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IDENTIFICATION OF THE RISK OF DISTURBANCES OF OPERATION OF TRANSPORT INFRASTRUCTURE IN CRISIS CONDITIONS

IDENTYFIKACJA RYZYKA ZAKŁÓCEŃ EKSPLOATACYJNYCH INFRASTRUKTURY TRANSPORTOWEJ W WARUNKACH KRYZYSU

A b s t r a c t

The paper contains a specification of the notions of risk, transport infrastructure and crisis situation. The study also presents selected methods of identification of risks to transport infrastructure facilities, based on the example of a bridge facility.

Keywords: crisis situations, risk assessment, transport infrastructure

S t r e s z c z e n i e

W artykule dokonano specyfikacji pojęciowej ryzyka, infrastruktury transportowej oraz sytuacji kryzysowej. W pracy przedstawiono również wybrane metody identyfikacji ryzyka obiektów infrastruktury transportowej na przykładzie obiektów mostowych.

Słowa kluczowe: sytuacje kryzysowe, ocena ryzyka, infrastruktura transportowa

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1. Introduction

Bridge structures, as elements of transport the infrastructure, are categorized as critical infrastructure facilities. Even a temporary exclusion of such facilities may cause a paralysis of the logistic system in the given region, or part of the country. That awareness gives rise for the need to introduce special security measures associated with the protection of bridge facilities. The main reason for this is because they can become the target of sabotage or terrorist acts.

One measure against such an attack may be reliable risk analysis, based on a meticulous identification of hazards, i.e. the potential risk factors, and on the assessment or quantification of the results of their occurrence. The problem of assessment of the risk when maintaining the transport infrastructure in crisis situations, especially as regards bridge facilities, is the subject of the Authors' studies [1, 2].

The study contains a specification of the notions of transport infrastructure and crisis situations. The study also presents selected methods of assessment of risks of operation disruptions to transport infrastructure facilities, based on the example of bridge facilities. The risk analysis was described in the light of the procedures applied in the USA and Canada. These methods were compared with the authors' method.

2. Specification of transport infrastructure and crisis situation

A. Kogut [3] stated that the notion of infrastructure is assumed to describe all the appliances and institutions necessary for the correct functioning of the economy of the given country. In turn, the notion of transportation is understood as activities aimed at moving specified things (persons and property) with the use of the appropriate means of transport [3].

It may be assumed that the transport infrastructure consist of the transport network and means of transport [4]. The main structure of the transport network consists of line elements (various transportation routes) and point elements (transportation ports and hubs) [4].

In Poland, as in most countries, the transport infrastructure is composed of five types of transportation, i.e. motor vehicle, train, air transport, and inland and sea shipping and pipeline and energy transport [3].

Motor vehicle and road transportation are the most popular types of transportation in Poland. In both cases the transport infrastructure consists of the line elements that belong both to road and rail transportation [4]. In turn, the facilities which are inseparably connected with both road and rail networks are bridges, of which there are various kinds of bridges, viaducts, overpasses, footbridges and culverts.

In turn, the transport system belongs to the infrastructure. In act [5] the critical infrastructure is defined as the systems and the functional facilities (including building facilities) used, among others, for providing the efficient functioning of the public administration authorities. Therefore, the protection of that infrastructure covers activities aimed at providing the functionality and continuity of the activities of its respective elements. The aim of those activities is to prevent threats and reduce and neutralize their effects, as well as to quickly restore that infrastructure, for example in the case of failures or various terrorist acts [5].

According to Z. Zamiar and L. Wełyczko [6], for a specific phenomenon (event) to be called a crisis, it must occur suddenly, genuinely, be unacceptable for the given environment, and endanger its interests. The subject literature also uses the notions of crisis situation and crisis condition. The notion of a crisis condition is a legal condition announced by the public administration authorities for the purpose of solving a crisis situation. In turn, the notion of crisis situation can be understood as the course of phenomena and processes after a violation of the balance of systems and processes (e.g. social or environmental systems and processes), that results in a threat to life, or the natural environment, etc. A crisis situation may also result in a disturbance of the activities of the public administration institutions. The resolution of crisis situation is possible with the use of crisis management tools [6].

