XIX SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '20

RANKING OF LEVEL CROSSINGS IN THE PLANNING PROCESS TO SAFETY IMPROVEMENT USING THE VIKOR

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Abstract *– Level crossings are places where two modes of traffic intersect: road and railway. Bearing in mind that the accidents that happen to them are most often with severe consequences, there is the obligation of every society to undertake activities aimed at raising the level of safety in the zone of level crossings. These activities include the application of various technical solutions that require investments, which points to the fact that raising the level of safety at level crossings is a process that must be carefully planned. The problem arises when it is expected to determine which level crossings should be chosen to investing immediately, and which of them can be left for the next phase. In this paper, the VIKOR method was applied in order to obtain the rank of level crossings that could be used in the planning phase of the strategy for improving the level of safety at the crossings. Seven level crossings were selected and their characteristics were observed, such as the frequency of road and railway vehicles, their speeds in the crossing zone, visibility from the road to the railway tracks, the structure of road vehicles and the average annual number of traffic accidents on them. The paper shows that in the process of planning the strategy of investment in road-rail crossings, the methods of multi-criteria decision-making have a significant place.*

Keywords – Railway safety, Level crossings, Multicriteria decision making, VIKOR.

1. INTRODUCTION

Level crossings are the only places where two types of traffic meet, road and railway. Bearing in mind that the differences in the mass and speed of vehicles of these two types of traffic modes, it is clear that the consequences of traffic accidents at crossings have very serious consequences, especially for participants in road traffic. Therefore, it is necessary for each society to invest additional funds in order to raise the level of safety at level crossings.

There are two basic ways to increase safety at level crossings:
1. Using organizational measures and
2. Applying technical solutions

Organizational measures include the adoption of various regulations through laws and bylaws that regulate the right of way (all road vehicle have to miss trains), speed, visibility from road to the railway and some other parameters that affect the safety at crossings. These measures can contribute to increasing the safety of users of level crossings, but in practice they have been shown to be insufficient without additional measures.

The application of technical solutions implies technical systems which warn drivers that a train is approaching, close road traffic and ensure the safe passage of the train. The safest solution is the one that provides absolute safety, and such a solution can be achieved only in one way, by overpasses or underpasses the railway lines. This solution is the best, but it is also, the most expensive solution from the financial aspect.

In practice, it has been shown that the solution lies in a compromise between finances and an acceptable level of security. This means that, depending on the available funds, it is necessary to make a strategic plan according to which investments will be made in safety improving at level crossings.

The safety on the level crossings is affected by a number of factors. However, it is difficult to say which of the factors and how much affect the safety at the

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crossings. Also, sometimes we find ourselves in a situation where we lack data on some level crossings that are necessary to make a calculation. In such situations, we need a method that is based on the assessment and evaluation of parameters that affect the safety at the crossings. One such method is VIKOR, which is applied here in the fuzzy environment. VIKOR in fuzzy environment was applied for solving various railway infrastructure problems [1 -5].

2. MULTICRITERIA DECISION MAKING AND VIKOR

Multicriteria decision making (MCDM) is a discipline that belongs to Operational Research and is used when it is necessary to make a decision based on certain criteria that are most often conflicting. The greater the number of such criteria, the more complex the decision-making process.

There are numerous methods of MCDM process, and PROMETHEE, ELECTRE, TOPSIS, AHP and others are just some of the ones that are most used in these problems. One of the newer method that is increasingly finding a place in the scope of decision making problems is the VIKOR method (Multicriteria Optimization and Compromise Solution), which was developed to solve the problem of multicriteria optimization of complex systems [8]. It deals with the ranking and selection of alternatives from a set of alternatives and defines a compromise solution to the problem with conflict criteria.

Step 1. Defining the problem and the goal of the decision-making process - In this step the problem should be carefully defined and it should be clear what is the way out of the model.

Step 2. Define a set of final solutions and criteria on the basis of which the evaluation of alternatives is performed.

Step 3. Define a scale in the form of linguistic evaluations of criteria, as well as a group of experts from different fields, interested in the problem. Experts are performing evaluations of alternatives by criteria.

Step 4. The calculations of parameters f_j^* i f_i^- $(j = 1, 2, ..., n)$, for all chosen criteria:

$$f_j^* = \max_i x_{ij} \quad (1)$$

$$f_j^- = \min_i x_{ij} \quad (2)$$

Where $\boldsymbol{x_{ij}}$ ($\boldsymbol{i = 1, 2, …, m}$) i ($\boldsymbol{j = 1, 2, …, n}$) are elements of the matrix of transformed linguistic assessments according to the appropriate scale

Step 5. The calculations of the parameters $\boldsymbol{S_i}$ and $\boldsymbol{R_i}$, $\boldsymbol{i = 1, 2, …, m}$:

$$S_i = \sum_{j=1}^{n} w_j\left(f_j^* - f_{ij}\right)/\left(f_i^* - f_i^-\right) \quad (3)$$

$$R_i = \max_j w_j\left(f_j^* - f_{ij}\right)/\left(f_i^* - f_i^-\right) \quad (4)$$

Where w_j are weighted coefficients of criteria.

