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Automated Fare Collection Systems based on check-in and check-out – premises of implementation in Urban Public Transport

A. URBANEK
UNIVERSITY OF ECONOMICS IN KATOWICE, 1 Maja 50, 40-287 Katowice, Poland
EMAIL: anna.urbanek@ue.katowice.pl

ABSTRACT
In the era of dynamic development of ICT and its increasingly common use in every aspect of life, automated fare collection systems in the public transport became a standard in large cities throughout the world. The systems implemented worldwide, including Poland, differ in assumptions and technologies used. A part of the solutions already implemented is based on the so-called Check-In and Check-Out model, which raises a lot of social fears. The aim of the paper is to present premises that are decisive for the implementation of e-ticket systems in urban public transport, which are based on the registration of the entry to and exit from a vehicle.

KEYWORDS: Automated Fare Collection System, E-tickets, smart card, urban transport, public transport, CICO

1. Introduction

Some 200 years ago the population of cities constituted a mere 3% of total population, whereas nowadays over half of the population (54%) lives in towns and cities. In the member states of the European Union, city dwellers account for some 75% of the citizens, and by 2050 that number is forecasted to increase to about 84% [1]. The increasing number of inhabitants in cities, coupled with the expectations concerning good conditions for living and moving about in cities, is a challenge for urban transport, as transport is one of the factors that enable the development of towns and cities.

The quantitative development of transport in cities is limited not only by the urban space available, and the throughput of transport network, but also by the possibilities of financing investments using public funds. Hence the substantial role of information concerning demand for transport services, which becomes the basis for making decisions concerning the strife for most efficient use of resources already possessed. This information is available due to information and communication technologies (ICT), which are implemented ever more commonly also in urban public transport, mainly in the form of automated fare collection systems. Those systems are the source of large amounts of data concerning mobility, transactions made, as well as transport-related behaviour of city inhabitants. A part of the solutions implemented all over the world is based on the obligation to register the entry and leaving the vehicle. The paper presents examples of such systems and - with the use of case studies of two systems already implemented and being operational – the prerequisites that are decisive for their implementation have been discussed, along with the problems related to their social acceptance.

2. Electronic ticket systems based on CICO

Modern electronic ticket technologies enable automatic payment of the fare directly on board of the vehicle, most often by means of electronic money. The carrier most frequently used is a contactless electronic card, functioning in the form of a prepaid city card. It is also ever more common to implement systems in which it is possible to pay the fare on board the vehicle, by means of a bank card, as well as by

means of mobile devices, in the form of electronic payments from the bank account, using the Near Field Communication (NFC) technology, or via special applications that generate QR codes, corresponding to various types of tickets. The popularity of contactless electronic cards in the systems of electronic payments for urban transport services results from a relatively wide functionality of that solution, as:

- they may be used as instrument (carrier) of electronic money and function as bank cards,
- they may be the carrier of tickets valid for not just one organizer of public transport but many [2],
- smart cards can also be used for encoding individual entitlement for reduced fares, even in respect to several organizers of public transport,
- they may be bearer cards or personalized ones, that is valid for a specific user, in both cases each card has its unique number,
- they may be carriers of periodic/season tickets as well as single tickets, and may function in the systems for dynamic settlement of travel costs,
- they may be used as city cards and may enable payments for other municipal services, such as parking or paying the charges levied by city institutions [3].

It is possible to distinguish two leading types of solutions implemented for automated fare collection in vehicles: systems which require registration merely of getting on board a vehicle, as well as those which require the registration of bother getting on and off the vehicle. In electronic ticket systems which demand only that the passenger registers the fact of getting on board the vehicle, the passenger is charged the fare (buys a single ticket), paying the amount determined beforehand. Single tickets may be purchased directly in the vehicle, e.g. by means of approaching/inserting the card to the reading device, or may be purchased and encoded on the card earlier, while its activation takes place in the vehicle. The ticket price may vary due to the means of transport selected, time of day for travelling, or day of the week. An example of such a solution may be the Ventra system, implemented in 2013 in Chicago, where the price of a single ticket depends only on the mode of transport and the number of changes of transport means in a definite time period [4].

