ASSESSMENT OF STATIC RESILIENCE OF OBJECTS IN THE RAIL TRANSPORT

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Resume

Resilience is the ability of an object to retain its basic functions in the case of adverse events from an external or internal environment. Adverse events can jeopardize the operation of an object or cause it to become completely inoperable. The assessment of static resilience should be dealt with mainly by objects that are included in local, regional, national, and international critical infrastructure. Critical infrastructure is the basis of today's modern functioning society.

The paper is focused on design of the static resilience evaluation of objects in the rail transport. The proposed method of static resilience assessment is based on safety pillars and is applied in a case study to a specific object of the rail transport. This approach is original in the conditions of the Slovak Republic.

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1 Introduction

The quality of the state‘s transport system is crucial for development of all the sectors of the national economy and, at the same time, for an adequate quality of life. The most developed countries in the world are constantly building their transport infrastructure. An example is China, where 750 meters of a new highway are built every hour. The well-built and continuously maintained point, line and area facilities of the transport infrastructure are the basis for providing logistics activities for companies, transport services for the population and defence for the state. In the new European strategy for 2021-2030, „security and resilience“ is one of the six defined thematic groups. The transport system of the state consists of several types of transport. The article will pay attention to rail transport and focus mainly on rail infrastructure [1].

One of the monitored parameters of the quality, safe and modern infrastructure is its resilience. Resilience represents the ability of an element to absorb, adapt and quickly recover the activity of the element, namely an object, as a result of an adverse event. In practice, one encounters adverse events of a natural and anthropogenic environment. Adverse events can lead to significant disruption in functioning of individual facilities in the rail transport [2].

Importance of the rail transport in Slovakia lies in its connection with pan-European corridors and its use in national as well as international transport of passengers and goods. Because of the key importance of the rail transport at the national and international level, it is necessary to focus on assessment of its static resilience.

Resilience is a way to increase the safety/security of facilities belonging to the rail infrastructure. By quantifying the static resilience, the facility operator can obtain the necessary information about the individual evaluated areas and to detect deficiencies promptly, to which he can react in advance. The paper is focused on design and testing of the static resilience evaluation of selected objects in rail transport. From the point, line and area objects, the article has focused on the area object - the railway station.

As part of the draft static resilience assessment, safety pillars were used that can comprehensively cover several safety areas. By increasing the level of resilience, it is possible to ensure their functioning, respectively maintaining the basic functions in the case of an adverse event and thus does not interfere with functioning of other elements of the system that are interconnected with them.

2 Institutional and juridical frame of critical infrastructure

Today‘s society often has to deal with threats that arise in the external or internal environment. Their influence disrupts functioning of processes in the affected element, or their influence can lead to the complete failure of ongoing processes, on which other elements and the company itself depend. Objects without which the state's economy cannot function properly are included among the elements of critical infrastructure. Critical infrastructure is a set of elements whose damage or failure can have a negative impact on the population and the economy of the state. Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European Critical Infrastructure and the assessment of the need to improve their protection defines critical infrastructure Art. 2 *„as a component, system or part thereof located in the Member States, which is necessary for the maintenance of the fundamental functions of society, health, protection, safety, quality of life of the population from an economic and social point of view and the disruption or destruction of which would have serious consequences in the Member State due to the impossibility of maintaining these functions“* [3].

Within the European Union, there is a European Railway Agency (hereinafter ERA). The ERA ensures better functioning of the rail infrastructure and contributes to the efficient functioning of the Single European Railway Area. The ERA acts as a superior body to help coordinate the necessary changes leading to the creation of a single European railway area. In the field of safety, it aims to develop a harmonized approach to rail infrastructure safety, develops a technical and legal framework to remove technical barriers, improves the availability and use of rail infrastructure information, issues vehicle authorizations and single safety certificates [4].

The ERA's activities also include the provision of the Common Safety Methods (hereinafter CSM) application. Each rail line, rail infrastructure manager and entity in charge of maintenance should ensure that all suppliers and other parties working on the rail system implement risk control measures. To that end, they should apply the threat monitoring methods set out in the CSM. These methods are applied through contractual arrangements. As these agreements are an essential part of the rail infrastructure safety management system, they should be available on request from the ERA. Member States are obliged to cooperate in safety management. Common safety targets and the CSM applications have been gradually introduced [5].