Step 6. The calculation of the paremeter Q_i, $(i = 1, 2, ..., m)$:

$$Q_i = \frac{v(S_i - S^*)}{(S^- - S^*)} + (1 - v)\frac{(R_i - R^*)}{(R^- - R^*)} \quad (5)$$

Where $\boldsymbol{v}$ is the coefficient for the group of maximum benefit.

Step 7. Ranking of alternatives by parameters S, R and Q, starting from the smallest values for each of these parameters.

Step 8. Analysis and interpretation of the obtained results. In this step, the fulfillment of the conditions necessary to give preference to an alternative is examined. Thera are two conditions:

1. Accepteble advantage

$$Q\left(A^{(2)}\right) - Q\left(A^{(1)}\right) \geq \frac{1}{J - 1} \quad (6)$$

Where J is the number of criteria considered in model.

2. The alternative $A^{(1)}$ must be the best ranking by parameters S and R, too

The compromise solution is adopted based on the maximum value of the parameter S (maximum utility) and the minimum damage represented by the minimum value of the parameter R. Both values are taken into account in calculation of the parameter Q for the compromise solution.

3. THE APPLICATION OF THE MODEL TO THE PROBLEM OF LEVEL CROSSING RANKING

The aim of this paper is to determine the most endangered level crossing from the group of considered crossings, comparing the selected criteria. In the level crossing chosen in this way, investments should be made in order to raise the level of safety. In this paper a group of seven level crossings is considered and marked with A1 - A7. Criteria that were considered for each crossing are: number of road vehicles using the crossing during 24 hours, number of railway vehicles using the crossing in 24 hours, average occupancy of the crossing by one train, visibility from the road to the railway, speed of road vehicles during crossing, speed of railway vehicles, whether there were traffic accidents at the crossing in the previous period and how many of them, as well as if there are side roads that joint to the road that intersects the railway, near level crossing.

Two groups of experts participated in the research, based on which the ranking process was conducted: economical and traffic engineer profession. For linguistic assessments of criteria and weighting coefficients, five-point scales were used. For weighting coefficients of criteria were used assessments: VIN -

Tab. 1. Linguistic assessments of criteria by experts

Criteria	INV (Investor)	TEN (Traffic Engineer)
C1 - Number of road vehicles	VSG	VSG
C2 - Number of railway vehicles	SIG	VSG
C3 - Level crossing occupancy by train	INS	MSG
C4 - Visibility from railway tracks to road	INS	MSG
C5 - Road vehicle speed	SIG	SIG
C6 - Railway vehicle speed)	VSG	SIG
C7 - Number of accidents	SIG	VSG
C8 - Number of access roads	VIN	INS

Tab. 2. Evaluations of individual criteria

Expert	Level crossing	Criteria							
		C1	C2	C3	C4	C5	C6	C7	C8
Expert 1	A1-Stopanja	P	VN	N	P	VP	N	SP	P
	A2-Veliki Crljeni	SP	P	N	P	P	N	P	P
	A3-Šid	P	P	SP	VP	SP	P	SP	N
	A4-Lazarevac	SP	SP	N	N	VP	N	N	SP
	A5-Laćarak	VP	SP	SP	VN	P	P	SP	SP
	A6-Gruža	P	N	SP	VN	VP	P	SP	N
	A7-Negotin	P	VN	VP	N	P	SP	P	SP
Expert 2	A1-Stopanja	VP	VN	VN	P	P	VN	SP	P
	A2-Veliki Crljeni	N	P	N	VP	SP	N	P	P
	A3-Šid	P	VP	P	VP	N	P	SP	VN
	A4-Lazarevac	SP	SP	N	SP	P	N	N	N
	A5-Laćarak	VP	SP	SP	N	SP	P	SP	SP
	A6-Gruža	P	N	SP	N	P	P	SP	VN
	A7-Negotin	P	VN	VP	SP	SP	SP	VP	SP

very insignificant, INS - insignificant, MSG - Middle significance, SIG - Significant and VSG - very significant. For evaluations of individual criteria: VN - very unfavorable, N - unfavorable, SP - moderately favorable, P - favorable and VP - very favorable. In such way, two groups of linguistic estimates were formed. The input parameters are shown in Tables 1 and 2.

A value of 0.5 is adopted for the value of parameter V. The calculated parameters of $\boldsymbol{S_i}$, $\boldsymbol{R_i}$ and $\boldsymbol{Q_i}$, as well as the obtained rank are shown in Tables 3 and 4.

