Eva BRUMERCIKOVA, Bibiana BUKOVA
University of Zilina
Univerzitna 1, 01026 Zilina, Slovakia
Henryk KOMSTA, **Iwona RYBICKA***
Lublin University of Technology
Nadbystrzycka 38 D, 20 – 618 Lublin, Poland
Corresponding author. E-mail: i.rybicka@pollub.pl

MULTI-CRITERIAL EVALUATION OF ELECTRONIC PAYMENT SYSTEM VARIANTS AND EVALUATION OF RESULTS OF AN EMPIRICAL RESEARCH FOCUSED ON AN ELECTRONIC PAYMENT SYSTEM

Summary. While choosing an electronic payment system intended for an immediate communication of a user (passenger) with an electronic terminal of a service provider (carrier), it is necessary to respect system parameters of presented technologies (NFC, EMV, and ABT). The methodology of choosing an electronic payment system within public transport may be divided into three steps as follows:

- outlining criteria for variants evaluation,
- multi-criterial evaluation of variants, and
- evaluation of empirical research results.

The presented article introduces more results of the research within VEGA project solving. Specifically, the article presents results of the multi-criterial expert decision-making problem using the WSA (Weighted Sum Approach) method and the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. At the end of the article, there are presented results of empirical research studies focused on an electronic payment system used in public passenger transport. The empirical research studies were realized in the Slovak Republic in 2014, 2016, and 2018.

1. INTRODUCTION

Currently, the development of electronic payment systems has achieved a considerable progress in many payment types, including the area of public transport. Utilisation of new payment systems (NFC - Near Field Communication, EMV - Europay/MasterCard/Visa, ABT - Account Based Ticketing) contributes to a higher satisfaction and fluency of passengers' movement within public transport. At the same time, new systems increase the efficiency of a fare withdrawal. Main objectives of electronic payment systems include the efforts to reduce costs of travel document distribution, options to implement new services, as well as to extend the number of passengers through simplifying the purchase of travel documents, or strategic planning of transport services [1, 12].

The implementation of an electronic payment system that would improve the quality of payment in comparison with the current state (mainly where the only option to buy a travel document is represented with a paper form) brings plenty of advantages. These advantages may represent the availability of a payment for a travel document for a passenger, statistical handling of data about the extent of utilising transport means for a carrier, or increasing the effectiveness of creating a schedule adapted to passengers' needs [5].

2. CHARACTERISTICS OF PROGRESSIVE METHODS OF PASSENGER HANDLING

NFC is a technology enabling a fast and safe data exchange within the distance of 4 cm. It is supported with a series of smartphones (these devices may be called NFC mobiles) and tablets; the technology is safe thanks to a very short scanning distance, and no identification is required. Owing to this reason, the connection is automatic and extremely fast. NFC also works on a principle of NFC tags. These chips are hidden in stickers or labels, which may be attached or otherwise placed almost on any place. For example, it can be a rear side of a mobile phone or a contactless chip card [2, 13].

EMV (three companies co-working on the development of EMV) is a global standard for credit and debit cards based on a chip technology. The aim of EMV is to establish standards for handling debit and credit transactions and to ensure global interoperability of the chip technology. The keystone of an EMV standard is a microprocessor positioned in a chip, which is part of a payment card. This standard is currently used while paying with payment cards [6, 11].

The heart of the ABT system of handling a fare is its functioning on a cloud level, where processes are executed in real time, however, are not readable for passengers. The ABT system stores data about customers, tickets, and tariffs only into a database. Thus, different modules, such as a fare calculation, can always access all existing files. Each passenger has an identification card, which associates them with their account in the database. Through the ID, which can be loaded electronically, a user can utilise services of a transport company to the full. Operating devices with interfaces, so-called field devices, serve for communication among passengers and the ABT system. Passengers can utilise electronic ID cards, bank cards, and mobile phones issued on the basis of transit services. The costs of a fare withdrawal are cut down as a result of reducing the fees for a transit card system administration and costs of infrastructure [4].

