Fare Collection and Fare Policy

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No longer do mass transit riders have to fumble for coins, a line of angry commuters stretching behind them. Most transit systems are making use of new technology to make payment faster and easier. There are a variety of payment technologies to consider: smart cards are becoming mainstream, international technology standards are progressing, and near field communication – the cutting edge of fare payment technology – is increasingly being enabled in mobile devices.

As a result of these innovations, fare policy is now limited only by institutions and ideas. Automated fare technology can bring substantial benefits to transit operators, including the potential for virtually limitless fare structures. Also, newer technologies have significantly lower life cycle costs than older ticketing systems. This paper reviews the range of transit ticketing systems and fare policies in operation or soon to be implemented in the cities represented at the 2013 Transit Leadership Summit: Hong Kong, Montreal, New York, Seoul, Singapore, Vienna and Washington, D.C.[1] By discussing the benefits of new capabilities in the context of these major transit agencies, this report aims to highlight how transit agencies might learn from one another as they consider future fare policies and structures.

Table 1 briefly describes the fare payment technology used by, and planned by, Transit Leadership Summit participants.

Technologies and Potentialities

Table 2 shows the variety of potentialities – fare products, data observations and passenger conveniences – that are available with different types of automated fare collection. Magnetic stripe cards, which require a physical swipe, have been common in transit systems for more than 30 years. Smart cards, first introduced in the late 1990s, are microprocessor-embedded devices issued by the transit agency that communicate with readers at a very short range so that they do not have to touch the readers, i.e., they are contactless. Smart cards may be configured for use only in a transit system (such as in Montreal and Washington, D.C.) or they

1 This report is informed by questionnaires completed by representatives from MTR Corporation (Hong Kong), Agence métropolitaine de transport (Montreal), Metropolitan Transportation Authority (New York), Seoul Metropolitan Government (Seoul), Land Transport Authority (Singapore), Wiener Linien (Vienna), and Washington Metropolitan Area Transit Authority (Washington, D.C.).

Table 1: Fare Payment Technologies

City, Transit Agency	Primary Fare Technology	Fare Structure*	Recent Developments or Future Plans
Hong Kong, MTR	Smart card	Distance-based	Considering open payment/NFC
Montreal, AMT	Smart card	Distance-based	Considering Open Payment/NFC
New York, MTA	Magnetic stripe card	Flat fare	Has piloted Open Payment/NFC
Seoul, SMG	Smart card & Open Payment/ NFC	Distance-, Time- and Mode-based	Mid-2000s reorganization integrated fare systems
Singapore, LTA	Smart card	Distance-based	Plans to reduce redundancies among multiple operators via cloud computing
Vienna, W.L.	Photo-card yearly pass; honor system	Zone-based	Considering multi-function smart card
Washington, D.C., WMATA	Smart card	Distance-based	Implementing Open System/NFC

* Fare structure: Note that all transit agencies have more complex fare structures than shown in this table. The table reflects the *primary basis* for fare prices. Transit operators may also provide concessions by passenger class, free or reduced transfers, discounts for bulk purchases, period passes, benefits for retail-related loyalty, different fares depending on payment media, and other variations.

may be accepted for small purchases such as for retail and parking (in Hong Kong and Singapore). Open payment/NFC refers to transit operators using readers that accept payment from third party smart cards (such as MasterCard PayPass or VISA Wave) and near field communication-enabled mobile phones (referred to in the industry as NFC).

Of the Transit Leadership Summit participants, most use smart cards (Montreal, Hong Kong, Washington, D.C., Singapore and Seoul). New York City uses a magnetic stripe system; Vienna uses a time-stamp paper ticket and cardboard yearly pass with a photograph and the honor system, and is considering a smart card system. Seoul has incorporated open payment/NFC with its smart card system, and Washington, D.C. is planning to transition to open payment/NFC systems in the future. None of these operators uses all of the potential applications listed in Table 2, either due to explicit policy, proprietary agreements restricting the use of technology, or political considerations.

Table 2: Potential Applications of Fare Technologies

Potential Applications	Magnetic Stripe	Smart Card	Open Payment System / NFC
Discounts by passenger class (senior, student)	x	x	x
Daily, monthly passes	x	x	x
Seamless intermodal transfer (a)	x	x	x
Distance-based fares	x(b)	x(b)	x(b)
Time-of-day-based fares	x(c)	x	x
Real-time origin and destination data		x(b)	x(b)
'Best Fare' policy(d)		x	x
Use fare card as debit/credit card		x	
Use fare media for retail purchases, parking, tolls, bike share		x	x
Use credit card for transit system entry			x
Use mobile phone for transit system entry			x
Fare cards are insurable	x (e)	x	n/a
Passengers top up cards, check past transactions online		x	x
Use employment/student identification cards for transit system entry			x
Personalized marketing (f)	x(g)	x	x

(a) Seamless Intermodal Transfer: Passengers can transfer between buses and trains without acquiring a ticket or other proof of payment.

