Improving public transport ticketing through smart cards

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Improving public transport ticketing through smart cards

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The use of an electronic smart card as an alternative means for users to access and pay for transport services is now emerging as a viable option for many operators. With the recent introduction of the Oyster smart card by Transport for London and the plans by a number of passenger transport executives and transport operators to launch smart-card ticketing, the UK is on the verge of an influx of transport and local authority-led smart-card schemes. Interoperability between schemes is being tackled by ITSO (the Integrated Transport Smart-card Organisation) which will deliver a final version of a national specification for transport smart cards in early 2004. This paper examines what smart cards are, why smart cards are now being widely adopted, and finally will consider their benefits and impact on the public transport industry.

1. INTRODUCTION

Smart-card technology is by no means new; it was invented more than 30 years ago and implementations have been made with smart cards for almost two decades. However, in the transport sector many of the early pioneering trials of smart-card ticketing were based upon a technology push rather than a market pull, which created a number of spectacular (and costly) failures[1] which largely discouraged the UK transport industry from investing in the technology throughout most of the 1990s. Notwithstanding this, by the late 1990s there was a gradual realisation in the UK transport industry that there may well be some real benefits for public transport in exploring the adoption of smart-card ticketing, following the success of large-scale electronic ticketing schemes in Asia, leading examples being Hong Kong and Seoul, Korea. Small-scale demonstrator schemes also emerged in the UK with varying degrees of success; however, what they did achieve was to foster dialogue and awareness within the transport industry of smart cards and their capabilities.

This also led to a realisation that potentially there could be a lot of uncoordinated and non-interoperable electronic ticketing schemes across the UK—which in a stroke would inhibit one of the key benefits of a smart card, namely the ability of the card to hold contracts and tickets with a number of different operators to facilitate, if desired, seamless ticketing between public transport operators and/or between different operating regions of the UK. The then DETR White Paper *A New Deal for Transport*, published in July 1998,[2] explicitly mentioned smart cards as the future of high-quality 'integrated ticketing' in the UK and directly led to the formation in 1999 of ITSO (the Integrated Transport Smart-card Organisation) to address the integration and interoperability issue between operators. Before examining the above issues in more detail it is worth tackling the fundamentals as to what is a smart card and what are the key technological issues associated with the cards and systems.

2. WHAT IS A SMART CARD?

A smart card is essentially a credit-card-sized piece of plastic which has a microchip embedded in it. This chip is the 'smartness' of the smart card, and performs all the functions required by the card (storing data, processing data, writing data, etc.). Smart-card chips come in two broad varieties: memory-only chips, with storage space for data, and with a reasonable level of built-in security; and microprocessor chips which, in addition to memory, employ a processor controlled by a card operating system (similar to any PC), with the ability to process data onboard, as well as carrying small programs capable of local execution. The main storage area in such cards is normally EEPROM (electrically erasable programmable read-only memory), which—subject to defined security constraints—can have its content updated, and which retains current contents when external power is removed (analogous to a PC's hard drive). Newer smart-card chips may have dedicated co-processors to perform certain functions at optimum speed (such as complex cryptographic routines required for certain security regimes).

A smart card is therefore characterised uniquely by its chip, the ability to read and write data, and with its ability to store much more data (currently up to about 64 000 bytes) all within an extremely secure environment. This makes the card a reusable ticket or token which can hold credit or subscription rights, details of the card holder (if necessary) and access to a range of services and applications (dependent on the complexity and configuration of the chip and card operating systems). The security ensures that the data cannot be copied or altered by a non-authorised third party and thus gives the card a long-use life and the ability to store both high-value tickets (say an annual rail pass or an airline ticket) as well as low-value ticketing (bus/metro day or single tickets) in a secure and trusted way.

The portability, flexibility and convenience of having just one smart card which could hold a range of tickets, other transport products and third-party services, such as local authority

'city-card' applications or some private-sector applications, has led to the UK public transport sector strongly embracing the technology over the past few years—which is a complete turnaround from the mid-1990s where probably less than 50 000 transport smart cards existed in the UK as a whole.