3. WSA (WEIGHTED SUM APPROACH) METHOD

The principle of the WSA method lies in the maximization of the variants' utility using the weights of evaluated criteria.

The method of calculation using WSA:

a) Determination of an Ideal Variant H and a Basal Variant D of a Criteria Matrix Y:
The ideal variant H represents a hypothetical variant which achieves the highest values according to all criteria. The basal variant D represents a variant that achieves the lowest values according to all criteria [7, 8].

Table 1

Ideal and Basal Variant of an Initial Criteria Matrix Y

	Simplicity and Convenience	Compatibility	Safety	Universality	Speed	Versatility
Ideal Variant	9.1	10	10	10	10	10
Basal Variant	7.4	6.9	9.5	9.1	9.2	8.5

b) Transformation of a Criteria Matrix Y to a Normalised Criteria Matrix R according to the Formula:

$$r_{ij} = \frac{y_{ij} - D_j}{H_j - D_j}$$

(1)

r_{ij} - a normalised element in the i-th row and j-th column of the matrix R; y_{ij} - an element in the i-th row and j-th column of the matrix Y; D_j - a basal variant of the j-th element; H_j - an ideal value of the j-th element

Table 2

Transformed Normalised Matrix R

EPS	Simplicity and Convenience	Compatibility	Safety	Universality	Speed	Versatility
NFC	0	0	0.6	0	0	0
EMV	0.941176	1	1	0	1	1
ABT	1	0.483871	0	0	0	0.466667

c) Calculation of a Weighted Utility of a Variant a_i according to the Formula:

$$u(a_i) = \sum_{j=1}^{n} v_j * r_{ij} \qquad (2)$$

$u(a_i)$ - a utility of a variant in the i-th row v_j - a standardised weight of a criterion in the j-th column; r_{ij} - a normalised element in the i-th row and j-th column of the matrix R

Table 3

Weighted Utility of Variants

EPS	Simplicity and Convenience	Compatibility	Safety	Universality	Speed	Versatility	Sum
NFC	0	0	0.171429	0	0	0	0.171429
EMV	0.179272	0.142857	0.285714	0	0.238095	0.095238	0.941176
ABT	0.190476	0.069124	0	0	0	0.044444	0.304045

The variant that achieved the highest value of utility $u(a_i)$ is evaluated as an optimal variant using the WSA method. According to the WSA method, the most appropriate electronic payment system in public transport is the EMV technology, i.e. Europay/MasterCard/VISA.

4. TOPSIS METHOD

The principle of TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method lies in the minimization of the deviation from the ideal variant [9,14].
   a) Calculation of a Normalised Criteria Matrix R according to the Formula:

$$r_{ij} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{m}(y_{ij})^2}} \qquad (3)$$

where r_{ij} - a normalised element in the i-th row and j-th column of the matrix R and Y_{ij} – an element in the i-th row and j-th column of the matrix Y.
After this transformation, the columns in matrix R represent unit vectors according to the Euclidean metric.
   a) Calculation of a Weighted Criteria Matrix W according to the Formula:

$$W_{ij} = r_{ij} * v_j \qquad (4)$$

where W_{ij} - a weighted element of the matrix W; r_{ij} - a normalised element in the i-th row and j-th column of the matrix R, and v_j - a normalized weight of a criterion in the j-th column.

Table 4

Normalised Criteria Matrix R

EPS	Simplicity and Convenience	Compatibility	Safety	Universality	Speed	Versatility
NFC	0.353541285	0.3296534	0.4682033	0.4347602	0.4395378	0.4060947
EMV	0.373382916	0.4148699	0.4148699	0.4148699	0.4148699	0.4148699
ABT	0.404920631	0.3737729	0.4227193	0.427169	0.4093703	0.4093703

Table 5

Weighted Criteria Matrix W

EPS	Simplicity and Convenience	Compatibility	Safety	Universality	Speed	Versatility
NFC	0.067341197	0.047093	0.133772	0.020703	0.104652	0.038676
EMV	0.071120555	0.059267	0.118534	0.019756	0.098779	0.039511
ABT	0.077127739	0.053396	0.120777	0.020341	0.097469	0.038988

b) Determination of an Ideal Variant H and a Basal Variant D with Respect to Values in the Weighted Criteria Matrix W