(b) Distance-based fares and real-time origin and destination data collection require the passenger to swipe or tap (also called "tag") at egress (when exiting the station or bus). Among Transit Leadership Summit participants, Singapore and Seoul require tapping when exiting all modes; Hong Kong and Washington require it for rail only; Montreal and New York City do not require interaction with readers when exiting any mode.

(c) Time-of-day-based fares could be accomplished with a magnetic stripe system, but it would preclude other functions such as daily passes simultaneously. This is because the magnetic stripe system cannot access more than one 'purse'; while the cards can potentially hold both a monthly pass and cash, for example, one of those 'purses' must be expended before the other can be accessed.

(d) "Best Fare" policy refers to restricting the total amount a passenger can pay in a given duration. In London, for example, passengers using multiple single-journey fares find the total they've paid at the end of a day capped at the price of the daily pass.

(e) Each magnetic stripe card has a unique serial number that could allow for insurability.

(f) Personalized marketing based on data from fare collection may be restricted by regulations intended to preserve privacy. Some data (i.e. gender, residential location and consumer behavior) may be collected by transit operators when passengers register their smart cards, or by third parties when passengers use their credit cards. These data may not be linked, however, depending on regulations of both the credit card/payment industry and transit agency jurisdiction.

(g) Magnetic stripe or simple cardboard cards can be linked to a specific passenger who pays by automated debit. For example, in Vienna, passengers use cardboard cards with their photos affixed and the transit operator markets directly to these passengers using data provided when setting up automatic payments for yearly passes.

Benefits of Advanced Fare Technology

Advanced fare technology offers a wide range of benefits. For passengers these include convenience, and for the operators better ways of managing demand and/or addressing equity concerns through differentiated fares, cost savings, revenue-raising and improved data collection.

Passenger Convenience & Throughput

Conventional level of service indicators for transit agencies are speed, reliability, frequency and coverage. Advanced fare technology can provide improvements to speed of ingress. In Singapore, for example, commuter throughput at train stations doubled when the system switched from magnetic stripe to contactless smart cards. Bus dwell times (the time spent at the curb waiting for passengers to pay and take their seats) are reduced as well. In Seoul, the T-money card permitted more complex transfer allowances, distance-based fares and pricing, resulting in faster buses (by 8.3 percent) and more bus riders (by 1.6 percent). An equally important improvement that results from advanced fare technology is increased passenger *convenience*.[2] Passengers using smart cards pay less frequently and have more choice in how they pay; they can refill cards automatically from their bank accounts and can attach transit cards to credit cards. NFC-enabled phone users purchase fares directly from any NFC-enabled poster or sign, including from maps. Passengers handle their cards less often; entry and exit are made without removing the card from a wallet or handbag. Smart cards come in many forms such as fobs, bracelets, mobile phone cases and other devices that are easier to access than cards. Open payment systems further expand convenience by decreasing the number of separate payment media a passenger must carry, and increasing the information directly available to passengers regarding routes and arrival times. These improvements may seem peripheral to transit system operations, but there is evidence that they attract and retain passengers. Passenger experience may be a greater determinant of travel behavior than conventional metrics; passenger attitude is largely shaped by features such as convenient payment systems, and passenger attitude helps explain mode choice.[3]

2 Vienna's system, while not an "advanced" fare technology, is able to offer many of the same conveniences listed here because of its gate-free honor system and use of ancillary internet-based payment applications.

3 Van Acker, V., B. Van Wee, and F. Witlox. "When Transport Geography Meets Social Psychology: Toward a Conceptual Model of Travel Behaviour." *Transport Reviews* 30 2 (2010): 219-40; Kitamura, R., P.L. Mokhtarian, and L. Laidet. "A Micro-Analysis of Land Use and Travel in Five Neighborhoods in the San Francisco Bay Area." *Transportation* 24 2 (1997): 125-58; Shankelman, Jessica. "Public Transport Gets Smart." *The Guardian,* January 8, 2013.

Differentiated Fares

Advanced fare technologies vastly increase the potential fare structures available to transit agencies. Single-journey tickets or tokens are restricted to a single price. Magnetic stripe cards can provide period passes (such as monthly passes) or bulk discounts (e.g., 10 percent bonus for purchase of $20 or more) and may be enabled for zone charges. Smart cards and open payment/NFC systems enable the transit agency to charge different amounts depending on the time of day, mode, route, number of transfers, and (where passengers tap their cards at exit) by fine gradations of distance. These differentiated fares, when informed by rich data sets provided through advanced fare technology (discussed below), can be used to manage demand, increase revenue and address equity considerations.

