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METHODS FOR MEASURING PASSENGER TRAFFIC IN URBAN TRANSPORT

This article presents different methods of measurements number of passengers using urban transport vehicles. Direct count of passengers by selected people, visual monitoring of public transport vehicles, an automatic measurement system with infrared sensors or electronic ticketing (the most frequently used methods) are described below. Some of these methods are recommended for he various financial settlements between the service buyer and the service provider.

METODY POMIARU LICZBY PASAŻERÓW KORZYSTAJĄCYCH Z POJAZDÓW TRANSPORTU MIEJSKIEGO

Artykuł prezentuje różne metody pomiarów liczby pasażerów w pojazdach transportu zbiorowego. Przedstawiono wykorzystywaną metodę bezpośredniego liczenia przez wyznaczone osoby, wykorzystanie monitoringu wizyjnego, pomiary z wykorzystaniem sensorów podczerwieni oraz wykorzystanie danych z systemu biletu elektronicznego. Wskazano także na możliwość wykorzystania wyników przykładowo dla rozliczeń pomiędzy przewoźnikami i organizatorami transportu.

1. INTRODUCTION

The changes occurring in operation of urban transport i.e. separating the functions of a service buyer and a service provider, marketisation of service provision and an obligation to conclude contracts between a public entity and a service provider have resulted in a need to measure passenger traffic and calculate profitability of lines, and ultimately to apply measuring results in settlements between the service buyer and the service provider. A particularly important issue is automation of a passenger traffic measurement process, which will lead to regular conduct of measurements. High accuracy of collected data is also expected.

The passenger traffic measurement results for specified lines or routes were once used predominantly in preparation of timetables. The collected data could be estimated and approximate, since the point was to check where vehicles were underused or where they were overused.

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The article presents a variety of passenger traffic measurement methods, focusing on systems based on sensors placed on or near doors or based on data collected from fare charging systems using electronic cards. There are also other measurement methods e.g. by direct count of passengers by selected people or drivers or conductors. It is also possible to estimate passenger traffic by means of visual monitoring. These measurements for specific transport lines focus invariably on getting access to the information on passenger traffic for specific routes of all the vehicles on transport lines.

2. DIRECT COUNT OF PASSENGER TRAFFIC BY SELECTED PEOPLE

Although, as a rule, passenger flow measurements abroad are conducted using automatic systems, Poland continues to use a human factor for that purpose. There are several reasons behind that situation, e.g. for many years there was no need to carry out such measurements on a wider scale, neither was there any access to modern technologies. The fact that the labour costs in Poland used to be a few times lower than in better developed countries should not be neglected either.

The method for direct count of passengers by selected people may be recommended in cases when measurements are not regular but are conducted on an ad hoc basis in order to identify the passenger flow status on a given day or any other relatively short period of time. However, in cases when measurements are repeated and cyclical by their nature, for example in order to spot differences in passenger flows in various periods of time throughout the year or even within a month and a week, this method would require continuous involvement of a lot of people, and from an economic point of view, it would therefore be more likely to be replaced by automatic methods.

Measurements of passenger flows by direct count are usually carried out on all routes of vehicles on specific lines on typical weekdays as well as Saturdays and Sundays and, if needed, during various holiday seasons. They mainly involve counting of passengers getting on and off though specific doors of a given vehicle at every stop of the route in question, and then completing collective tables (reports) for the vehicle subject to the measurement. The reports, supplemented with operational data from the timetable, form the basis for calculation of the key indicators of transport services consumption such as: an average occupancy rate, a number of passengers per vehicle-kilometers, a maximum number of passengers in a vehicle, an average length of a journey, transport work (passenger kilometers), a number of passengers carried, etc. The data are presented in total figures or average figures, in a graphic form or a tabular form, depending on needs.

The number of people involved in counting of passenger flows in vehicles depends on the scope of measurements, a size of a fleet of vehicles in traffic in a given area and the required accuracy of measurements. Generally, two to three persons or more, if needed e.g. in tram sets composed of a few cars, are employed per vehicle. On lines where there are small passenger flows, usually one person is sufficient to carry out measurements.

