THE ROLE OF SMARTCARD DATA IN PUBLIC TRANSPORT

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ABSTRACT

The provision of smartcard systems in urban public transport is expanding rapidly. In addition to operational and marketing benefits, they provide a wide range of data on system usage. At the aggregate level, total ridership can be measured more precisely, and components such as demand by time of day analysed. Anonymised disaggregate data can be used to examine origin-destination patterns, extent of interchange and variations in trip rates per cardholder. However, a number of limitations exist, including data quality, whether exit as well as entry to the system is recorded, and the degree to which comprehensive data on all operators in the same area is obtained. There is still a role for manual data collection, to complement that from smartcards, and identify factors such as ultimate origin & destination, journey purpose, etc. These issues are examined with reference to a number of practical examples in Britain.

Keywords: smartcards, trip rates, interchange, data quality

INTRODUCTION

General Issues

Within this paper an overview is provided of the potential of data from smartcard systems. In many cases, these systems have been introduced primarily for pricing, revenue control and accounting reasons, enabling a wider range of pricing options to be developed, and for more accurate and comprehensive validation of ticket use. This in turn reduces scope for fraudulent travel. In addition, a wide range of other types of data is produced from such systems, the potential of which has not yet been fully explored. In this paper, we examine a number of such developments, illustrated with specific examples. The work described arises from a long-standing interest in measurement of public transport ridership and demand patterns in research the University of Westminster, and in recent years specifically on smartcard systems as such.

TRADITIONAL TICKETING SYSTEMS

Traditional public transport ticketing was based on a cash transaction for each trip made. In the case of bus systems in Britain, each time a bus was boarded a ticket was issued. On rail and metro systems (such as the London Underground) through ticketing to the ultimate destination is more common. In other countries, a cash-paid ‘transfer’ ticket, permitting transfer within the same mode (e.g. bus) or between modes (e.g. bus and tram) within a defined time period has also been common practice.

Such ticketing systems enabled aggregate statistics to be compiled of total revenue and trips made, by route (or station of entry) and time period (such as day of week, or longer periods). In the case of most bus journeys, and some rail trips, time of issue of the ticket also marked (approximately) the start of the journey. However, much rail data (as retained in the current British rail national database LENNON, for example) records the date when a ticket was sold and/or first valid for use, rather than timing of the journey(s) as such.

The development of electronic ticket machines (ETMs) for use in the bus industry in the early 1980s enabled data to be stored for each ticket issued, which could subsequently be downloaded at a depot, enabling detailed analysis by route, time of day, ticket type, etc. (Mellor and White 1987). However, the use actually made of this data appears to have been relatively limited - in practice often confined to traditional aggregate output measures. Even for journeys paid in cash, there are also limitations – for example, in the case of a return ticket, no data was collected on timing of the return leg.

Another limitation of such systems was that use of tickets giving unlimited travel was poorly recorded - for example, passes giving free concessionary travel to groups such as older passengers, season tickets, or travelcards (the last being tickets providing for unlimited travel within defined zones of a network, usually for more than one mode – such as the London Travelcard for underground, bus and surface rail services). In some cases, an average utilisation per period may be assumed, refined by use of sample surveys. In others, principally on bus networks, a button can be operated on ETMs to record each such boarding (but dependent on observation by the driver).

The use of magnetically-encoded paper tickets, such as those still used extensively on the rail system in Britain, enables more accurate validation of use, and permits some types of analysis similar to those found with smartcards to be carried out – such as linking of successive boardings within the same trip, or estimation of trip rates by period card holders. Examples are provided by Hofmann et al (2009). However, as in the case of ETMs, the extent of such analysis appears limited in practice.

THE POTENTIAL OF SMARTCARDS

Basic operating features

Where a smartcard is used in place of a traditional season ticket, travelcard or free travel concessionary pass, in which the number of journeys within a defined zone and time period is unlimited, there is little difference from the users' point of view, except that smartcards (especially of the contactless type) may be marginally quicker and more convenient than displaying a pass, and certainly easier to use than inserting a magnetic card into a ticket reader slot. It is thus unlikely that smartcard use *per se* will make any marked difference to user behaviour at the individual level (for example, to make more trips).

However, from the operator's viewpoint considerable advantages may exist. Especially for bus services, much greater accuracy in validation may be possible than through visual driver inspection, and a more detailed categorisation of card types may be possible. In addition, precise data on time of entry to the vehicle or station may be obtained, and possibly other data (discussed further below).

