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AN APPLICATION OF THE AHP METHOD FOR EVALUATION OF LEVEL CROSSING DESIGN IN A CONGESTED URBAN AREA: CASE STUDY LC SOKOLSKA IN ZAGREB, CROATIA

Summary. The AHP method(Analytic Hierarchy Process), as a part of the Multi-Criteria Decision-Making (MCDM) process, is one of the most used methods worldwide for dealing with the complexity of transport project evaluation. A level crossing (LC) is a place where road and rail cross. Therefore, LC is a place where there isa high risk of accidents.The aimof this study is to develop an AHP model for evaluating the alternatives for the reconstruction of LC in a congested urban environment through the weighting of various interdisciplinary criteria and sub-criteria. The AHP model considers six criteria:safety, traffic indicators of the functional efficiency, costs, social benefits, ecology, the time required for reconstruction of LC and their 15 sub-criteria. The model has been tested on LC Sokolska, located in the city of Zagreb, Croatia. Three possible alternatives were proposed to suit the location and the traffic conditions. The alternatives were evaluated according to the developed AHP model and the Expert Choice software package.Asensitivity analysis was performed to confirm the acceptability of the optimal solution.

1. INTRODUCTION

Level crossings (LCs) are intersections of road and rail, which represent traffic points with a high risk of accidents. There are 1,503 level crossings (LCs) in the Republic of Croatia, out of which 61% have passive protection and 39% have active protection. In the last ten years, there have been several serious accidents and also accidents as result of the reckless behaviour of unauthorized persons crossing the railway or moving along it in places where it is not allowed, resulting in death, serious injuries, train congestion and material damage[1]. The traffic culture of car drivers can be observed from the data on the breakage of barriers/half-barriers at LCs, of which there are about five hundred per year. However, according to statistics, there is no highly significant number of traffic accidents at the LC Sokolska (in Zagreb, Croatia). The rules of crossing the railway are violated daily, from which it can be concluded that there is a potential riskof traffic accidents. The high concentration oftraffic of motor vehicles, pedestrians and cyclists should also be highlighted. The current situation is unsustainable, and it is necessary to reconstruct the LCSokolska, which will enable safer flow of traffic [2, 3].

Due to the complexity of LCs, the approach of evaluating new solutions using several interdisciplinary criteria is essential. Several criteria areestablishedin the evaluation of projects usingmulticriteria decision-making methods. Multi-Criteria-Decision-Making (MCDM) is an important technique that presents a systematic approach for helping decision-makers in the field of transport and traffic [4]. Numerous multicriteria models have been applied insocially important investment projects, especially transport and traffic infrastructure [5, 6]. These methods differ primarily in their optimization criteria. One of the most used methods for evaluating projects in transport is the AHP method (Analytic Hierarchy Process). The AHP methodwas formulatedby Thomas L. Saaty in the 1970s with the aim of solving complex decision-making problems, when there is a large number of decision-makers andseveral criteria. Its main advantage liesin the fact thatthe decision-making can be adaptedin terms of the number of attributes, or criteria and Alternatives that are decided at the same time, and thatcan be described both quantitatively and qualitatively. The AHP method allows for flexibility in the decision-making process. It helps decision-makers set priorities and make the best decision, taking into account both the qualitative and quantitative aspects of the decision[7]. The application of the AHP method is significant in large projects that require substantial capital investment and have great social significance (e.g. transport infrastructure investment projects). AHP is extensively applied for problem-solving in the field of transport [8-13].

This paper aims to determine the optimal solution of securing the LC Sokolska in Zagreb, Croatia,which will increase safety at the level crossing, increase the flow of vehicles in the zone of the LC andreduce congestion at the crossing and the surrounding roads. For this purpose, the existing condition of the LC and roads in the environment will be analysed, on the basis of which new solutions for the reconstruction will be proposed and evaluatedusingthe AHP method.

2. METHODOLOGYOF THE AHP METHOD

Thomas L. Saaty developed the AHP method to evaluate complex multi-criteria-decision-making problems [14]. The strength of the AHP method as one of the multicriteria methods is that it can be easily adapted to different numbers of attributes, criteria, their sub-criteria and alternatives (variants). Goal (objective), criteria, sub-criteria and alternatives form a hierarchy structure of the AHP model. All attributes can be described both quantitatively and qualitatively. According to Saaty, decision-making about the priorities means decomposing the decision process into four main steps: define the problem, structure the decision hierarchy, construct a set of pairwise comparison matrices and use the priorities obtained from the comparisons to weigh the priorities in the level immediately below, which should be done for every element. The process of weighing and adding continues until the final priorities of the alternatives in the bottommost level are obtained [15].

