Smart cards in public transportation: spatial platforms, diffusion and externality creation

Tuomo Kinnunen*, Pekka Kess and Jukka Majava

Industrial Engineering and Management, University of Oulu, P.O. Box 4610, Oulu, FI-90014, Finland
Email: tuomo.kinnunen@oulu.fi
Email: pekka.kess@oulu.fi
Email: jukka.majava@oulu.fi
*Corresponding author

Abstract: This original research evaluates contactless smart card technology as a source of innovation in public transportation. Ticketing and fare collection are in global transition from cash, paper tickets and contact cards to contactless payment. The global diffusion of contactless smart cards has progressed slowly by the local diffusions of separate platforms following the 1997 launch of Octopus platform in Hong Kong as the first successful large-scale implementation. This research utilises the principles of a multiple case study and a multi-sided platform as a theoretical frame to analyse four well-diffused platforms: Octopus, Oyster, EasyCard and OV-chipkaart. The results show that common strategies are shared for the design and expansion of multi-sided platforms in public transportation while strategies toward other sectors differ. Although limited to four cases, from a managerial perspective, this paper demonstrates that the utilisation of original technology platforms is more dependent on institutional and societal factors than technological frame.

Keywords: diffusion; e-payment; innovation; intermediary platform; operations management; public transportation; smart card; technology.

Reference to this paper should be made as follows: Kinnunen, T., Kess, P. and Majava, J. (2016) 'Smart cards in public transportation: spatial platforms, diffusion and externality creation', Int. J. Modelling in Operations Management, Vol. 6, Nos. 1/2, pp.47–58.

Biographical notes: Tuomo Kinnunen is a project manager and a doctoral student in Industrial Engineering and Management at the University of Oulu. He has a Master’s degree in Industrial Engineering and Management. He has worked in several international research projects. His research work and interest include business ecosystems, innovation platforms and product development covering different angles.

Pekka Kess (Dr. Sc., Dr. Eng.) is a Professor of Industrial Engineering and Management at the University of Oulu, Finland. He has extensive managerial experience from both universities and industrial enterprises. He has worked in managerial positions in chemical, steel and electronics industries as well as in software business. He has been an active project evaluator in European Commission as well as a manager in international research and development projects. His research areas are in business ecosystems, strategic management,
production organisations, knowledge management with specialisation in knowledge transfer and e-Learning.

Jukka Majava works as a post-doctoral researcher in Industrial Engineering and Management at the University of Oulu. His industrial experience includes technology and ecosystem marketing, partner and project management, and business and supply chain development at Nokia Corporation. His research areas of interests include product innovation, business networks and supply chain development.

This paper is a revised and expanded version of a paper entitled ‘Smart cards in public transportation - Global diffusion, locat platforms’, presented at the MakeLearn & TIIM 2015 Joint International Conference in Bari, Italy, 27–29 May 2015.

1 Introduction

Public transportation plays a central role in meeting the mobility demands of people in urban environments in a sustainable way. Significant efforts towards more favourable, seamless public transportation have been made worldwide, and many new systems are being developed (Han, Van Dender and Perkins, 2012). One significant area of development within recent decades has been to enhance the efficiency and convenience of ticketing and fare collection (Fleishman et al., 1996). This essential subsystem of public transportation is currently in transition from cash, paper tickets and magnetic stripe technology to contactless technologies, with smart cards being the dominant medium (Puhe, Edelmann and Reichenbach, 2014). This global transition is enabled by information and communication technology development and driven by spatial smart card platforms to meet the needs of users, operators and urbanising societies. The development of smart card technology is guided by the fact that travellers value convenient and inexpensive ways to pay for their trips, the mass use of public transportation calls for fast and automated solutions, and the societal need for fluent urban mobility requires integrated and fair payment solutions (Andrews, 2013).

A spatial smart card platform in public transportation operates in a two-sided transaction market reflecting the needs of both travellers and public transport operators. The two groups of customers engage with the platform to transact with one another. The network externality of such a platform is twofold: the operators value greater numbers of travellers and increased revenue, while travellers value operators and mobility services that use the same platform and are accessible through one smart card (Evans, 2003).