The second type of systems – ever more frequently implemented worldwide – is represented by solutions based on the obligation of registering the fact of getting on and off the vehicle, in which the cost of travel is calculated in a dynamic way. Various methods of identification of entering the vehicle and leaving it are used. The technology most frequently utilized worldwide is the so-called Check-in/Check-out (also named CICO, Tap-In/Tap-Out, or Touch-In/Touch-Out), which requires the passenger to physically register the fact of entering the vehicle and of leaving it, via passing the contactless electronic card or mobile device, e.g. a smartphone in front of the reader located near the door of the vehicle. Solutions are also possible, which enable automatic detection of a card in the vehicle, which do not require the passenger to take any additional action (Walk-in/Walk-out or Be-in/Be-out) [3].

Systems for dynamic settlement of travel cost, often called the ”pay as you go” systems, are systems which demand registration of entering and leaving the vehicle, in order to calculate the fare for the distance actually covered, travel time, number of stops travelled – depending on the fare applied by the transport organizer. The system then calculates the fare due and charges the passenger account. Most often the passenger is motivated to register the moment of leaving the vehicle if at registration of getting on the vehicle the maximum fare is charged for the travel, e.g. to the end of the line, and the passenger gets a refund if the travel was shorter than that. Table 1 contains examples of systems implemented worldwide, which are based on dynamic settlement of travel cost in the CICO mode.

Automated fare collection systems enable the introduction of a more flexible pricing policy concerning urban transport services. For example, in Greater London, on the lines where the transport organizer is Transport for London (TfL) the zone dependent fare is in place (London is divided into 9 zones), whereas fares differ depending on the means of transport the passenger uses, there are also price differences depending on the day of the week and time of day (peak hours and off-peak hours). On the railway lines served by regional service providers for National Rail outside London the distance-dependent fares are in place, yet in the Greater London area the fare has been unified with the TfL system, where zone dependent fares are paid. A substantial advantage of that system lies in the fact that a passenger who uses urban public transport several times a day will never pay a total fare price that would exceed the price of a day (24-hour) ticket [5].

Table 1. Examples of electronic fare collection systems based on dynamic settlement of trip cost in the CICO mode [own study based on [5,6,7,8,9]]

Oyster Card	**Octopus Card**	**T-Money**	**EZ Link**	**ŚKUP**
City				
London (UK)	**Hong Kong (CN)**	**Seoul (KR)**	**Singapore**	**29 cities making up KZK GOP (PL)**
Year of implementation				
2003	**2007**	**2004**	**2002**	**2015**
Scope of available services				
public transport possibility to pay fares in vehicles with bank cards	public transport institutions of culture and recreation (cinemas, theatres, swimming pools), retail (shops, supermarkets etc.), access to buildings, confirmation of attendance at schools, at work, taxi, tourist card, payments for parking, vending machines	public transport, institutions of culture and recreation (cinemas, theatres, swimming pools), retail (shops and restaurants), taxi, payments for parking, vending machines	public transport, institutions of culture and recreations (cinemas, theatres, swimming pools), retail (shops and restaurants) confirmation of attendance at schools, at work taxi, payments for parking, vending machines, private buses, electronic road pricing, vehicle entry permit payments,	public transport, institutions of culture and recreation (cinemas, theatres, swimming pools), payments for parking, payments for public services in town hall institutions, libraries, electronic signature

Applied fare system				
Fares based on zones and differentiated depending on day of the week, time of day, and means of transport	Fares based on distances travelled for all means of transport	Fares based on distances travelled for all means of transport	Fares based on distances travelled for all means of transport	Fares based on distances and on zone and travel time

Hong Kong, Seoul, and Singapore are examples of cities, in which the passenger pays for all modes of transport in accordance with the distance actually travelled. One tariff system applies, yet the prices in specific distance ranges depend on the means of transport [6, 7, 8].