To define the relative importance of criteria and sub-criteria in terms ofthe objective of research, the criteria are ranked using a Saaty scale [14]. The Saaty scale contains9 intensities, five main levels of intensity (1, 3, 5, 7, 9; 1 means equal importance, 3 means moderate importance, 5 means strong importance, 7 means very strong or demonstrated importance, 9 means extreme importance) and four intermediate levels (2, 4, 6, 8; 2 means weak or slight, 4 means moderate plus, 6 means strong plus, 8 means very, very strong).

The software Expert Choice ranks criteria and sub-criteria using the Saaty scale from 1 to 9. A ranking (grade) from 1 to 9 is assigned to a criterion or sub-criterion depending on its importance. Various methods determine the importance of criteria and sub-criteria, and for examples similar to our research, a survey of experts is often conducted. In our study,we did not conduct a specificsurvey of experts to determine the weights of criteria and sub-criteria. Still, we selected them based on comparison ofsimilar studies (for example, the methodology developed in [16]).

The optimal alternative will be selected based on the defined total weight priority vector by synthesizing all weight vectors, and the following expression describes it:

$$W_i = \sum_{j=1}^{n} c_j w_{ij}, \quad \forall i = 1,...,m \tag{1}$$

where: W_i - weight, priority of alternative i; c_j - weight of criterion $j (j = 1, 2, ..., n)$;
w_{ij} - weight of alternative i regarding criterion j.

Saaty proved that for the consistent reciprocal matrix, the largest eigenvalue is equal to the number of comparisons, or $\lambda_{max} = n$. Then, he defined a measure of consistency, called the Consistency Index (CI), which indicates the deviation or degree of consistency using the following formula:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (2)$$

When consistency has been calculated, the result needs to be compared with that of the same index of a randomly generated reciprocal matrix from the scale of1 to 9, with the reciprocal forced. This index is called the Random Index(RI). The ratio CI and RI for the same-order matrix is called the Consistency Ratio (CR):

$$CR = \frac{CI}{RI} \quad (3)$$

The CR of 0.10 (or 10%) is appropriate when five or more elements are compared. However, if four elements are compared, a CR of 0.08 (or 8%) is recommended, and in the case of three elements, a CR of 0.05 (or 5%) is recommended. If CR is greater than 10%, 8% or 5% (depending on thenumber of elements), the preference needs to be revised.

3. CASE STUDY: APPLICATION OF THE AHP METHOD FOR EVALUATION DESIGN OF THE LEVEL CROSSING SOKOLSKA IN ZAGREB

The methodology for determining the optimal alternative of LC based on the applied AHP method contains the following steps (Fig. 1):

• Analysis of the current situation of LCSokolska
- Collection ofdata from infrastructure managers: characteristics of the current traffic network, time table, daily number of trains, accidents statistics;
- Traffic count: number of LC users (pedestrians and cyclists), collection of real data onthe size and distribution of the current traffic load, time of LC closure;
- Surveys and video surveillance of LC users: evaluation of pedestrian and cyclist behaviours at an LC, drivers' habits and their traffic culture.

• Proposal of new alternatives of LC Sokolskapossible for reconstruction;
• Evaluation of the proposed Alternatives using the AHP method using the software tool Expert Choice (defining of the hierarchical structure of the AHP model, ranking of criteria and sub-criteria, evaluation of alternatives, selection of the optimal alternative); and
• Sensitivity analysis using Expert Choice software.

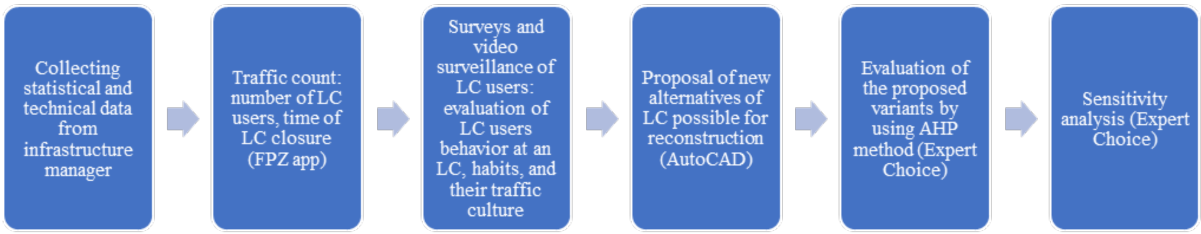

Fig. 1. Case study: steps for the evaluation of a level crossing design

3.1. LC Sokolska – problem and study area

The LC Sokolska is located in the western part of the city of Zagreb in the densely populated Črnomerec district. It is located on KM 428 + 686 international double-track railway M101 DG - S. Marof - Zagreb GK. Along with the two-track railway intended for passenger traffic at a distance of 22 m, there is also an industrial track that connects the Vrapče container terminal, where only freight railway traffic is allowed. Although there is a recommendation for such a high-ranking international railway to avoid level crossings, this crossing is level and provided by barriers operated by a crossing guard. The maximum permitted train speed on this section is 60 [km/h]. A total of 226 trains pass through this LC daily [2, 3].