Smartcard technology also enables the operator (or controlling authority) to introduce greater variation in pricing policy, notably through finer differentiation between peak and off-peak periods, than is possible using manual validation.

More radical changes become possible where the proportion of cash-fare handling can be substantially reduced. This may depend primarily on the scale of price differentials between different ticket products (as in the case of Oyster in London). On rail systems, station staffing may be reduced (subject to the need for a minimum level to supervise entry/exit gates), and on buses reduced dwell time at stops enables faster and more reliable journeys to be operated (together with cost reductions where fewer buses and drivers are needed to maintain a given service frequency). Such improvements may also stimulate increased ridership, estimated through demand elasticities for in-vehicle travel time and for reliability.

Where several operators provide services within the same network, the higher quality of data resulting from smartcard use may give them greater confidence in introducing joint ticketing (such as a common travelcard) given the ability to a allocate revenues. This in turn may enable a higher proportion of off-bus ticketing, and hence the benefits described above. Clearly, this is easier to achieve in a network operated under a common framework, such as the bus services contracted to Transport for London in which a common fare structure and ticketing technology can be specified as consequence.

Evaluation of benefits

It should be noted, however, that different evaluations of the monetised benefits of smartcards may be produced, dependent on whether a comprehensive economic evaluation (including passenger time savings) is being made, or a purely financial one from the operator's perspective (savings in operating costs, and any extra revenue resulting from faster or more reliable journeys). These are evident in the consultation report on smartcards issued by the British government's Department for Transport in August 2009 (DfT 2009a), which produced very large estimates of economic benefits. A total of £2,600m per annum was quoted in its section 12.9, which may compared with total passenger revenue for the local bus industry of about £4,500m in 2008/09 (derived from DfT 2009b, Table 1.1). Of this, £1,414m was in the form of shorter bus dwell times and £927m of reduced road congestion, but only £27m bus driver cost savings.

These issues may be illustrated by a simple example. Suppose an existing bus operation is based purely on cash-based fares, with an average marginal boarding time per passenger of 6 seconds. On a peak journey, some 50 passengers board the vehicle (all alighting at the city centre) giving a total boarding time of 50 x 6 = 300 seconds (5 minutes). If all cash fare transactions are replaced by use of smartcards, at a marginal time per passenger of 1.5 seconds, total boarding time would be reduced to 50 x 1.5 = 75 seconds (1 min 15 seconds), a saving in vehicular journey time of 225 seconds (3 minutes 45 seconds). Dependent on the relationship between round trip time and headway, this might enable the operator to reduce the number of vehicles and drivers needed to maintain a given service level (by definition, if headway were less than 3 minutes 45 seconds, at least one vehicle would be saved).

From the passengers' viewpoint, however, aggregate time savings would be much greater, since each passenger experiences not only the saving in their own boarding time, but that from all other successive passenger boardings. Suppose, for example, that on average each passenger boarding the peak vehicular journey experiences delay caused by 24 other passengers boarding after they have done so (for a peak load of 50, clearly the first passenger to board will be followed by 49 others, the last passenger to board experiencing only their own boarding time: the actual average will depend upon the boarding and alighting pattern). In this case, the average passenger will experience a saving of 25 x 4.5 seconds = 112.5 seconds (1 minute 52.5 seconds). This may be expressed directly in monetised terms by using established values of time (making the usual assumptions about linearity in aggregating small time savings). The reduced total dwell time at stops would also reduce delays to other vehicles held up behind the bus during this process.

New products

In addition to converting existing products to smartcard format, scope exist for new products to be offered, notably a stored value facility enabling less frequent users to gain the benefits of non-cash ticketing, with a deduction each time a journey is made (known as 'pay as you go' in the case of London Oyster). Discounts can be offered *vis a vis* single cash fares, and capping to ensure that costs are no higher than using other ticket types (as in the case of London, where day use of the Oyster is capped below the equivalent cost of a cash-purchase one-day card). In this case, we may expect more noticeable changes in user behaviour, since convenience is greatly increased, and the marginal cost of additional journeys reduced *vis a vis* cash.

New products may also include smartcards offering public transport use with other activities (such as payment for park & ride, parking in general, local authority services, etc.)

Some limitations

A requirement for successful off-vehicle systems (both smartcard and earlier forms) is ease of access to initial purchase and subsequent renewal facilities. Rail and metro stations offer an obvious point of sale, complemented by outlets such as local shops. On-line renewal and purchase greatly widens the scope.