Smart cards in public transportation have been studied from several perspectives, e.g. technological, operational and data use. This study contributes to the knowledge of smart cards in public transportation as a multi-sided platform and positions spatial smart card platforms within management research on platforms. This research is part of a larger study on platforms for innovation in spatial contexts, which are becoming increasingly important for many countries and regions that are seeking new economic growth (Majava et al., 2014). Technological platforms are recognised as one source of innovation, and as one such key platform, contactless smart card technology is investigated in this paper. A thorough understanding of successful platforms and their
diffusion is necessary since spatial platforms may best be diffused by replicating successful implementations and avoiding ‘reinventing the wheel’ phenomena. The research question of this study is condensed as:

**RQ** How are spatial smart card platforms diffusing and creating externalities?

This research was conducted commercial the principles of a multiple case study. The literature part of the study was built on the platform literature and especially multi-sided platforms. For the background, we briefly studied the invention, development and global diffusion of smart cards in public transportation. We then analysed four successfully diffused spatial smart card platforms using publicly available data sources. The main managerial implications and conclusions are discussed in the end of the paper from the viewpoint of platform expansion and future opportunities. This study addresses the research question in a qualitative manner through both the literature and the analysis of existing platforms.

2 Smart cards and platforms

2.1 Smart card technology and its diffusion in public transportation

Contactless smart cards are a combination of two core technologies:

1. radio-frequency identification technology
2. the integration of a chip onto a plastic card.

Both technologies were invented and developed before 1980 (Landt, 2005). The commercialisation of the technologies was initiated in the early 1980s, e.g. in public phones and the banking sectors in France (Puhe, Edelmann and Reichenbach, 2014). Small-scale pilots of contactless smart cards in the public transportation sector subsequently began in the early 1990s and were extended to numerous cities in developed countries worldwide within 5 years (Fleishman et al., 1996). The first large-scale smart card platform implementation, the Octopus system in Hong Kong, was launched in 1997, and three million cards were issued within the first 3 months (Ma et al., 2008). The timeframes of the invention, development and diffusion of smart cards in public transportation are depicted in Figure 1.

Figure 1 The creation and diffusion of contactless smart cards in public transportation
The diffusion of smart cards in public transportation is reflected in the size of the global smart card market in the transportation sector. Figure 2 illustrates the rather slow global progress from 1999 to 2009, although active piloting and early success stories existed.

**Figure 2** Yearly shipments of contactless smart cards for the transportation sector, excluding memory cards (based on Eurosmart Figures 1999–2014) (see online version for colours)

Various reasons for the slow global diffusion have been reported. The lack of compatibility and a common standard for contactless smart card technologies have restrained adoption and global market formation, and caused the slow price erosion of contactless transportation smart cards and device technology. Indeed, there are several competing standards and proprietary technologies still in use (Pelletier, Trépaniera and Morencyb, 2011). Besides the technical aspects, the legal and economic issues are significant, and institutional and governance issues must be addressed by the stakeholders to ameliorate this situation (Puhe, Edelmann and Reichenbach, 2014).

### 2.2 Platforms

Management research on platforms emerged in the 1990s, and interest has been growing steadily since then in several distinct research streams, categorised as, for example, organisational, product family, market intermediary and ecosystem streams (Thomas, Autio and Gann, 2014). Internal platforms, e.g. organisational and product platforms, are arranged within a common structure to efficiently develop and produce a stream of derivative products. This paper focuses on external ecosystem platforms that act as a foundation upon which stakeholders can develop their own complementary services and innovations (Gawer and Cusumano, 2014).

Recent studies, such as research on smartphone industry, have suggested that a platform is not only about technology, but also the result of certain business behaviours and relationships between actors in an ecosystem. In addition, the role of applications is very important in platform diffusion (Kenney and Pon, 2011). This kind of ecosystem platform requires a leading organisation that creates a shared vision to join ecosystem organisations together and promotes the operations of the platform (Gawer and Cusumano, 2014; Majava et al., 2014). The formation of such platforms demands authorised decision-making and managerial structure to enable platform development as
well as effective participation of ecosystem companies and fluent services for platform users (Gawer, 2009; Gawer and Cusumano, 2014). The common benefits of ecosystem platform approach include enabling new kind of collaborative development with cost and risk sharing, as well as access to resources that are typically beyond individual organisation’s reach (Iansiti and Levien, 2004; Gawer and Cusumano, 2014).

2.2.1 Intermediary platforms

Thomas, Autio and Gann (2014) argued that the operations of an ecosystem platform are driven by three distinct leverage rationales - production, innovation and transaction - and market intermediary platform follows the transaction leverage logic. The transaction leverage logic can be very powerful, as demonstrated by the success of Google in creating a multi-sided platform where the main revenue stream is advertising (Osterwalder and Pigneur, 2010).