Pedestrians, cyclists and motor vehicles move across the LC Sokolska. The width of the road at the LC is 7.70 m, which is not enough for safe traffic. According to the measurements, it was determined that during peak hours, when there is the largest number of LC users and when trains often pass through the crossing, the barriers are lowered for as long as 9 minutes, creating long queues for both motor vehicles and pedestrians and cyclists. This causes frequent non-compliance with traffic regulations by the users of this LC, of which the following stand out (Fig. 2):

- pedestrians and cyclists pass under the barrier and cross the track while the barrier is lowered and a train is expected to arrive;
- the area provided for the movement of pedestrians and cyclists is insufficient and there is often collision of flows between pedestrians and motor vehicles, given that they use the same traffic area that is insufficient for the safe movement of pedestrians, cyclists and motor vehicles;
- due to the close proximity of the Kustošija railway station, pedestrians often walk along the line (railway tracks) to shorten the journey to the railway station;
- passengers getting off the passenger trains at the Kustošija railway station often walk along the line (railway tracks) to reach the LC more easily;
- when drivers notice that the barriers are being lowered, they immediately increase their speed and cross until the barriers are lowered almost to the end. This often leads to barrier breakage and considerablematerial damage; and
- at night, the lighting of the LC is very poor, which makes the LC even more dangerous for pedestrians, cyclists and drivers moving at night.

Fig. 2. Problems at LC Sokolska (poor infrastructure and level crossing users' behaviours)

3.2. Data collection

Basic technical and statistical data on LC Sokolska were obtained from the infrastructure manager (HŽ Infrastruktura). At this LC, in the last eight years, there have been two accidents, with one seriously injured person and ten barrier fractures. There are no data in the statistics on the large number of avoided accidents witnessed by railway workers from the field, and at this LC, the rules of crossing the LC are violated on a daily basis, from which it can be concluded that there is potential riskof traffic accidents.

Data on traffic counting, surveys and video surveillance were obtainedfrom previous research [2, 3]. The results of the traffic count indicate the total number of LC users, but also the data on the number of users who cross the LC properly or improperly. Traffic counts were conducted in the morning (7:00 - 8:00) and afternoon peak hours (16:00 - 17:00). The data of the morning and afternoon peak hours are similar (departure, return from work), and the morning data are from 593 vehicles (Fig. 3), 427 pedestrians and 46 cyclists. The data obtained by video surveillance of a large proportion of offenders are particularly significant (Fig. 4).

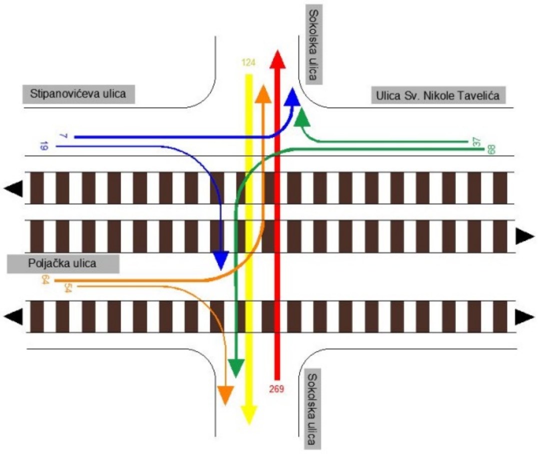

Fig. 3. Load of traffic flows by motor vehicles in the morning peak hour

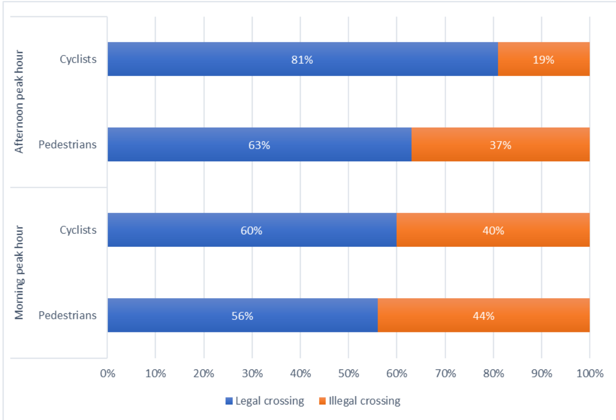

Fig. 4. Level crossing users' behaviour

The total number of passenger trains passing through LC Sokolskain 24 hours is 135 trains, while the number of freight trains is 91;therefore, the total number of trains passing through LC Sokolska in 24 hours is 226 [2, 3].