There is a wealth of literature around the use of price to manage demand. The full body of evidence and theory will not be explored here; much of it reinforces the general principle that fare price can shift ridership patterns enough to moderately reduce crowding and increase operational efficiency in the long term.[4] Along with simple peak period pricing, transit operators can use differentiated fares to exploit different sensitivities to fare price by payment method, income class and fare structure.[5]

New fare technologies expand the potential for addressing equity concerns and raising revenue by differentiating fares by passenger class. Most agencies offer reduced fares to students, seniors and disabled passengers using specialized cards. In some cases the transit operator internalizes the cost of the reduction, while in others it is paid by a government agency that administers programs for students, seniors or the disabled. While reduced fares are possible with conventional fare technology, advanced technologies can make them more convenient and flexible. Instead of requiring a station agent to visually confirm a discount pass, advanced fare payment systems read the pass and process the appropriate fare. Open payment systems can be interoperable with smart cards provided by social service agencies. For example, in Germany, France and other countries citizens are issued a smart card for use of the healthcare system; in the U.S., "food stamp" cards are embedded with microprocessors; these could potentially be used for free or reduced transit access for certain passengers, perhaps according to a reimbursement arrangement with the social service agency. Colleges and universities regularly issue smart cards as student identification as well as to ration printing, gain access to facilities, and receive discounts from retailers; these could be accepted on transit as well. Washington, D.C. has a complex fare structure to address differing abilities to pay that could be rationalized by using smart cards. Currently, low income jurisdictions sell lower priced fares locally and reimburse the transit agency (WMATA) for the difference. By directly subsidizing the passenger, rather than all travelers originating in the low-income jurisdiction, WMATA could create

4 For a review of fare elasticities, see Button, K. *Transport Economics*. Northampton, MA: Edward Elgar Publishing, 2010, and Balcombe, R., et al. *The Demand for Public Transport: A Practical Guide*. London: TRL Limited (2004).

5 Taylor, Kendra C., and Erick C. Jones. "Fair Fare Policies: Pricing Policies That Benefit Transit-Dependent Riders." Ed. Johnson, Michael P. Vol. 167. *International Series in Operations Research & Management Science*: Springer New York, 2012. 251-72; Hensher, D.A. "Establishing a Fare Elasticity Regime for Urban Passenger Transport." Journal of Transport Economics and Policy (1998): 221-46.

a more equitable, simplified and expanded system. Passengers in need could be directly subsidized through a social service office, employer or institution which in turn purchases full-fare passes from WMATA. Because smart cards can be remotely programmed, it is possible to personalize the level of fare discount benefits. For example, when an unemployed passenger finds a job, his smart card could be updated from charging discounted "job search"-level fares to charging the full fare, or perhaps a discounted fare for a low wage job.

Overpayment can become a problem as fare structures become more complex.[6] Smart cards and open payment systems can enable a "best fare" policy wherein a single passenger does not exceed a given expenditure limit on transit fares in a set duration. For example, London's "capping" system corrects the problem of passengers purchasing incorrect fares and spending more than necessary for a trip.

Both "social fare" policies discussed here – a "best fare" policy that guarantees the price regardless of ability to pay for all trips in advance, and a set of discounts available to lower income and marginalized groups – would free transit agencies from the affordability and equity considerations that have historically depressed base fare prices. Transit systems that were built prior to magnetic stripe technology – including New York and Vienna – historically used a single flat fare for all journeys. The base fare was kept low to maximize overall affordability, with extra concessions for seniors, students and the disabled. New technology enables transit operators to consider higher fares as socially just when implemented alongside expanded discounts.

The adoption of these social policies must be weighed against the effect on revenue and diversion from transit agencies' core mission. It would require a shift to an explicit statement of institutional goals for affordability, not often considered by transit agencies, along with demand management and cost recovery. Among the agencies surveyed for this report, all provide discounts for seniors, students and the disabled, but none includes affordability in its fare-setting formula.[7] Only Singapore explicitly addresses affordability in its fare policy. There, the Public Transport Council estimates the burden of the fare on a representative household in the second-income quintile to determine whether the fare is becoming less affordable.[8] As income inequality grows in urban areas, fare affordability is becoming a more relevant and more complex metric.[9]

Transit operators may be institutionally disinclined to address affordability and interagency concessions. Transit agencies often tout their ability to operate "like a business," unlike typical government agencies. "Social fares" emphasize that transport is a public service that in some cases is delivered based on need rather than ability to pay. This may be ideologically uncomfortable for transit agencies. The prospect of "social fares" also raises the issue of transit agencies entering agreements with non-transit government agencies, specifically inter-agency reimbursement relationships. Inter-agency relationships require resources management and political acumen, and may not be viewed as central to the transit operator's goals.[10]

