Research Paper Engineering

# Application of Multi-criteria Evaluation Method for the Selection of Check-in System in Urban Public Transport

**Ivana Olivkova** VSB – Technical University of Ostrava, Faculty of Mechanical Engineering, Institute of Transport, 17.listopadu 15, 708 33 Ostrava-Poruba, Czech Repubic

**Dr.Zuzana Svedova** Transport Research Centre, v.v.i. (CDV, v.v.i), Lisenska 33a, 636 00 Brno, Czech Republic

**ABSTRACT**

In the transition to a new system or upgrading an existing check-in it is necessary to take into account several important facts affecting the activity and organisation of urban public transport (PT), the quality of transport process, and the associated satisfaction of passengers. This article is focused on the possibilities of modern check-in technologies, which are intended for the urban public transport, their subsequent comparison and evaluation

**KEYWORDS** urban public transport, check-in system, multi-criteriaevaluation.

## 1 INTRODUCTION

Check-in system is a key interface between the carrier and the passenger. This term has been associated with tariff and Conditions of Carriage, used in the sense of realization fare collection, points to the organization of getting in and out of the PT vehicle, and the definition of paid transport space within the stations. It also defines a method of selling tickets and their validation, proof of the travel document when controlled by an authorized personnel. The fare collection system must be primarily supported by appropriate distribution of tickets, their suitably wide range, clearing, information system support, the benefits of dispatching system for individual transport operators etc. [6]. Currently various market pressures to improve fare collection system based on paper ticket, whether in the form of a draft of new system or in potential measures to improve the current situation. For this reason, the article focuses on the possibilities of modern check-in technologies that are used for public transport, their subsequent comparison and evaluation.

## 2 Method of multicriteria evaluation of alternatives

In the theory of decision-making there are several methods of multi-criteria evaluation of alternatives. The aim was to select methods that allow the evaluation criteria with respect to their relative importance and therefore they can be used in selecting the appropriate check-in system.

**From the above, there are the following objectives:**

1. Proposed method of multicriteria evaluation of options for selecting the check-in system in public transport
2. Experimental verification of the proposed method, making multi-criteria evaluation of alternatives in the public transport fare collection system based on processing traffic survey selected group of experts.

**These objectives are further processed together and divided into five consecutive steps:**

a) choice of assessment options,
b) defining evaluation criteria,
c) determining the weights of each evaluation criteria,
d) sub (isolated) evaluation of the options,
e) multi-criteria evaluation of alternatives.

Traffic survey conducted in November 2011, reaching a selected group of evaluators (experts on traffic issues). We addressed 32 evaluators. The evaluators were informed about the various options and check-in systems based on their expertise evaluated these variations through criteria. Evaluators answered questions through a pre- prepared questionnaire.

### 2.1 Choice of assessment options

Options (alternatives) are defined as specific decision options that are available for sale. This chapter is to analyse the possibilities of modern technology in the departure control systems. Specifically, it will be the technology of SMS tickets and the use of RFID (Radio Frequency Identification).

#### 2.1.1 SMS ticket

SMS ticket is a specific type of electronic travel document that allows electronic ordering of tickets through SMS sent from a mobile phone. Payment is done by sending short text messages SMS in a special form on a specific phone number. The service system returns a message that a passenger shows when checked by transport inspection of travel documents as the authorized employee may check the display unit of the passenger mobile device [6].

#### 2.1.2 RFID Technology

Another alternative is to use non-cash handling technology RFID (Radio Frequency Identification) allowing contactless identification and data transmission by synergies of electromagnetic alternating fields acting between the chip and the sensor. As data media passive or active chips are used. The application of the technology can be found not only for public transport check-in system, it is also used as warehouse automation technology, attendance, access respectively, catering systems etc. [6].