The survey was conducted to obtain data on the patterns of behaviour of LC users (pedestrians and cyclists). The concept of the survey was taken from an earlier study designed at the Faculty of Transport and Traffic Sciences [17].

The survey contained nine short and concise questions, on the basis of which information was obtained on the users' gender, age structure and place of residence, the reasons for illegal crossing of the LC and how familiar the respondents are with the penalty amount for illegal crossing of the LC. Out of a total of 142 respondents, 45% were male, while the remaining, 55%, were female. This LC is mostly used by people aged 26 to 60 years. The majority of respondents, i.e. 69% lived near the LC, while the remaining 31% lived outside Zagreb and travelled to work by train. The reasons for switching to LC provided werevaried. As many as 51% of respondents cited going to work as a reason. One of the questions in the survey questionnaire was: "Do you cross the LC illegally?". As many as 84% of respondents stated thatthey cross the LC while the barriers are lowered, and only 16% of them stated that they do not cross the LC while the barriers are lowered. The biggest reason for improper crossing is haste, and this is followed by the respondents stating that the barriers stay lowered for too long. This user perception is accurate. During data collection on the field and primarily video surveillance, we foundthat the barriers were lowered 55% during the morning peak hour and 51% during the afternoon. These data show that barriers are often lowered, which leads users to disregard traffic rules and regulations. The most extended barrier lowering time in the morning peak hour was 484 s, and in the afternoon peak hour, it was 519 s. The reason for this is the high densityof railway traffic, given that it is an international two-track mainline. Therefore, this time of closure cannot be shortened. The respondents statedthat the barriers go down long before the train arrives and, therefore, they decide to cross illegally. A large proportion of respondents (78%) wereunaware that there was a penalty for improperly crossing the LC [2, 3].

The survey obtained data on the patterns of behaviour of LC users that significantly contributed to the planning of proposals for new Alternatives for the reconstruction of LC Sokolska.

3.3. Proposal of new Alternatives

Three possible designs for the reconstruction of the LC Sokolska in Zagreb are proposed to improve the level of traffic safety and capacity.

Alternative 1

Alternative 1 considersthe construction of a pedestrian and cyclist underpass (Fig. 5).