In order to determine the stability of the solution, a sensitivity analysis was performed. In this analysis, the value of parameter V was changed within the interval [0, 1], with a step of 0.1. The change in the rank of the considered level crossings depending on the parameter V is shown in Figure 1.

From Table 4 it can be seen that the level crossing ***A3*** has the highest ranking according to the parameter $\boldsymbol{Q}$. Both criteria, that are necessary to be met, in order to be able to say that one alternative is superior to the other, are met here:

1. $Q(A^1) - Q(A^2) \geq \frac{1}{J-1}$,

   Where $\boldsymbol{J}$ is the number of considered alternatives and
2. The alternative A3 has the highest rank considering parameters S i R.

Therefore, the obtained result shows that according to the criteria taken into consideration, the level crossing A3 (Šid - the main railway line to Croatia) is the most endangered and this level crossing should be in that, of the observed crossings, this level crossing should be in a shortlist for investment.

4. CONCLUSION

The paper uses the VIKOR method for determining the priorities of investment in level crossings. It has been shown that this method can be easily applied to problems in which, based on the selected safety criteria of level crossings, it is possible to determine the priority of investments in raising the level of safety at them.

Tab. 3. Calculations of parameters S_i, R_i and Q_i

	Criteria										
	C1	C2	C3	C4	C5	C6	C7	C8	S_i	R_i	Q_i
A1	0.03	0.22	0.11	0.03	0.00	0.15	0.06	0.00	0.61	0.22	0.90
A2	0.11	0.02	0.10	0.03	0.04	0.14	0.01	0.00	0.46	0.14	0.38
A3	0.04	0.00	0.06	0.00	0.09	0.00	0.06	0.08	0.33	0.09	0.00
A4	0.08	0.09	0.10	0.10	0.00	0.14	0.11	0.06	0.68	0.14	0.69
A5	0.00	0.09	0.07	0.12	0.04	0.00	0.06	0.04	0.42	0.12	0.26
A6	0.04	0.16	0.07	0.12	0.00	0.00	0.06	0.08	0.54	0.16	0.58
A7	0.04	0.22	0.00	0.10	0.04	0.07	0.00	0.04	0.51	0.22	0.75

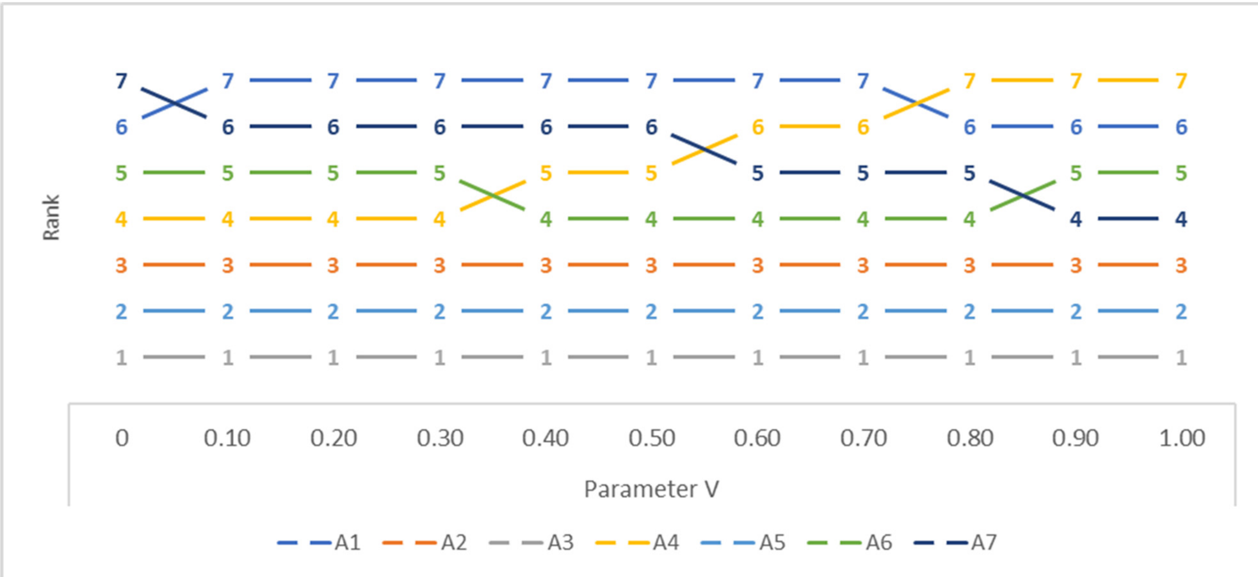

Fig.1. Sensitivity analusis of the alternative rankings depending on the coefficient V

The results suggest that this method can be applied as a preliminary method when it is necessary to, make selection of all level crossings into groups of more and less endangered (for example on one territorial unit, or on the observed railway line). In the second phase, detailed tests would be performed.

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