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RISK ASSESSMENT OF CRITICAL INFRASTRUCTURE ELEMENTS IN ROAD TRANSPORT

Zdeněk Dvořák, Bohuš Leitner,Mária Lusková, Ladislav Novák, Eva Sventeková
Zdenek.Dvorak@fsi.uniza.sk, Bohus.Leitner@fsi.uniza.sk, Maria.Luskova@fsi.uniza.sk, Ladislav.Novak@fsi.uniza.sk, Eva.Sventekova@fsi.uniza.sk

University of Zilina, 1.maja 32, 010 26 Zilina
SLOVAKIA

Key words: *risk assessment, critical infrastructure, road transport, two-level model.*

Abstract: *The article describes suitable methods of qualitative and quantitative risk assessment of critical infrastructure elements in road transport. The risk assessment consists of identification of risk sources, risk analysis and risk management. The authors are focused on the application of risk assessment methodology on road objects in their research. Within the identification of risk sources they studied theoretically possible risks and they concentrated especially on the most possible risks. Within the risk analysis the authors defined risk matrix. The most important theoretical contribution is a two-level model developed to assess risks in road traffic. This model was then used for a specific bridge in Bratislava. In this research project, the authors brought new scientifically substantiated solution of the critical infrastructure elements evaluation.*

1. INTRODUCTION

Researchers and teaching staff from The University of Žilina have been working on the project APVV-0471-10 “Critical infrastructure protection in the transport sector” and the project co-financed by the European Regional Development Fund, ITMS 26220120050 of “Centre of excellence for systems and services of intelligent transport II”. Within this project a broad base of theoretical knowledge has been developed. Projectsresearchers focus their attention on all modes of transport, by now they had published one scientific monograph and above fifty scientific articles. At present documentation for the accreditation of new study program in the first and second level of the higher education called “Security and critical infrastructure protection” was prepared and is on accreditation process.

The article is focused on risk investigation and evaluation of importance of particular object for critical infrastructure. There are different approaches within evaluation of critical infrastructure elements among Ministry of Transport, Construction and Regional Development, National Highway Company, Slovak Road Administration and scholars.

Evaluation of elements in European critical infrastructure is based on Europeancriteria’s, evaluation of elements in national critical infrastructure is based on national criteria’s (they were confidential in Slovak republic) and evaluation of elements in regional critical infrastructure (nest CI) is based on regional criteria’s. If the investigated element is not part of European or national critical infrastructure it can still be a part of regional critical infrastructure. There were defined specific criteria’s for evaluation of elements as a part of national critical infrastructure based on Europeancriteria’s. Those criteria’s are adjusted to size of population both on European as well as on national level. This pattern enables to set criteria's for regional level also. There may be approximately 20 - 40 regional critical infrastructure elements in Slovak republic. [1, 2, 3]

2. RISK EVALUATION FOR POTENTIAL ELEMENT OF CRITICAL TRANSPORT INFRASTRUCTURE IN ROAD TRANSPORT

Risk evaluation for potential element of critical transport infrastructure in road transport is based on investigating of circumstances, identification of possible sources of risk, analysis of those risks and their evaluation. Basic document for identification of risks for critical infrastructure element is a database of possible sources of risks which has been proposed for different types of transport. For particular types of transport there may be hundreds of risk sources.Theoretical base for evaluation of risks in transport is matrix of criticality, where the data are evaluated on qualitative, quantitative and semi quantitative bases.

The matrix of criticality contains two basic values (possibility or probability of occurrence and seriousness of effect or consequence), where possibility or probability of occurrence is evaluated with values 1-5 (1 is very low possibility or probability of occurrence and 5 is very high possibility or probability of occurrence) and seriousness of effect or consequence is evaluated with values 1-4 (1 is negligible consequence and 4is catastrophic consequence). Weighted average of results of matrix of criticality indicates the risk of evaluated critical infrastructure element in road transport. The result value indicates if the risk on element of critical transport infrastructure is negligible (1-3)acceptable (4-6), high (8-12), or non-acceptable (15-20). [1, 4, 5]

The next step is evaluation of risks for elements in critical infrastructure. This evaluation is dependent on availability of all needed information and the data are evaluated on qualitative, quantitative and semi quantitative bases.