3. SMART-CARD TECHNOLOGY FOR INTEGRATED TICKETING

3.1. Improving the payment mechanism and information flow

The way in which fares, tolls, and other fees for the use of a transport service are collected is one of the most important aspects in determining customers' satisfaction with both new and existing transport schemes. Benefits may be achieved by improvements in speed and the flexibility of payment itself, if new technologies are employed. However, the additional information on customers' trips, their profile and preferences for payment, may also open the way to offering customer-loyalty and reward schemes and a better understanding of the customer's needs and journey patterns.[3] The airline and fuel-vending industries already make widespread and successful use of such loyalty schemes.

In many cases, conventional means of revenue collection are labour-intensive, can be insecure and cause delays in boarding times and are relatively inflexible. To improve this, many operators have tried to replace the collection of actual money by some other form of payment which also has the effect of reducing the potential for fraud, reduce the security concerns and logistics costs with handling cash, as well as providing a more 'closed' audit trail. In fare collection on public transport, this has included a wide range of methods, such as: travel passes; vignettes; single- or multi-journey tickets; tokens; and various automated means, such as magnetic cards or ID tags.

Until recently, few options were open to a transport service provider for the improvement and enhancement of payment systems, which would both benefit the customer and make the collection of the revenue more secure, efficient and flexible. However, the introduction of the smart card as a tool for carrying electronic credit or information pertaining to the user's subscription offers new and innovative ways of improving the collection and payment of fares. To complete the transport picture: smart cards are also now being deployed with systems using (so-called) intelligent transponders, which enable the payment of tolls, congestion charges and parking fees from equipped vehicles travelling on roads at normal speeds. Where such schemes exist, this paves the way towards opening a whole new market for associated 'value-added service' (access and payment for driver information, route guidance, parking reservations, etc.). From the perspective of integrated transport it is apparent that the smart card itself can provide the common interface tool between three of the key elements to improving transport, namely: managing demand through road-use charging; and making public transport more attractive through both better, integrated ticketing and the provision of high-quality information that could be accessed through a personalised card.

The card itself may also be the direct tool which is the key to accessing information. Indeed, this can be done in a personalised way, whereby user-related data stored on the card can configure the information terminal to meet that user's particular requirements. The potential for providing additional information services to customers or to other agencies offers new and innovative revenue-earning possibilities for transport operators.

3.2. Technology issues associated with smart cards

Smart-card technology has really developed in leaps and bounds in the last three years. The real cost of producing cards is reducing, as the scale of production runs is increasing (obviously, the limitation here is the cost of the silicon), and the reliability of the cards is also increasing (although, in most cases still not wholly satisfactory)—even for contactless cards—which is now making this technology robust enough to be viable for commercial use. Standardisation is also moving forward with final draft standards for contactless cards now published (ISO 14443[4]) and some application standards emerging in Europe, from the standards committees CEN TC224 and CEN TC278. Inevitably, as with all rapidly developing techniques, some issues remain to be resolved. These are discussed below under the headings of Interfaces, Memory, Reliability and Security.

3.2.1. Interfaces. When selecting a smart card for a particular application, one of the most important criteria that must be considered is how that smart card communicates with other devices—that is, the outside world. There are two basic choices of smart card interface.

(*a*) *Smart card with contacts* where the card has a set of six or eight metal contacts on the surface of the card. When the card is inserted in a reading device, spring-loaded contacts make a connection to each of these metal pads (such cards can been seen in use for telephone payments and bankcards).
(*b*) *Contactless smart cards* where the card uses inductive or r.f. coupling to communicate with the reading device. Generally, the card needs to be placed in very close proximity to the reader (known as 'proximity' cards), although a new standard for cards and tags being read at a distance of up to 1 m was published in June 2000, known as the 'vicinity' card standard.[5]

Smart cards with contacts must comply to the ISO standard 7816,[6] whereas those without contacts are yet to be fully standardised (partially, through ISO 14443[4]). However, the inconvenience of actually inserting contact cards in a reader is off-putting when passengers are boarding vehicles or paying a fare at a barrier/entry gate. The time required to complete the payment may be perceived as quite long (in practice, usually only a few seconds). Therefore, mechanisms for overcoming this have been developed. For transport applications, the two most common are as follows.

