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Proposal AHP method for Increasing the Security Level in the Railway Station

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Abstract

Railway stations are objects that have a social significance because they provide services to customers and passengers of rail transport. There is a high frequency of movement of people in their premises and their near surroundings, but at the same time, it is true that these objects are characterized by a high level of vulnerability. In order to increase the level of vulnerability and safety, measures are usually taken in the form of regulations, rules on behavior in the building, movement in the building, prohibitions in the building, etc., but also the security elements that make up the protection system are used. How the security elements will be deployed and used must be thought and designed and only then decided on their application. It is the process of selection and application of security elements, which is the task of the subject decision-making that must be considered according to specific criteria, which will compare the individual possibilities or variants of using the elements. The decision-making process according to several criteria and variants is called multi-criteria decision-making. One of the methods used to calculate the optimal or most suitable variant for a railway station is the AHP method (analytical hierarchical process. In the article, the author describes the theoretical apparatus of multi-criteria decision making and the AHP method, which he applies in a case study to a specific object.

Keywords: AHP method, multi-criteria decision making, railway station

1. Introduction

In the conditions of the Slovak Republic, railway stations are often undersized by safety elements. This fact allows perpetrators of offenses and crimes less afraid of clarifying the acts and their subsequent arrest. According to Hofreiter

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(2015), railway stations can also be considered as magnets of crime, because in their immediate vicinity there are often inadaptable persons, gaming houses and criminal persons in the conditions of the Slovak Republic.

In order to partially reduce them and protect the railway station building, as well as those using rail transport and railway station services, measures need to be applied. The Railways of the Slovak Republic (ŽSR), as the majority state enterprise owning the majority of railway stations, has adopted a number of regulations to increase safety at stations. These are, for example, regulation ŽSR Z2 *Safety of employees in the conditions of the Railways of the Slovak Republic*, regulation ŽSR Z9 *Permitting entry to the railway circuit in the administration of the Railways of the Slovak Republic*, regulation ŽSR R3 *Management of safety risks of the railway system in the conditions of the Railways of the Slovak Republic* and others related to security issues, for example works Dvorak et al (2012) and Dvorak et al (2016). In addition, Leitner et al. (2015) state that measures in the form of regulations, a suitable solution is a protection system consisting of security features. Safety features must comply with the regulations and standards to which they fall in order to fulfill their purpose and security class. The protection system can have different variants, which must be assessed according to the individual and specific needs of a particular object. Multi-criteria decision-making is a suitable tool for this process. Multi-criteria decision making can be used by the subject of the decision making in choosing the optimal variants. Boroš et al. (2018) state that subject of decision-making is usually a high-level security expert who is able to identify, analyze and assess risks and threats and eliminate as much as possible the negative consequences of potential negative phenomena on people or objects of interest.

2. Multi-criteria decision making and AHP method

Sharma et al. (2018) state that multi-criteria decision-making is a flexible tool for the decision-making process that can be applied to different areas of research and areas of focus. When choosing the designed solutions for securing the object, it is necessary to consider on the basis of what criteria the subject of decision-making will choose the optimal variant. It is important whether the variant will protect the person or the element. Opinions in practice are also divided on this issue, as a railway station can be considered as an element of critical infrastructure Leitner et al. (2017) or as a soft target Kalvach and Vangeli (2018). Multi-criteria decision making has several methods, some of which are by Velasquez et al. (2013):

- Multi-Attribute Utility Theory (MAUT),
- Analytic Network Process (ANP),
- Analytic Hierarchy Process (AHP),
- Fuzzy Theory,
- Case-Based Reasoning (CBR),
- Data Envelopment Analysis (DEA).

The author of the article chose the AHP method because it is not so demanding on input data, it has a clear hierarchical process even for people who see the decision-making process for the first time and fast results verifiable by the amount of software support.

The author of the AHP method is Thomas L. Saaty, who is considered to be the founder of the theory of analytical hierarchical process, extensive decision-making, multicriteria decision analysis, analytical network process and its generalization to dependency and feedback decisions. Leitner (2018) state that the AHP method is based on a pairwise comparison of the degree of significance of individual criteria and the degree to which the evaluated solution variants meet these criteria. However, the rating scale is much more complex. Xitlali et al. (2014) state that the evaluation is in both cases (comparison of criteria and variants) based on the so-called "Expert judgment", in which experts in the field compare the interactions of two factors. Nefeslioglu et al. (2013) state that AHP is a method designed to solve complex situations in which an effective decision is needed. This method allows for the subject of decide-making to divide the problem into smaller parts and create a hierarchical model. The use of the AHP method consists in dividing the main decision problem into separate elements and their pairwise comparison.