Qualitative evaluation:

- Probability of occurrence adverse eventand its consequences are evaluated with use of different expressions – very low, low, probable, high, very high. Their consequences are evaluated with use of different expressions – very low, low, probable, high, very high. Probability of occurrence - non-critical, boundary, critical and catastrophic.
- Table nr. 1 – matrix of criticality is used for evaluation. This table offers a god overview, but not detailed enough and it should be used as a support or help tool in risk evaluation.

Quantitativeevaluation:

- The evaluation determined probability values, such as. the frequency and intensity of adverse events and over time, as a consequence the value of economic costs, or injury to health and life,
- On the basis of those values be weighted in the same way as in the methodology of classification element in CI.

Semi quantitative evaluation:

- In this evaluation scales are used 1-5 the probability of threats and 1-4 to the impact of hazards
- The risk is expressed by the product of the score, also verbally. [5]

3.APLICATION AND VERIFICATION OF PROPOSED MEASURE

The aim of this article is to verify ways and possibilities how to use proposed two level measures for identification CI elements and evaluation of road transport elements. The procedure was applied to a particular section and Harbour Bridge in Bratislava. The Harbour bridge was selected due to its use and location (in the case of disposal, there are detours, but the impact on transport in Bratislava would be very negative). Most are characterized by above average traffic intensity. The purpose of practical application is given to determine whether the bridge can be classified into CI road transport and evaluate the risks to the bridge most negatively affected. Another objective is to verify whether the proposed methodology is applicable in this case

Characteristics and selection of a specific portion

The Harbour Bridge section - Mierová street in the capital Bratislava has a length of 3,500 meters and the main object of this section is Port bridge, which was built in order that the third bridge of the Danube in Bratislava. The bridge is 460 m long (4 arrays with ranges of 102 m, 204 m, 64 m, 90 m), 29.4 m wide. Most weighs 12,016 tons and was built in the period from April 1978 to December 1985. Already in December 1983 was in early use right handed driving belt bridge. Total construction costs at that time amounted to 1.085 billion crowns.

TheHarbour bridge has two floors, the first floor is a double-track electrified line 6.5 meters wide, the upper level leads four-lane highway D1 in width and 26.5 meters.The bridgeis clearly the most fully-loaded construction facility in Slovakia, where the traffic volume exceeds 100,000 vehicles per day. Despite the fact that over the Danube River in Bratislava lead 4 bridges and one of them, de-commissioning of the bridge would have far-reaching consequences for transport in Bratislava and for transit traffic in Slovakia, at the same time had great negative economic consequences for the functioning of the state.

Withdrawn from service bridge, would mean to divert the highway into the city. According to the results of simulation tools Aimsun would create traffic jams. Traffic would be disastrous collapse of the economic consequences for the city of Bratislava, and the whole Slovak economy. It follows that detours would be financially extremely difficult and in some cases would have to take place outside the territory of Slovakia. [2]

4. ARRANGEMENT THEHARBOUR BRIDGE TO CI IN ROAD TRANSPORT

The first step in the two-level model is to assess whether the studied object element of the critical infrastructure. Prepared on the basis of method were calculated by weighting of each of the input data obtained by statistical indicators, according to expert estimates or data conducive to addressing similar situations. [2, 6, 7]

Characteristics of criteria:

- K1 – Transport parameters (intensity, throughput)

K1 express the intensity of traffic or throughput of transport on assessed sector, which is expressed mostly in the form of parameter: traffic intensity K1.1. The criterion value reflects real data, quantitatively describing the occupancy of a transport section during different times of the day (rush hour, night mode, low mode). This is shown by the number of vehicle units (next v.u.) per hour or day. Maximum concentration of traffic flows in road transport is mainly transmitted through international road network (e.g. TEN) and through national highways and expressways of I. class.

- K2 - The size and character of the object (time and financial costs of construction, nature of the building - a tunnel, a bridge, an elevated crossroad, etc.)