In terms of data collection, a comprehensive record is generally possible where entry/exit gates have to be used (as is the case at almost all London Underground stations). Data may be less comprehensive where open access is provided, and only stored value users may have strong incentives to check in and check out. On buses, entry-only validation is currently the norm in Britain, hence estimates may have to be made through other means of trip length. In cases where fares graduated by distance still apply (the majority of the systems outside London in Britain) and the compensation for concessionary travel is derived accordingly, then it may be necessary for the driver to ask the passenger for their destination, in which case an alighting stage will be keyed in (as is the case in Scotland). However, this negates much of the potential boarding time savings with smartcards, especially where a paper ticket is still issued.

Rail system usage, while potentially picked in up at both entry and exit to the system, may also be affected by incomplete records. Where faults occur in validators or back-up services, or stations are unstaffed (either permanently, or at certain periods), then incomplete trip records may be produced (giving either entry, or exit, but not both trip ends). This can be mitigated by automatic monitoring of equipment to ensure that reliable operation is attained. Whereas the holder of a stored value card generally has an incentive to validate a smartcard on both entry and exit to a system, this is not necessarily the case for cards giving unlimited travel within certain zones and/or periods (travelcards, concessionary passes giving free travel). Checks need to be made on data quality prior to more detailed analysis.

Limitations may also arise through the cost of smartcard systems, and it is notable that almost all examples in Britain have been installed through public funding, with the principal exception of First in Bradford (discussed further below). Indeed, even within the public sector a cautious approach is often taken. For example, the Commission for Integrated Transport has examined replacing Bus Service Operator Grant (in effect, a rebate of 80% of the fuel duty paid for local bus services) by an 'incentive per passenger' scheme, in which a flat rate per passenger would be paid to bus operators. This would clearly require improved data collection, but the Commission's report still recommends use of ETM rather than smartcard systems, on cost grounds (Commission for Integrated Transport 2009).

Management attitudes and those of controlling authorities may also be a factor in exploring the analysis of data and application of policy options emerging. Although a great deal of cost and effort has been put into installation of smartcard systems, relatively little has attention has been paid to their application. For example, a survey by Hobbs and Streeting (2009) of reasons cited for the introduction of 28 smartcard systems in public transport indicated that only five had introduced time-of-day pricing.

There are also limitations on the types of data that may be collected through smartcard systems *vis a vis* manual surveys – for example, journey purpose, or attitudinal data. Smartcard data may be used to replace much routine data collection previously carried out manually (such as trip rates by concessionary pass holders) but such surveys will continue to be necessary for other purposes. It is also important to bear in mind that when reference is made to trip 'origin' or 'destination' derived from smartcard data, these are not the ultimate origins and destinations of the individual traveller, but points of entry and exit to the public transport network. In the case of a network in which all modes and operators are covered by a common smartcard system, then data will be comprehensive at this level, but where coverage is not consistent then an incomplete picture may be given.

Where users access the system within walking distance, then assumptions may be made about the potential catchment areas of stops or stations to identify a broad area within which trips originate or are destined. However, this will not be the case for private motorised access (such as park & ride). There is thus a continued role for direct manual surveys, to obtain data not directly generated by smartcards, and to validate assumptions made in analysis of smartcard data (for example, relationships between time of day and trip purpose; walking distances to/from stations and stops). Conversely, there is much less need than previously for manual surveys to estimate trip rates per card holder, trip making by time of day, or interzonal flows within the public transport network.

THE DERIVATION OF DATA FROM SMARTCARD SYSTEMS

Examples considered here stem from work conducted at the University of Westminster, together with reference to published work by other researchers in this field. Dr Mousumi Bagchi examined two of the earlier systems in Britain – that in Southport (Merseyside) for pensioner concessionary travel, and the system introduced commercially by First in Bradford for a range of bus user types. Results are summarised here, a fuller account being available in Bagchi and White (2005). Subsequent research has focused on the Oyster card in London, now one of the world's most extensive smartcard systems, for which more detailed examples may be found in White, Bagchi, Bataille and Wells (2009).

Aggregate data

The simplest application of smartcard data is to substitute for that routinely collected by operators, usually on a four-weekly cycle, both trips made and revenue collected. In the case of bus services, this usually corresponds to each passenger boarding being counted as a 'trip'. In comparison with traditional data collection, smartcards enable easier identification by time period, route and ticket type (especially between various forms of travelcard or pass).