Operational Cost Savings

Smart card and open payment/NFC systems generally cost less to operate than conventional ticketing technology. There is no comprehensive analysis of costs available; transit agency organizational structures vary widely, and each agency accounts for fare collection costs differently.[11] Anecdotal evidence and a review of the literature suggests a few generalizations: the capital cost of smart cards is higher than magnetic stripe or paper tickets,[12] but life-cycle costs are dramatically lower; likewise, the initial capital expenses of installing new readers is more than compensated by declining costs of collection. While a comparative cost-per-transaction is not known, and there are fees related to each transaction, in general costs have declined with new fare technology. In Singapore, agency expenses related to fares and ticketing (life-cycle costs) declined by 6 percent after implementation of smart cards. In Hong Kong, the cost of operating magnetic stripe technology is at least double the cost of the smart card system. Part of these savings is due to lower cost for ticket recycling, equipment maintenance, cash handling and the cards themselves. Hong Kong began phasing out magnetic tickets in 2013. In Washington, D.C., for example, the average cost per dollar for collecting cash fares is more than twice the cost of collecting credit/debit fares ($0.10 versus $0.04). Accepting cash slows the transaction process time, and requires a very labor-intensive cash handling process. Credit card fees are low by comparison.

Other cost savings are derived from lower maintenance expenditures. Smart cards are much more durable than magnetic tickets; in Hong Kong, smart cards need to be replaced after 30,000 cycles (trips with use at entry and exit) while magnetic tickets only last about 60 cycles. In Singapore, the failure rate for smart cards is one in 25,000 transactions compared to one in 5,000 for magnetic stripe cards.[13]

Finally, the cost of the fare media is rapidly declining. In Singapore, a new smart card that cost $4.00 SGD in 2009 is now $1.80 SGD.[14] An open payment system reduces costs further by minimizing in-station ticketing infrastructure and the number of cards a transit operator issues. It also off-loads back office revenue allocation as the transit agency becomes one of many merchants

6 Lathia, N., and L. Capra. "Mining Mobility Data to Minimise Travellers' Spending on Public Transport." ACM KDD, San Diego, California (2011).

7 Hong Kong, Singapore, Montreal and Washington, D.C. use a fare setting formula that accounts for costs and wages. The fares are adjusted according to the formula with some regularity, although the timing and frequency of adjustments may not conform to an established schedule.

8 In the U.S., transit operators comply with federal regulations (Title VI) by examining whether changes to fare structure disproportionately burden racial/ethnic minorities. They must also ensure that discounts are available to all regardless of ability to pay. While these in effect produce lower and therefore more affordable fares, the policies do not require examining affordability per se. Fares are therefore maintained at universally low levels for universal affordability.

9 Vasconcellos, E.A. *Urban Transport, Environment and Equity: The Case for Developing Countries*. London: Earthscan Publications, 2001.

10 Despite the ideological challenge, some transit agencies are leveraging advanced fare technology for social fares. Reisman, Will. "Muni and Other Agencies Consider Basing Fares on Income." *The Examiner,* November 30, 2012.

11 In the U.S., the Smart Card Alliance has attempted to consolidate information on costs. See "Planning for New Fare Payment and Collection Systems: Cost Considerations and Procurement Guidelines": Smart Card Alliance, March 2010.

12 A full-featured contactless smart card costs between 90 cents and $1.00 to produce, which is 25 times more expensive than a magnetic stripe card that costs four cents on average. Quibria, N. "Emerging Payments Industry Briefing: The Contactless Wave: A Case Study in Transit Payments." Boston, MA: Federal Reserve Bank of Boston 9 (2008).

13 Prakasam, S. "The Evolution of E-Payments in Public Transport's Experience." *Japan Railway & Transport Review* 50 (2008): 36-39.

14 $4.00 SGD equals approximately $3.20 USD or €2.48. $1.80 SGD equals $01.44 USD or €1.12

in an established payment-system architecture. Washington, D.C. anticipates substantial cost savings when it implements its planned open payment system. The savings will come from shedding a proprietary technology, reduced reliance on agency-issued fare media and increased availability of self-service functionality.

Data Collection

Automated fare collection creates data on station entry that can help transit operators diagnose crowding as well as route and station underutilization. Smart cards are capable of storing considerably more data than magnetic stripe cards: with magnetic or other stored value "memory" cards, the data stored is limited to the number of memory cells. Magnetic stripe cards can typically carry about 140 bytes of data, while smart cards carry anywhere from 1KB to 5MB. Smart cards include microprocessors which are capable of performing multiple functions. Smart card and open payment/NFC systems also enable agencies to adopt account-based models where data are stored on the host system and not on the card.[15] Smart card data can thereby show individual passenger flows, allowing a more robust investigation of travel behavior and greater ability to estimate and manage demand.[16] When coupled with exit gate tapping, operators can observe the origin and destination of journeys in real time.[17] These data are regularly used by transit agencies, including those represented at the Transit Leadership Summit, for daily operations, strategic planning, and transport demand modeling. Finally, open systems can match travel patterns with consumer behavior, creating data sets of great value to marketers.