All methods have certain disadvantages and a degree of subjectivity. Among the disadvantages of AHP are by Macharis et al. (2004), the artificial restriction of the use of a 9-point scale. In practice, this can be an example if variant A is five times more important than variant B, which in turn is five times more important than alternative C, there is a serious problem with the evaluation. The AHP method cannot cope with the fact that variant A is 25 times more important than alternative C. Another disadvantage of this method according by to Nefeslioglu et al. (2013)

which is often mentioned also in another publications and scientific articles is the degree of subjectivity of the assessor's expert judgment and a certain dependence between the criteria and variants, as the chosen criteria may skew the results for a particular variant.

3. Case study

The reference object for the application of the AHP method will be the Zvolen railway station. It is a detached building located near the city center. Due to the scope of the article, a detailed description of the internal and external environment of the building, which was acquired by inspections of the building, communication with ŽSR employees and the railway police and previous research, will not be provided. The decision problem will be the object protection otherwise called by Loveček et al. (2018) deep multilayer protection consisting of:

- perimeter protection,
- door/wall protection,
- area protection,
- object protection.

3.1. Pairwise comparison of criteria

Based on the object and the situation in its internal and external environment, the author proposes the following variants to improve the current state of multilayer protection in Table 1. It is important to state that the protection system is proposed by the author against human factors or anthropogenic threats, not from natural elements. For object protection, a cash register will be considered in the "Information" room directly in the building.

Table 1. Proposed security variants.

Protection layer	V1	V2	V3	V4	V5
Perimeter protection		MBS	MBS + VSS	MBS + SeSe	SeSe + VSS + MBS
Door/wall protection		MBS	MBS + IAS	VSS + SeSe	VSS + IAS + MBS
Area protection			IAS	IAS + VSS	SeSe + IAS + VSS
Object protection				MBS	IAS + MBS

Designation in Table 1: MBS = Mechanical barrier systems; IAS = Intruder alarm systems; VSS = Video surveillance systems; SeSe = Security Service

An empty "box" in Table 1 means state without any addition or improvement of the current situation. That means used doors, opening panels and others do not have a safety class, so the potential perpetrator will not have worsened conditions of breakthrough resistance than it could be in the case of elements with a better security class or the condition will not change in any way. After determining the variants, it is important to choose criteria according to which the individual variants of the protection system will be compared.

- Criterion 1 = amount of operating and realization costs
- Criterion 2 = reliability of the protection system
- Criterion 3 = suitability for the specific environment of the object
- Criterion 4 = resistance of the protection system to attack
- Criterion 5 = flexibility of the protection system

It is necessary to compare the defined criteria in pairs and estimate their significance with each other, determine non-standard shape (relative significance) and convert them to a standardized shape. The pairwise comparison method was chosen to determine the shape. The evaluated criteria will be entered into the Saaty matrix based on a scale of 1-9, with 1- being equivalent, 9- an absolutely preferred criterion.

Table 2. Pairwise comparison of criteria.

K1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K2
K1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K3
K1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K4
K1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K5
K2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K3
K2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K4
K2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K5
K3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K4
K3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K5
K4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	K5

From the given pairwise comparison of criteria in Table 2, it was possible to create a non-standardized matrix of relative significance in Table 3 and its modification to a standardized shape Table 4. The procedure consisted in comparing for example criteria K1 with K2 the author determined the higher significance for K2, and in the non-standardized matrix of relative significance in Table 3, he wrote the relation that holds for K1 1/5 = 0.2 in the diagonal and in K2 in the diagonal under K1 was written the number 5. All criteria were followed, according to the author's expert estimate, after filling in each required number in the non-standard matrix. These numbers were also added in pillars and written in the SUM row for clarity. The SUM row was then used in the modified matrix (Table 4), so the standardized matrix of relative significance, where each number from the original non-standardized matrix of relative significance was divided by the required number from the SUM pillar.

Table 3. Non-standardized matrix of relative significance.