**Applying passive chips**

In public transport the trend is in the application of smart cards for checking regular passengers, which replace paper travel documents. Contactless cards are used primarily for their speed and ease of use by passengers. The most widespread contactless smart card in the Czech Republic, MIFARE uses Smart Card chip, the one is one of the most progressive and the most widespread in their domain. The card is an intelligent storage medium with a high degree of security and therefore its use is safe for many other applications [6]:

- Electronic wallet - pay for individual journeys, the card is preloaded with the amount of money delivered by a pas-

senger and the actual price for the ride is deducted.
- Season ticket - use time tickets is dependent on the type of tariff plan. It is possible to limit the number of such trips, the validity of a season ticket, the card is equipped with a photograph of the holder, the carriage can be restricted to a certain area or selected PT lines, etc.
- The combination of an electronic wallet and a season ticket - you can use the contactless card, which contains a pre-loaded "electronic wallet" along with a season ticket. This combination is particularly useful for payment for baggage, passenger companions etc., while using the season ticket.
- Other possible applications - for example for using parking systems, used to pay for meals and identification purposes, borrowing books, etc.

**Passive technology - Procedure Check -In / Check- Out**
The checking procedure is based on the principle of handling logging in and out of the passengers through the smart card; the passenger is checked by means of an electronic wallet with the allocation of appropriate financial amount. Checking terminals are located on each door. When entering the vehicle and attaching a smart card to a terminal the electronic wallet counts a deposit ticket to the destination stop. When a passenger is to exit he/she attaches the card to a terminal again and this deposit will recalculate the price that corresponds to the actual distance travelled. The check-in method, which is used by passengers that do not possess time fare, simulates a single electronic ticket. Frequent flyer card works as a subscription fare and passenger is usually not required to attach the card to the terminal. This method of checking poses increased demands on the passenger's frequent manipulation with a smart card and also on the required equipment of the carriers' vehicles [6].

**Passive technology - Procedure Check –In**
Check-in method is similar to that of check-in/check-out, but passengers handle with a card to check only when entering the vehicle. In the case of using electronic wallet the appropriate amount of money by tariff is subtracted from passenger's wallet and a paper document used for control purposes is issued, so when compared to cash passenger ticketing this saves time and effort of the driver. The smart card fare with time is attributed to the terminal to check its validity, which prints automatically a paper document with information about the validity of the time fare. In the case of a passenger the discounts (children, students) must be entered on the chip with additional information about the type of discounts, the same applies for the card mode check-in/check-out [6].

**Active technology - Procedure Be- In / Be- Out**
Unlike passive systems, active checking of a passenger is here not required, thus eliminating any further manipulation of the media when getting in and out. The presence of a passenger in the PT vehicle is detected with Be-In/Be-Out system through a specific personal smart cards or mobile phone with an embedded chip that is active and reports cyclically in the search for connection. All the journeys are automatically registered. [6].

**NFC technology**
NFC (Near Field Communication) is a technology enabling contactless data exchange between two NFC devices over a distance of 2-10 cm. In simplicity, it can be described as a technology that combines Smart Card (RFID) and mobile phone. NFC is also compatible with cards standard ISO IEC 14443 A (Mifare technology), which is used for electronic ticketing in public transport, but also as a means of payment (card).

**Users with the help of such a device were able to [4]:**
- Make payments,
- Use it as an electronic key - the key of the car, office, etc.,
- Access to information about products or services when holding the phone and retrieving information,
- Read discounts from coupons or "smart" billboards,
- Keep electronic ticket / tickets to travel by various means of transport, parking or access to various social events,
- Store the personal information,
- Share contacts, send a business card, send pictures to print etc.

Based on the completed questionnaires there were identified fare collection systems through the evaluation criteria and comparison of six variants:

1. The paper ticket ,
2. Check- In,
3. Check -In / Check- Out,
4. Be- In / Be- Out,
5. SMS
6. NFC

**2.2 Definition of evaluation criteria**
The criteria are defined as the views based on which the variants are assessed. For the evaluation of options base I have selected, after analysis and consultation with experts, five criteria that best describe the most important qualities that check-in (payment) system in public transport must have:

1. Ease of checking - it is mainly the issue of uniform tariffs and conditions of carriage for passengers understandable,
2. Speed of checking - Support for fast transactions at check-in not to cause delay for travellers to exchange/get in the PT vehicle.
3. Multifunctionality - an extension of the use of check-in system to other areas than just transport,
4. Operation reliability - the general ability of the checking system to perform the required function for a specified period of time, taking into account the effects of operational and other conditions,
5. Operation costs - a crucial factor for effective management and maintenance of the system, together with a draft tariff system operates on an early return of investment.

