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THE APPLICATION OF THE PROGRESSIVE DECISION-MAKING METHODS IN THE ELECTRONIC PAYMENT SYSTEM IN PUBLIC TRANSPORT

Summary. In 2018, there was an empirical research conducted in passengers' interest in innovative methods of passenger handling within passenger transport in the Slovak Republic. The research determined the knowledge of passengers regarding new methods, namely, NFC technologies, EMV technologies and ABT technologies. The article defines the methodology of choosing an electronic payment system within public transport, followed by partial results of research multicriteria evaluation of alternatives electronic payment system in public transport. For evaluation of variants, an electronic payment system within public transport was the selected method of a total utility.

1. INTRODUCTION

Currently, the development of electronic payment systems achieves a considerable progress in many payment types including the area of public transport. Utilisation of new payment systems (NFC, EMV and ABT) 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 documents 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, 2].

The implementation of an electronic payment system which 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 [3].

1.1. Innovations of an electronic system of payments in public transport

Multiple countries not only in Europe, America and Asia utilise in the sphere of public passenger transport some new innovative technologies and systems that improve the quality of transport services for customers. Technologies used abroad provide passengers with comfort and convenience. The following technologies are commonly applied in foreign countries: NFC (Near Field Communication) and EMV (Europay/MasterCard/VISA). The newest technology that utilises electronic identification cards of citizens (electronic ID cards, so called eID) to identify a passenger and to calculate a fare is the Account Based Ticketing ("ABT") technology.

NFC is a technology enabling a fast and safe data exchange within a 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 required. Owing to this reason, the connection is automatic and extremely fast. NFC also works on the principle of NFC tags. These are chips hidden in stickers or labels which may be attached or otherwise placed almost on any place. For example, it may be the rear side of a mobile phone or a contactless chip card [4]. The NFC specification is as follows: frequency: 13.56 MHz; bandwidth: 2 GHz; range: 20 cm; and bandwidth: 106, 212, 424 or 848 kbit / s. Two Near Field Communication modes can be distinguished - active and passive. In active mode, two devices (initiating and target) communicate by generating a signal. One of the devices is waiting for data, and its electromagnetic field is turned off. In the passive mode, the initiating device generates an electromagnetic field and the target device modulates it. The target device is then powered by the power of the electromagnetic field of the initiating device [5].

The main applications of NFC technology are contactless payments made by telephone. There are many more applications. In the future, NFC may contribute to the total elimination of paper tickets in public transport, because all of them can now be stored in one place - on a smartphone. The same applies to loyalty cards and discount coupons in shops and restaurants. Automatic pairing of wireless devices, reading information and downloading offers from specially marked posters and billboards, the possibilities of practical use of NFC in the field of wireless communication are virtually limitless [6].

EMV (three companies co-working on the development of EMV) is a global standard for credit and debit cards based on 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 [7, 8]. The name of EMV comes from the original creators - Europay, MasterCard and Visa. Chips replace old magnetic strips, which are often copied or duplicated, and add another very secure level of fraud protection. In combination with the required PIN, which is necessary to authorize the transaction, the chips create a barrier difficult to overcome by cheaters [9].

EMV and NFC technologies complement each other. EMV is a global payment standard supporting both contactless and non-contact transactions carried out in a terminal compliant with this standard. NFC is a technology that enables communication between nearby electronic devices, such as a telephone or watch and a payment terminal. Although the course of payment looks different (in one case we insert the card into the chip reader, in the other case - we attach it to the NFC reader), both card and contactless payments in the EMV standard are safer and authenticated. Most readers accepting cards with an EMV chip also support the NFC technology required for Apple Pay payments [10].

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. As a result of reducing the fees for a transit card system administration as well as costs of infrastructure, the costs of a fare withdrawal are cut down [11].

NFC in mobile phone

This chapter describes the processes in which a transport card is involved when it is in an NFC mobile phone. The purpose is to give a view of the card life cycle and the implications involved for successfully achieving the implementation of the NFC mobile phone in public transport.

Differences when the card is in the NFC Mobile Phone

When a transport card is placed in a mobile phone, some important differences occur that need to be pointed out for a better understanding of its implementation implications in public transport.