Table 6

Ideal and Basal Variant of a Weighted Criteria Matrix W

	Simplicity and Convenience	Compatibility	Safety	Universality	Speed	Versatility
Ideal Variant	0.067341197	0.0470933	0.1185343	0.0197557	0.0974691	0.0386757
Basal Variant	0.077127739	0.0592671	0.1337724	0.0207029	0.1046519	0.0395114

c) Calculation of the Variants Deviation from the Ideal d_i^+ and the Basal d_i^- Variant according to the Formulae:

$$d_i^+ = \sqrt{\sum_{j=1}^{n}(w_{ij} - H_j)^2} \tag{5}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}(w_{ij} - D_j)^2} \tag{6}$$

where d_i^+ - a deviation from the ideal variant, d_i^- - a deviation from the basal variant, w_{ij} - a weighted element of the matrix W, D_j - a basal variant of the j-th column of the matrix W, and H_j - an ideal variant of the j-th column of the matrix W.

d) Calculation of a Relative Indicator of the Variants Deviation from the Basal Variant according to the Formula:

$$c_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{7}$$

where c_i - a relative indicator of a variant deviation; d_i^+ - a deviation from the ideal variant, and d_i^- - a deviation from the basal variant.

Table 7

Calculation of the Variants Deviation from the Ideal and the Basal Variant

EPS	d_i^+	d_i^-
NFC	0.0002847	0.0002447
EMV	0.0001649	0.0003037
ABT	0.000141	0.0002553

Table 8

Relative Indicators of the Variants Deviation from the Basal Deviation

NFC	0.4622066
EMV	0.6480883
ABT	0.6442968

The variant with the highest value of the deviation indicator c_i is evaluated as an optimal variant using this method. The TOPSIS method evaluated the EMV technology, i.e. Europay/MasterCard/ VISA, as the best electronic payment system in public transport.

5. CONCLUSION OF EXPERTISE DECISION MAKING METHODS OF THE EPS

An optimal variant would be the one which would get the value of one (1) in the resulting evaluation. This variant would achieve the best values out of the available evaluation scale in all evaluation criteria. The result of the entire calculation is thus mainly affected with values of the input criteria matrix and the vectors of individual criteria weights [10].

The table data imply that multi-criterial decision-making methods (total utility, WSA, and TOPSIS) match in the order of individual variants. The EMV technology has been evaluated as the most appropriate variant of passenger handling in public passenger transport; it has reached the highest values in the input matrix, too. The technology has got the highest score regarding compatibility, safety, universality, speed, as well as versatility. The EMV technology has already achieved some results in the practice. Inhabitants have got used to a cashless payment system, which has been proved with statistic data of the Slovak Banking Association. It states that there were 5,228,729 payment cards issued by December 31, 2018. However, it is necessary to point out that public transport is also utilised by children who do not hold any payment cards. From this point of view, the ABT technology might rather be accepted; passengers would register using their electronic ID card, so called eID, which should be owned by all citizens of the Slovak Republic including children from their birth by the end of the year 2021 [3].

Table 9

Mutual Comparison of Results of Multi-Criterial Decision-Making Methods

EPS	Total Utility Method	WSA Method	TOPSIS Method
NFC	0.8628571	0.171429	0.4622066
EMV	0.9809524	0.941176	0.6480883
ABT	0.9171429	0.304045	0.6442968

6. RESULTS OF EMPIRICAL RESEARCH

As part of solving several VEGA projects, some empirical research studies were realized in 2014, 2016, and 2018, which focused on the following:

- the analysis of railway transport passengers' interest in the introduction of a cashless payment for tickets using a payment card (2014),
- the analysis of passengers' preferences regarding individual types of systems of payment for a ticket (2016), and
- the analysis of passengers' interest in new systems of passenger handling (2018).

The analysis of respondents' structure for individual years is given in Table 10.