It is expressed as a quantitative indicator which reflects the time and financial requirements for particular object, and it is evaluated based on two factors: the time requirements for construction (K2.1) and the financial cost of construction (K2.2). Weight of particular criteria is determined by the relation:

(1) $K2 = (K2.1 + K2.2)/2$ [euro/ unittime]

- K3 - The costs to restore functionality

It presents quantitative estimate of financial costs and time needed for reaching the original state (removal of debris, construction of new building, etc.). The difficulty of renewal is an essential criterion for the possible exclusion time of element - bridge, tunnel, road or other object. In its objective quantification, other factors such as level of training of reconstruction units, availability of materials and the renewal play an important role. The criterion for difficulty of recovery (K3) consists from costs of recovery (K3.1) and time needed for recovery (K3.2). Weight criteria are determined by the relation:

(2) K3 = (K3.1+K3.2)/2 [euro/ unittime]

- K4 - Material value of the object

Criterion reflects the financial impact of the loss of control which will affect the operating company. Criterion value object (K4) is primarily dependent on the current net book value of the building. The documentation of the object which is called passports of various elements of road infrastructure presents residual value of the object.

- K5 - The economic impact

Represents the impact on gross domestic product (next GDP), the severity of economic loss or deterioration of the quality of products or services, where more than 0.5% of GDP will be an element of CI. Criterion economic impact (K5) consists of the share of the total economic impact (calculated as the sum of losses = cost of a detour (K5.1) + financial expenses (K5.2) + the cost of restoring the damaged environment (K5.3)) divided by gross domestic product. Thus, the relationship is:

(3) K5 = (K5.1 + K5.2 + K5.3)/3 [percent]

- K6 - Uniqueness of the object

K6 expresses the uniqueness of the object, possibility of replacing its function in case of functionality loss. For example to assess the impact of the outage of a particular stretch of road and ability of road infrastructure to function without such object.The uniqueness of the object is the criterion by which we can assess its indispensability, the consequences of loss of its function on the transmission performance of the infrastructure and it is mostly a matter of subjective assessment.

- K7 - Probability of an attack on the object and its impact on users

K7 quantitatively express value, which is describing the possibility of danger to the object by terrorist activity and qualitative / quantitative assessment of the impact of deliberate action on society. Probability of a terrorist attack is evaluated based on the criteria of probability (K7.1), and the impact on society (K7.2). K7.1 sub-criterion is 75% of the weight of criteria and weight criteria is determined by:

(4) K7 = (K7.1+K7.2) /2[number/ unittime]

- K8 - Probability of an extraordinary event

K8 express probability of an extraordinary event (next EE) together with an estimate of the potential impact on society. Probability criterion of EE is evaluated based on the criteria of probability (K8.1) and their impact on society (K8.2). K8.1 sub-criterion weight is 66% probability of EE criteria. Weight criteria will be calculated by following formula:

(5) K8 = (K8.1+K8.2)/2 [number/ unittime]

Substituting the values of criteria weights in the formula:

$$K = f[(K]_1, K_2, K_3, K_4, K_5, K_6, K_7, K_8) \quad \sum_{i=<1;5>}^{8} K_i = 40, \qquad K_i \geq 8 \tag{6}$$

we obtain final value:

$$K = f(5,5,5,5,4,5,1,2) \quad \sum_{i=<1;5>}^{8} K_i = 32, \qquad K_i \geq 8 \qquad (7)$$

Since the sum of all the criteria assessed border (32 points), must be based on the methodology of the first level to assess whether the control is indispensable road, maximum use and whether its disposal jeopardize the smooth running of the state (region). Of statistical indicators Slovak Road Administration is obvious that The Harbour Bridge in Bratislava is the capacity utilization, whereas in 2012 it underwent an average of 101,652 vehicles daily.

The bridge structure is used up, it would be very difficult to transport volume, which it passes to move the daily detours, whose capacities are not designed for such number of vehicles. Moreover, diversion of the D1 motorway section from port bridge into the city centre because of detours would transport collapse in negative consequences in the public and private sectors. After application and assessment of all the criteria is more than justified to include The Harbour Bridge in Bratislava between elements of critical infrastructure in the road transport subsector. [8]

5.RISK ASSESSMENT FOR ACTING HARBOUR BRIDGE

The second step of the proposed two-tier methodology is the assessment of the risks affecting the Harbour Bridge. At first it is evaluating ambient respectively. determine the context, this means that we can determine what the real threat to the performance The Harbour Bridge. The focus is directed to all natural resources, human resources, technical resources, infrastructure condition and other sources of potential threats acting on the object. The second step, identifying risks, it is necessary to identify all possible sources of risk in acting on the element under consideration, the basis consists of a database of potential sources of risk.