The advantage of this method, first of all, lies in the fact that costs are related to the duration of measurements, as the people employed (on a mandatory contract basis) are usually paid per every hour worked. Furthermore, if the number of controlling persons is properly adjusted to the size of the passenger flows and the number of doors in a vehicle serving the given line, a very high accuracy of measurements is achieved, which is frequently quite difficult to ensure using automatic systems. Nevertheless, a disadvantage of the direct count of passengers is a possibility that counting persons may affect the measurement results, which

reduces the possible applications of this method in various financial settlements where the basis is the number of passengers using specific transport lines.

Consequently, a decision to choose this method for counting passenger traffic has to take into consideration a number of the aspects described above. Comparing e.g. the costs of passenger traffic count using this method and using automatic methods, an approximate point may be determined for every vehicle where the application of automatic systems pays off. The comparison which follows is based on an assumption that measurements are to be taken by an urban transport organizer, and in the Polish conditions this is a budget unit or an intercommunal union in most cases. To determine this point, the following assumptions were accepted:

- two persons are employed under a mandatory contract at a given time to conduct direct measurements on a vehicle, and they earn PLN 10 gross per hour i.e. approx. 200% of the minimum wage and approx. 70% of the average wage in the national economy for 2004, calculated per 1 hour, according to the data of the Central Statistical Office [1],
- compensation for one person, entering the data into the computer and analyzing the results, is established at the level of an average wage in the state economy for 2004 (i.e. approx. PLN 14 gross per 1 worked hour),
- daily cost of direct measurements is approx. PLN 300 (with 15 hours of measurements),
- purchase cost of computer hardware and software needed to prepare measurement results is approx. PLN 4,000
- hardware and software operation cost amounts to approx. PLN 5 daily,
- purchase cost of an automatic system per one vehicle is approx. PLN 30,000
- daily operation and maintenance cost of a automatic system is approx. PLN 25.

The point where the two daily measurement cost lines for both the methods cross is presented in figure 1.

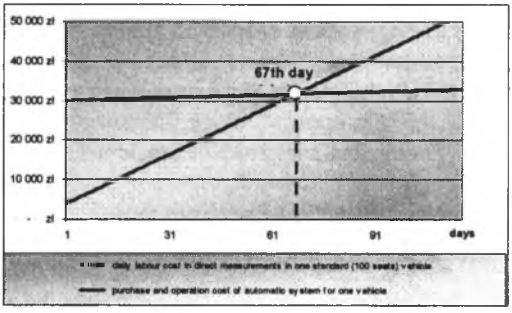

Fig.1. Comparison of profitability for direct count methods (source: the author)

With the accepted assumptions, the lines cross on the 67th day of continuos measuring i.e. after that period the costs of measurements carried out by people exceed the purchase cost of an automatic system. Different data may, of course, be accepted when estimating this period (e.g. concerning the size of the compensation, or a unit price of the counting system, which may go down with the number of vehicles increasing).

Direct measurements can also be conducted by vehicle service staff i.e. drivers or possibly ticket controllers or conductors, in particular if vehicles are customarily entered using front doors and tickets are shown to the driver. Note that entering vehicles through front

doors is common in countries where passenger flows on bus lines are much smaller than in Poland. In general, in the Polish conditions the method of measurement of passenger flows by drivers in urban transport is not used at present and it is unlikely to be applied in the nearest future. However, in the long run, this is possible.

The front door entry system is commonplace in domestic, regional and local transportation services rendered by PKS. Drivers with fiscal cash registers record sales of tickets for specific tours. A problem may be posed by periodical tickets (to be shown to the driver when entering a bus), which are assigned to given routes, therefore profitability of the line can be calculated without any sensors.

If the vehicle service staff are to count passengers, they would have to be equipped with a device that allows them, on one hand, to sell tickets and on the other hand to record the passengers getting on and off and types of tickets held by them. Every passenger who gets on buys a ticket from a driver or a conductor – and then the device records the sale automatically - or shows a ticket. In this case the driver or the conductor presses an appropriate button on the device – every button corresponds to a different ticket type. In addition, every leaving passenger is also recorded by the device – a separate button for passengers getting off.