Despite improved potential data collection, transit agencies with even the most advanced fare systems may not realize the full benefits of that potential. Transit operator use of the data often depends on institutional, rather than technical, arrangements. For example, a back office "data warehouse" may be operated under a proprietary agreement that precludes easy access to data for transit agency managers. The use of data to inform routing, scheduling or fares may also be impeded by institutions that are reluctant or lack the capacity to utilize the data (as in Singapore). In open systems, credit card privacy regulations prevent linking personal data with trip patterns: in Hong Kong, the benefit of the data collected accrues mainly to the private, retail-oriented corporations that accept Octopus cards. Thus despite a wealth of new data, institutional arrangements – largely established prior to implementation of advanced fare technology – restrict realization of the benefits of these data. Some transit agencies – including in Washington, D.C. and Hong Kong – are using voluntary passenger registration to collect more data: passengers can opt-in to a registration system wherein they agree to make some passenger-level data available for the operator's use. Transit agencies have used incentives, including card discounts, to encourage registration. However, these methods involve self-selection and therefore may not be valid for all purposes.

15 Account-based models are also possible in low-tech, honor systems such as in Vienna.
16 Elliott, Mark. "High Performance Meets Intelligence: The Importance of Advanced Fare Management." *Mass Transit* February 11, 2011.
17 Entry-only systems can use algorithms to link passenger station origins with likely destinations. This is true of both magnetic stripe systems such as New York City and smart card systems such as Montreal.

Common Experiences and Lessons Learned

Each transit agency approaches the issue of fare technology and fare structure in its unique historical, institutional and political context. Its existing physical infrastructure and regulatory climate shape the options that a transit agency can realistically pursue. The agencies at the Transit Leadership Summit represent a wide variety of contexts, each presenting its own challenges to implementation of new technology or innovative fare structures. There are several commonalities, however, which may be informative for agencies regardless of context.

Beware of proprietary arrangements

For transit operators, off-the-shelf technology can be very attractive. Developing technology in-house can be expensive, redundant to efforts already underway in the payment industry, and can distract from the transit operator's core mission. Buying technology, however, often requires entering a proprietary arrangement which can inhibit flexibility. Singapore's experience with Sony FeliCa smart cards is informative. The off-the-shelf technology was successful for seven years (2002-2009) but ultimately proprietary restrictions limited the scope of applications. Only after developing a set of national standards could Singapore begin charging distance-based fares by the kilometer, for example. Seoul and Washington, D.C. had similar experiences: in Seoul, the proprietary MiFare card limited intermodal transfers and fare structure complexity; in Washington, D.C., the Cubic GoCard chip technology became obsolete and was no longer manufactured, requiring an expensive hardware and software retrofit to read and process a new contactless chip. Washington, D.C. and New York exemplify how proprietary arrangements can limit back office data management. Restricted to a single vendor and outdated hardware, the transit agency is unable to access real-time data or even updated origin and destination flows without a tedious process. Any change to the fare structure is expensive for the transit agency in both cost and time.

Expect passenger acceptance

In all cases studied for this report, passenger acceptance of new fare technology quickly exceeded expectations: pilot projects with small groups of commuters proved successful, and passengers using the first stations with available readers adopted the new technology quickly. Fare incentives can spur usage, but *agencies report passenger convenience as the most important factor*.

Specifically, both Hong Kong and Washington, D.C. found that the ability to maintain higher stored values on smart cards was the convenience that led many passengers to switch to the new technology; in Washington, D.C., the further improvement in card durability (from paper magnetic stripe cards to smart cards) led to passenger acceptance. This is the case even though advanced fare technology often provides less information at the reader – the point of use – than conventional fare payment. Contactless smart card readers can provide remaining balance information when the passenger taps the card at the gate, but not all do; open payment systems generally do not provide this information at the gate. The cost of the trip is generally only available through station-based kiosks and online/mobile applications, rather than at the turnstile. Also, distance-based fare structures do not allow passengers to easily know the cost of the journey before embarking. Discovering the cost requires using a trip planning tool or reading a complex matrix. There is evidence that this switch from information provided at the turnstile to information-on-demand has little effect on passengers (except to speed ingress). In Washington, D.C., a survey of smart card users found that passengers were ignorant of the amount left on their cards at any given time, but did not consider it a substantial problem.