The CSMs are further specified in general methods of risk assessment, risk monitoring and safety. They also focus on the management system requirements, on supervision and on the fulfilment of safety objectives [6].

Each national critical infrastructure is unique and represents a set of elements that are closely interconnected. For the needs of application of Directive 2008/114 / EC into the Slovak legal environment that is Act no. 45/2011 Coll. on Critical Infrastructure, which represents the legal framework for critical infrastructure in Slovakia. The law defines the basic requirements associated with the issue of critical infrastructure. An important part of this research is Annex no. 3 to Act no. 45/2011, which contains a list of sectors and subsectors [7]. Within the transport sector, there is a railway subsector, which is the subject of this contribution. The rail infrastructure is very important from the point of view of Slovakia's transport system because it is a part of the Pan-European transport corridors. The detailed specification of the rail transport subsector in Act no. 45/2011 Coll. is not mentioned, but its further definition can be found in the National Program for Protection and Defense of Critical Infrastructure in the Slovak Republic from 2008 (hereinafter National Program). The National Program is the only document that closer specifies the rail transport subsector and other subsectors, as well. The National Program lists elements of critical infrastructure in the conditions of rail transport, such as important rail junctions, fuel depots, electrical substations enabling the supply of electrified lines and others. Furthermore, the National Program also states the method of protection of these elements. The protection of the rail infrastructure elements is ensured through the human factor, technical means and adoption of measures to reduce risks, i.e. reducing vulnerability [8].

In relation to the issue of critical infrastructure in Slovakia, it is necessary to mention the methodological guidelines, which are of a recommendatory nature and supplement Act no. 45/2011. The first document that precisely covers the area of safety/security measures is Methodological guideline no. 29014 / 2014-1000-53190 MH SR on safety/security measures for the protection of critical infrastructure elements in the energy and industry sectors. The methodological guideline deals with the protection of critical infrastructure elements. The Annex defines the zones and a description of their safety for specific elements of critical infrastructure in the energy and industry sectors [9]. The second document is Methodological guideline no. 1321 / 2011-1020 of the Ministry of Economy of the Slovak Republic on the protection of sensitive information on critical infrastructure and on the manner of handling this information. In practice, the methodological guideline is supplemented by other legal documents related to information security [10]. It is also important to mention Act no. 69/2018 Coll. on Cyber Security and on Amendments to Certain Acts, which is connected with the issue of critical infrastructure and the protection of elements itself.

Maintaining the continued functioning of the critical infrastructure elements is not just about complying with legislation and recommendations. Objects included in critical infrastructure must focus on several areas that could affect their operation. Disruption of the the elements function can be caused by various risks, which need to be detected as soon as possible when they cannot yet cause massive damage to functions of the object [11]. A possible way to identify the sources of these risks is through the process of assessing the level of static resilience. By determining the level of resilience, one can detect weaknesses that can cause the element to fail. The subsequent part of the paper is devoted to approach to the resilience issue and the method of evaluating the static resilience of elements included in the railway subsector.

Under Act No. 513/2009 Coll. on railways, safety is addressed in Article I in the fifth part. This section defines the safety of the railway system. The railway safety system consists of *„safety requirements for the railway system as a whole for its subsystems, including the operation of the railway infrastructure and traffic management, as well as for synergies between the infrastructure manager and railway undertakings and other entities affecting the safety of the European Union rail system"* [12].

The law further states that in determining the minimum level of safety/security, the risks associated with:

- passengers,
- the staff of the infrastructure manager and railway undertakings, as well as the staff of supply services for the railway system,
- road users at level crossings, pedestrians at crossings and other persons, without prejudice to the applicable legislation concerning the liability of the party to the accident,
- persons moving unauthorisedly in the perimeter of the track and in the premises of the infrastructure manager,
- societal risks [13].