Aggregation by time period

We can split the market into fine segments by time period (day of week, hour, or shorter intervals), defined by time at which a card was validated for a specific trip. This enables time of day profiles to be compiled for different days of the week (such as Mondays to Fridays, Saturdays and Sundays). Seasonal variations may also be examined. These may also be defined by user type and ticket product loaded on the card (adult, child, pensioner; travelcard, pay as you go, etc.). Such data is of interest in showing smartcard use patterns in their own right, but also becomes representative of the market as a whole as the share by smartcard increases. In the case of bus trips in London, this had already reached 85% by March 2007, although somewhat lower in the case of Underground travel (TfL 2007, pages 26 and 29).

It is also possible to identify the number of individual cards validated on any one day, and hence the average boardings per card on the day they were used. While one might expect this to be close to 2 (i.e. one trip in each direction) it may be practice be somewhat higher, especially on bus systems, since cards are validated each time a vehicle is boarded. Figure 1 shows an example from work by Helene Bataille, of total Oyster card boardings on London Buses for a two-week period in Spring 2008 (avoiding Easter), giving the average pattern on weekdays (Mondays to Fridays). Note that, at that time, children of school age with free travel passes were not necessarily required to validate them on boarding, resulting in potential understatement of their travel at peak recorded, indicated by red circles (a situation since rectified). Similar graphs may be produced for Saturdays and. Sundays, and by user type (child, pay as you go, Freedom Pass, Travelcard).

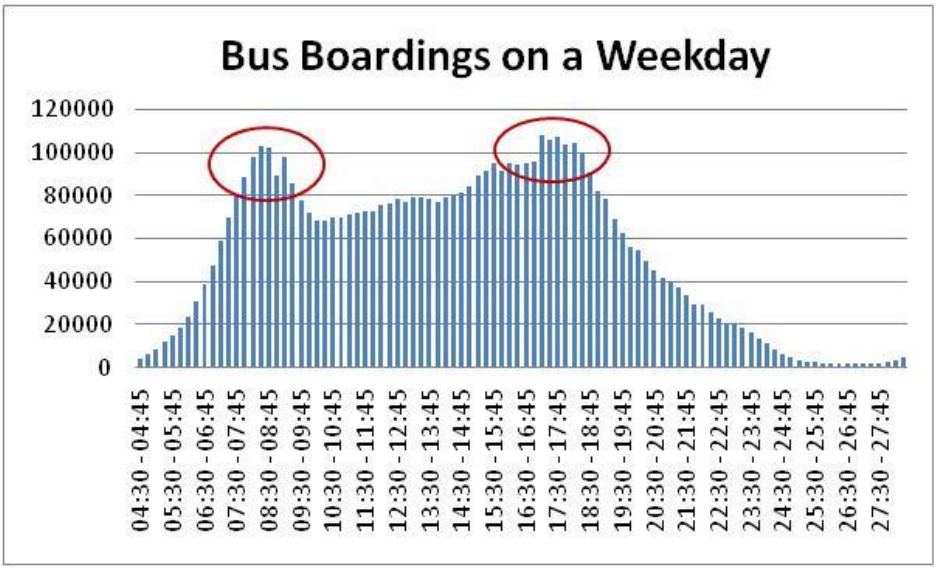

Figure 1: Profile of bus boardings using Oyster cards in London, spring 2008
(average for a two-week period, Mondays to Fridays)

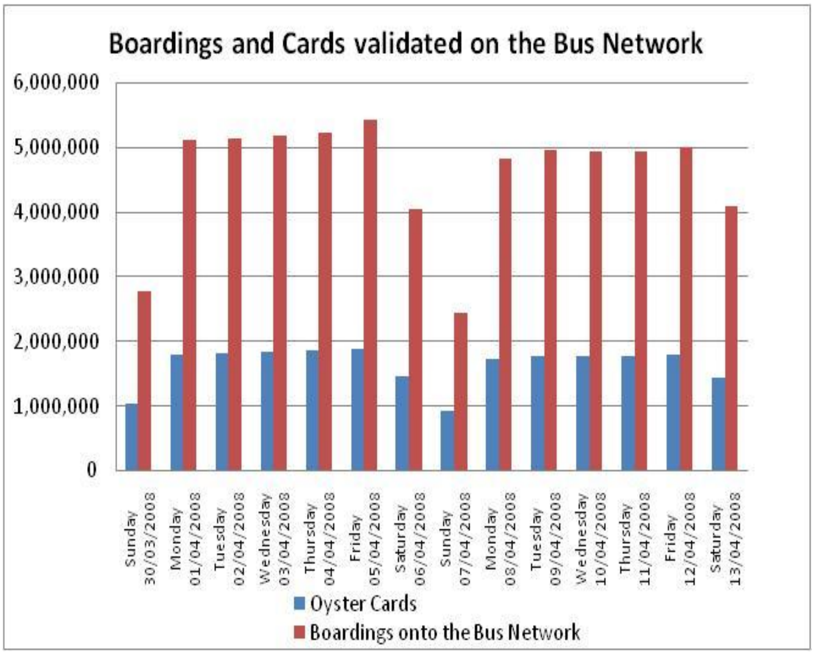

Figure 2: Number of individual cards validated on specific dates, and total boardings attributed to such cards, Spring 2008