The cash fare can be accommodated

To comply with universal service obligations, transit agencies must provide a way for passengers to pay cash for their fare. The potential for differentiated fares raises the additional problem of equitable fare prices for those passengers who will continue to pay for a single journey with single-use fare media: unbanked[18] passengers, infrequent travelers, and the unplanned trip. Transit agencies must consider the extent to which they can justly offer discounts to non-cash users. For example, only about half of urban residents in the U.S. have smart phones.[19] A discount for NFC-enabled devices, therefore, may not be politically acceptable or socially just, even though fare collection through NFC costs the agency much less than conventional fare collection.
Single-trip tickets represent a small and shrinking share of fare transactions. In Singapore, only 2.5 percent of passengers purchase single-journey tickets in the station; in Washington, D.C. it is less than 10 percent. In Hong Kong, 94 percent of passengers use smart cards, and in Montreal around 90 percent. Advanced fare technology decreases the share of passengers using cash by attracting them with greater convenience and boarding speed.
In addition, for most of the cities participating in the Transit Leadership Summit, the unbanked population is a relatively small group.[20] Urban populations are more likely to have bank accounts and smart phones than rural populations.[21] Nevertheless, this group must be accommodated by providing an alternative to using bank cards, credit cards and mobile phones for payment. Retailers can sell *low-balance cash cards* compatible with both magnetic stripe and smart card readers. Consumers are already familiar with these cards as gift cards, welfare cards and campus cards. These general-purpose prepaid cards do not require a bank or credit card company relationship. They can be topped up with cash at retail outlets and with the issuing institution.[22] To cover the cost of the card, transit agencies may (as many do now) charge $1 or $2 for the initial purchase of the card and may choose to reimburse the passenger for that amount, along with any remaining balance, when it is turned in. This last step (infrequently pursued by passengers) could be accomplished by retailers, or by mail and with checks or wire transfers, eliminating the necessity for station agents to handle cash.

Multiple technologies can coexist

New technologies can be implemented incrementally. Not all passengers must change their behavior at one time, and not all technology must be replaced en masse. Introducing a new fare technology system to passengers usually occurs in stages. There is often a pilot phase which tests the technology with a group of commuters, university students or government employees.[23] This is followed by a public awareness campaign to widely introduce the technology to passengers.[24] Finally the new readers, information booths and other infrastructure are installed in stations, and the new fare media is sold. While integrating legacy systems comes at a cost, systems can operate with older methods of fare payment in tandem with the new method over a fairly long transition period. *Smart card and NFC readers have been successfully integrated with magnetic stripe technology* in Hong Kong, Montreal, Seoul and Washington, D.C. In Montreal, for example, some of the transit operators in the AMT region added smart card readers to their existing magnetic stripe readers, while others replaced their readers with new ones that had both magnetic stripe and smart card capability. NFC readers are now available that use the same infrastructure as smart card readers.

Institutional intransigence limits the benefits of new technology

From the passenger's perspective, the convenience of new fare technology is realized as soon as readers and fare media are available system-wide. From the agency's perspective, however, the benefits (other than cost savings) may require

18 Passengers without a bank account.

19 The share of urban residents with smart phones grows each year, as does the income diversification of this population: Pew finds that lower- and middle-income urban residents are discontinuing land lines and cable television in favor of smart phones. Horrigan, J. "Home Broadband Adoption 2009." *Pew Internet & American Life Project* (2009).

20 The percent of adults holding an account at a formal financial institution are: 88.7 in Hong Kong, 95.8 in Canada, 88.0 in the United States, 93.0 in South Korea, 98.2 in Singapore, and 97.1 in Austria. In the New York-New Jersey metropolitan area, 9.7 percent of households or 700,000 are unbanked. Demirguc-Kunt, Asli and Leora Klapper, 2012. "Measuring Financial Inclusion: The Global Findex Database." *World Bank Policy Research Working Paper 6025*, World Bank, Washington; Burhouse, S. and Yazmin Osaki. "National Survey of Unbanked and Underbanked Households." *Federal Deposit Insurance Corporation*, September 2012.

21 Chaia, A., et al. "Half the World Is Unbanked." *Financial Access Initiative Framing Note*. Washington (2009); Horrigan, J. "Home Broadband Adoption 2009." Pew Internet & American Life Project (2009).

22 A Guide to Prepaid Cards for Transit Agencies: Smart Card Alliance, February 2011.

23 For example, last year, Philadelphia began rolling out a smart card system by first issuing renewable smart cards only to students and university employees and a small pilot group of commuters. It was later expanded to monthly pass buyers and then weekly pass buyers at certain venues. Vending machines will be the next stage. Schmitz, Jon. "Pa: Weekly Transit Passes Now Smart Cards." *Pittsburgh Post-Gazette* December 21, 2012.