According to the study [6], crisis management is a collection of the activities by suitable institutions, the purpose of which is to analyze risks and threats, monitor risk factors, as well as to prevent the occurrence of crisis situations. The tasks of those institutions also include planning, organizing, introducing and controlling activities aimed at creating the conditions for resolving crisis situations, and the resolution of such situations itself. Crisis management in the subject literature is defined from three points of view, i.e. the functional, institutional and theoretical point of view [6].

According to R. Grodzki [7], the taxonomy of threats in crisis management consists of assigning the threats to the respective groups that characterize the given threats. Of course, in crisis situations not all of these groups of threats have the same priority of significance. First and foremost, threats are analyzed in terms of their source, then the level of destruction, and then the spatial scope [7].

In terms of the sources, natural, technical and anthropogenic threats exist [7]. Natural threats include geological threats (e.g. earthquakes or volcano eruptions) and climatic threats (e.g. floods, strong winds or hailstorms). The remaining threats in that group are, among others, various epidemics, plagues of insects or rodents. Technical threats include, among others, failures of technical equipment, catastrophes and fires. In turn, anthropogenic threats include terrorism, military threats, social threats (e.g. civil commotions, alcoholism or unemployment) and various types of threats caused by the so-called human errors [7].

3. Method of specifying the risk of damage to bridge facilities based on the procedures applied in engineering troops of the US military

According to the recommendations of the U. S. Department of Transportation Federal Highway Administration, the risk R of damaging a bridge facility may be specified as follows [8]:

$$R = IF \sum_{i=1}^{n} (OF_i \times VF_i) \tag{1}$$

where:

- n – the number of threats to the given bridge facility;
- IF – the significance coefficient (so-called weight of the given bridge facility) which reflects the social-economic influence of the given bridge facility on its surroundings,

OF – the occurrence coefficient which is the value of the probability of the occurrence of the given threat,

VF – the sensitivity coefficient which reflects the consequences of the occurrence of the given threat.

It is assumed that each coefficient in equation (1) is a number between <0; 1> and should be calculated based on [8]:

$$IF\ (or\ OF\ or\ VF) = \sum_{i=1}^{n} (w_j \times v_j(x)_j) \tag{2}$$

where:

x_j – the j value of that attribute,

$v_j(x_j)$ – the function describing the j utility value of that attribute (a number from the scope < 0; 1>),

w_j – the coefficient of significance (the weight) for the j of that attribute (a number from the scope < 0; 1>), which may be determined with the use of one of the assumed mathematical methods, e.g. the analytic hierarchy process (AHP).

J.C. Ray in his study [9] suggested a good method of calculating risk R of damaging any bridge facility, in terms of the threat of terrorist attacks, based on the assumptions presented in the study [8]. He suggested that risk R should be calculated for each combination of risk factors (threats) with regard to the selected, crucial elements of a bridge facility based on the following equation [9]:

$$R = O \times V \times I \tag{3}$$

where:

O – the occurrence coefficient specifying the probability of occurrence of the basic threat which has an actual effect on the analyzed element (component) of a bridge facility;

V – the sensitivity coefficient, specifying the resistance of the given element of the bridge to the activity of the main (basic) threat;

I – the significance coefficient, specifying the importance of the given element for the durability of the structure of the bridge.

According to the author of the study [9], the basic threats (risk factors) are:

- improvised explosive devices transported on vehicles or manually in packages;
- non-explosive cutting devices, such as acetylene-oxygen blow torches or angle grinders;
- fires;
- crashes of large motor vehicles, (e.g. trucks, tank trucks, TIR trucks, etc.) into the load--bearing elements of a bridge.