An intermediary platform operates in a two-sided or multi-sided market where the platform creates value and network externalities when all the sides have joined it (Hagiu, 2014). Network externalities are positive feedback loops that can grow at increasing rates as the adoption of the platform and the number of complements rise (Gawer and Cusumano, 2014). Intermediary platforms include exchange platforms, e.g. eBay; advertiser-supported media, e.g. newspapers; transaction systems, e.g. payment cards; and hardware/software platforms, e.g. video game consoles (Sriram et al., 2014). Spatial smart card platforms belong to the transaction system category, similar to payment cards. Such a platform offers the opportunity to transact through the platform as the main product acts as the ticketing and fare collection medium in public transportation.

2.2.2 An example of a multi-sided smart card platform in public transportation

This example is based on the features of OV-chipkaart platform, which is used to process public transport ticketing and payments in the Netherlands. The platform organisation, Translink Systems (TLS), facilitates transactions between travellers and public transportation operators and provides a range of other services. Figure 3 illustrates the example.

Figure 3 An example of a smart card platform in public transportation (TLS, 2015)
2.2.2.1 Transaction processing

Processing the millions of daily transactions is an important activity for TLS. OV-chipkaart transactions can be divided into the following categories: card transactions (the card and cardholder’s details), product transactions (products purchased and journeys made using the product) and credit transactions (card credit and travel on credit) (TLS, 2015).

2.2.2.2 Scheme provider

The scheme comprises the complete regulations and agreements between the parties using the OV-chipkaart system. OV-chipkaart is a single, comprehensive, open-architecture system and works in the same way throughout the Netherlands and for all connected participants. The scheme provider is responsible for the security and reliability of the OV-chipkaart system (TLS, 2015).

2.2.2.3 Card production

Three kinds of OV-chipkaarts are available: personal, anonymous and business OV-chipkaarts. The platform organisation produces and delivers OV-chipkaarts to its (business) customers or directly to cardholders (TLS, 2015).

2.2.2.4 Consumers

The platform organisation provides consumer services for user convenience, e.g. the convenience of automatic reloading, and the ability to check card credits and view travel details. The cardholder services are available online at ‘My OV-chipkaart’ (TLS, 2015).

2.2.2.5 Business market

The business OV-chipkaart is aimed at mobility service providers interested in developing services for the business market and, ultimately, for business passengers. It provides convenience for both employers and employees by eliminating the need for employees to declare their travel expenses by invoicing employers directly later. Mobility service providers can link their own and other services to the business OV-chipkaarts (TLS, 2015).

3 Results and discussion

The results of this study are based on the analysis of four smart card platforms that have been successfully diffused within their spatial contexts: Octopus (Hong Kong), Oyster (London), EasyCard (Taipei) and OV-chipkaart (the Netherlands). The first two are pioneering examples from Asia and Europe, while the remaining two can be seen as early followers. The basic features of the four platforms are presented in Table 1.
## Smart cards in public transportation

### Table 1 Four contactless public transportation smart card platforms

<table>
<thead>
<tr>
<th>Platform</th>
<th>Octopus</th>
<th>Oyster</th>
<th>EasyCard</th>
<th>OV-chipkaart</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area</strong></td>
<td>Hong Kong, (cross-border), parts of China</td>
<td>Greater London area</td>
<td>Greater Taipei area, other parts of Taiwan</td>
<td>The Netherlands</td>
</tr>
<tr>
<td><strong>Scope of use</strong></td>
<td>All public transport, retail, tourism, e-government, online payments</td>
<td>All public transport, tourism</td>
<td>All public transport, retail, tourism, e-government, online payments</td>
<td>All public transport, mobility</td>
</tr>
<tr>
<td><strong>Other applied technologies</strong></td>
<td>Hybrid, NFC devices</td>
<td>Hybrid, EMV</td>
<td>Hybrid, NFC devices</td>
<td>–</td>
</tr>
<tr>
<td><strong>Issued cards [millions]</strong></td>
<td>27 in circulation</td>
<td>70</td>
<td>50</td>
<td>22</td>
</tr>
<tr>
<td><strong>Transactions per day [millions]</strong></td>
<td>&gt;13</td>
<td>&gt;13</td>
<td>5.7</td>
<td>&gt;5.7</td>
</tr>
<tr>
<td><strong>Platform owner</strong></td>
<td>Octopus cards limited</td>
<td>Transport for London (TfL) – a statutory corporate</td>
<td>The EasyCard corporation</td>
<td>Trans link systems (TLS)</td>
</tr>
<tr>
<td><strong>Platform founder</strong></td>
<td>Five major transport operators</td>
<td>Transaction systems limited a.k.a. TranSys consortium*</td>
<td>Taipei city government, 12 bus companies, several banks and private companies</td>
<td>The five largest public transport companies in the Netherlands</td>
</tr>
</tbody>
</table>

*The original Oyster platform owner was Transaction Systems Limited a.k.a. TranSys Consortium comprising four technology vendors. The system was originally created, and has been maintained, via a public finance initiative (PFI) contract, known as PRESTIGE, held between TfL and TranSys.