The Ministry of Transport and Construction of the Slovak Republic (hereinafter MinDop) is a state administration body of the Slovak Republic, which, within its defined competence, also performs activities in the field of rail transport [13-14]. Within the organizational structure, the safety of the rail system is handled by the Crisis Management and Cyber Security Department.

The Transport Authority of the Slovak Republic (hereinafter DU SR) also falls under the competence of the MinDop. The DU SR according to Act no. 402/2013 Coll. on the Office for the Regulation of Electronic Communications and Postal Services and the Transport Authority is divided into the following three divisions:

- Railways and Railways Transport Division,
- Civil Aviation Division,
- Inland Navigation Division [15].

For the needs of the article, which focuses on the rail infrastructure, division of the rail and transport on the rail is described in more details. This division is legally governed mainly by Act no. 514/2009 Coll. on railways, Act no. 258/1993 Coll. on the Railways of the Slovak Republic and Act no. 259/2001 Coll. about Railway's Company Slovakia a.s. The Division of Rail and Transport on Rail is divided into basic sections, namely:

- regulation, permits and licenses on rail,
- safety and interoperability of subsystems,
- state professional technical supervision [16].

At the end of the analytical part on institutions and the juridical framework, the goal of this research is described. As a part of the ongoing research, controlled interviews were conducted with five employees of MinDop, DU SR and Railways of the Slovak Republic (hereinafter ZSR). During these interviews, the interest of the practice in the results of research in the field of resilience was confirmed. Given the expected challenges for the period 2021-2030 in the field of transport, the attention of researchers is focused on the area of „security and resilience". Within the framework of the long-term cooperation of the University of Zilina with institutions and companies in the field of transport, current problems and challenges for the needs of practice have always been solved within the research. As a part of the current applied research, this is based on projects that have been realized in the past decades, research is currently directing mainly towards the area of effective use of information and communication technologies. The researchers intend to create an expert information system which, using the 5G networks, SMART solutions and the Internet of Things, will bringthe unbiased information in real-time to support traffic management and support planned maintenance and renewal, for the needs of the rail infrastructure manager objective. The main goal of applied research for the needs of the rail infrastructure manager is to create a theoretical apparatus and software product, which will be tested and verified in cooperation with the ZSR as a tool for the new safety dispatching of the ZSR [17].

3 Literature review

The first major source was a US document in 2013 focusing on the overall framework of risks, vulnerabilities and resilience. The framework for creating the Resilience Measurement Index, real-time data collection, self-calculation and presentation of Resilence Measurement Index results was presented for the first time [18].

Next is the 2015 ETH Zurich document - Measuring Critical Infrastructure Resilience: Possible Indicators. The authors defined here the absolute and relative assessments of resilience. They focused on potential critical infrastructure resilience assessment indicators and made a significant contribution to definition of the resilinece index for the Swiss critical infrastructure [19].

Nan and Sansavini focused on the individual phases of resilience - absorption, adaptation and recovery. They were the first to publish an integrated metric for system resilience quantification and a hybrid modeling approach for representing the failure behavior of infrastructure systems [20].

Kozine, Petrenj and Trucco were focused on research approach that is capabilities-based, where a capability is defined as a combination of assets, resources and routines specifically arranged to accomplish a critical task and assure a key objective. Another benefit is in defining the intra and inter-institutional capabilities, which are grouped into clusters according to the resilience phase (preventive, absorptive, adaptive and reconstruction). The result of their research is the interconnection of technical, operational, social and economic systems [21].

A complex approach to assessing resilience has been addressed by Rehak et al. in [22].They developed the Critical Infrastructure Elements Resilience Assessment methodology (hereinafter CIERA). Their contribution is a description of a complex approach to assessing technical and organizational resilience, as well as identifying of weak points in order to strengthen the resilience [22].

In the USA the Presidential Policy Directive-Critical Infrastructure Security and Resilience calls for proactive and coordinated efforts to strengthen and maintain a functioning, secure and, above all, resilient critical infrastructure [23]. Robust systems would help to reduce the likelihood of adverse events, or allow the element to respond effectively in the case of an adverse event.