It is also possible to identify the number of individual cards validated on any one day, and hence the average boardings per card on the day they were used. The average in the case above was 2.8, with little variation by day of week. While one might expect this to be close to 2 (i.e. one trip in each direction) it may be practice be somewhat higher, especially on bus systems, since cards are validated each time a vehicle is boarded, and additional trips may also be made (for example, returning home at lunchtime, or in the evening). In some cases, usage may show peaks at both 2 and 4 boardings per day, for these reasons. It is also possible, mainly in the case of bus services, to find cards used for a single boarding per day. This can arise where the reverse leg is made using a different mode, such as a short trip made one way on foot, the other (with shopping, for example) by bus.

Two issues of definition arise at this point:

(a) What is a ‘trip’? A boarding identified at validation may either be a single trip in its own right (for example, home to work) or part of a linked trip within the same mode (e.g. successive boardings on two different bus routes within a short time period – an example is discussed further below – or between modes within a network using the same smartcard system). By making assumptions about the time interval within which such interchange takes place, an estimate of the proportion of linked trips may be derived - see Hofmann, Wilson and White (2009) and Bagchi and White (2005). Definitions used in manual travel diary surveys, such as the National Travel Survey (NTS) in Britain, may also be employed in which a distinction is made between ‘trips’ (journeys from one activity to another) and ‘boardings’. A ratio between the two may be derived and used to factor boardings into trips. A benefit of smartcard data is that more comprehensive records of boardings may be obtained than before, but this may produce some ‘growth’ attributable to the method of data collection as such, and cause discontinuities in time series. For example, total bus ridership estimation in London is now based primarily on Oyster data, but a substantial discontinuity exists between estimates of bus journey stages (boardings) in 2006/07 (1,880m) and 2007/08 (2,176m), an apparent growth of 15.7%. TfL estimate that the changes in definition increased estimates of bus journey stages by about 10%. Hence, on a more consistent definition the net growth between those years would have been about 5.2% rather than 15.7% [inferred from TfL 2010, pages 47 and 48].

(b) What is an ’active’ user or card? We can estimate trips made in a particular time period and cards valid at that time. Hence, a trip rate per card can be derived. In the case of cards which require frequent renewal, such as a travelcard, this is reasonably straightforward (although of course not every card is in use on every day for which it is valid). However, in the case of less frequently used types of card (notably concessions for those aged 60 upward in the British case) this is much less clear, especially where some time has elapsed since a general renewal of such cards has taken place. A distinction thus needs to be drawn, if measuring trip rates, between rates for cards which were actually used during the period sampled, and a rate derived by dividing all trips made by a particular card product by all such cards assumed to be on issue. This was examined in the Southport and Bradford cases, showing that as longer sample periods (up to 35 days) were taken, more occasionally used cards were picked up, lowering the average trip rate (Bagchi and White 2005). One must also be cautious in assuming that trips derived represent a single user. While this is explicitly the case for some types (such as concessionary passes) operators may choose to make other ticket types inter-available (as in the Bradford case) and hence data collected indicates trip rates of the cards, not individuals.

Aggregation of spatial data

Just as data may be aggregated for time periods, this may be done spatially. In the case of rail systems with entry and exit gates a fairly comprehensive picture of flows between specified origin and destination stations may be built up, albeit their routeing within complex networks (such as London Underground) may involve several alternative paths (especially within the central area), and hence it may not be possible to assign loadings to particular sections with great precision.

However, the greater volume of smartcard data may give much more robust estimates, albeit confined to the particular modes and operator(s) on which the smartcard system applies. For example, if 10 million trips between the same zones (stations) were recorded on a smartcard system, average trips recorded per potential flow would be about 160. Note that it does not follow that all potential flows actually exist, but that where they do exist, more robust sample sizes may be obtained.