**Note:** NFC, near field communication; EMV, Europay, MasterCard, and Visa, is a global standard for inter-operation of credit and debit card transactions. Hybrid = Bank card integrated with public transportation functionality.

According to Puhe, Edelmann and Reichenbach (2014), an integrated smart card platform requires stakeholders to work together and establish common agreements. The owners/founders of all the studied platforms include major public transportation operators in their regions, which can be seen as a significant enabler for smart card adoption and diffusion. In the case of EasyCard, the founders included non-transport stakeholders, e.g.
from the public sector and financial institutions, demonstrating the potential for a wide scope of smart card applications from the very beginning.

Selected events and characteristics of the platform expansion of the case studies under review are shown in Table 2. Once they had overcome the regulatory barriers, Octopus and EasyCard expanded into micro-payments, e.g. in the retail sector. Oyster and OV-chipkaart, on the other hand, have focused exclusively on the public transportation and mobility sectors. The recent decision by Transport of London (Oyster platform) to integrate contactless bank cards (EMV standard) as an acceptable fare payment medium is an interesting experiment as it may break through the existing barriers and lead to a global payment platform that is also applicable in public transportation (Transport for London, 2014).

Table 2 Expansion of the four public transportation smart card platforms

<table>
<thead>
<tr>
<th>Platform expansion aspects</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Octopus</td>
<td>The Hong Kong Monetary Authority authorised Octopus to become a deposit-taking company in 2000 (Octopus, 2015). This allowed the company’s expansion into a wider range of different applications, and Octopus quickly became a dominant full-payment intermediary in Hong Kong (Poon and Chau, 2001; Ma et al., 2008), with online payments being recently added to its basket of payment method services. Currently, a multiple number of Octopus cards are in circulation per a Hong Kong citizen, 99% of the citizens own the card and many citizens own several cards (Octopus, 2015)</td>
</tr>
<tr>
<td>Oyster</td>
<td>Despite the wide diffusion of Oyster, the platform business model has proven to be challenging, and the cost of revenue collection has remained high. Oyster has sought cost reductions by integrating pure contactless bank cards into the same fare payment system. Launched in December 2012, more than 11 million bus journeys have been paid for using this option (Transport of London, 2014)</td>
</tr>
<tr>
<td>EasyCard</td>
<td>Until 2009, Taiwan’s Banking Act prevented non-banks, such as EasyCard, from expanding into multipurpose payment schemes (Tan and Tan, 2012). Since then, EasyCard has aggressively expanded its scope and scale towards multipurpose cards and national adoption. ‘Its ultimate aim is to allow people to travel around Taiwan with only one card’ (EasyCard)</td>
</tr>
<tr>
<td>OV-chipkaart</td>
<td>OV-chipkaart, as well as the antecedent fare and paper ticketing system, Strippenkaart, were fully integrated in urban and regional transport systems nationwide. Strippenkaart was introduced in 1980 and officially withdrawn in November 2011 (Cheung, 2007, 2012). OV-chipkaart has expanded into the new market of business travel service providers. The business OV-chipkaart has been extended to flexible business travel via a range of value-added mobility services aimed at business customers (TLS)</td>
</tr>
</tbody>
</table>

TLS, trans link systems

Contactless smart card technology provides certain direct benefits as reported in, for example, Octopus (2015), but successful smart card platforms also create indirect benefits, or externalities. Table 3 summarises the common externalities related to spatial smart card platforms that were identified and classified in this study.
Table 3  Spatial smart card platform externalities