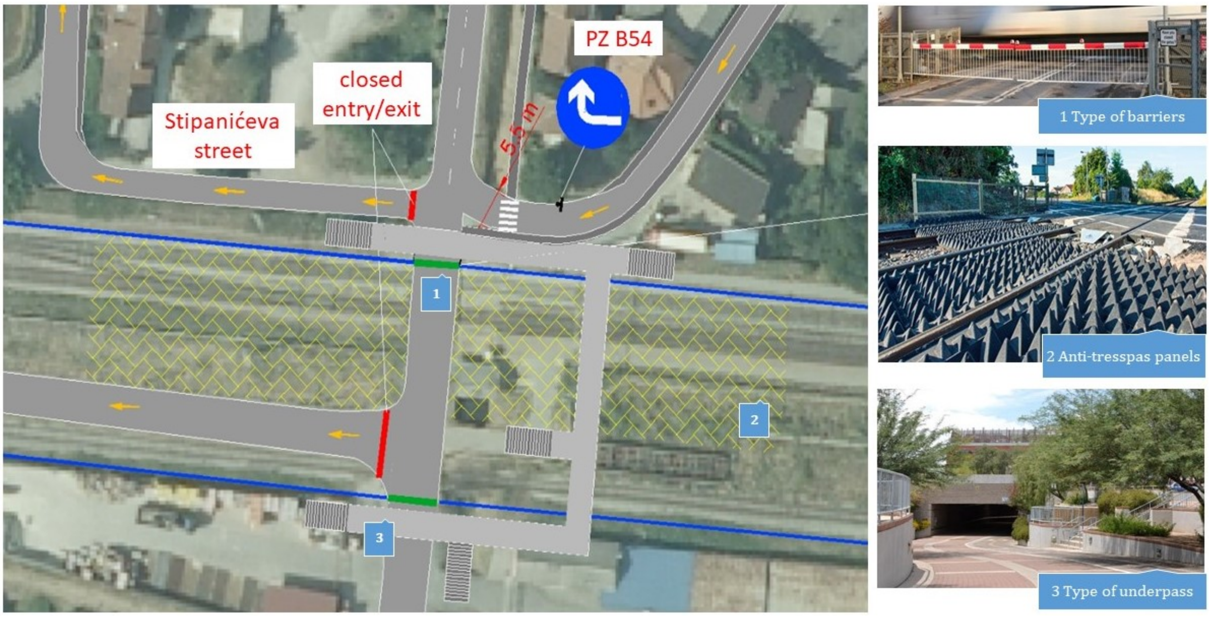

Fig. 5. Proposal of Alternative 1

The construction of an underpass would eliminate the conflict points between road and rail traffic, i.e. primarily of cyclists and pedestrians with the rail vehicles.The construction of the underpass would ensure smooth passage of pedestrians and cyclists under the very busy railway line. The underpass would be built on the current site of LC Sokolska. The length of the underpass would be about 50 metres. It would extend from Sv. Nikola Tavelić, i.e.Stipanovićeva Street, under the railway tracks for passenger trains and under the industrial track, and the exit would be next to the industrial track. The underpass would have 5 entries/exits. Since,apart from pedestrians, the underpass would also be intended for cyclists, it is necessary to adjust the traffic infrastructure: setting up entry/exit ramps is essential for cyclists and people with disabilities. Also, when designing underpasses, it is necessary to make sure that the underpasses are not deep, narrow and dark so that their users do not feel unsafe. Therefore, the underpass should be open, bright and airy to make the underpass users feel safe when using it.

The level of awareness about the dangers of crossing an LC during lowered barriers is very low; hence, there is a possibility that pedestrians will not use the built underpass. Therefore, it is necessary to find a way to motivate the users to use the built underpass. Accordingly, additional equipment is proposed at LC Sokolska:

- the installation of a new protective fence that will make it impossible to pass through it as is the case with the existing one in the length of 60 metres to the south and 130 metres to the north (marked blue in Fig. 5);
- installation of anti-trespass panels. Thisis an innovation that prevents pedestrians from walking on the track. Thegoal is to create a physical barrier that restricts pedestrian access in places not intended for crossing. Panel surfaces can be made of different materials such as wood, rubber, etc. They consist of pyramids that are not of the same size, which makes it even more difficult to walk across the panels. It increases the safety of passing over the LC, and is very easy to install and easy to remove and replace. The lifespan of these panels is over 25 years. These panels would be placed on both sides of the LC, i.e. between the rails and next to them (the position of the anti-trespass panels on the LC in question is marked in yellow in Fig. 5); and
- installation of new barriers. The existing barriers are such that the users can easily pass them by slipping under them. Accordingly, it is necessary to install barriers that will completely prevent

the passage of pedestrians and cyclists. Fig. 5 shows the type of half-barrier that is proposed to be installed to prevent pedestrians from slipping under the half-barrier.

In the narrower gravitational area of LC Sokolska, additional changes are proposed that would contribute to the optimal flow of traffic (change of direction of some streets, addition of horizontal and vertical signalization, etc.). These proposals are not described in detail in the paper, but are explored in [2, 3].

Alternative 2

For Alternative 2, the construction of an underpass for motor vehicles is proposed. The underpass would completely separate road traffic from rail traffic, and traffic safety would be significantly higher. Although there are two underpasses not far from LC Sokolska, one at an air distance of 350 metres and the other at 1,400 metres, such a proposal is justified due to the high traffic congestion in the gravitational area of the LC. Vehicles travelling on these underpasses mostly come from the north (Ilica), and before the said underpass, the vehicles encounter a bottleneck thatforms when the vehicles turn from Ilica to ZagrebačkaRoad. Due to the bottleneck on Ilica, long waiting queues are formed. Additional problems are created by shopping malls and public institutions, as well as parking spaces located right next to the road. Onanalysing the traffic flows, it was determined that up to 70 buses pass through Ilica during the peak hour [2, 3]. In the vicinity of the intersection of Ilica - ZagrebačkaRoad,there are bus stops that do not have a dead end, which further complicates the flow of traffic during peak hours. Fig. 6 shows the proposal of the underpass on the Sokolska Street. The total length of the underpass would be about 300 metres, and two 3-metre-wide traffic lanes are planned. With the construction of the underpass, the traffic load on Sokolska Street is expected to increase. The plan is to build an underpass for pedestrians and cyclists that would have similar features as in Alternative 1. The only difference is that in this Alternative, there would be a total of four entries/exits to/from the underpass. The positions of the entries/exits to in/from the underpass as well as the underpass itself are shown in Fig. 6.

As in Alternative 1, in addition to the listed solutions, it is proposed to install additional equipment that includes protective fences, anti-trespass panels andnew barriers. The advantage of such a solution is that it would maximize the safety of all traffic participants. The construction of the underpass would attract a higher traffic flow, and thus higher traffic density. The main disadvantage of this solution would be that the construction of the underpass is very demanding and requires a lot of space, and Sokolska Street is not verywide. The problem is in the southern part of Sokolska Street because some of the existing buildings would have to be demolished and the issue of land ownership should be resolved. Resolution ofland ownership creates high costs, and given the analysis of traffic flows, the question is how financially viable this solution would be.