**2.3Determination of the weight of the individual evaluation criteria**
The second step is to determine the weight of each evaluation criteria. Weights of evaluation criteria reflect their importance numerically; the importance from the point of view of the evaluators.

The weights were calculated on the basis of preferential ranking criteria that evaluators determined through a questionnaire. Under this method, the evaluator determines the right order of significance criteria from most important (This criterion takes the first place in order) to the least significant (last in preferential order).

**For the determination of non-standard weight the following equation is applied [1]:**

$$k_i = n + 1 - p_i \quad (1)$$

$k_i$ - not standardized weight of $i^{th}$ criterion [-]

n - number of criteria

$p_i$ - the order of $i^{th}$ criterion in its preferential arrangement

Due to the requirements of comparability weights to the criteria established by different methods these weights should be normalized (the sum of the standardized set of criteria weights is equal to one). The standardization of criteria weights is done according to [1]:

$$v_i = \frac{k_i}{\sum_{i}^{n} k_i}$$

$v_i$ - standardized weight of $i^{th}$ criteria [-]

$k_i$ - not standardized weight of $i^{th}$ criterion [-]

n - number of criteria

In the table 1 there are average values of the weights calculated from all the evaluators' values.

**TABLE 1 Average values of single criteria weights**

| Assessment criteria | Average weight of the criteria |
|---|---|
| Ease of checking | 0,13 |
| Speed of checking | 0,18 |
| Multifunctionality | 0,21 |
| Operation reliability | 0,22 |
| Operation costs | 0,26 |

**Source: the Author**

**1.3 Partial (isolated) evaluation of the options**

The evaluators were informed about the various options of check-in systems and based on their expertise these variations were evaluated through criteria. Evaluation of individual criteria i=<1;5> was conducted by the evaluators by assigning a value of utility $u_i = 1$, $u_i = 0{,}75$, $u_i = 0{,}5$, $u_i = 0{,}25$ or $u_i = 0$. The evaluators assigned to each option an expression of the good value, benefits assessment (valuation, value) expressed as a real number. The higher the number was, the higher the evaluator preferred the variant.

Table 2 shows the mean value (benefits) of evaluation criteria assigned to the assessed options.

**TABLE 2 Average values (benefits) of evaluation criteria assigned to the assessed variations**

| Criteria \ Variations | Paper ticket | Check-In | Check-In/ Check-Out | Be-In/ Be-Out | SMS | NFC |
|---|---|---|---|---|---|---|
| Ease of checking | 0,74 | 0,68 | 0,62 | 0,89 | 0,72 | 0,78 |
| Speed of checking | 0,62 | 0,76 | 0,51 | 0,98 | 0,43 | 0,81 |
| Multifunctionality | 0,05 | 0,59 | 0,55 | 0,61 | 0,41 | 0,94 |
| Operation reliability | 0,87 | 0,76 | 0,47 | 0,63 | 0,46 | 0,62 |
| Operation costs | 0,65 | 0,67 | 0,56 | 0,51 | 0,75 | 0,61 |

**Source: the Author**

**1.5 Multicriterial assessment of variations**

The benefit values for the evaluated variations of PT checking systems (j=1,2, …, 6) can be calculated for selected criteria (i=1, 2, …,5). In this case the following relations can be used (3) [2].

$$U_j = \sum_{k=1}^{q} \sum_{i=1}^{n} u_i\left(x_{i,j}\right) \cdot v_{i,k} \quad (3)$$

$U_j$ - overall benefit of jth variation [-]

$u_i(x_{i,j})$- partial function of benefit of $i_{th}$ criteria of jth variation

$v_i,k$ - weight of ratio of relative importance ith criteria from the point of view of $k_{th}$ evaluator

n - number of evaluation criteria

q - number of evaluators

If the partial function and weighting of each criteria is known, we get for all evaluators partial benefit $j_{th}$ variations and the total benefit of $j_{th}$ variation, then we set a weighted sum of these partial benefits (3).