There is no universal definition of resilience that can be applied to all the research areas. In practice, one may encounter application of this term in various scientific disciplines, such as psychology, economics, medicine, environmental sciences and safety. The critical infrastructure area uses the definition: *„resilience is the ability to absorb, adapt and / or recover rapidly from a potential adverse event“* [24].

In general, it can be stated that resilience is the ability to adapt to foreseeable or unexpected adverse events [25]. In addressing the issue of resilience in the rail transport, attention needs to be paid to researc.

Besinovic in [26] has defined the resilience of the rail infrastructure as the ability of the system to provide services under normal conditions, as well as to resist, absorb, react quickly and recover from adverse events. Author explored the possibilities of measuring and quantifying resilience. The acquired knowledge should form a mainstay in understanding the requirements related to the resilience of rail infrastructure. There is scope for a better understanding of possible applications for resilience assessment and design of resilient rail transport systems.

Deloukas and Apostolopoulou addressed the static and dynamic resilience in transport in [27]. The paper is composed to assess the urban transport resilience. The practical demonstration was applied to the Athens metro. Authors constructed the risk scenarios for the risk of an attack on the metro, which took into account the static and dynamic resilience of urban transport. The static resilience is related to robustness, i.e. the ability of the urban transport system to absorb the effects of the adverse event and to retain its basic functions, i.e. enabling the transport of persons when the section is decommissioned. In the static resilience, the focus is on replacing the metro with other modes of transport, such as bus lines. The dynamic resilience has focused on the rapid recovery of the damaged infrastructure and resuming of the transport services.

Adjetey-Bahun et al. presented a new approach to dealing with adverse events in [28], the concept of resilience, which allows not only to measur the ability of the system to absorb failures but to obtain information about the ability to build speed, as well. That is not a traditional approach to risk management that focuses on the probability and consequences of events. Part of the authors‘ work is a simulation model for quantification of resilience in public transport systems, which have integrated subsystems, e.g. telecommunication, organizational. The model was subsequently applied to the Paris rail transport system. Following its application, they concluded that the rail transport system remained resilient even when train speeds were reduced.

The issue of transport infrastructure resilience is also being addressed by the European Commission, which has launched the RESIST project, which is funded by the EU‘s research and innovation program in 2020, [29]. The project has taken a holistic approach to the strengthen road critical infrastructure. The primary goal of the RESIST project is to create a methodology and tools for risk analysis and management focused primarily on highway construction. The methodology and proposed tools should be applied to all the extreme natural and man-made adverse events. The aim is to increase the resilience of the transport infrastructure and protect the interests of users and operators of European transport infrastructure. Although the project is primarily focused on transport infrastructure, it provides a lot of information that can be used in research activities related to the rail transport, as well.

When examining information sources from specialist publications and websites, the researchers concluded that the issue of assessing the static resilience in the rail transport has not been comprehensively addressed so far, so there is a latitude for new ideas and innovations that would shift the issue of critical infrastructure protection in Slovakia and world ahead.

In the above-mentioned information sources and juristic acts, attention is paid only to some parts of this research. To move the knowledge further, the attention of researchers should be focused on a new method of quantitative evaluation of static resilience of objects in rail transport, which is based on predefined indicators in individual areas of safety.

Based on the research carried out at the researchers‘ workplace, the safety pillars were gradually defined based on relevant and objectively measurable indicators; pillars of safety, which allow to comprehensively cover the functioning of the most important parts of safety and security in the building. If one can quantify the level of individual areas, one can detect shortcomings and then take measures that will increase the resilience and safety of the element. Each safety pillar should have identified indicators to assess the area. Hofreiter