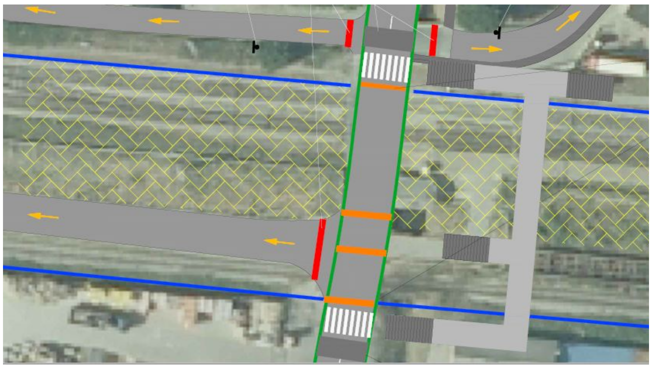

Fig. 6. Proposal of Alternative 2

Alternative 3

Alternative 3 presents a proposal for the complete closure of the LC Sokolska for motor vehicles, which would be redirected to the adjacent underpasses located only 350 metres and 1,400 metres from the LC in question. The LC Sokolska would still remain open to cyclists and pedestrians, for whom the construction of an underpass is proposed. The underpass would be built on the current site of LC Sokolska. When designing the underpass, it is very important to make sure that the underpass fits into the environment and that its features are acceptable to the users to be used, and to motivate the pedestrians and cyclists to use the newly built underpass, additional equipment consisting of protective fences and anti-trespass panels should preventtrespassing. Given that the closure of the LC in question for motor vehicles is planned, it is necessary to envisage the relocation of Poljačka Street, which would be solved as in Alternative 1. This alternative is the least financially demanding.

3.4.The AHP Model for the reconstruction of LC Sokolska

The hierarchy structure of the AHP model includesgoal/objective, criteria, sub-criteria and alternatives. The Expert Choice is a software tool that can be used to evaluate the proposed and possible solutions by the AHP method.The model considers six criteria (safety, traffic indicators of the functional efficiency, costs, social benefits, ecology, the time required for reconstruction of LC) and their 15 sub-criteria (Fig. 7).

3.5. Results

After the problem has been structured, ranking of the criteria and sub-criteria is performed, followed by evaluation of the alternatives according to each criterion and sub-criterion to obtain the optimal solution.Thesoftware Expert Choice was used for ranking criteria, sub-criteria and alternatives.

The criterion *Safety at LC Sokolska* has been allocated the highest importance (.399) because of serious consequences causedby traffic accidents on the level crossings. The next criterion by importance is the criterion *Traffic indicators of functional efficiency at LC Sokolska* (.243). The third important criterion is *Time for reconstruction* (.106), followedby the *Ecologicalindicators* (.095) as the fourth important criterion.The *Cost* indicator (.086) is the fifth criterion regarding the importance of investing financial means rationally in relation to the obtained benefits. Ranked last are *Social benefits*(.072) due to all the advantages brought about by the improvement of the traffic system, thus improvingthe quality of the mobility of the society(Fig. 8).

After ranking of the criteria, the sub-criteria were ranked as part of each criterion (Figs. 9-13).

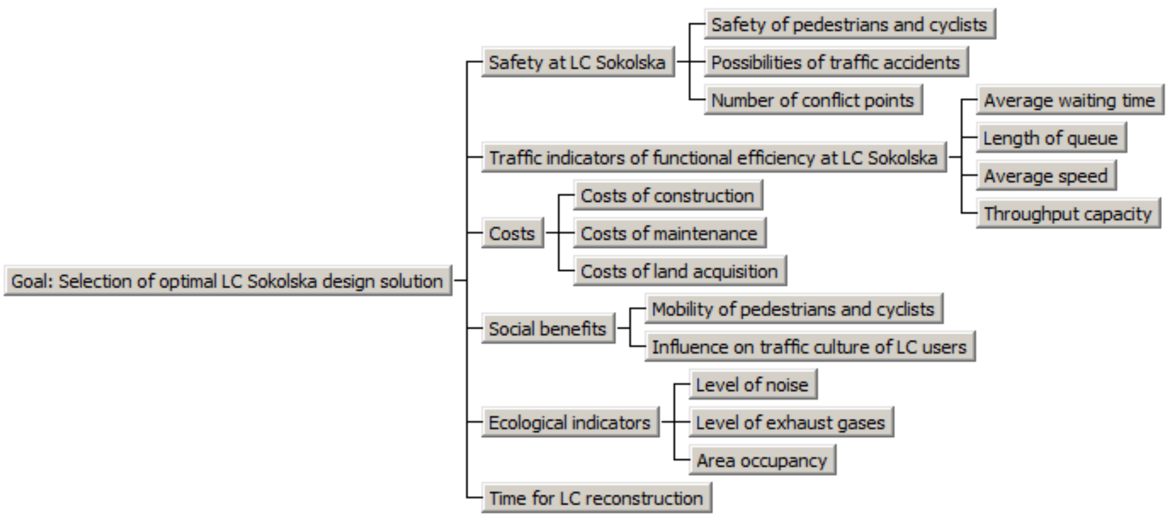

Fig. 7. Hierarchy structure of the AHP model (Expert Choice software)

After evaluating the Alternatives according to each criterion and sub-criterion applyingthe AHP method, *Alternative 3* (47.6%) wascalculated as the best traffic solution,including a number of functional traffic solutions to increase the safety and urban mobility of the LC Sokolska region. Thisis followed by *Alternative 2* (28.9%) and *Alternative 1* (23.5%). The ranking of Alternatives is shown in Fig. 14.