Table 10

The Analysis of Structure of Empirical Researches Respondents regarding
the Number of Respondents and the Percentage

	2014	**2016**	**2018**
Number of Respondents	102	685	519
Male	44 %	50.6 %	58 %
Female	56 %	49.4 %	42 %
Age Structure	-	-	-
0 - 14	0 %	16 %	4 %
15 – 24	43 %	54 %	25 %
25 – 44	39 %	24 %	43 %
45 – 64	16 %	5 %	20 %
Over 65	2 %	1 %	8 %
Economic activity	-	-	-
Pupil	-	3 %	4 %
Student	26 %	50 %	12 %
Employee	55 %	40 %	61 %
Self-Employed Person	8 %	2 %	10 %
Unemployed	5 %	4 %	9 %
Retiree	6 %	1 %	4 %
Frequency of Travelling	-	-	-
Daily	23 %	19 %	9 %
1 - 2-times per week	53 %	33 %	20 %
1 - 2-times per month	14 %	20 %	19 %
Occasionally	10 %	28 %	51 %

From Table 10, it is clear that the structure of respondents regarding their sex was mostly the same. As to the age structure in all researched years, the greatest groups included intervals of 15 - 24 years and 25 - 44 years, which is related to the economic activity. Most respondents came from the group of students and employees. A big difference can be seen in the frequency of travelling where in 2018 more than 50% of respondents replied they travelled by train only occasionally.

Other parts of empirical researches were focused on a method of buying a ticket used by respondents. Table 11 contains answers of respondents when asked about the method of buying a ticket in individual years, given in %.

<div align="right">Table 11</div>

Method of Buying a Ticket in Individual Years (in %)

Payment System	2014	2016	2018
Cash	89%	79%	44%
Cashless with a Payment Card	8%	10%	12%
Cashless with a Contactless Payment Card	3%	8%	19%
Internet Banking	0%	3%	25%

Based on the results presented in Table 11, it may be stated that the system of buying tickets changed in the course of 4 years. In 2014, up to 89% of respondents preferred the cash payment for a ticket, and in 2018, there were only 44 % of respondents preferring such a system. Likewise, the Internet banking was preferred and used by more and more respondents in the course of those 4 years. In 2014, the Internet banking was used only by customers of RegioJet; currently, also customers of ZSSK use the Internet banking to pay for a ticket. Still it may be noted that a big number of passengers buy tickets in a cash desk, paying cash or cashless.

In 2014, the empirical research was concluded with questions regarding the respondents' opinion on the safety of buying a ticket using a cashless payment, and opinion on the introduction of a service of a payment for a ticket cashless using a payment card directly in the means of transport. Overall, 59% of respondents considered the cashless payment safe, even though they mentioned their preference of a cash payment. The empirical research in 2014 was concluded with a question regarding the respondents' opinion on the option of paying for a ticket using a payment card directly in the train. Overall, 82% of respondents would welcome such an option.

The empirical research conducted in 2016 focused on using NFC technologies. In that year, more than 55 % of respondents did not know about the option to pay with a mobile phone via NFC technology, though many respondents were using a smartphone supporting this function. Afterward, the NFC technology was explained to respondents, which was followed with a question if they would use a mobile phone to pay for a ticket. Overall, 36 % of respondents replied they would not use the NFC technology owing to their concerns about the mobile phone loss, discharge, theft, and subsequent abuse as well as due to their low trust in new technologies. The empirical research conducted in 2016 brought some interesting results. There was a hypothesis that young people younger than 24 years and university educated people would prefer a cashless payment for a ticket. The hypothesis was rejected as both young and university educated respondents preferred the cash system of payment for a ticket. The cashless payment system was more preferred by a group of self-employed respondents and respondents from Bratislava Self-Governing Region.