3. VISUAL MONITORING

One method of estimating the consumption of carriage capacity in urban transport vehicles is visual monitoring of public transport vehicles. Such monitoring, through a system of cameras, may register the picture from a passenger area, and apart from applications aimed at control of certain occurrences (vandalism, theft, disputable situations during ticket control etc), may also be used to estimate the number of passengers in a vehicle. As it does not calculate the transport capacity consumption parameters for a given line, as described in the previous section, visual monitoring, should only be treated as an additional option for using cameras since their basic function in a vehicle is to ensure safety for passengers. A driver, who is shown the view of the vehicle interior, may react when noticing any disturbing events e.g. by an automatic call for the appropriate service. Due to the type of data provided, this method cannot be used in various financial settlements between the service buyer and the service provider.

Monitoring, using a system of cameras located in various points all over the town, may be used, for example, in urban transport management, as well as to estimate the occupancy rates for vehicles and observe passenger turnover on stops within the reach of cameras. In general in differing towns in Poland such systems are used by the police or the municipal guard, however urban transport management authorities may co-use such a system, participating in its maintenance costs at the same time. Taking into account a relatively high cost of the monitoring system, such joint use may seem the best solution in terms of costs.

It should be pointed out that the mode for transmitting the picture is a decisive factor in maintenance costs of these systems. Nevertheless, following the quick development of data transmission technologies and increasing flow capacity of transmission networks, we can expect a quick drop in data transmission prices in the nearest years, and consequently, cameras are going to be introduced in numerous towns on a bigger scale than nowadays.

Cameras in such a system should be able to work in infrared, which makes them useful also in periods with limited visibility. A minimal magnification for these cameras is approx. 70 times (such cameras are used in Katowice).

Please note that both visual monitoring of the vehicle interior and monitoring of points within the transport network should be treated as a useful tool in traffic management, but this method is not practicable in financial settlements based on passenger traffic.

4. AUTOMATIC PASSENGER COUNT BY VEHICLE DOOR SENSORS

A method which eliminates a human factor (people employed to count, drivers) when measuring passenger flows is an automatic measurement system for passenger traffic in vehicles. Owing to that, this method may find its applications in regular measurements conducted on a bigger scale. The system automatically registers the number of passengers getting on and off at a given stop. This is carried out by means of sensors placed e.g. at every door.

These may be infrared sensors, which are sensitive to motion or temperature change, or an alternative solution can be used when a special mat placed on the vehicle floor registers changes in load. Using special scalers, a temporary number of passengers in a vehicle can be determined.

The collected data are recorded in a vehicle computer and after coming back to the base they are fed into the depot computer, from which they can be transferred e.g. to the head office of the transport organiser.

In this passenger traffic measurement system is introduced on transport lines, assuming that every vehicle should be controlled at least once a year on every transport line, it would be necessary to install counting and data transferring devices in a few percent of vehicles serving a given area. The scope of measurements, as well as a number and a type of a fleet on transport lines should be taken into consideration. It is also important to be able to decide freely about the fleet when directing vehicles to serve indicated lines, which is particularly significant when there are a number of transport service providers in a given area. However, in order to get up-to-date data required to accurately estimate seasonal changes in demand for transport services, the input data for analysis of profitability of lines and related financial settlements between the service provider and the service buyer, it would be recommended to equip a minimum of 10% of vehicles with such devices, taking into account the restrictions mentioned above.

One of the existing solutions for automatic measurement is an IRMA (InfraRed Motion Analyzer) system. A concept diagram of the IRMA system is shown in figure no.2.