In the case of bus services, O&D data may be of more variable quality. Where a fare stage system is in use, as commonly found in Britain (fares graduated by distance intervals, usually around 1 km upward) then the stage in which a smartcard holder boarded the bus can be identified, but where simpler structures are in use (such as flat fares) this may be more difficult (use of bus location systems such those based on GPS, if linked to the smartcard system, clearly enable much greater precision). Where only entry validation applies, then the alighting point is not known. Where simple trip chains apply (e.g. a return journey, home – work - home) then inferences may be made, based on the assumption that boarding point for the return trip is close to alighting point for the outward trip (and vice versa), but this is less applicable in complex networks, although good approximations can be made in some cases. Examples are discussed in Trepanier et al (2007) and Hofmann and O'Mahony (2005).

USE OF DISAGGREGATED DATA

Inference of linked trips

In addition to the use of aggregate data as described above, smartcard data also creates scope for disaggregating travel patterns in greater detail. It should be emphasised that this does not involve any identification of the individual card holder by name or address. The data is still anonymised, but by examining usage of a sample of individual cards (which can be assigned notional IDs) a more detailed understanding of the market can be obtained.

As mentioned above, on bus systems, recording boardings results in some overstatement of trips as such. By examining a sample of individual cards, trips made on each within a defined period can be identified (by mode, route number/station, boarding time, etc.) and classified by type of product on the card (such as travelcard, or concessionary pass). Where two successive boardings are made within a short period (such as 40 minutes) it is reasonable to assume that these are successive links in the same trip, rather than return journeys. The proportion of such boardings may then be calculated, and an adjustment factor from boardings to trips derived.

For example, in the Bradford and Southport cases, a time of 30 minutes between successive boardings was assumed (given the compact nature of each area, the Bradford card then being confined to an inner part of the city). On this basis, averages of 1.04 and 1.08 boardings for each linked trip were made by concessionary pass holders in Southport and Bradford respectively, implying that the vast majority of trips were single bus rides. However, for those using a travelcard in Bradford the ratio was 1.25, consistent with evidence that this type of ticket tends to be used by those making more complex journeys in which interchange is more likely to be involved (Bagchi and White 2005). In work by Hofmann and O'Mahony (2005), usage of buses in a larger city was examined, assuming a limit between successive boardings of 90 minutes, giving a similar ratio of 1.21. A detailed examination of this approach is shown in the work of Seaborn et al (2009), including sensitivity tests for a range of assumed interchange times. It should be noted that where bus-to-bus interchange is being examined, and cards are validated only on entry (as in the cases described above), then the interval between successive validations will include both the in-vehicle journey time on the first bus, and any walking and waiting time prior to boarding the second bus. As Seaborn et al note, for rail systems with exit reading, then a shorter interval (between exiting one station and entering the next, where stations are adjacent but barrier exit/entry is required) will be appropriate. For bus/rail interchange, a short interval will likewise be appropriate for rail exit to bus boarding (dependent on frequency of bus services involved), but for bus to rail interchange a longer period is appropriate (due to the need to include the in-vehicle element of bus journey time, if there is no exit validation)

It is also possible to calibrate assumptions regarding the maximum time intervals between successive boardings for this analysis from existing manual survey travel diary data, which may vary by trip purpose.

Roles of travelcards and stored value cards

In principle, one might expect these products to serve quite distinct markets, the travelcard being suited to the frequent commuter (work or education), typically travelling five days per week, and stored value to less frequent occasional users (shopping, leisure, etc). However, dependent on fare structure, there may be a category at the margin of using either product. There is evidence, for example, of number of users travelling four days per week (Bagchi and White 2005) who might choose either to use stored value (or a succession of one-day cards) or a travelcard. This is also associated with a shift from the traditional five-day working week, with some travellers being part-time workers, or possibly those who telework from home one or two days per week within a five-day working week.

In the London case, the pattern is somewhat more complex, as price differentials in the TfL fare structure mean that it may be cheaper for a user only making simple trip chains five days a week (even in the peak) to use Oyster pay-as-you-go (PAYG), rather than purchasing a Travelcard. For example, under the fare structure applicable from 2 January 2009, a traveller between zone 3 (middle ring suburbs) and zone 1 (central area) could buy a Travelcard for £30.20 per week. The Oyster single fare on the Underground in the peak was capped at £2.70, so for someone making a simple return journey on five weekdays, the cost was only £27.00 per week using PAYG. Hence, cases may be found of substantial PAYG use even in peak periods, as well as during off-peak periods by occasional users as one would expect. This extent of such patterns will depend on the fare structure set by the operator or controlling authority.