An interesting example is also the Silesian Card of Public Services (ŚKUP) system, implemented by the *Municipal* Transport Union of the Upper Silesian Industrial District (KZK GOP) in Katowice, Poland – the biggest organizer of urban public transport in Poland. It is a union of 29 municipalities located in the central part of the province of Silesia, which jointly organize local public transport. There are two types of fares for using the transport organized by KZK GOP. In the system of dynamic costing, distance based fares are charged, yet the passengers may also use single tickets in zone and time based fare, where the fare depends on the number of zones travelled or the time the travel took (transfers allowed). In case of single tickets in the zone and time based fare, it is mandatory to check out upon leaving the vehicle only in case the passenger intends to transfer to another vehicle, as allowed for short term validity tickets – which are valid for one, two, or three or more adjacent municipalities – or for a specific time of 15 minutes, 30 minutes, or 60 minutes after first validation of the ticket. In such a case, the passenger who wants to transfer to another vehicle during the validity of a single ticket, should check out upon leaving one vehicle and check in upon entering another one. In case of periodic/season tickets the passenger is obliged only to check in, while check out is not obligatory. However, passengers who regularly check out upon leaving the vehicle may get a discount when purchasing the next ticket. The data collected by KZK GOP show that some 30% of all season tickets are sold with a discount resulting from regular check out [10].

3. The use of data from CICO system - the case study of Oyster Card in London

Dynamic pricing of fares based on the check and check out registration system allows the organizer of public transport to gain detailed knowledge concerning traffic flow. That is particularly important from the perspective of managing the public transport offer, in particular the identification of the number of passengers travelling in the vehicles on specific sections of routes, identification of revenues generated on individual lines, sections of those lines, attributing them to respective municipalities, and – in case of integrated tickets – the settlements between various organizers, service providers, and other entities functioning in the public transport system.

Oyster is a system of automated collection of fares, based on contactless electronic cards, implemented by the organizer of public transport in the Greater London area, which is Transport for London (TfL). Oyster card is a carrier of season tickets, it also enables payment for single travels under the system of dynamic fares, based on the check and check out registration. Check-in and check-out registration is mandatory, both in case of single fares and season tickets. The CICO system comprises all means and modes of transport within the Greater London area, thus the Underground, DLR (Docklands Light Railway), London Overground, TfL Rail, and National Rail lines. Buses and trams make an exception, as the system of dynamic costing does not function there. In those vehicles, it is obligatory to register only the check in, while the single fare is collected "beforehand" after you check in on board the vehicle. In the Oyster system it is possible to make payments on board the vehicle not only by means of Oyster cards themselves, but also by means of contactless bank cards [5].

Systems of automated collection of fares, such as Oyster, are the source of a large amount of varied data concerning mobility, transactions made, and transport-related behaviour of users. An integral part of such a system is the IT infrastructure in the vehicles, such as on-board computers, GPS devices for location purposes, which are the source of data concerning movement of vehicles. TfL also obtains current information about traffic in the city, from the city monitoring system, as well as directly from the users. The tfl.gov.uk portal has some 12 million users a month, with TfL having some 2.9 million social media followers, who participate actively in the exchange of information concerning the current situation in the city (in 2014 TfL received merely 290 emails from users) [11].

Large sets of data obtained from electronic ticket systems are used in the process of managing public urban transport. Tfl uses such information first of all for the needs of current management of transport offer, thus for adjusting the network of connections to the needs of passengers, optimization of lines and frequency of services, optimizing the time needed for transfer between vehicles, adjusting the capacity of vehicles, or introducing changes resulting from the construction works or repairs in the city. It is worth adding that the Oyster system is also used for communication with specific passengers. An example here may be the closing of Putney Bridge in 2014, due to urgent need to make repairs. Data from the Oyster system enabled to identify some 40,000 users who made 111,000 bus trips a week that crossed the bridge. Thanks to the thorough knowledge concerning the nature of those trips it was possible to create a convenient alternative offer for those passengers, about which the passengers were informed via emails sent to them [11].