(*a*) *Hands-free card wallet* where the contact card is inserted into a wallet, which has the ability to communicate over a range of a few metres. This enables a transaction between a contact smart card and a reading device to be performed as a person with the wallet passes a beacon or through a portal.
(*b*) *Smart card with transponder*, the transponder being a higher-performance communications device, with some built-in intelligence of its own. Generally, such devices are not used for public transport applications but rather for longer-range communications between moving vehicles

and a roadside system such as automated toll collection and congestion charging systems, and is currently under trial in the UK's National Road Charging Technology Trial, DIRECTS, in and around the city of Leeds.[7,8] Nevertheless, the technology is interesting because the smart card used in such systems is of the same type used for fare payment. Thus, the possibility of using a single smart card for many transport services may be considered, providing the customer with an attractive and flexible system for cashless payment.[9]

More recently, a number of integrated circuit (IC) suppliers have brought out a range of smart cards which provide for both a contact and a contactless interface, the so-called 'hybrid' and 'combi' cards. The first cards on the market to deliver both contact and contactless functionality were the hybrid cards, produced with two electrically isolated systems, in which the microprocessor and associated circuitry for a contact smart card is used for, say, banking and financial-sector applications, while a separate microprocessor, associated circuitry and contactless interface on the same card satisfy the needs of the transport sector. However, the goal (from a cost and reliability viewpoint) has now moved on towards a smart card with two interfaces and only one chip-set—the so-called combi-card or dual-interface card. Although currently rather expensive in comparison to contactless-only cards, many new transport smart-card schemes and those jointly with local authority citizen card schemes seem to largely be adopting this class of card. The card types are illustrated in Figs 1(a)–(d).

The dual-interface card also bridges the gap between key service sectors as the perceived requirement industry is that the public transport sector needs only a contactless card, while more 'secure' transactions (as perceived by banks and government departments) need a contact interface which cannot (as easily) be hacked into. The first commercial use of dual-interface cards was (a) in the EU-funded ADEPT II project in Thessaloniki, Greece,[10] which used the card for automatic tolling (inserted in a transponder using the contact interface), parking payment and public transport (using the contactless interface); and (b) a city-card for public transport ticketing, ID and other functions in Turku and Tampere in Finland, under the ADEPT III project.[11–13] Fig. 2 shows some of the card reading equipment used on the buses in Tampare, and Fig. 3 shows the stated advantages of using combi-cards by passengers.

3.2.2. Memory. The size of the dynamic memory on a smart card into which data can be written or changed is limited, at present, both by the cost of this kind of memory (EEPROM) and by the physical size of the memory chip within the card's processor. Many of the first generation of 'read–write' cards offer only a few hundred bytes of EEPROM; however, commercial cards with 4, 8 and reliably up to 64K bytes are now available—albeit at a cost. Cards with 100K+ bytes are also emerging but at a laboratory evaluation stage. From experience, one would suggest 2–4K bytes of memory is sufficient to store the financial balance and contract information, plus an auditable register of around 100 of the most recent transactions (containing information such as time, location, service, charge and final balance). However, the memory is really a function of what and how many applications the card is expected to support and this largely determines the unit cost of the card.

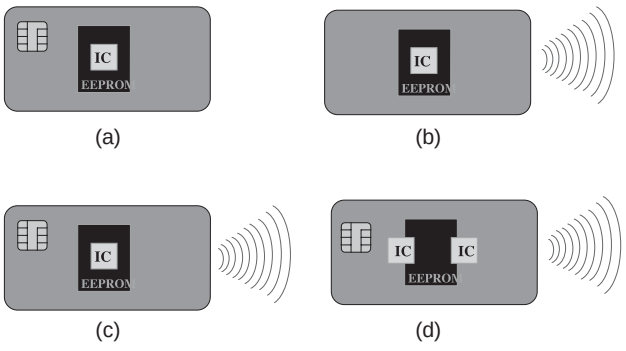

Fig. 1. The various types of smart card: (a) standard contact card, with one chip-set and one interface; (b) contactless card, with one chip-set and one interface; (c) combi-card, with one chip-set and two interfaces; and (d) hybrid-case, with two chip-sets and two interfaces

3.2.3. Reliability. Card reliability remains an important objective. Concerning the overall mechanical reliability of the cards, clearly the more complex the card, with more chips and bonding wires, the more likely is the card to fail before expected. This, to some extent, can be overcome by reducing the number of chips through greater integration.