- The transport card becomes "virtualized" inside the mobile phone's secure element (SE), therefore ceasing to exist as a physical card or physical chip.
- The transport ticket is also "virtualized" inside the card, but this in fact is nothing new as it is already happening in current transport cards.
- The SE is a support that will be able to hold other transport cards or other types such as bank cards, as well as other services, communications etc., which means that it can no longer be owned by the transport company.
- As the card will be located inside the mobile phone, it may be accessed remotely at any time communication is activated.
- The mobile phone environment, and more with the NFC environment, makes it possible to make payment transactions from the mobile phone, which leads the way to card top-ups without having to go to a top-up point.
- As NFC technology is currently an emerging technology and has many requirements associated, it cannot always be guaranteed that the card will be downloadable to all mobile phone models in the market, meaning that the user will always have a choice during card request process on the mobile phone.
- The contactless card has certain limitations, among them its interaction capacity: we can only obtain information on the card if we hold it near a terminal that powers it and is able to authenticate and obtain the corresponding information. NFC makes it possible to remove this obstacle, as mobile phones today have large screens, connectivity and processing capability [12].

Ticket life cycle

The ticket life cycle diagram is complex. By way of an example, a typical diagram is included to show it (Fig. 1).

Identity control in case of personalized tickets - if the ticket requires the user to have specific characteristics. The user must be clearly identified despite not having a physical card with a photograph.

Transactions in general by lists - contactless cards are processed remotely by lists of cards that are sent to the devices and when they locate them, they act. With NFC technology, this may be done immediately. For example, if the user has 3 additional trips owing to an incident, this balance may be increased remotely at any time.

Remote charging - the ticket may be recharged remotely and in real time, without the need to have to wait to pass a top-up or validation point which has been reached by a list of cards that have made a top-up purchase on the web site [11]. The following diagram shows An Exploration of the NFC-related elements on mobile handsets.

ABT without or with EMV

If ABT is not based on bank cards, there is no contractual need for a PCI-certified path. In this case, a payment Back-office is not necessary. The same architecture can be used for ABT and Card Based. It can even be the same system if it is limited to one operator or to a shared system.

In the following architecture, validations are split by the validator (Fig. 2).

However, it is also possible that all the validations go first to the card-based back-office, and then, only ABT validations are transferred to the ABT back-office. Alternatively, it is possible that the ABT is before the card-based B-O. The major benefit of such a solution is that no modification is needed at validator level [13].

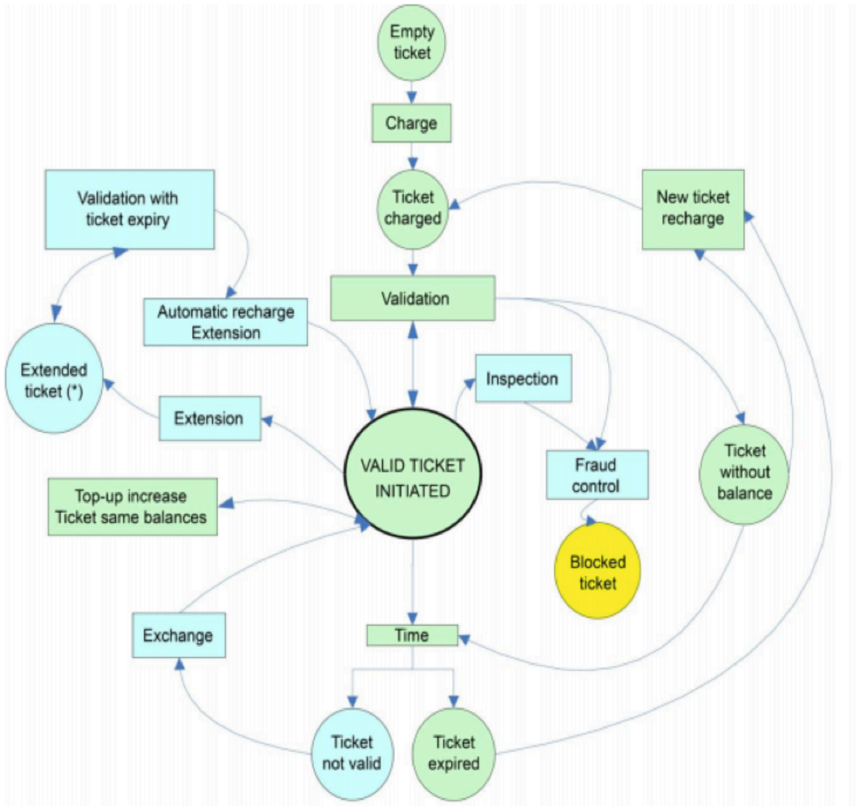

Fig. 1. Ticket life cycle [11]