The data concerning the demand for services is also used for the purpose of long term planning of the transport offer, thus for the construction of traffic models and forecasts for the purpose of urban development and extending the public transport network. Since 2005, TfL has been cooperating in that respect with Massachusetts Institute of Technology (MIT). Moreover, the information from the Oyster system is made publicly available to all users registered in the open data programme. At present, 8500 developers are registered in the programme, and open data feeds nearly 500 travel apps in the

UK. It is worth adding that the applications are used by about 42% of all inhabitants of London [5], [11]. Via the applications, available by means of smartphones for example, they obtain the information adjusted to their needs, e.g. concerning changes in timetables, traffic congestion in the city, or crowds in specific means of transport.

4. Safety of personal data and protection of users' privacy – case study of the Silesian Card of Public Services (ŚKUP)

The collection of data concerning the registered check-in and check-out in urban transport vehicles raises concerns related mainly to protection of privacy and personal data. The interest in personal data security is something natural, particularly in the context of ever more frequent use of information technologies in all spheres of life and – as consequence – collecting and processing of personal data on unprecedented scale. It can be noted that concerns pertaining to observing privacy are common for all technologies, which connect the device or card with a specific user, and allow to gather data about the behaviour of that user (cell phones, banking systems – credit or debit cards, or cards used in the health care system, public transport, etc.). Modern systems of electronic payments based on smart cards, such as the Silesian Card of Public Services (ŚKUP) system, meet the highest safety standards determined by banking systems [12,13].

It is important to take into account the fact that protection of personal data is very strictly regulated in the European and Polish legislation. In the ŚKUP project the personal data is processed in a way that guarantees compliance with the requirements of the Act of Law of August 29, 1997 on protection of personal data, and executor orders to that Act, which is supervised by respective institutions, among them the Inspector General for Personal Data Protection [14].

The contractor for the ŚKUP system is a consortium made up of Asseco Poland S.A. and mBank S.A., the latter being a commercial bank. Personal data of personalized card users is collected in the process of card ordering, and is processed for the purpose of concluding the Agreement for card use and the execution of that agreement. ŚKUP cards are issued by mBank, which has been entrusted by KZK GOP with the task of processing personal data for that purpose. mBank, in turn, entrusted the processing of personal data to DanubePay, which is the acquirer for the ŚKUP system and manages the process of card personalization. It is in the IT system of the acquirer that personal data is gathered and processed. When submitting the application for a personalized card, be it via the Customer Portal or in customer service points, a form is filled, which is automatically transferred by the ŚKUP IT system to the acquirer system and is not stored directly in the ŚKUP system. The processing of data in ŚKUP project is carried out mainly in banking systems, and the level of data safety is maintained at the level applicable in banking institutions [15].

In order to study the flow of passengers and settlements with municipalities, KZK GOP uses the data concerning tickets purchased, as well as registration of check-in and check-out events in urban transport vehicles. The data concerns the volume and amounts of transactions and registered types of tickets/fares. For the purpose of settlement of subsidies, KZK GOP – via the appropriate module serving the purpose of report generation – also obtains information about fare reductions and municipalities of residence, for the passengers using public urban transport. The knowledge concerning the municipality of residence of the passengers is very substantial from the point of view of mobility analyses and building of traffic models, which are used in the process of transport offer management. In such a vast and complex area where urban transport services are provided, which is the area of 29 municipalities belonging to KZK GOP, this is of great importance, as there are municipalities which generate mobility, there are also municipalities which absorb a substantial portion of the passenger traffic, such as the city of Katowice – the biggest city in the area which receives a substantial portion of passengers from other cities and towns of the Silesian conurbation, on everyday basis [15].