3.2.4. Security. Security of smart cards and their associated systems is always an issue that is endlessly debated and focuses on three levels.

(*a*) Physical
- How good is the card's tamper-resistant module?
- How easy and viable is reverse engineering?
- What happens in a misoperation (clock, temperature, voltage, card removal, etc.)?

(*b*) Logical
- Cryptographic capabilities? (Data encryption standard (DAS)/Rivest Shamir Adleman algorithm (RSA))

Fig. 2. Paying with a contactless smart card in Tampare, Finland: some of the card reading equipment

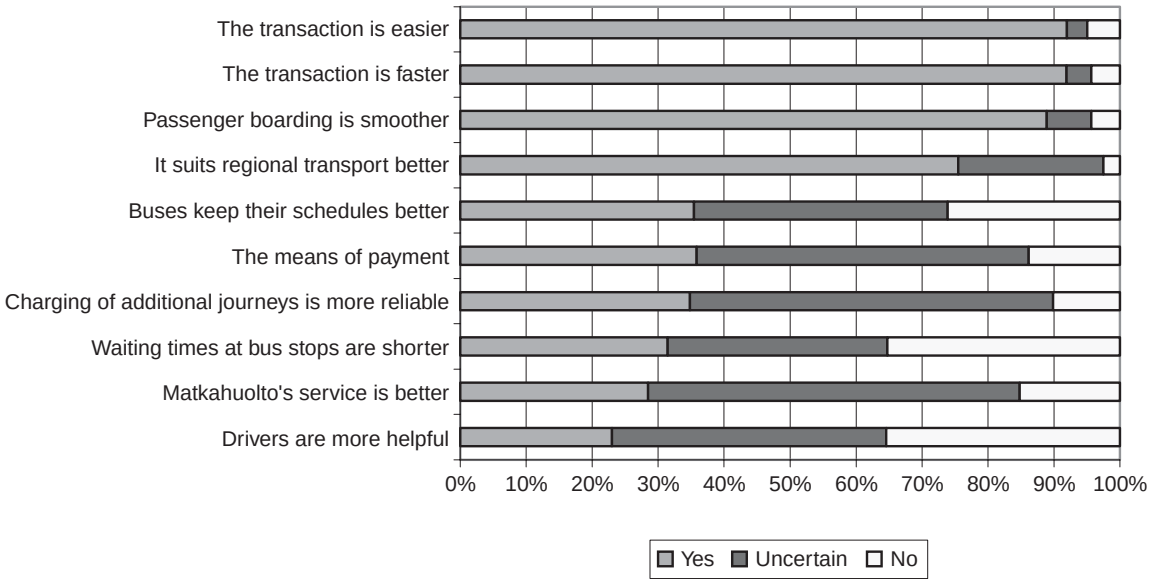

Fig. 3. Advantages and disadvantages of using the combi-card (sample 160 passengers, Tampare, Finland, May 2000)

- Protocol error handling?

(*c*) Other interfaces

- Security of the contactless and other systems' interfaces?

For most of these, the important criterion seems to be the cost and difficulty of 'cracking' the card and the motivation to do so. Clearly, banks find the security offered by contact smart cards acceptable—judging by how many electronic purses and payment cards are coming onto the banking market. However, one should never be complacent with this issue. Indeed, it is only now that medium/large-scale implementations of smart cards are occurring that the motivation for fraud by criminal gangs is likely to begin. The security schemes adopted by card schemes such as ITSO are at many levels in terms of protecting cryptographic keys and the data infrastructure (through secure public key infrastructure (PKI)); this also requires that every card reading terminal is fitted with an ITSO SAM (security application module) which is very similar in physical look and operation to a SIM card in a mobile phone.[14]

It is worth emphasising that the security features built into smart-card chips are among the most sophisticated of their type available in the commercial world. Data residing in the chip can be protected against external inspection or alteration, so effectively that the vital secret keys of the cryptographic systems used to protect the integrity and privacy of card-related communications can be held safely against all but the most sophisticated forms of attack. The ingenuity of the cryptographers further supplements the physical security of the chip, ensuring that penetrating a card's security does not compromise an entire card scheme.