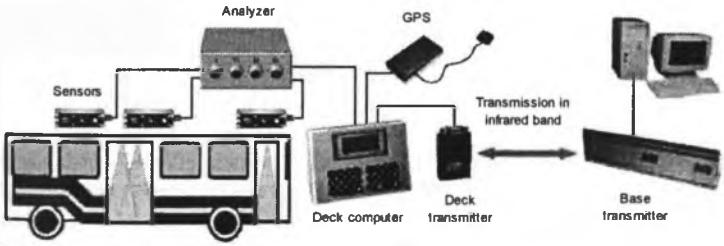

Fig.2. Concept diagram of the IRMA system (source: website of Emtal Sp. z o.o.: http://www.emtal.pl)

The system is composed, among the others, of special infrared detectors placed over doors of a vehicle, which register persons getting on and off at specific stops. The data are then transferred, through special analyzers, to a deck computer, which is usually located in a diver's cockpit. Then the data are relayed to the system operator's computer. To make a full use of the IRMA passenger flow measurement system, the data related to passenger turnover has to be matched against concrete stops. This may be carried out manually by pressing an appropriate functional button on the deck computer keyboard by the driver or automatically by means of a GPS receiver. In the latter case, the deck computer memory stores geographical coefficients of stops and if the vehicle is within +/- 15 m from the stop point, the passenger turnover data will be linked to this stop [2].

An advantage of the automatic traffic measurement is, first of all, elimination of the human factor that might affect the measurement results and the speed of generating results from a big number of measurements, which make the method preferable when implementing settlement systems based on passenger traffic. The downside, however, is a relatively high cost related to equipment and service in case there are a lot of vehicles. Analysing the data concerning implementation of the automatic passenger flow measurement systems in Poland we may notice that the purchases of the system have so far been aimed at testing – in most cases appropriate devices were purchased for 1-3 vehicles. Only in Białystok 56 of such sets were purchased totally [2]. Therefore we may expect that when purchases are made on a mass scale and the automatic passenger flow measurement system becomes more widespread, the current prices of the necessary vehicle equipment may fall by as much as several tens of percent.

5. SYSTEM BASED ON ELECTRONIC TICKET

A solution that may provide the most information on passenger journeys is an electronic card ticket. These cards can be divided into memory cards and microprocessor cards, depending on their data processing capacity. Memory cards (without a microprocessor) are the simplest and the cheapest electronic cards. They have no advanced security controls to prevent reading and changing of stored data. Microprocessor cards – so-called 'smart cards' – contain a microprocessor, in addition to a memory, which can process data. Application of integrated circuits gives them a lot of advantages such as big data storage capacity, data processing capacity, good security controls, complicated algorithms to encode transaction data, a possibility to re-enter data and a possibility to use them in multilateral services.

Electronic cards in collective transport make it possible to offer a wider range of prices, adjust prices to the real quality of a given service, potentially use data to plan routes and lines and to implement loyalty schemes. Limitations in wider applications result from substantial costs of purchase, implementation and operation of this fare charging system. Appropriate terminals connected to the IT network are needed to fill up cards. Ticket controllers have to be equipped with readers. Furthermore, means of transport are to be equipped with appropriate devices to enable collection of fares and data transfer.

Generally implementation of an electronic ticket involves changing a data carrier, usually a paper one, which is still commonly used. To obtain complete information on passenger traffic inside vehicles, passenger turnover at specific stops, types of journeys taken on specific types of tickets as well as the structure of tickets on every line, an average length of a journey broken down into ticket types and an average length of a journey for a given line, it is necessary to equip vehicles additionally with special ticket punchers or automatic readers

at entrance doors. This is justified only if the electronic ticket is going to be introduced for the majority of passengers and if their journey is recorded twice – on its commencement and on its end in a given vehicle. This also concerns persons who take advantage of free of charge transport, in compliance with the transport tariff. In this case, by analysing data from ticket punchers, the system is able to calculate automatically the profitability of every line, which can be used e.g. to develop the rules for calculating subsidies for specific transport lines, depending on their profitability. In addition, the system can detect when a passenger has no valid ticket (using automatic readers at vehicle doors) and transfer this information to the driver, with a sound signal to switch on at a given door.

Taking into consideration the passengers' current habits, a need to have the electronic ticket recorded twice in a vehicle seems quite difficult to implement, especially for periodical tickets and free-of-charge transits. However, due to potential benefits and a quick progress in IT technologies it may be expected that the electronic ticket will gradually replace the paper ticket in collective transport, with full acceptance by passengers enjoying the comfort it offers. Otherwise, a supplementary questionnaire survey would have to be conducted, and this would entail considerable expenses.

