 7816 command set and file structure also allows CEPAS to coexist with EMV and contactless credit-card applications on one card.

It makes sense to leverage the credit-card infrastructure whenever possible, because the banking sector is the most pervasive issuer of credit cards, which are the commonest payment mechanism in the world. Creating a micropayment e-Purse (like CEPAS) on a contactless (or combi) credit card is a logical extension of the credit-card infrastructure to bring micropayments within the banking sector.

The credit-card industry also has a well-established business model for managing liabilities and risk on a fairly large scale. Incorporating micropayments within the credit-card domain via an e-Purse like CEPAS offers micropayment applications with a common framework while utilizing the risk model established by credit-card providers.

## Card Development Challenges

Since 2005, LTA engineers have been working closely with card vendors to ensure the CEPAS system is implemented according to specifications and that performance requirements are met. Developing a suitable CEPAS card to serve both public transport needs, as well as in-vehicle applications, such as electronic toll collection, has been challenging due to need for very high transaction speeds at toll points coupled with backwards compatibility with current card readers in the Singapore LTA and new in-vehicle units. More than 2000 test scenarios (automated scripts) were conducted at both vendor and LTA test laboratories. Extensive load and stress tests were conducted to ensure there are no blind spots within the reader detection field (typically not less than 8 cm). Temperature-chamber, burn-in tests ensured cards can withstand temperatures up to 85°C during operation. To rigorously evaluate the performance and reliability of the system, 0.5 million transactions were carried out in MRT stations and buses and 1.3 million transactions were simulated in vehicles. The entire development effort took 2.5 years.

## CEPAS for LTA

Backend processing and security systems have been developed to support CEPAS for the Singapore LTA. At the same time, new business rules and operational procedures have been established for handling cards from different card issuers. Briefly, we have built a new clearing house to process new smart cards that will meet our national standards. So any approved institution, such as a bank or credit card company, can issue these cards and up to four issuers can be accepted by the clearing house. Consequently, we have implemented new business rules to accommodate multiple issuers. However, we can only convert to the new cards progressively and there is a 12-month overlap period where both old and new cards can be used.

During this period, we must maintain two systems with significantly higher costs than a single system and more complexity. In electronic road pricing for cars, the systems will run in parallel for at least 3 years, because it will take much longer to withdraw the older cards and convert in-vehicle units to new units.

## Symphony Backend for e-Payment

Symphony for ePayment (SeP) is the backend processing and clearing system developed for the PTS and non-transit micropayments to support CEPAS. The SeP performance must clear 20 million transactions per day, and process 500 online transactions per second with an online enquiry response time of less than 0.3 s. It is designed to provide next-day revenue allocation and settlement reports and significantly reduce the technical barrier to new entrants for PTS ticketing.

## Conclusion

The CEPAS focus has been on developing an e-Purse specification meeting diverse requirements, such as transaction speed, reliability, security, etc., with integration into a contactless or combi-credit-card. It has been designed to evolve with future technology, so enhancements can be added to encompass more applications when required.

The next cut in the cost of fare revenue collection in Singapore is likely to come from acceptance of multi-application cards from multiple issuers, which is made possible by CEPAS. It is now up to service providers and card managers to adopt the new technology and business models to benefit from this development. Today, there are about US$20 billion in cash transactions each year, offering huge potential benefits for early adopters.

### Further Reading

CEPAS a.k.a. SS518

Gazetted and published by SPRING Singapore.
Describes the technical requirements for an e-Purse card that can be used by different issuers and merchants.
Provides the command sets and data bytes that can be used for contactless e-Purse applications and focuses on the debit and credit areas.
Developed by the Cards and Personal Identification Technical Committee of the IT Standards Committee comprising vendors, regulators and card issuers.

CEPAS References

SS 468 : 1999
Specification for stored value card application

ISO/IEC 7816-3 : 1997
Identification Cards—Electronic signals and transmission

ISO/IEC 7816-4 : 2005
Identification Cards—Organisation, security and commands for interchange

ISO/IEC 7816-9 : 2004
Identification Cards—Commands for card management

ISO/IEC 14443-3: 2001
Identification Cards—Contactless integrated circuit cards—Proximity Cards—Initialisation and anti-collision

**Silvester Prakasam**

Mr Silvester Prakasam is now leading a team to replace the current system with a new open system which will merge the payment infrastructure for Public Transport and congestion pricing. For this purpose CEPAS was developed. The total current card base of 15 million memory cards will be progressively replaced by Type B microprocessor cards. In 1994, he spearheaded trials on the Contactless Smart Card and launched the Enhanced Integrated Fare System project for the public transport system in 1998. He was the Project Director for this project which implemented a common smart card system across the public transport network at a total cost of US$200m in 2002. To date, 10 million cards have been issued. He has degrees in Science (Statistics) and Engineering (Electrical). He was with the Singapore Airlines for 10 years before joining the Mass Rapid Transit Corporation in 1983. There, he was involved in the building of the first rapid transit system for Singapore.