It is because of these security and data storage features that smart cards are rapidly being embraced as the consumer token of choice in many areas of the public sector and commercial worlds. The internet, in particular, is focusing the need for online identification and authentication between parties who cannot otherwise know or trust each other, and smart cards—coupled with effective cardholder verification techniques—are believed to be the most efficient and portable way of enabling the new world of e-trade. Governments are looking at the use of smart cards with biometric authentication as the means of introducing ID cards, and transport has recognised that the smart card offers the opportunity to revolutionise ticketing, improve quality of service and most importantly join up services between operators and between regions using the smart card as an interoperable ticket. Interoperability is the key requirement to facilitate universal consumer acceptability: the ability of a card function developed by one organisation to be used without difficulty in schemes owned and operated by many organisations—almost a de-deregulation of certain public transport operations.

4. SMARTCARDS FOR THE PUBLIC TRANSPORT INDUSTRY

4.1. Early trials

As mentioned previously, there were a few flirtations and experimental schemes for public transport ticketing with smart cards in the mid-1990s. Some acted as the key drivers in raising the debate on smart cards in the UK transport industry.[15]

These schemes are now discussed in turn.

(*a*) *Milton Keynes*. This is the oldest recorded scheme in the UK, initiated in 1990 (although it has had a few upgrades), which offered stored value ticketing on buses from two different operators as well as being used as concessionary passes for some 15 000 travellers.

(*b*) *Mersey Travel*. This is one of the most cited of the early trials which commenced in Southport in 1996. Here more than 10 000 elderly travellers could use the concessionary smart-passes on some 80 buses. The scheme extensively monitored customer perception, satisfaction and usage. Moreover, the scheme also demonstrated that the data from the scheme could be used to more accurately record the usage of the card and (potentially) the apportioning of concessionary revenue between operators.

(*c*) *Harrow*. In 1996 London Transport introduced smart-card ticketing on two trial routes through Harrow. The trial was aimed at raising the awareness of smart cards, testing the robustness of the technology and examining customer and staff attitudes to the technology. The success of the trial and the subsequent evaluation helped to influence London Transport to go for a full-scale 'new ticket media' Private Finance Initiative contract to update ticketing, underground and station gates. The project, known as PRESTIGE, has just begun to deliver smart-card tickets across the now TfL (Transport for London) public transport network.

(*d*) *Hertfordshire*. The HertsPass scheme was launched in 1997 as a concessionary smart card for the elderly and schoolchildren for a single bus operator. In 1999 the cards were accepted on all operators' buses in the county—with a total of 20 000 issued cards. In 2000 a dual-interface card, the Omnicard, was added to the scheme to enable university students to travel and also to access and pay for various services around the campus.[16]

The above list is by no means exhaustive but does highlight the more significant early pioneers. Nevertheless, these early smart-card schemes showed that, even with what was then a fairly cumbersome and slow technology, smart cards could offer real benefits and a viable alternative to paper tickets and passes for many ticket products (such as concessionary fares and monthly passes). However the real benefits would accrue, these ticketing schemes could be made flexible and interoperable. This would require an unpresidented 'buy-in' by all the key players in the public transport industry.

4.2. Interoperable smart-card ticketing

In response to the concerns that the use of public transport smart cards in the UK could be fragmented and thus not deliver the benefits, cost reductions and economy of scale that a more integrated system would offer, ITSO was formed in 1999. ITSO (the Integrated Transport Smart-card Organisation), brought together all the key public transport players in the UK—the supply industry, bus and train companies, the passenger transport executives (PTEs), TfL, many local authorities and the Department for Transport (DfT)—to build an interoperable smart-card specification and supporting environment for the UK transport environment. The work to achieve this has been generously supported by the DTLR and then DfT with significant corresponding funding from the PTEs and other members of ITSO.