24 Singapore focused on stakeholder buy-in when replacing the magnetic card system. It took nine months. Student cards and a commuter pilot period were important, along with passenger education. Prakasam, S. "The Evolution of E-Payments in Public Transport's Experience." Japan Railway & Transport Review 50 (2008): 36-39.

institutional shifts to fully realize. Institutional arrangements can limit the extent to which the technology is used for innovative fare structures, or how data is mined for improved operations or marketing. Advanced fare technology lends itself to experimentation: There are myriad fare structures available and data can be gathered at a very fine level. Experiments with innovative fare structures are difficult to accomplish, however. Some transit agencies must undergo a political process to change fare prices, while others are tied to a formula; changing fare structure is complex and politically charged in all cases. Issues of fraud and cost can present political hurdles even when there are feasible solutions. The use of data is likewise constrained by the parties using it. As discussed above, contractual arrangements and regulations intended to promote security can create barriers to an agency's access to fully disaggregated travel behavior data.

Conclusion

As the payment industry advances, passenger expectations are likely to change. Passengers are already learning to expect transit systems to provide real-time arrival information, interactive maps, and seamless intermodal and inter-agency transfers. The payment industry is further raising consumer expectations for fast, contactless, cashless payments; rewards for frequent purchases; easy transaction tracking; and negative balance protection. Transit operators in Singapore, Hong Kong, Seoul and other major cities have found that incorporating these features into their transit ticketing technology has boosted passenger convenience and operational efficiencies. Transit operators planning to adopt new fare technology in the future, such as those in New York and Washington, D.C., hope to maximize the benefits of new technologies. There are challenges for all involved. Proprietary arrangements can undermine operational cost savings and the potential benefit of improved data collection. Institutional structures can limit innovative fare structures and experiments with routing, scheduling and fares enabled by both the payment technology and data collected with it. These structural impediments to change must be addressed alongside decisions regarding fare technology implementation.

Appendix: Advanced Fare Technology Studies

Improving Fares and Funding Policies to Support Sustainable Metros

Argues that transit operators would benefit from a more principled approach to fare setting and regulation. Fares should be adjusted regularly and systematically; fares should better reflect the costs of inputs and affordability, support the imperative to renew assets and enhance service quality and, through differential pricing, more closely reflect the variable cost of travel.

Anderson, R. et al. *Improving Fares and Funding Policies to Support Sustainable Metros*. Transportation Research Board 91st Annual Meeting. 2012.

Pervasive Technology and Public Transport: Opportunities Beyond Telematics

Reviews the range of advanced traveler information systems that provide real-time information to passengers. The range includes static and dynamic versions of transit agency data as well as crowd-sourced data. Also discusses the benefit of in-transit services such as Wi-Fi connectivity, as compared with conventional operational improvements.

Camacho, T., M. Foth, and A. Rakotonirainy. "Pervasive Technology and Public Transport: Opportunities Beyond Telematics." *Pervasive Computing, IEEE* 99 (2012): 1-8.

Avoiding the Crowds: Understanding Tube Station Congestion Patterns from Trip Data

Devises a simple tool to predict crowding on a per-station basis using one month of data from London's Oyster cards. In residential stations, there is a steep morning peak period where passengers enter the station, and a less-steep evening peak when passengers exit; in business district stations, the pattern is reversed. In transport hub stations, the peaks are consistently steep at both morning and evening. Evening peaks are further characterized by three distinct sharp peaks at 30-minute intervals, suggesting both business and social adherence to hourly schedules. Considers how providing information to passengers on crowding might alter travel behavior, relieving crowding and better utilizing trains at the shoulders around peak periods.

Ceapa, I., C. Smith, and L. Capra. "Avoiding the Crowds: Understanding Tube Station Congestion Patterns from Trip Data." Proceedings of the ACM SIGKDD International Workshop on Urban Computing. (2012).

Establishing a Fare Elasticity Regime for Urban Passenger Transport

Estimates cross-elasticities for mode and fare classes (single- vs. multi-trip ticket) using an extensive survey from metropolitan Sydney and advanced microeconomics techniques. Finds that increasing the price of a multiple-trip transit ticket leads to higher revenue growth and smaller patronage declines than increasing the price of single-trip tickets, especially in bus riders. Also finds that passengers are more likely to switch modes (train to bus and vice versa) than to switch fare classes. Changes in public transport fares regardless of fare class do not necessarily lead to greater car use, whereas changing the cost of car use does affect the use of public transport.

Hensher, D.A. "Establishing a Fare Elasticity Regime for Urban Passenger Transport." *Journal of Transport Economics and Policy* (1998): 221-46.