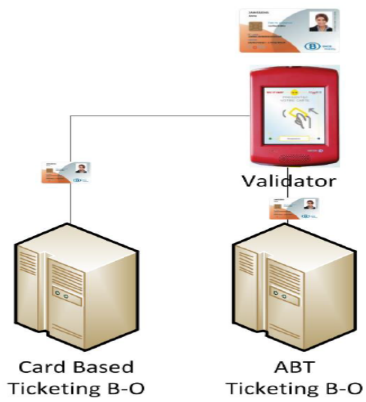

Fig. 2. Validations split by the validator (calypso) [13]

The way to implement it to have a minimal change on the back-end is the following:

- Two contracts must be created: One contract for anonymous prepaid value contract. This contract can be renewed like normal contracts. This contract has the remaining value as counter. One contract for post-paid ABT approach. This contract has a validity period and for the rest is like a LP (limited partnership).
- Adaptation must be done on the back-end to send all the validations to the calculation engine.
- Adaptation must be done also to accept return of calculation for 3 aspects:
  - Adaptation to counters on card anonymous value contracts to pay back amounts owing to capping or interoperability rules.
  - Amount to be invoiced for postpaid contracts.
  - Amount to be paid to other actors for post-paid contracts [14].

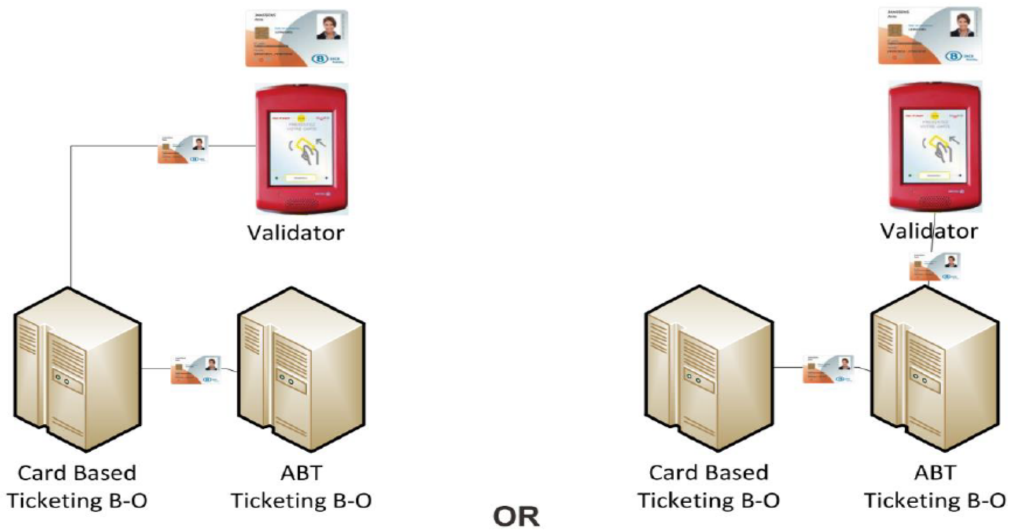

Fig. 3. Cased Based after or before ATB Ticketing B-O [13]

For post-paid accounts, the ABT contract will be similar to a pass with a validity period corresponding to the payment authorization period. It can be renewed with a new authorization. The contract can also be black-listed if the account is disabled before the end of validity period.

"Classical", i.e., card based, contracts have priority on the ABT one. ABT is only used when no other contract present on the card can be used.

For prepaid-anonymous contracts, it must be checked that the user does not exceed the prepaid amount. Because it is impossible to have all the validators permanently online, there must be an amount counter on the card. Interoperability rules like P+R for example, and rules like "pay less for a second trip" or capping rules can be managed from the card or by the backend and refilled the card via green list. In any case, the back-end is mandatory for revenue distribution.

Prepaid cannot be used for all service. For bike sharing, for example, even if the rental cost can be covered, the price to be paid if the bike is lost cannot be covered.

2. METHODOLOGY OF CHOOSING AN ELECTRONIC PAYMENT SYSTEM WITHIN PUBLIC TRANSPORT

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. The methodology of choosing an electronic payment system within public transport may be divided into three steps as follows [15]:

- outlining criteria for variants evaluation,
- evaluation of variants comprised of multiple criteria, and
- evaluation of empirical research results.