Fig. 8. Ranking of criteria (Expert Choice software)

Fig. 9. Priorities of sub-criteria of the criterion *Safety at LC Sokolska* (Expert Choice software)

Fig. 10. Priorities of sub-criteria of the criterion *Traffic indicators of the functional efficiency of LC* (Expert Choice software)

Fig. 11. Priorities of sub-criteria of the criterion *Costs* (Expert Choice software)

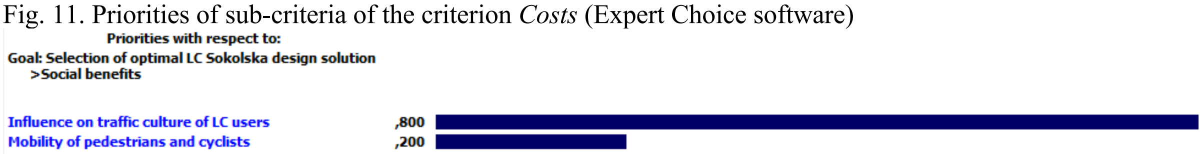

Fig. 12. Priorities of sub-criteria of the criterion *Social benefits* (Expert Choice software)

Fig. 13. Priorities of sub-criteria of the criterion *Ecological indicators* (Expert Choice software)

Fig. 14. Ranking of Alternatives (Expert Choice software)

3.6. Sensitivity analysis

Sensitivity analysis is a complementary analysis that enablesthe determination of "critical" variables or model parameters, and its main goal is to assess the acceptability of the project if the values of critical project parameters are changed. Critical variables are those variables whose variations, whether positive or negative, can have the greatest impact on the financial or economic results of a project. The optimal Alternative according to the AHP model is Alternative 3, and the highest-ranked criterion is Safety on the LC, whose value is 39.9% (Fig. 15).

Todeterminethe sensitivity of the Alternatives to changes in the importance of the criteria, the importance of the cost parameter was changed. With large investments, the costs often change during the project planning. Therefore, a model with a change in the cost criterion was tested to observe whether the change would affect the choice of the optimal Alternative. Our idea was to test whether the optimal choice would change if the cost criterion were second in importance. To make it second, we increased its importance from 8.6% to 25.1%. Having done this, the best traffic solution still remained Alternative 3, and the second place was taken by Alternative 1 (Fig. 16).

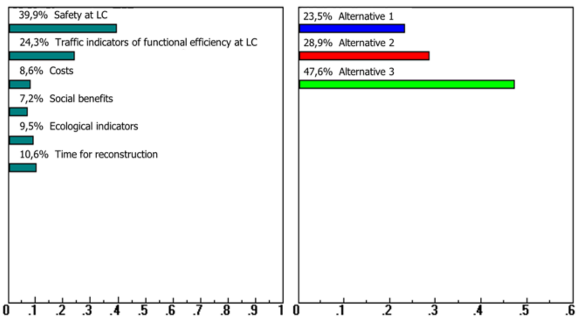

Fig. 15. Dynamic graph - the optimal solution (Expert Choice software)

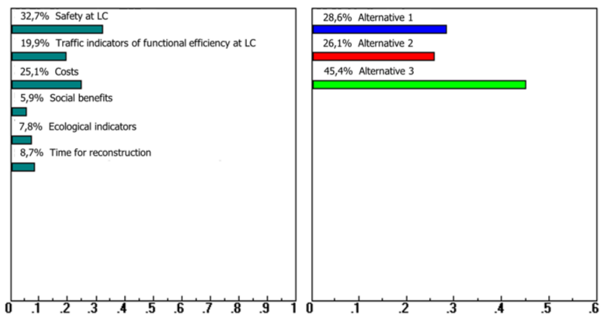

Fig. 16. Dynamic graph - after sensitivity analysis (Expert Choice software)

4. DISCUSSION AND CONCLUSION

Thisstudy aimed to determine the optimal solution of LC based on the evaluation carried out by a multicriteria analysis using the AHP method. LCs are complex traffic points athigh risk of traffic accidents;thus,to determine a new optimal solution, it is necessary to take into account all parameters relevant to LC, qualitative, quantitative, technical, economic, environmental, etc.