Each Risks KI road transport has been assigned a numerical value.From the preliminary assessment of the risks identified, and then their classification according to specified criteria, the possibility of occurrence of a hazard and the impact of this danger comes that identified risks are mainly in the range of acceptability and uncertainty respectively, border risks. Being the most threatening factors for KI in road transport is a means of transport, transport of dangerous goods, heavy snow, inattention and the resulting threat. The fair values calculated risks to particular threats represent less than 10-6. To be accountable normal values promoted abroad (compared to the level of safety in rail transport will usually range below 10-7).Individual weights are assigned according to risk assessment of the likelihood of occurrence and size effects. [7, 9]

Table 1 Evaluation risk matrix

Probabilityoccurrence	Impact(consequences)				
	insignificant (1)	small (2)	medium (3)	large (4)	catastrophic (5)
very high(A)	**V (A1)**	**V (A2)**	**E (A3)**	**E (A4)**	**E (A5)**
high(B)	**S (B1)**	**V (B2)**	**V (B3)**	**E (B4)**	**E (B5)**
medium (C)	M (C1)	**S (C2)**	**V (C3)**	**E (C4)**	**E (C5)**
small(D)	M (D1)	M (D2)	**S (D3)**	**V (D4)**	**E (D5)**
verysmall (E)	M (E1)	M (E2)	**S (E3)**	**V (E4)**	**V (E5)**
M:	Small risk				
S:	Medium risk				
V:	High risk				
E:	Extremeriskrequiresimmediatecorrection				

(Source: authors, by Slovak Technical Norm 01 0380)

Based on expert estimates of risk, the risk in Table 1some of the identified risks sources included among the risks are high. In this way they were dealt with all the relevant risks acting on the Harbour Bridge.

The most serious risks of operating in the Harbour Bridge can be considered dangerous goods, inattention road transport, but also a means of transport, the technical condition is often not prescribed requirements. These were the sources of risk classified as high risk. Conversely landslide or sabotage the risks to Harbour Bridge rather negligible. The result of the risk assessment Harbour Bridge is the fact that there were no unacceptable risks.

6. CONCLUSIONS

1. The article presents two-level model for road transport which were defined for becoming a professional alternative to the classified criteria set by the Ministry of Transport, Construction and Regional Development of Slovakia.
2. It gives a comprehensive look at the issue of critical infrastructure in the transport sector especially in the sub-sector road transport in Slovak Republic.
3. The authors introduced the method of quantification criteria for objects in road infrastructure, which were applied to selected sections of first class roads.

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ОЦЕНКА НА РИСКА НА КРИТИЧНИТЕ ЕЛЕМЕНТИ НА ПЪТНАТА ИНФРАСТРУКТУРА

Зденек Дворак, Бохус Леитнер, Мария Лускова,
Ладислав Новак, Ева Свентекова
Zdenek.Dvorak@fsi.uniza.sk, Bohus.Leitner@fsi.uniza.sk, Maria.Luskova@fsi.uniza.sk, Ladislav.Novak@fsi.uniza.sk, Eva.Sventekova@fsi.uniza.sk

Университет в Жилина, 1.мая 32, 010 26 Жилина
СЛОВАКИЯ

Ключови думи: *оценка на риска, критична инфраструктура, автомобилен транспорт, двустепенен модел.*

Резюме: *Статията представя подходящи методи за количествена и качествена оценка на риска на критичните инфраструктурни елементи в автомобилния транспорт. Оценката на риска се състои от идентифициране на източниците на риск, анализ на риска и управление на риска. Авторите се фокусират в тяхното изследване върху прилагането на методология за оценка на риска на пътни обекти. По време на идентификацията на източниците на риск те изследват теоретично възможните рискове и се концентрират най-вече върху най-вероятните рискове. В рамките на анализа на риска авторите дефинират матрица на риска. Най-важния теоретичен принос е двустепенен модел, разработен за оценка на риска на пътния трафик. Този модел е използван за конкретен мост в Братислава. В този изследователски проект авторите дават ново научно доказано решение за оценка на критичните инфраструкторни елементи.*