The exact data concerning the flow of passengers and revenues from tickets/fares on specific lines may also serve the purpose of expanding the level of detail in mutual settlements between operators/service providers or municipalities, which jointly organize public transport in the specified area. The scope of data used in such a case depends on the assumed model of financing. In case of the ŚKUP project, one of its main assumptions was to base the settlements on data obtained from the system. The new model of financing urban transport in KZK GOP assumes using the data from check-in and check-out registration for the purpose of calculating bus line profitability. To calculate the revenues from tickets for a specific line, it is necessary to connect the information about (season and single) ticket price/fare with the total number of kilometers travelled during the ticket validity, broken down into lines and areas of specific municipalities [16].

However, for the purpose of studying the flow of passengers, in the ŚKUP system the information concerning fare reduction or municipality of residence is not connected with other personal data of card users, e.g. name and surname, or detailed address of residence. The card number is the sole identifier (that applies both to personalized cards and to bearer cards). In the ŚKUP system, no information is provided about the user of such a card, thus there are no possibilities of connecting the card usage data with personal data of the user, as personal data is not saved in the ŚKUP IT system. Also the card readers in vehicles are able to read the card number and the encoded authorization for reduced fare or for traveling free of charge, yet do not read information about the card user, nor do they save such information in the system. So, in such cases there is no personal data processing. KZK GOP, as the administrator of ŚKUP system, as well as other entities participating in the project execution, have no access to the acquirer system. The database containing personal data at the acquirer level, and the database containing information about flows of passengers are separate and function independently. In relation to that, KZK GOP does not connect such information in the process of studying passenger flows and management of urban public transport.

This does not mean, however, that KZK GOP has no access to individual data of card users whatsoever. Only and solely at the request of the passenger, and only after the passenger provides her/his card number and resident identification number (PESEL)

can the properly trained staff that handles complaints have access to the history of trips made and personal data of the passenger. It is necessary for processing the complaints related, for example, to incorrect fare charged on board the vehicle, or technical problems with the functioning of ticket validation machines, etc. Having the insight into the history of trips made by a given passenger allows to identify the error in a specific vehicle and return the money incorrectly collected to the passenger.

It is worth stressing that such procedures are similar to those we encounter e.g. in case of banking systems. When making cashless transactions with the use of bank cards, the bank IT systems also collect information about the type and structure of expenditures made. Thanks to it, electronic making systems ever more often offer their clients the statistics of purchases made, while in case of erroneous settlement of transactions, on the customer's request the bank identifies transactions, checks their correctness and makes suitable corrections.

5. Social acceptance for CICO system – public opinion surveys preceding the implementation of Silesian Card of Public Services (ŚKUP) system

At the stage of developing the KZK GOP fare for transport of passengers and luggage in urban transport system, which was to be binding after the implementation of ŚKUP project, a literature survey was conducted, consisting of a review of experiences of other cities worldwide, concerning the implementation of automated fare collection systems in urban transport, as well as opinion surveys. In September 2012 a passenger opinion survey concerning the new fare of KZK GOP and ŚKUP system was commissioned from an independent opinion poll survey agency, TNS Polska S.A., experienced in that field. The contract with them concerned the organization and execution by TNS Polska S.A. of a quality survey, employing the Focus Group Interviews (FGI) method, and preparation of a report from the survey, as well as analysis of the results obtained. The survey was conducted in accordance with the methodology and highest research standards.

Focus Group Interviews (FGI) are a quality research method consisting of a discussion with survey participants, conducted by the moderator. A focused interview follows a defined scenario of the survey, and is most often focused around pre-determined topics. The survey takes about 1.5 to 2 hours, and is not only watched but also recorded, so that a detailed analysis of all statements of survey participants is possible. The greatest advantage of such a survey method is the possibility of receiving detailed information from survey participants, their opinions, ideas, and judgments concerning a specified topic. The discussion creates conditions to substantiate the opinions expressed by survey participants and – if need be – developing it by introducing additional topics [17, 18].