<table>
<thead>
<tr>
<th>Externalities</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>One smart card as a payment medium: the more public transportation, mobility and other services are integrated onto the card, the more convenience and value for the user</td>
</tr>
<tr>
<td>Operator</td>
<td>The more users carry the card, the more journeys are made. A platform may increase revenues and share transaction costs. Operational data assists businesses in improving their service and operational models, e.g., utilises capacity and staff more efficiently</td>
</tr>
<tr>
<td>Public transportation system</td>
<td>Smart card platforms generate databases that provide good insights into travel patterns. It is an invaluable reference source in creating new transport systems or making adjustments to existing public transport routes (EasyCard)</td>
</tr>
<tr>
<td>Societal externalities</td>
<td>As the above externalities together indicate, public transportation may shift to become a more favourable mobility option than private transport leading to less congestion and more sustainable mobility in a society</td>
</tr>
</tbody>
</table>

The studied smart card platforms serve as global benchmarks on spatial ticketing and payment platforms, in terms of operations, diffusion and externalities. These platforms have led the way of exploiting contactless smart card technology in ticketing and payment locally while diffusion on a global scale was slowly beginning. The intermediary platform logic and locally common ways of organising platform operations to enable externalities, as illustrated by the case examples, may outline potential development paths and necessary goal setting for most other contexts and locations.

Mobile payment technologies, global payment systems and increasingly always and everywhere available broadband connection may affect significantly in the direction of future development in the mobility ticketing and payment sector. Regardless on used technologies, the commitment and the capability of spatial mobility stakeholders, such as policy makers, public authorities and transport operators, to implement common platform for ticketing and payment may determine the success of diffusion. Naturally, the geographical coverage and the scope of services of a platform must be broad enough to address the mobility needs of the users and the operational efficiency of the platform.

Without a common platform organisation and key stakeholders’ commitment to platform development, it is hard to implement successful contactless ticketing and payment scheme with extensive user adoption, as the slow global diffusion of mobility smart cards indicates. Building and managing such a platform is not easy process either, e.g. as experiences of building and implementing Dutch nationwide OV-chipkaart between 2001 and 2014 exemplifies. Multisided platform research and theory suggest that a critical challenge is the chicken and egg dilemma, or as Hagiu (2014) states: “no side of the platform will join without the others.” This may be critical point to understand in the very beginning for all the key platform stakeholders.

4 Conclusion

Sustainable mobility in urban environments is founded on comprehensive public transportation systems that are easy and convenient to access and use. This study analysed the spatial platforms of smart cards in public transportation in terms of diffusion and externalities. Public transportation smart cards have diffused slowly on a global scale
but rather rapidly in certain local contexts. Hong Kong-based Octopus smart card and payment platform is the pioneering example of the latter. The results show that the scope expansion of platforms from public transportation to micro-payment systems has significantly accelerated and helped to enhance diffusions of the Octopus and Taiwan-based EasyCard platforms. The London-based Oyster and Dutch OV-chipkaart platforms have limited their scope to the public transportation and mobility sectors for the present. Our findings suggest that the most prominent and proven global scaling-up mechanism has been the replication of successful platform settings and operations into other locations and contexts.

This study identified the different approaches to utilising technological platforms for innovation. The approaches were based on decisions made within various organisations, indicating the importance of these managerial decisions in terms of platform expansion. A significant enabler for studied spatial smart card platforms was that they were implemented in certain limited spatial contexts where the major public transportation operators were committed to the platform from the very beginning. From a theoretical perspective, the empirical data analysed in this paper provide new knowledge about the use of technological platforms to enable innovation. This study extends platform management research by demonstrating the use of spatial smart card platforms in public transportation. Spatial smart card platforms share similar transaction leverage logic as global payment cards.

An open question arising from this study for smart societies is that how many smart card platforms are needed in a society, not only for mobility but also for example for identification, touristic use and as an access to public services? Transaction leverage logic indicates that the more services are integrated onto one card, the more convenience and value it has for the user, the more users are joined the platform and the more revenue are generated for service providers. Thus, societal platform externalities for sustainable mobility and for regional economy necessitate centralising into one or few smart card platforms across the regions and the sectors of application.

This paper was limited to four case studies, which itself justify the need for further research on this topic. Future studies could deepen the existing knowledge of public transportation smart card platform strategy options and reflect on the factors affecting future global diffusion. Such studies may address spatial mobility smart card platforms, spatial multipurpose smart card platforms, convergence with global platforms in telecommunications or the financial sector, such as mobile phones or contactless bank cards, or other technological or social innovations.

**Acknowledgements**

The abstract of this paper has been presented and published at the MakeLearn & TIIM 2015 Joint International Conference Managing Intellectual Capital and Innovation for Sustainable and Inclusive Society, held in Bari, Italy, 27–29 May 2015. The authors are grateful for the financial support of Tekes, the Finnish Funding Agency for Innovation.
References