ITSO also has the aim of taking the UK specification into the European environment and has been active in both the CEN and ISO standardisation bodies in developing a hybrid specification which can be adopted by the European public transport industry. Indeed in parallel with the release of the final working specification for ITSO (version 2.1) in the UK.[17] CEN TC224 has been issuing a final draft for comment on the European derivative of ITSO, the IOPTA specification.[14]

What is significant about ITSO is that it has developed a specification that can be bought into at different levels, in the sense that you can limit the functionality of the issued card to a few products and possibly an electronic purse—or have a much more complex card structure for multiple applications. Moreover, the ITSO module can obviously exist on an ITSO card, but can also be put as a 'guest' module on other smart cards, such as those being issued by local authorities. The specification attempts to be as inclusive as possible by allowing cards of different configurations and standards to be used within the scheme, such as ISO 14443 type A and B cards, and thus being seen to not be too prescriptive to the card-supplying industry.

ITSO, as a specification, has taken a lot longer to develop than originally envisaged and to an extent this has held back the roll-out of smart cards in the UK transport industry, as the scheme operators have been waiting for a stable version of the specification to be published by the DfT. This has been compounded by further tardiness in the design, delivery and accreditation of the ISAM (ITSO security access module) which is required in each card reading device, on buses, at metro and train stations, and at ticket and retail sales points. Indeed, much of the delay can be attributed to the need to ensure the security is watertight with all the potential parties who may opt in to the ITSO interoperability scheme and also the corresponding need to develop a conformance and compatibility testing process for all equipment and cards in the ITSO scheme. Two other significant factors in the delay chain were (*a*) the fact that the sheer complexity of the scheme and contractual arrangements between all entities in the scheme were underestimated (but a great deal was learnt from this exercise) and (*b*) the time taken to elaborate the business case as to why the public transport industry and suppliers should join and adhere to the scheme. These problems have now been largely resolved to the satisfaction of most parties.

Nevertheless, the business case as seen by many operators is fairly marginal for transport alone.[18,19] Where the business case does seem to offer real positive returns is when the transport smart-card scheme is introduced in partnership with local authority 'city-card schemes'. This has been demonstrated in the profusion of shared schemes that have either been implemented recently or will do so in the near future, including

(*a*) the Cornish 'Key-Card'[20]
(*b*) the West Yorkshire YOR-Card[21]
(*c*) the London Connects card (linked to the TfL's Oyster Card)[22]
(*d*) the Nottinghamshire Card
(*e*) the North East Regional Smart Card (NERSC)
(*f*) the North West Region NOW-Card, to name but a few.

In part-recognition of this, the Office of the Deputy Prime Minister (ODPM) allocated £4.5 million in the financial year 2003/04 to fund a one-year National Smart-card Project. This project will reduce the risk to local authorities who are considering deploying smart cards by sharing knowledge, providing software, pilot implementations, guidance on standards, business cases, and best practice guides for public sector city-card schemes to essentially do for local authorities what ITSO has done for smart-card interoperation in the transport sector.

The delivery of the interoperable smart-card specification for transport is seen as one of the cornerstones of the Government's 10-year transport plan as it facilitates the progressive roll-out of interoperable smart-card schemes across the UK. These schemes,

(a) (b) (c)

Fig. 4. (a) Fare payment; (b) Telephone; (c) Booking and paying for theatre tickets

it is hoped will make the prospect of travelling by public transport more attractive to users—as one ticket can be used for several modes, which is both convenient as well as saving time through faster payment, boarding times and ease of purchasing a single ticket. Linking many of the transport schemes to broader local authority schemes will open up a wide range of additional services to the card holder, such as access to leisure, parking, cultural and library facilities (Fig. 4), the ability to e-transact with local government on a range of services through a secure ID, and purchase services through an e-purse on the card.[23]