The aim of the survey conducted by TNS Polska S.A. and commissioned by KZK GOP was to find out the opinion of passengers and to identify the needs concerning the new fares system. The survey was conducted on 18th and 24th of October, 2012 in two age groups: age range 19-30 years, and over 30 years of age. The survey participants had to meet certain criteria, among them the following: living in the area of KZK GOP member communities, using public transport provided by KZK GOP, as well as specific requirements concerning professional activity, so that the survey groups reflected the passenger structure as much as possible [19].

A substantial part of focused interviews was devoted to the obligation to check in and check out. It results from the surveys conducted that this requirement was not a problem for the passengers interviewed. They only expressed their concern related to the behaviour of passengers in cases when vehicles are crowded with passengers. In the discussion, there were also opinions expressing concern regarding the running conditions of all devices. It is worth noting that even passengers from the second group, of older age, did not oppose the introduction of check-in and check-out obligation, even in case of passengers entitled to travel free of charge.

However, the most significant thing was that the survey subjects fully supported the collecting of data concerning registered check-in/check-out incidents, and processing it for the purpose of adjusting the transport offer to the needs of passengers, indicating even that it is a factor that encourages the use of ŚKUP cards. The respondents noted several advantages related to collecting individual data about trips, which enabled to control one's expenditures. Despite the concerns related to the organization of the check-in/check-out registration system in vehicles, the respondents pointed out that the system may be much faster and passenger friendly than the system based on validation of paper tickets [19].

In summary it can be stated that – in the opinion of respondents – the advantages related with gathering data about passenger flow from the check-in/check-out registration system exceed by far the possible disadvantages that result, first of all, from the required change of habits. In the opinion of passengers, the very process of checking in and checking out is not onerous, and in many cases it may even be more friendly than the validation of paper tickets.

6. Conclusion

A portion of the electronic systems of fare collection in urban transport, implemented worldwide, is based upon the check-in/check-out registration model, the so-called CICO. The CICO model is applicable mainly in the systems based on dynamic costing of trips made, still the obligation to check in when boarding the vehicle and to check out when leaving it may also apply to season tickets encoded on the cards.

The electronic ticket systems based on the CICO model are ever more frequently implemented in big urban conurbations, in which there are many providers of services, as well as many means of transport or – as in case of KZK GOP – the case is that several organizers co-operate for integrated system of urban transport. The analysis of literature concerning that issue, and the solutions implemented worldwide show that this technology creates

unprecedented possibilities, that have not existed before, for the transport organizer to obtain accurate data concerning the quality of services provided, and demand for services. The exact knowledge about transactions made, that is the kind, and number of tickets purchased, with purchase time included, allow for more flexible and innovative development of prices for services. Moreover, the data concerning the flow of passengers is used in the process of current and strategic management of the transport offer, the aim of which is, first of all, a more attractive public transport, thus its enhanced competitiveness in comparison with other forms of mobility, particularly in comparison with private cars, and – in consequence – the increased efficient of services provided.

Despite the fact that automated fare collection systems based upon the CICO model may be the source of many economic and social advantages, the possibility of collecting exact data concerning demand causes certain social concerns regarding the safety of personal data and protection of privacy. The problem, which often creates a barrier preventing the implementation of such systems, is the need to change the existing habits that passengers have, and the assurance that obtaining information about check-in and check-out registration in urban transport vehicles does not breach the right to privacy, while the collected data is safe and used in compliance with the law. The factors which significantly influences the social acceptance of that solution include proper functioning of ticket validation devices in vehicles or at stations/stops, their sufficient number, as well as swift performance of all actions. It is also important to provide easily accessible and legible information concerning the advantages resulting from the changes introduced.

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