Evaluation is carried out in the form of a table comparing variation assessment (check-in systems) by the total utility $U_j$ (Table 3).

**TABLE 3 Average assessment of variations according to the overall benefits**

| Criteria \ Variations | Paper ticket | Check-In | Check-In/ Check-Out | Be-In/ Be-Out | SMS | NFC |
|---|---|---|---|---|---|---|
| Ease of checking | 0,10 | 0,09 | 0,08 | 0,12 | 0,09 | 0,10 |
| Speed of checking | 0,11 | 0,14 | 0,09 | 0,18 | 0,08 | 0,15 |
| Multi functionality | 0,01 | 0,12 | 0,12 | 0,13 | 0,09 | 0,20 |
| Operation reliability | 0,19 | 0,17 | 0,10 | 0,14 | 0,10 | 0,14 |
| Operation costs | 0,17 | 0,17 | 0,15 | 0,13 | 0,20 | 0,16 |
| Overall benefit of the variation | 0,58 | 0,69 | 0,54 | 0,69 | 0,55 | 0,74 |

**Source: the Author**

**4 Conclusions**

The method of multicriteria evaluation of options was used to evaluate the best check-in system technology and that was NFC technology, which was compared with other options and gained the higher value of the benefit of multi-functionality. The resulting value of the total benefits are not significantly different at Check-In Procedures and treatments Be- In / Be-Out. Be- In / Be- Out has the highest benefit at the criterion rate of clearance (the fastest check-in). Compared to modern ways of check-in paper travel documents still retain an important position, especially due to its operational reliability.

Among the least competitive technologies SMS fares and procedure Check -In / Check- Out are recognized. For SMS tickets this is mainly caused by the low value of the benefit criteria for clearance speed and reliability. Check-In / Check-Out has a low benefit criteria for ease of handling.

To conclude the proposed method for evaluation of multi-criteria variations as a tool for selecting appropriate check-in system in public transport are important results of the experiment, which show that the complex utility functions in a relatively simple form is a good approximation of the actual preferences of the subjects.

Greater differentiation between the variations of check-in procedures can achieve more significant differences between the values (benefits) evaluation criteria and also significant differences between the weights of individual criteria. The questionnaire survey would have to be answered by more respondents who are also very well aware of the operational characteristics of the above mentioned check-in technologies.

**AKNOWLEDGEMENT :**

This work was part of the project DOPSITReg. No.CZ.1.07/2.3.00/20.0226 funded under the Operational Program Education for Competitiveness.

## REFERENCES

[1] FOTR, J., DĚDINA, J., HRŮZOVÁ, H. Manažerskérozhodování. Praha: Ekopress, 2000. 231 s. ISBN 80-86119-20-3. | [2] FOTR J.- PÍŠEK M. Exaktnímetodyekonomickéhorozhodování. ACADEMIA Praha, 1986. | [3] PÍŠKOVÁ, V. Vícekriteriálníhodnocení variant I. VÚVA, Praha, 1993. | [4] CARR, M. Mobile Payment Systems and Services: An Introduction visiongain: M-Payments 2008 | [5] OLIVKOVÁ, I. Aplikacemetodvícekriteriálníhorozhodováníprihodnoceníkvalityveřejnédopravy. Perner'sContact IV/2011. Univerzita Pardubice 2011. s. 293-303. ISSN 1801-674X. | [6] KŘIVDA, V. - OLIVKOVÁ, I. - PAĽO, J. - RICHTÁŘ M. Dopravnítelematika. Vysokoškolskáučebnice ŽU Žilina, 2009.384 s. ISBN 978-80-8070-981-5. |