The novelty of our research in this paper lies in the multidisciplinary approach introduced in various applied methods for data collection and interdisciplinary selection of criterion and sub-criterion in the hierarchy structure of the AHP model. Although the AHP method as a part of the MCDM process is one of the most used methods worldwide for dealing with the complexity of transportation project evaluation, this method isnot used often to evaluate the alternatives for LC reconstruction. In our paper, we wanted to present the application of the AHP method to choose the best solution for LC reconstruction.

The methods used during this research to collect data are the traffic counting method and the survey method. The counting method was carried out to obtain data on the number of users crossing the LC and the data and the traffic load of the traffic flows. Also, it was necessary to observehow the presence of video surveillance will affect the LC users. In addition, video surveillance during counting was also used to verify the traffic counting. The survey method was used to collect data, attitudes and opinions on the subject of research. The survey contained nine short questions to ensure a higher turnout of respondents. The counting method showed that 23% of pedestrians cross the LC illegally, while the other 67% of pedestrians cross properly. During peak hours, the barriers on the LC in question are lowered for about 53% of the time, which means around 32 minutes.

The survey method showedthat the LC wasmostly used by people aged 26 to 60 years. The majority of respondents, i.e. 69%, lived near the LC, while the other 31% lived outside Zagreb and travelled to work by train. A total of 84% of the respondents answered that they cross the LC improperly, and the other 16% stated that they cross only when the barriers are raised. Most users justified their improper crossing of the LC by having to rushto work. During the survey, it was found that 77% of the respondents werenot aware of the penalty for improper crossing of the LC. Some of the respondents did not even know that there was a penalty for illegally crossing the LC.

After the implemented methods, the problems were identified at the Sokolskalevel crossing. Namely, at the LC in question, the primary problem is non-compliance with the traffic rules, i.e. illegal crossing of the LC. The reason for this stems from the long closure of the LC. Apart from pedestrians and cyclists, the motorists oftenaccelerate trying to pass under the barriers already starting to be lowered, which results in barrier breakage. However, there would certainly be more traffic accidents if the barriers were not controlled by a crossing guard, who often stops the lowering of the barriers to prevent traffic accidents. The next problem is the insufficient width of the LC, which leads to collisions of flows of pedestrians, cyclists and motor vehicles. It is also not uncommon for pedestrians to walk along the LC to shorten their journey. An additional problem is created by lighting:sufficient illumination of the LC is not provided.

Based on a detailed analysis of the existing condition, three Alternatives for the LC reconstruction have been proposed. Alternative 1 proposes the construction of an underpass, a change in the direction of traffic flows, closure of Poljačka Street, the installation of a protective fence, anti-trespass panels and new barriers. Alternative 2 proposes the construction of underpasses changing the direction of traffic flows, closing Poljačka Street, arranging the intersection Sokolska Street - Rudeška Road - Zagrebačka Road, shaping the radius when turning from Ilica to Sokolska Street, installing a protective fence, anti-trespass panels and a new barrier. Alternative 3 proposes the construction of an underpass, closure of the LC for road motor vehicles, the installation of a protective fence, anti-trespass panels and new barriers.

To determine the optimal Alternative, the proposed Alternatives were evaluated by multicriteria analysis, i.e. by the AHP method using Expert Choice software. The results of the analysis showed that the optimal traffic solution is Alternative 3. Considering the current situation, Alternative 3 is optimal, and compared to Alternative 2, it is concluded that the LC in question is still not busy enough to choose Alternative 2 for the reconstruction. On the east and west sides, not far from the LC in question, there are underpasses for motor vehicles and the distribution of traffic from the LC in question should not lead to new problems, and the so-called "shallow" underpass would make it easier to cross the relevant LC. The implementation of Alternative 3 will enable greater throughput of pedestrians and cyclists, as well as comfort during the passage through the Sokolska LC, and will maximize the safety of pedestrians and cyclists. Also, there are no points of conflict between motor vehicles and pedestrians/cyclists, which means that the possibility of accidents is minimal. In addition, noise and exhaust emissions will be significantly reduced, improving the usability of adjacent underpasses and making it more difficult for pedestrians and cyclists to cross the LC.

Multi-criteria decision-making and application of the AHP method enable the selection of the optimal Alternative of LC based on their evaluation by criteria and sub-criteria. The application of the AHP method required a high degree of detail of interdisciplinary input data, both quantitative and qualitative.Finally, the decision-making process, and thus the decision-making oninvestment arecomplex. The decision-makers must have a vision of the future and, accordingly, make decisions based on the results of applied scientific methods. The AHP method, in the framework of the multicriteriadecision-makingprocess, can significantly contribute to the improvement of thequality of decision-making in the field of transport infrastructure, in this case level-crossing in urban areas.

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