However, it would appear that threats to the Polish transport network that group of threats should also include, among others:

- crashes of marine means of transport into the intermediate supports of the existing spans,
- crashes of rail vehicles (locomotives or whole trains) into the load-bearing elements of a bridge (viaduct).

However, it is more time-consuming to determine the database of the neuralgic load-bearing elements of bridges, because, unfortunately, every time it is determined by the individual structure of a bridge facility. Therefore, the number of those elements will be

directly related both to the load-bearing structure of a bridge span and its supports, and to the type of construction material used for its construction. Therefore, in the modern structures of bridges (e.g. hanging bridges, suspended bridges, pylon bridges), the number of those elements may be considerable and often exceed 10 [9].

4. The original method of specifying the risk of damage to bridge facilities in the light of terrorist attacks

In study [1] the authors suggested determining the risk R_i of damage to the *i*-bridge facility in the given area with the use of formula (4), i.e. as the product of the p_i probability of the occurrence of that event and the c_i consequence resulting from destroying it, divided by the sum of those products for all the *n* analyzed bridges [1]:

$$R_i = \frac{p_i c_i}{s} \tag{4}$$

where:

$$s = \sum_{i=1}^{n} (p_i c_i). \tag{5}$$

At the same time assuming that the value of p_i probability and c_i consequence is a number from the scope of <0, 1>. And assuming that both the sum of the *p* probability of destroying all the bridge facilities, and the sum of *c* consequences of destroying them, as well as the *R* risk of damaging all the *n* selected bridge facilities in the analyzed area of the country is equal to one.

The authors proposed to use one of the multi-criterion analysis methods for assessing the probability and consequences of damaging bridge facilities – in particular the Analytic Hierarchic Process method [10] or the Bellinger's method [11]. The detailed method of calculations has been presented, among others, in studies [1, 2].

5. Proposal of the method for determining the risk of damage to bridge facilities, used by the engineering troops of Canada

The team of S. Bourdon suggested [12] another interesting solution for the assessment of the *R* risk of damage to any bridge facility as a result of a terrorist attack, is using the following formula:

$$R = E \times P \times C \tag{6}$$

where:

E – the projected annual number of terrorist attacks;
P – the probability of success of a terrorist attack;
C – the expected result (consequence) of a successful terrorist attack.

According to S. Bourdon's team [12] the aim of the so-defined notion of risk is to establish what the sensitivity of a given bridge facility to the occurrence of a terrorist attack is. That sensitivity is described in relation to the accounting period of one year.

6. Conclusions

The advantage of the method presented by Duchaczek and Skorupka [1, 2], which allows risks to be simultaneously assessed for several bridge facilities in the given area of a country, is the possibility of simultaneously comparing the risk of damage to several facilities in terms of the same criteria.

The method used by US Army engineering troops[9] associated with the assessment of damage to a respective structural element of an analyzed bridge facility, in terms of the selected risk factors (here – terrorist attack), allows for a very detailed analysis of the given structure. Therefore, its usefulness to those responsible for the operation of one selected bridge is high, and its use for such cases is justified. However, it seems that for those organizing logistics (transport) protection resulting from the execution of crisis activities in the given area of a country, it is of little practical use. This results from the fact that the obtained risk assessments did not take the same criteria into account, due to the diverse load-bearing elements of the respective bridges, and so the comparability of the achieved risk assessments is therefore incomplete. That method does not indicate explicitly which facilities should attract special attention, and so should receive more forces and resources for securing them.

Another method proposed by the team of S. Bourdon [12] is also worth noting. Here the assessment of the *R* risk of damaging a bridge facility refers directly to the number of terrorist attacks performed over the assumed accounting period, which seems very justified from a practical point of view. Its disadvantage is that it is missing empirical data.

The issue of risk assessment in a broad sense is the subject of numerous studies associated with the engineering of construction undertakings [13–15] and with the construction logistics [16]. Therefore, it seems that in the future the risk assessment methods presented may also be adapted also to those areas.

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