The empirical research conducted in 2018 was in general focused on progressive methods of passenger handling, and specifically, it was focused on the respondent's knowledge of NFC, EMV, and ABT systems of passenger handling. Just the question regarding preferences in payment method showed significant changes when compared with research studies conducted in 2014 and 2016. The aforementioned table implied that although in 2014, the cash system of payment for a ticket was used by 89% of respondents and in 2016 it was 79% of respondents, in the year 2018, only 44% of respondents used a cash payment system to buy a ticket. A big difference is also noticeable in using the Internet banking; in 2014, no respondent was using the Internet banking, but in 2018, it was 25% of respondents, and 31% of them used a cashless system of payment for a ticket.

Respondents were allowed to express their opinion on a cashless payment; they mainly stated that the cashless payment is fast, comfortable, and inevitable nowadays; however, they also mentioned the necessity to keep the cash payment.

The question where respondents were asked if they were familiar with the aforementioned systems of passenger handling allowed for more options. Most respondents (33 %) knew the NFC technology. An interesting founding was that even though respondents were using a cashless payment, they were not aware of the fact that such a payment was possible only via the EMV technology; only 16.5% of respondents replied they were familiar with this technology. Not surprisingly, the ABT technology was known by 10.3% of respondents, as it is a newer method of passenger handling. None of these technologies were known by almost 54% of respondents. Afterward, individual technologies were explained to them to find out which method of passenger handling would be preferred.
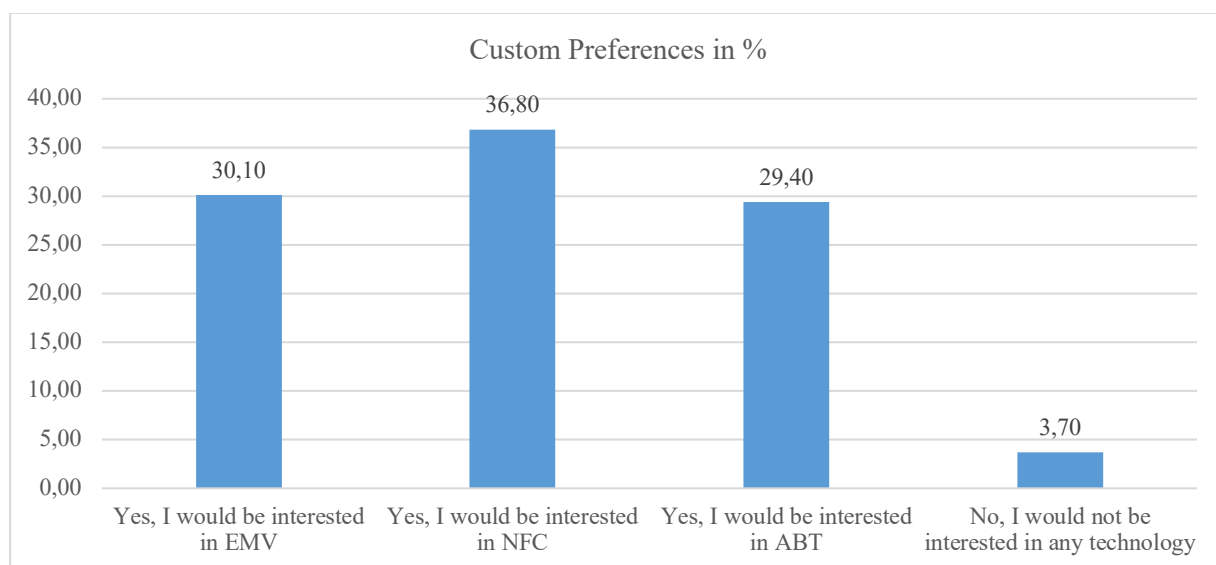

Fig. 1. Results of Respondents' Preferences

7. CONCLUSION

Nowadays, hardly anybody doubts the speed of information transfer. The cybernetic space has its own rules as well as traps. A synonym of the word "cybernetic" conveys the meaning of "electronically handled". Services in passenger transport utilise the cyber space in their business activities. New technologies enable passenger carriers to increase the comfort of buying the services for passengers. Thanks to the conducted research, we have come to the conclusion that a better customer awareness of new electronic payment systems is needed here.

Acknowledgment

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