Figure 1 *Pillars of the safety management system*

Table 1 *Example of the design of indicators within the individual pillars*

design of indicators					
physical safety	fire safety	environmental safety	operational safety	safety and health at work	information security
unauthorized entry into the premises of the reference object	fire alarm	periodicity of drainage system inspection	occurrence of a malfunction of the system for proving identity check-in	expertise of employees	security of passwords
unauthorized access to the reference object	availability of firefighting equipment directly in the building	noise pollution	development of security plans	handling of hazardous substances	defining access to information
application of image surveillance systems in a reference object	smoke and heat removal equipment	the threat to the building by floods	prevention of fault events in the system	control of use of the PPE and control of their condition at the workplace	operating system updates
time for overcoming perimeter protection and approaching the reference object	level of fire safety	amount of annual investments aimed at environmental protection	development of an analysis aimed at prevention of major accidents	regular health and safety training	regular inspections of accession measures
time of overcoming the mantle protection of the reference object and penetration into the object	damage to the building due to fire	certification of the environmental management system according to the ISO 14001 standard	IRS response time to an adverse event	impact of the work environment on quality of the employees‘ health	operating system software protection
time to overcome spatial protection and approach the protected interest	degree of protection of escape routes	creation of environmental reporting	risk of electricity interruption	expertise of employees	performing an internal security audit

and Byrtusova dealt with safety indicators in[30] where they defined indicators as data, respectively data files, expressing the state of the system. The authors stated that indicators can express the normal, desired state of the system, or the transition of the system to a state of increased instability, predictability and manageability Durech also followed up on the issue of safety indicators in his dissertation and proposed a method of effective evaluation of the rail station safety using the safety indicators [31].

A holistic approach needs to be taken when creating a new resilience assessment procedure. In practice, this means that when examining a certain issue, it is necessary to focus on the whole as a whole, not just on certain parts. As stated by authors in [32], which focuses on resilience engineering, resilience are the

***Table 2** Example of the individual indicators evaluation*

pillar	indicator	indicator description	value
physical safety	time for overcoming perimeter protection and approaching the reference object	a) The reference object is at a distance of 200 m from the fence, the fence is 2 m high and equipped with other wire, the fence is still equipped with detection systems based on optical cables that send a signal via a communicator to the CPD receiver (centralized protection desk). The overcoming time is estimated at 10 min or more.	3
		b) The reference building is at a distance of 100 m from the fence, the fencing is 2 m high, the building has regular detours with its SBS. The overcoming time is estimated at 5 min.	2
		c) The reference object is at a distance of 10 m from the fence, the fence is not in good technical condition, its height is 1.5 m. The overcoming time is estimated at 1 min.	1
fire safety	level of fire safety	a) The building has fire indicators in each room with a connection to the sprinkler; escape routes meet the requirements for a protected escape route, the fire protection plan is developed and methodical exercises take place once every six months to optimize the reaction and rescue process.	3
		b) The building has fire indicators in each room, the sprinkler is not installed within the reference building, the reaction to elimination of fire must be performed by an employee using fire extinguishers, the fire protection plan is prepared and revisions are carried out together with methodical exercises.	2
		c) The building has fire indicators only in places where there is a risk of fire, the sprinkler is not installed and the elimination of the fire must be performed by a worker using fire extinguishers; the fire protection plan is prepared by law, methodical exercises are performed irregularly.	1
environmental safety	certification of the environmental management system according to the ISO 14001 standard	a) The building holds the ISO 14001 certification.	3
		b) The object partly works according to the ISO 14001 standard or tries to obtain the given certification.	2
		c) The facility does not work in the environmental field with any standard.	1
operational safety	development of an analysis aimed at the prevention of major accidents	a) Analyses are prepared in accordance with internal regulations and look for better ways to innovate, employees are fully acquainted with the analysis. Analyses are performed once a year.	3
		b) Analyses are prepared in accordance with internal regulations every two years, no better ways are sought to innovate the current situation, employees are partially familiar with the analysis.	2
		c) Analyses are not prepared, i.e. employees are not notified.	1
safety and health at work	regular health and safety training	a) Trainings have an annual regular interval, lasting one full working time with a final verification of the employee‘s state of knowledge.	3
		b) The trainings have an annual regular interval, lasting one full working time without a final examination.	2
		c) Trainings do not have a regular interval set by law and therefore employees show shortcomings in the field of health and safety awareness.	1
information security	operating system software protection	a) The reference object has a paid updated software platform (anti-virus program) to prevent intrusion into the operating system and the data contained in it.	3
		b) The reference object has a paid non-updated software platform (antivirus program) to prevent intrusion into the operating system and the data contained in it.	2
		c) The reference object has a publicly available software platform (anti-virus program) to prevent intrusion into the operating system and the data contained in it.	1