Fundamental criteria which a modern system of passenger handling must fulfil the following:

- simple understanding of the system and easy operation - mainly issuing uniform tariff and transport conditions that will be comprehensible for a passenger,
- speed - support of fast transactions during passenger handling,
- safety - ensuring the highest possible data protection from a system misuse through an unauthorised manipulation, and demanding claims on personal data protection,
- compatibility - the adherence to uniform standards may ensure smooth compatibility of multiple carriers,
- complexity - the handling system may be extended with information and telematics systems,

- modularity - the possibility to sequentially add, modify, or remove individual system components, and
- openness - a request for an easy maintenance and service support independent on a system provider.

For evaluation of an appropriate electronic payment system, 6 fundamental criteria were set based on brainstorming with experts from the practice which give a true picture of attributes required for an electronic payment system in public transport [16]:

- simplicity and convenience - a payment should be as simple as possible for a user without a complex setting,
- compatibility - the development should be standardised in order to enable a further system extension; at the same time, it should be capable of communication with other systems,
- safety - users must trust in the payment system; a big emphasis must be put on personal data protection,
- universality - the application should not be limited (for example with a territory) within a single integrated transport system,
- speed - the speed of executing the entire payment process should be as highest as possible and acceptable for a passenger and a carrier,
- versatility - the payment system should not represent a payment system only in public transport.

3. EVALUATION OF VARIANTS OF AN ELECTRONIC PAYMENT SYSTEM WITHIN PUBLIC TRANSPORT COMPRISED OF MULTIPLE CRITERIA

For choosing an appropriate variant, a discreet decision model was chosen. Individual variants are here described explicitly using a list of variants evaluated according to individual criteria mentioned before.

The evaluation is described with a mathematical definition as follows [17]:

- a list of variants A = $\{a_1, a_2, \dots \dots, a_m\}$,
- a list of criteria F = $\{f_1, f_2, \dots \dots, f_n\}$,
- evaluations of variants according to individual criteria in a form of a criteria matrix Y:

$$Y = \begin{matrix} & f_1 & \cdots & f_n \\ \begin{matrix} a_1 \\ \vdots \\ a_m \end{matrix} & \multicolumn{3}{c}{\begin{bmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{m1} & \cdots & y_{mn} \end{bmatrix}} \end{matrix} \tag{1}$$

The objective of the decision method is to find such a variant which will achieve the highest possible assessment according to all criteria. Individual criteria were evaluated with values from 1 to 10. Table 1 is a starting criteria matrix of the task being solved.

Table 1

Evaluation of variants according to individual criteria in a form of a criteria matrix Y

	Simplicity and Convenience	Compatibility	Safety	Universality	Speed	Versatility
NFC	8	7	8	10	9	10
EMV	9	10	10	10	10	10
ABT	10	9	10	10	10	9

The NFC technology got fewer points with regard to a fact that in case of smartphones and tablets, the NFC chip is inactive, whereas in case of EMV and ABT, such a risk does not exist. In case of EMV and ABT, the payment is easy; moreover, in case of ABT, there is a secured online database where a passenger can check their own travel routes. An advantage of the ABT technology is that it keeps records of all "travels" of a registered passenger on their account, and at the end of the day, it generates the best option for the passenger, i.e., in case of a passenger who travels multiple simple travels using an urban mass transportation per a day, the back-office of the ABT technology may evaluate that for the given passenger it is more profitable to pay for a whole-day ticket based on a tariff instead of paying multiple single payments. In this case, the ABT technology is convenient and elementary with a high rate of comfort. Compatibility is ensured in case of ABT and EMV as both of them are standardised technologies; EMV is commonly used in all cashless payments in real life. According to an empirical research study that was conducted as part of VEGA project in 2018, inhabitants had the least trust in mobile phones. They put priority on protecting payment cards and ID cards from a theft. Universality could be ensured in all three variants. Versatility of using NFC and EMV technologies has already been tested in the practice. ABT is a new technology, but its versatility could be ensured in case of using an electronic ID card, so called eID, which should be used in communication with doctors and public administration. In the Slovak Republic, all citizens including children should have their eID by the end of the year 2021.