	K1	K2	K3	K4	K5
K1	1	0,2	0,33	3	1
K2	5	1	2	5	2
K3	3	0,5	1	4	3
K4	0,33	0,2	0,25	1	1
K5	1	0,5	0,33	1	1
SUM	10,33	2,40	3,91	14,00	8,00

Table 4. Standardized matrix of relative significances.

	K1	K2	K3	K4	K5	∑	Significance	Sequence
K1	0,10	0,08	0,08	0,21	0,13	0,60	0,12	3
K2	0,48	0,42	0,51	0,36	0,25	2,02	0,40	**1**
K3	0,29	0,21	0,26	0,29	0,38	1,42	0,28	2
K4	0,03	0,08	0,06	0,07	0,13	0,38	0,08	5
K5	0,10	0,21	0,08	0,07	0,13	0,59	0,12	4

After completion, all numbers in the individual diagonals marked in Table 4 were added as ∑ and divided by a number of criteria (5), that means, mathematically called, the significance of the criteria. All results and numerical values were rounded to two decimal places. Based on the stated relationships between the matrices, the most important criterion or priority of the criterion can be determined according to the highest numerical value in the resulting pillar significance of the criteria in Table 4.

The resulting order according to the pairwise comparison for the criteria we can see in Table 4. The main significance between the criteria has the criterion K2, that means the reliability of the protection system. Next procedure is to create matrices of individual variants on the basis of set criteria. Matrices and pairwise comparisons are performed in the same mathematical procedure, just compared with the set criterion. Each criterion must have its own scale of comparison for more valid and objective an expert estimate. For the range of the article are mentioned only evaluation scales for comparing variants.

3.2. Pairwise comparison of variants

With the amount of costs, the following funding will be estimated for comparison of variants:

- Variant 1 = zero cost,
- Variant 2 = up to 5000 €,
- Variant 3 = up to 10 000 €,
- Variant 4 = up to 50 000 €,
- Variant 5 = more than 100 000 €.

Table 5. Protection system reliability rating scale.

	Without security measures	MBS	IAS	VSS	SeSe
Assessment	1	2	3	4	5

In a pairwise comparison in Table 5, was in proposed measure added a value, which was added according to the proposed variants in Table 1 and subsequently compared.

Table 6. Qualitative assessment of the suitability for the specific environment of the object.

	Perimeter protection	Door/wall protection	Area protection	Object protection
MBS	Appropriate	Appropriate	Inappropriate	Appropriate
VSS	Appropriate	Inappropriate	Appropriate	Appropriate
IAS	Inappropriate	Appropriate	Inappropriate	Appropriate
SeSe	Appropriate	Inappropriate	Inappropriate	Inappropriate

In the pairwise comparison in Table 6, the value of 1 was added by the solver to the suitability of the proposed measure, in case of unsuitability -1, the pairwise comparison was continued according to the achieved values.

Table 7. Quantitative assessment scale of the protection system to attack.

	Without security measures	VSS	MBS	IAS	SeSe
Assessment	1	2	3	4	5

In a pairwise comparison in Table 7, was in proposed measure added a value, which was added according to the proposed variants in Table 1 and subsequently compared.

Table 8. Quantitative assessment scale of flexibility of the protection system.