Consumer's Perception of Fare When Using Farecard in Urban Railway Route Choice

A statistical analysis of attitudinal data for passengers on non-work trips on Tokyo's rail system. Tested hypotheses related to how passenger price perception varies according to payment method and fare media. Findings are mixed, but overall finds smart card users perceive the price of travel as lower than regular ticket users. Includes a literature review on fare media and payment methods and finds very little research on the subjects, suggesting a need for further study.

Kato, H., et al. "Consumer's Perception of Fare When Using Farecard in Urban Railway Route Choice." National Research Council (U.S.). Transportation Research Board. Meeting (82nd: 2003: Washington, D.C.).

Modeling Transit Rider Preferences for Contactless Bankcards as Fare Media

Surveys from Transport for London and Chicago Transit Authority show that most riders prefer to use transit agency-issued fare media rather than bank-issued smart cards to pay their fare. In its 2009 survey, TfL showed that 55 percent of riders prefer the TfL (Oyster) card, 31 percent prefer contactless bank cards, and 14 percent prefer the paper tickets. In a 2008 CTA survey, passengers were asked how likely they would be to use contactless bank cards to pay the fare. Forty-eight percent were very unlikely, 15 percent somewhat unlikely, 17 percent somewhat likely, and 20 percent very likely. In both places, those passengers more likely to prefer bank-issued smart cards included younger passengers and those who already have credit and debit cards.

Kocur, G. *Modeling Transit Rider Preferences for Contactless Bankcards as Fare Media: Transport for London and the Chicago Transit Authority*. Transportation Research Board 90th Annual Meeting. 2011.

Mining Mobility Data to Minimise Travellers' Spending on Public Transport

Links ticket purchasing behavior and public transport usage datasets to examine the relation between mobility and purchase habits. Finds that travelers overspend by approximately £200 million per year by buying incorrect fares. Passengers are relatively uninformed; there are few transparent links between passenger class and trip characteristics that reveal the best fare; and travelers have trouble identifying the best way to pay. Develops an algorithm for personalized ticket-purchase recommendations based on travel history data that can be accessed from fare technology.

Lathia, N., and L. Capra. "Mining Mobility Data to Minimise Travellers' Spending on Public Transport." ACM KDD (2011).

Smart Card Data Use in Public Transit: A Literature Review

Reviews smart card and NFC technology, privacy concerns and uses of data by transport operators. Anticipates linking socioeconomic data to the totally disaggregate data produced by advanced fare technology to overcome the privacy regulations preventing exploitation of this data. Finds the most promising research avenues include comparison of planned and implemented schedules, systematic schedule adjustments, and the survival models applied to ridership.

Pelletier, M.P., M. Trépanier, and C. Morency. "Smart Card Data Use in Public Transit: A Literature Review." *Transportation Research Part C: Emerging Technologies* 19 4 (2011): 557-68.

Fair Fare Policies: Pricing Policies That Benefit Transit-Dependent Riders

Analysis of a "best fare" system using smart cards. Finds that capping the aggregated cost of single passenger's trips at the cost of a multi-trip pass would create an equitable system for those passengers who cannot afford to pay for multi-trip passes in advance. Models a "best fare" system coupled with a base fare increase and finds it saves money for low income riders while raising revenue for the transit agency. Research is premised on the idea of multiple elasticities for multiple fare products, rather than broadly characterizing low income passengers as inelastic to fare prices.

Taylor, Kendra C., and Erick C. Jones. "Fair Fare Policies: Pricing Policies That Benefit Transit-Dependent Riders" Community-Based Operations Research. Ed. Johnson, Michael P. Vol. 167. International Series in Operations Research & Management Science: Springer New York, 2012. 251-72.

Controlled Public Transport Fares in the Developing World: Help or Hindrance to the Urban Poor?

Uses data from a transport planning survey of 57,000 households in Cairo, Egypt, to consider public transportation pricing for the urban poor. Referring to several case cities in the developing world and Europe, recommends Cairo incorporate transport into various welfare programs, none of which currently directly addresses transport. Emphasizes shifting subsidies from agencies to passengers.

Thompson, J.E., and K. Nagayama. "Controlled Public Transport Fares in the Developing World: Help or Hindrance to the Urban Poor?" ITE Journal (2005).

Does Transit Mean Business?

Surveyed U.S. transit agencies on the potential for differentiated fares given new fare technology. Finds that political and institutional resistance is the greatest obstacle to marginal cost pricing or any type of variable pricing. Transit agencies are found to be reactive to budgetary pressures, reluctant to change fare structures when changing the price, and focused on avoiding risk and minimizing public scrutiny. Transit agencies hold competing goals and ambiguous missions, leading to reactive rather than rational fare setting.

Yoh, A., B.D. Taylor, and J. Gahbauer. *Does Transit Mean Business? Reconciling Academic, Organizational, and Political Perspectives on Reforming Transit Fare Policies*: University of California Transportation Center, 2012.