If the electronic ticket replaces only periodical paper tickets, an additional function may be employed to count single-use tickets punched as this function is available in commonly used standard ticket punchers. In case of single-punch single-use tickets the number of punches should reflect the number of passengers travelling with single-use tickets. Then, however, no data can be collected on ticket types (reduced fare, number of zones, etc), the way and the destination of a given passenger as well as journeys undertaken by people authorized to travel free of charge. Therefore it is impossible to count an average length of a journey which is one of the factors affecting the profitability of a transport line, and consequently use it in financial settlements of various types between the service buyer and the provider of a given transport service.

The solution to be applied should be modern enough to form the basis for developing a tariff system in a flexible way and to widen a range of services on offer e.g. concerning access to or payment for other urban services (car parks, entrance tickets etc). Such a system should be able to separate payments into individual services and individual providers and, which is also important, anticipate a possible settlement of ticket revenues connected with tariff agreements concluded e.g. by a few urban transport management units.

If a new generation non-contact electronic ticket is chosen (peak sensors at doors, passengers are recorded when getting on and off without having to take out their tickets), the bus equipment cost may be comparable to the automatic passenger traffic measurement system. Moreover, irrespective of the solution, ticket controllers have to be equipped with controlling devices worth approx. PLN 3,000 per unit. Every card filling terminal would have to be equipped with a GPRS module card reader (costs approx. PLN 1,000). Points of sale and card personalization points would additionally need to have a computer, a printer for card personalization and optionally a digital camera (if a card is to bear a photo –then a periodical ticket holder or a reduced fare ticket holder would not have to present any other ID documents when controlled). Complete equipment for such a point costs approx. PLN 15,000. We should not forget about the cost of a card itself (approx. PLN 12 per a processor card), which can be partly passed on to a passenger in form of a deposit for issuing a card. All the costs quoted above concern individual orders and in case of big organizers and implementation of the program in the entire system, these costs may get halved by the economies of scale. For example, for a town with 380,000 population, such as Bydgoszcz, which is served by 48 bus lines and 8 tram lines (in total 205 buses and 42 tram sets), the implementation cost for the

complete electronic fare charging system using non-contact cards amounts to approx. PLN 25,000,000[3], as given in a website of Urban Roads and Public Transport Management in Bydgoszcz. The analyses conducted for Rybnik, with approx. 142,000 inhabitants, 39 transport lines, 77 buses within the Collective Transport Management, on the other hand, found that the implementation of the urban electronic card would cost approx. PLN 5,000,000 [4].

The two examples are given here to illustrate estimated financial expenses required to implement such projects. The scope of implementation in the examples differs so no direct comparisons could be made.

6. CONCLUSION

This article presents various methods for collecting information on passenger flows on transport lines. Depending on the reasons why such measurements are to be taken, we may choose the methods based on direct count of passengers by persons hired to do that or the automatic systems. In the former case, when the measurements are aimed at providing support when adjusting the transport offer to the passengers' needs and when modifying the timetables, the method described in point 1 seems sufficient. However, if the measurements are of a regular nature and are to be used in various financial settlements between the service buyer and the service provider, the automatic methods are recommended.

Every method described here, except for the direct count of passengers, requires substantial investment. The costs related to operation, implementation and collection of data on passenger flows are also considerable. However, after the investments are made, a variety of data can be obtained on passenger flows on individual transport lines, sections of a network and based on that the transport offer can be managed, and financial settlements between the service buyer and the transport service provider handled. Nowadays in Poland a generally used fare charging system is based on operating work performed (so-called vehicle-km), instead of a number of passengers carried or revenue generated by a vehicle, a given line or a carrier. This leads to a situation when carriers are concerned about vehicle-kilometers only, not about maximizing passenger transport. Of course, there are situations when transport services are going to be performed despite being unprofitable. This, however, does not undermine the importance of getting data on how much these lines are subsidized. This is one of the purposes of the implemented automatic measurement systems and the situation when these systems are implemented without using their all potential, as often happens, cannot be considered as appropriate.

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Reviewer: Prof. Barbara Kos