This was examined in work by Kate Holliday (White et al 2009), assessing use of both Travelcard and PAYG on Oyster on a rail route, which had installed gates at all its stations within Greater London and was thus able to offer both travelcard and PAYG facilities. An assessment in summer 2007 of travellers on weekdays showed a very similar distribution by time of day for both Travelcard and PAYG travel, further examination of PAYG use suggesting strongly that these were commuting trips. Both types of product showed strong peaks in demand at the usual commuting times.

In the case of bus travel, examined by Helene Bataille, bus pass use showed fairly strong peaks on weekdays (see figure 3), as might be expected for a period ticket. In terms of trips per pass (on days validated) a bi-modal distribution was found with peaks at 2 and 4 boardings per day (see Figure 4). Most passes were validated at least 4 days a week for those weeks in which they were used. In the case of PAYG bus travel, fairly strong weekday peaks were also found, but 39% of cards were used only on one day of the week in which

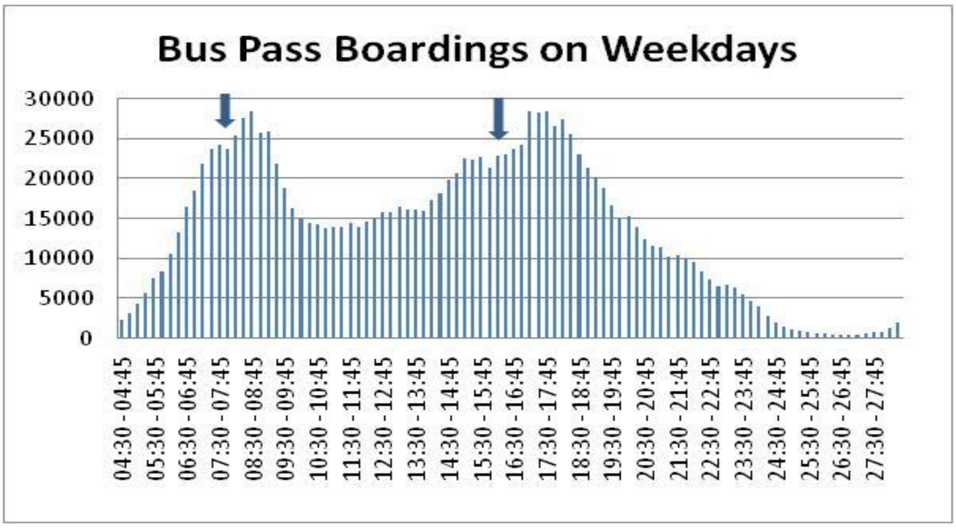

Figure 3: Distribution of Oyster bus pass boardings, Mondays to Fridays average, Spring 2008. Arrows indicate probable understatement of child travel

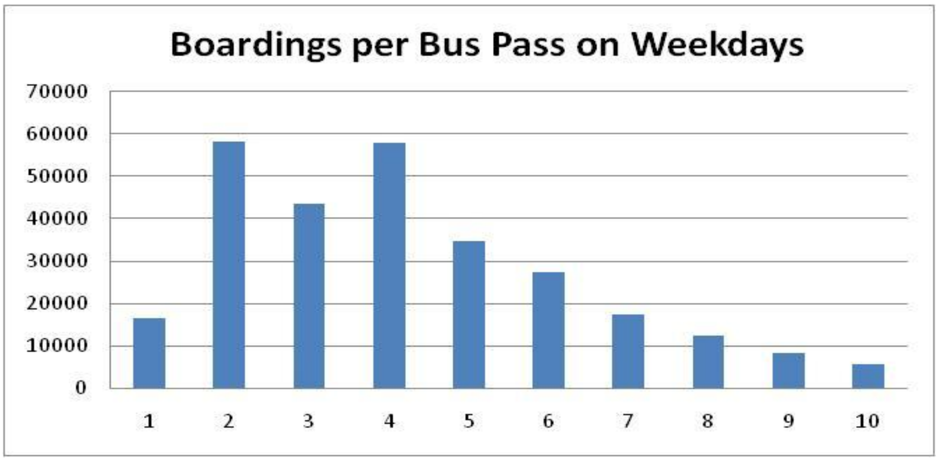

Figure 4: Boardings per Oyster bus pass, per day used, Monday to Friday averages, Spring 2008

their use was sampled. Most cards were used for either 1 or 2 boardings on the days on which they were validated. The bus pass is equivalent to a travelcard, but limited to bus use only, and hence offered at a lower price.

Some other applications of disaggregate data

Using a sample of anonymised cards and associated trips a number of other applications may also be considered:

- Identification of categories of user, identified by different patterns of trip frequency and timing, for example in work by Morency et al (2007), distinguishing patterns by students, the elderly and working age adult users.