	Without security measures	MBS	IAS	VSS	SeSe
Assessment	1	2	3	4	5

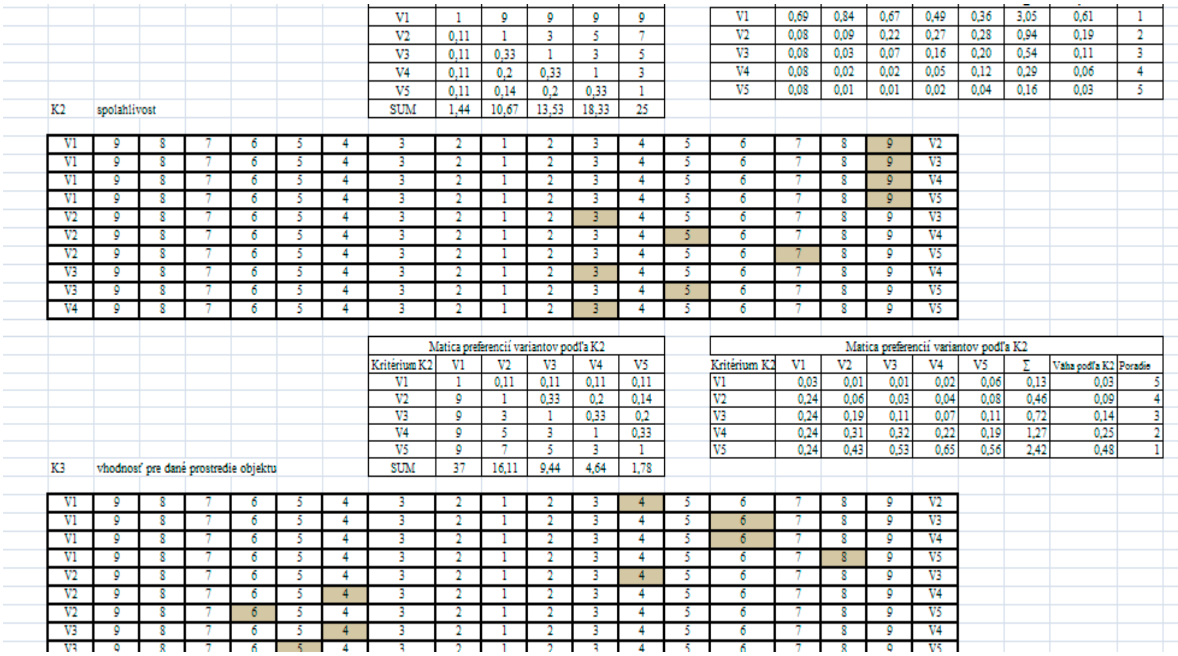
In a pairwise comparison in Table 8, was in proposed measure added a value, which was added according to the proposed variants in Table 1 and then compared.

4. Results

The calculation of the optimal variant was performed in Microsoft Excel (Fig. 1) by calculating the significance sum from the relations

V1 = K1 . V11 + K2 . V12 + K3 . V13 + K4 . V14 + K5 . V15 → V1
V2 = K1 . V21 + K2 . V22 + K3 . V23 + K4 . V24 + K5 . V25 → V2
V3 = K1 . V31 + K2 . V32 + K3 . V33 + K4 . V34 + K5 . V35 → V3
V3 = K1 . V41 + K2 . V42 + K3 . V43 + K4 . V44 + K5 . V45 → V4
V5 = K1 . V51 + K2 . V52 + K3 . V53 + K4 . V54 + K5 . V55 → V5

Sample calculation:
V1 = 0,12 . 0,61 + 0,40 . 0,03 + 0,28 . 0,04 + 0,08 + 0,03 + 0,12 . 0,03
V1 = 0,10



V1	1	9	9	9	9
V2	0,11	1	3	5	7
V3	0,11	0,33	1	3	5
V4	0,11	0,2	0,33	1	3
V5	0,11	0,14	0,2	0,33	1
SUM	1,44	10,67	13,53	18,33	25

V1	0,69	0,84	0,67	0,49	0,36	3,05	0,61	1
V2	0,08	0,09	0,22	0,27	0,28	0,94	0,19	2
V3	0,08	0,03	0,07	0,16	0,20	0,54	0,11	3
V4	0,08	0,02	0,02	0,05	0,12	0,29	0,06	4
V5	0,08	0,01	0,01	0,02	0,04	0,16	0,03	5

K2 spolahlivost

V1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V2
V1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V3
V1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V4
V1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V5
V2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V3
V2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V4
V2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V5
V3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V4
V3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V5
V4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V5

Matica preferencií variantov podľa K2					
Kritérium K2	V1	V2	V3	V4	V5
V1	1	0,11	0,11	0,11	0,11
V2	9	1	0,33	0,2	0,14
V3	9	3	1	0,33	0,2
V4	9	5	3	1	0,33
V5	9	7	5	3	1
SUM	37	16,11	9,44	4,64	1,78

Matica preferencií variantov podľa K2								
Kritérium K2	V1	V2	V3	V4	V5	∑	Váha podľa K2	Poradie
V1	0,03	0,01	0,01	0,02	0,06	0,13	0,03	5
V2	0,24	0,06	0,03	0,04	0,08	0,46	0,09	4
V3	0,24	0,19	0,11	0,07	0,11	0,72	0,14	3
V4	0,24	0,31	0,32	0,22	0,19	1,27	0,25	2
V5	0,24	0,43	0,53	0,65	0,56	2,42	0,48	1

K3 vhodnosť pre dané prostredie objektu

V1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V2
V1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V3
V1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V4
V1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V5
V2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V3
V2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V4
V2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V5
V3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V4
V3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V5

Fig. 1 Example of calculations in Microsoft Excel.