In the next step, it is necessary to set a weight (significance) of individual criteria. In order to determine weights was used a methodology, which was used as a ground; individual weights were discussed by experts from the field of transport telematics. Table 2 introduces average values of weights of individual criteria calculated for addressed 426 experts – evaluators [17].

Table 2

Average values of weights of individual criteria [17]

	Simplicity and Convenience	Compatibility	Safety	Universality	Speed	Versatility
Weights of Criteria	0.04	0.21	0.25	0.11	0.07	0.18

The task can be solved using 3 ways, namely the following:

- a method of a total utility,
- a WSA (Weighted Sum Approach) method, and
- a TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method [18].

4. THE METHOD OF A TOTAL UTILITY

Consumer preferences are a key issue in researching their market behaviour. Consumer behaviour is determined by needs, the list of which is long and open. Consumers make choices so that the existing benefits can be maximized with existing budget constraints. Any choices made individually are sanctioned with individual preferences, tastes and habits that are called preferences. Preference analysis and usability theory are the basis for multivariate measurement (conjoint analysis) [19].

For solving a given decision problem, to find an appropriate variant of an electronic payment system in public transport, the first method of a total utility was chosen; other methods would subsequently be used in the following part of VEGA project solving.

The calculation procedure using the method of a total utility is as follows:

a) Transformation of a criteria matrix Y to a normalised criteria matrix U

Based on a point evaluation of individual system variants according to selected criteria in the range from 1 to 10 points (Table 1), variants are assigned a utility value u_{ij} in the range from 0 to 1. Table 3 contains average values (utilities) of evaluation criteria.

b) Calculation of a Total Utility of Variants

At the construction of a total utility, an additive form of the function is applied [17]:

$$U\,(a_i) = \sum_{j=1}^{n} u_{ij} * v_j \qquad (2)$$

$U\,(a_i)$ - a total utility of a variant in the i-th row

v_j - a standardised weight of a criterion in the j-th column

uij - a normalised element in the i-th row and j-th column of the matrix U

Using the relationship (2), it is possible to express the total utility of a variant based on knowing the weights of a criterion and individual utilities of the variant with regard to individual criteria. The total utility will then be set as a weighted sum of these individual utilities. Table 4 contains individual utilities for individual variants and total utilities of individual variants.

Table 3

A transformed normalised matrix U

	Simplicity and Convenience	Compatibility	Safety	Universality	Speed	Versatility
NFC	0.8	0.7	0.8	1	0.9	1
EMV	0.9	1	1	1	1	1
ABT	1	0.9	1	1	1	0.9

5. CONCLUSION

Public transport in urban areas is becoming increasingly important. Given the present trends, e.g., increasing number of cars and congestion associated with it or crossing the permissible air pollution, this mode of transport should, according to many researchers, play a leading role. Dissemination of non-cash payments in public transport allows for reducing the costs of traditional ticket distribution, which improves the city's finances. A well-designed cashless payment system improves passenger travel comfort, and thus, it can effectively encourage city dwellers to choose public transport instead of their own car [20]. Payment cards have become an element of everyday life. They cease to serve only to withdraw cash from ATMs, as more and more often we pay with a card for all expenses. Based on the EMV standard, you can create a special product for municipalities interested in a significant increase in the service of residents and reduction of operating costs. This system can become a basic tool for settlement of residents and tourists visiting the city. Thanks to the universal payment schemes, the card can be used not only to regulate public transport charges, but also municipal charges such as rent, electricity, heating, gas or telephone. The possibility of non-cash payment for tolls can be, for example, a factor shaping transport behaviour - it increases the comfort of travellers who do not have to have cash with them. The possibility of paying with a card or smartphone in a vehicle makes life easier for tourists. There is no need to exchange money just to use public transport. The most important, however, is the comfort of travellers, because the payment is made directly in the vehicle we travel. There is no need to buy the ticket earlier [21].

The best (ideal) variant would be that one which would get the resulting value of 1. According to the method of the highest utility, the most appropriate electronic payment system in public transport is the EMV technology, i.e., Europay/MasterCard/VISA. This technology has already achieved some results in 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 5,183,733 payment cards issued by June 30, 2018. However, it is necessary to point out that public transport is also utilised by children who do not own any payment cards. From this point of view, the ABT technology might rather be accepted; passengers would register themselves using their electronic ID card, so called eID, which should be owned by all citizens including children from birth by the end of the year 2021. This article presents only one method of solution. Results of other two decision methods will be presented in following technical articles.

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