- Analysis of trip chains during the same day, i.e. successive trips (as distinct from boardings within a linked trip) made by the same cardholder. This enables timing of outward and return legs of simple trip chains to be analysed, and also more complex trip chains (where made within the public transport network) to be identified.

- Estimation of 'turnover' or 'churn' within public transport market. Another characteristic of the transport market is the substantial element of 'turnover' or 'churn', i.e. quite apart from changes caused by features of the transport system as such (e.g. price structure, or network size) there is a continual entry into and exit from the category of users for reasons connected with external factors such as changing place of residence, work, study, etc. Traditional aggregate data will show the net changes in total system ridership, but often the gross change (turnover) is much greater – for example, a net reduction of 2% in ridership in successive years could be the outcome of 12% of trips ceasing to be made and 10% of trips in the second year being 'new'. This has been identified in the past using longitudinal or 'panel' survey methods, but these are expensive to conduct and limited in scope.

- This phenomenon can be identified through traditional forms of sample survey, but is difficult to monitor on a large scale. It tends to be greater at the level of an individual route than the whole network, since someone relocating may continue to be a user of the network as such (for example, a resident in London holding an Oyster with a Travelcard might relocate their home or job within Greater London. This would represent 'turnover' at the route level, but not at network level). Smartcard data could enable the extent of this phenomenon to be assessed with greater precision, albeit care would be needed to identify turnover in the user market as such, and not simply that in the pattern of cardholding (which could be influenced, for example, by the cost of obtaining a new card vis a vis the effort and inconvenience of renewing an existing card).

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RECENT DEVELOPMENTS IN BRITAIN

A limitation of the London Oyster system has been that until recently comprehensive coverage was limited to the bus and underground networks directly controlled by TfL, together with Docklands Light Railway, and Tramlink (a light rail system in south London). Extensive suburban rail services operated by privatised Train Operating Companies (TOCs) were included in the Freedom Pass and Travelcard products, but few stations were fitted with validators for smartcards. From January 2010, use of Oyster pay as you go has been introduced on all TOC services within Greater London, making installation of validators at all stations a necessity. However, while the PAYG data is potentially comprehensive, due to the need to validate (on entry and exit) the problems of many stations being unstaffed, without entry/exit gates, remains (i.e. equivalent records are not obtained for Freedom Pass and Travelcard usage, even where these are based on smartcards). There is also a substantial element of magnetic card use still found, mainly due to their sale through TOCs. These are used not only on TOC services, but also on the underground (primarily within zone 1, the central area), limiting comprehensiveness of data obtained.

Further expansion of smartcard systems outside London is occurring, based on the ITSO common platform. This has been associated in particular with the need to monitor concessionary travel volumes for purposes of reimbursing operators. A comprehensive system is being introduced in Northern Ireland, and a region-wide system is also planned in Scotland. Elsewhere, the extent of implementation varies, due to deregulation of bus services and limited financial attractiveness for operators to invest in smartcards. Reform of the Bus Service Operator Grant (a rebate of fuel duty for local bus services) is taking place, in which incentives are now provided for operators to invest in smartcard systems.

Under the Local Transport Act 2008 it is possible for greater co-ordination to take place between competing operators, previously inhibited by competition legislation. This includes scope for joint ticketing, in which use of smartcards speeds up boarding, and enables more accurate allocation of revenue between operators (see comment above). The city of Oxford has been a notable example in which two operators compete on most major routes. An agreement under the 2008 Act enables closer co-operation between these operators, which will include use of a common smartcard.

CONCLUDING OBSERVATIONS

The continued growth in provision of smartcard systems is not necessarily matched by utilising the full scope for analysing the data produced from them, nor exploiting all the policy options they permit (such as greater differentiation in pricing by time of day).

As mentioned in the introduction to this paper, smartcard systems have been designed primarily to focus on financial reporting. It could be worthwhile giving more emphasis at the design and implementation phase to the data outputs required for transport planning purposes, and making such data extraction easier once the system is in operation, for example to match route sections (or bus stops) with other bus trip data.

While many issues have been discussed here in the specific context of smartcards, it should be noted that they are not necessarily unique to smartcards *per se*. The crucial aspect is the manner in which data is stored, both with respect to aggregate data and the ability to identify linkages between trips made by the same card on different types of service or operator. As discussed above, magnetic card data often has similar potential. They may also be applicable to data derived from other technologies, such as mobile phones, dependent on data storage and access.

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