Table 9 shows a clear processing of the results of individual variants according to the set criteria and the overall order of the optimal variants of the protection system for the Zvolen railway station.

4.1. Verification of results in a software tool

The results were verified using a software tool available on the 123ahp.com internet platform. On this platform, after registering the account, it is possible to create your own simulation model with several criteria and variants and thus verify the achieved results of each variant and criteria.

Table 9. Comprehensive evaluation of the AHP method.

Evaluation of variants according to selected criteria						
Criterias	Significance	V1	V2	V3	V4	V5
K1	0,12	0,61	0,19	0,11	0,06	0,03
K2	0,40	0,03	0,09	0,14	0,25	0,48
K3	0,28	0,04	0,26	0,45	0,13	0,12
K4	0,08	0,03	0,09	0,14	0,25	0,48
K5	0,12	0,03	0,10	0,13	0,29	0,46
Weighted sum		0,10	0,15	0,22	0,20	0,32
Sequence		5	4	2	3	1

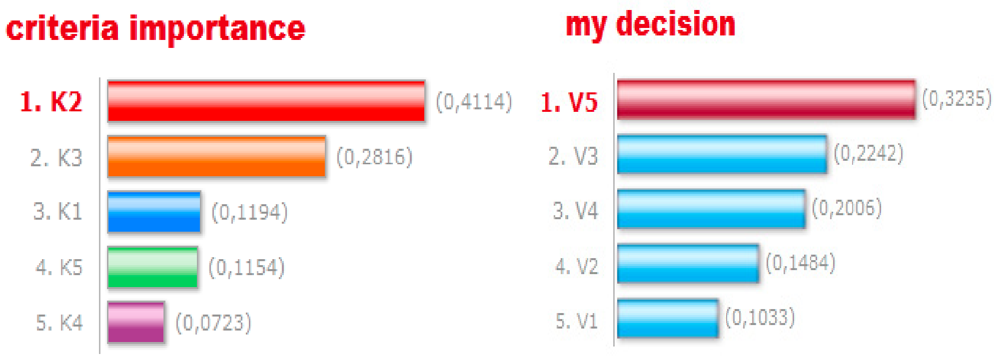


Fig 2. Calculation of the meaning of criteria in the 123AHP program and calculation of the optimal variant in the 123AHP program.

4.2. Interpretation of results

The optimal variant of the proposed system is variant 5 according to the selected criteria and variant 1 is the least suitable. The fact is that the number of security elements and measures, does not necessarily have to be appropriate to the specific environment, reliable, flexible and other factors that were taken into account in the expert judgment. Deficiencies in the expert estimation of pairwise comparisons may occur with the AHP method due to the choice of criteria and the subjective opinion of the evaluator. The results for the criteria and variants in the program matched the results. Using the software tool on web - *123ahp.com*, you can see in Fig. 2 that the same results were obtained in order, and the small deviation of the numerical values was caused only by rounding to two decimal places.

5. Conclusion

The aim of the article was to propose the use of a multi-criteria decision-making method to increase the level of protection of the Zvolen railway station. From the possible methods, the author chose AHP. The method consists in selecting variants on the basis of set criteria and their pairwise comparison and determination of the most suitable or optimal variant.

From the available information and interviews about the internal and external environment of the building consisting were chosen four layers, four variants of the protection system and five criteria for the decision problem. Option 5 was the most appropriate option according to the selected criteria. It is important to emphasize that this is not a number of proposed measures and security elements used. In this case study and the result, this can be seen in the result of variant 3, which turned out to be more suitable and optimal than variant 4, despite the smaller number of measures and security elements. Relationship calculations were solved by Microsoft Excel software.

The verified overall results of the standardized matrices and the order of variants and criteria were in the internet platform in the 123 AHP program and it can be stated that they matched. As mentioned in the article in multicriteria decision-making, there are also disadvantages for each method in the form of distortion of results and values. For this reason, the results obtained should be taken as the opinion of several people and a demonstration of the application of multi-criteria decision-making of the AHP method for the selection of the protection system.

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