From the public transport industry view, smart cards will provide market data and research on when and where their customers are using their cards—and thus be able to develop and re-engineer services to more readily meet the traveller's needs. Bagchi[24] recently demonstrated the great potential for using such data and the benefits that could be accrued. Local authorities and PTEs would also benefit from better control of concessionary travel budgets and operators would have the necessary data to facilitate better and more accurate distribution of multi-modal revenue pools. Smart cards would also offer, from the operators perspective, savings through reduced cash handling, reduced fraud and better revenue control. Carr[14] suggests that for the YOR card scheme the business case estimates that the initial project cost of €29·9 million with a net present value (NPV) (over 10 years) of €9·4 million and an expected internal rate of return (IRR) of 8% would see the initial scheme costs pay back in eight years. Clearly not all schemes have such marked returns; however, sensible and realistic business cases may be developed for many large schemes.

4.3. The London Oyster Card

One missed opportunity for full integration is the TfL's PRESTIGE project. It was unfortunate that the pan-London smart-card schemes contract was signed with the industrial Consortium Transys before the formation of ITSO, the consequence being that the London Oyster Card (as it was eventually branded) was launched in August 2003, as a smart travel card for London—without being ITSO compliant. The £1·2 billion PFI scheme has successfully launched the first phases of the scheme with monthly, annual and seven-day travelcards and bus passes now available as smart cards with further smart ticket products to follow. Initial evaluation suggests a high level of satisfaction with the technology and the reliability system as a whole (although the contactless cards must be held closer to the card reader than initially expected) and clearly the scheme will act as a showcase for other regions looking at introducing smart cards. In the autumn of 2003 an agreement was reached between TfL and the DfT which roadmapped a course towards 'virtual' interoperability between ITSO and the Oyster Card. However, full ITSO compatibility would clearly need major investment, which is yet to be secured, although the signs are encouraging.

Figure 5 shows a smart-card reader at an underground entry barrier, Fig. 6 a reader on a London bus, and Fig. 7 a hand-held reader for use by inspectors to read the smart cards.

Fig. 5. Using the Oyster Card at an Underground entry gate

Fig. 6. Smart-card reading equipment on a London bus

5. LOOKING TO THE FUTURE

It is now clear that smart cards will play a significant role in public transport ticketing for years to come. The UK is at the cusp of the large-scale deployment of smart cards for transport ticketing as well as a range of other services, both public-authority-led as well as private-sector-led. Through ITSO and the ODPM's National Project, common frameworks and specifications will be in place to enable operators to join existing schemes as well as initiate new schemes which can be made interoperable with the national framework.

Fig. 7. Hand-held smart-card reader for use by ticket inspectors

Achieving interoperability has a cost associated with it, as each terminal must be certified and also have an ISAM (or the local authority scheme equivalent) embedded in it. Local Authorities are looking to find ways of avoiding SAMs at all terminals and are investigating an approach using security module servers with closed networks. Currently it is unclear to many small bus operators whether there is significant benefit in going smart and being interoperable to make the necessary business case. However, in schemes likely to go live in the next year or so, such as YORcard, the PTE has made the case to, at least in part, subsidise the conversion to smart cards for small operators; in most cases the larger bus operators, as well as the train companies seem to have already made the case to adopt ITSO at the regional or national levels. However, until such schemes as YORcard and the other major schemes mentioned previously are evaluated and (hopefully) shown to be a success in terms of revenue and passenger generation as well as cost savings through better management information, it will be difficult to bring all the industry on board.

REFERENCES

1. Blythe P. T. *Smart Card Applications in Transport.* International Smart Card Industry Guide. Smart Card News, United Kingdom, 1994.
2. Department of the Environment, Transport and the Regions. *A New Deal for Transport—Better for Everybody.* DTLR, 1998.
3. Davis H. *A Loyalty and Rewards Card Proposal for the North East Regional Smartcard Scheme.* University of Newcastle upon Tyne, unpublished MSc thesis, September 2002.
4. International Standards Organization. *Identification cards—contactless integrated circuits(s) cards—proximity cards.* ISO, Geneva, ISO 14443.
5. International Standards Organization. *Identification cards—contactless integrated circuits(s) cards—vicinity cards.* ISO, Geneva, ISO 15693.
6. International Standards Organization. *Identification cards—integrated circuit cards with contacts—vicinity cards.* ISO, Geneva, ISO 7816.
7. Makinnon D. The DfT's DIRECTS project. *Proceedings of an IEE Seminar on Road User Charging*, London, March 2003.
8. Blythe P. T. Road user charging in the UK. Will we ever see an emergence of technical and political consensus? *Proceedings of the 10th World Congress on Intelligent Transport Systems and Services, Madrid*, November 2003.
9. Blythe P. T. DISTINCT: The smart card solution for public service across Europe. *Proceedings of Smart Cards in Public Services*, AIC Conference, Brussels, November 1999. (Invited Keynote Case Study.)
10. Mustafa M. Experiences from the DISTINCT and ADEPT II projects. *Proceedings of the 5th World Congress on ITS, Seoul, Korea*, October 1998.
11. Blythe P. T. and Holm C. Combi-cards in automatic public transport fare payment: the ADEPT III Project. *Proceedings of the 7th ITS World Congress on Intelligent Transportation Systems, Turin*, November 2000.

12. Blythe P. T. and Holm C. ADEPT III: piloting combi-cards for public transport ticketing in Finland. *Traffic Engineering and Control*, 2002, **43**, No. 1, 16–20.
13. Holm C. User acceptance of city card systems and automatic public transport fare collection. Final results of the Finnish ADEPT II sites. *Proceedings of the 5th World Congress on ITS, Seoul, Korea*, October 1998.
14. Carr J. ITSO versatile: delivering UK transport's interoperable smart card environment. *Proceedings of the 10th World Congress on Intelligent Transport Systems and Services, Madrid*, November 2003.
15. Department for Transport, Local Government and the Regions. *Public Transport 'Legacy' Smart Card Schemes. Upgrading to ITSO Compliance*. Department of the Environment, Internal Research Report, London, 2001.
16. Robson S. The Hertfordshire (UK) smart card. *Proceedings of Smart Card '98, London*, February 1998.
17. Integrated Transport Smart-Card Organisation. *ITSO Specification 2.1*. Department of Transport, HMSO, 2004.
18. Fahrety J. *The Business Case of an Integrated Transport and City Card in the North East of England*. Unpublished thesis, University of Newcastle upon Tyne, 2001.
19. Blythe P. T. Developing a business case for a transport and local authority smartcard scheme. *Proceedings of the IPCQ Conference on Ticketing in Transport*, London, March 2002.
20. Cosway R. The Cornish key card scheme. *Proceedings of the 3rd Moving On Conference, Nottingham, UK*, June 2003.
21. Keith B. What do bus and rail operators want from smart cards? *Proceedings of the Transport Card Forum*, Smartex, Newcastle, November 2003.
22. London P. The London Oyster Card. *Proceedings of the Transport Card Forum*, Smartex, Newcastle, November 2003.
23. Blythe P. T., Lawther S. J. and Shield C. M. DISTINCT: using transport applications as the key to developing business case for a citizen smart card. *Proceedings of the 6th International Conference on Applications of Advanced Technologies in Transportation, Singapore*, June 2000.
24. Bagchi M. *Use of Smartcard Data from Bus Systems for Travel Behaviour Analysis and Implications for Marketing*. PhD thesis, University of Westminster, 2003.

Related internet sites

⟨http://www.itso.org.uk⟩—the ITSO Home Page.

⟨http://www.dft.gov.uk/⟩—DfT homepage with information on ITSO, the National Project, the 10-year plan and the 1998 White Paper.

⟨http://www.smartex.com⟩—the Smartcard Club and the Transport Card Forum home page.

Please email, fax or post your discussion contributions to the secretary by 1 September 2004: email: kathleen.hollow@ice.org.uk; fax: +44 (0)20 7799 1325; or post to Kathleen Hollow, Journals Department, Institution of Civil Engineers, 1–7 Great George Street, London SW1P 3AA.