***Table 3** Final expression of static resilience*

total summary value	verbal expression	description
100%-92%	excellent level of resilience	A reference object characterized by an excellent level of resilience can withstand adverse events from external and internal environments without interruption or significant restrictions. The object has identified only minimal deficiencies in its system, which do not represent sources of risks that could affect its operation.
91%-75%	good level of resilience	A reference object characterized by a good level of resilience can withstand and maintain basic functions in the case of adverse events from external and internal environments. Deficiencies have been identified in the facility's system that may be a potential source of risks that could further affect its resilience and its functioning could be jeopardized in the future if the preventive measures are not taken.
below 75%	unsatisfactory level of resilience	A reference object characterized by an unsatisfactory level of resilience is not able to maintain its basic functions in the case of adverse events from external and internal environments. The system contains several shortcomings, which result in a reduction in the resistance of the object.

means, methods and technologies to overcome adverse events with the least possible harm and the subsequent construction of a system that will stronger and prepared for adverse events that may arise in the future. The safety environment analysis usually focuses on specific threats. Authors tried to establish a way of thinking that allows to manage all kinds of adverse events. Assessing the resilience of objects requires harmonization of knowledge in the field of safetty and resilience [32].

Enache and Letia paid attention to the rail infrastructure, which is characterized by complex safety and security systems supporting its management and monitoring, [33]. The authors stated that rail systems must maintain their resilience and ensure safety requirements without reducing efficiency. The proposed method is based on *Object Enhanced Time Petri Nets models*, which can simultaneously describe behaviour of all the components integrated into the infrastructure. The paper contains an example of application for a part of the rail system, safety and resilience of which were then analyzed.

The indicators can be specifically designed for the evaluated area and thus provide unique results. In connection with the safety indicators, several scientific publications have been published. Renard and Charles have focused their attention on underground system, which take into account the specifics of e.g. tunnels, automatic pilots, platform doors and others, [34]. A classification of safety indicators to identify information was subsequently introduced at a national level in France.

The above-detailed analysis of scientific information sources provides several findings. First, the issue of resilience research in scientific information sources is represented. Second, the authors bring theoretical knowledge linked to practical applications in several countries. Thirdly, the changing natural and social environment require a new set of boundaries for the resilience of transport infrastructure objects. The above findings and conclusions, in the area of the institutional and legal framework, imply an objective need for applied research. The following part of the article is focused on the demonstration of possible use of the safety pillars in the static resilience evaluation.

4 Evaluation of the static resilience of buildings in the rail transport

The static resilience assessment should be a comprehensive tool that can evaluate the areas located in each building or element of critical infrastructure. The method for the static resilience evaluation is based on application of the safety pillars, Figure 1. Specific indicators for the area of the rail transport are proposed for each pillar, Table 1. The proposed method of assessing the static resilience would be a comprehensive tool for the rail infrastructure objects, such as bridges, tunnels, stations, transhipments, etc. [35]

Each indicator shown in Table 1 is characterized in detail in Table 2. The indicators located in each area are evaluated by a quantitative scale from 1 to 3. In our case, the point value 3 is (excellent) assigned to the indicator, which is fully represented in the evaluated reference object. A point value of 2 (good) is assigned to the indicator if it does not meet all the requirements contained in the first point and a point value of 3 (excellent) cannot be assigned to it. A point value of 1 (unsatisfactory) is assigned if the indicator does not meet the requirements contained in the previous points. As 6 pillars were chosen and each of them has 6 indicators, this means that the maximum achieved quantitative sum represents a total of 108 points on the evaluation scale of 1 to 3. If the individual pillars are evaluated by expert estimation, one can sum them up and then calculate the level of static resilience in percent, according to:

$$I_p = \frac{100}{I_k} \times \sum I_j \,, \tag{1}$$

where:

$\sum I_j$ = the sum of the quantitative evaluations of the indicators for the reference object,

I_k = maximum value of quantitative evaluation of indicators,

***Figure 2** Indoor and outdoor environment of the Zilina railway station [37]*

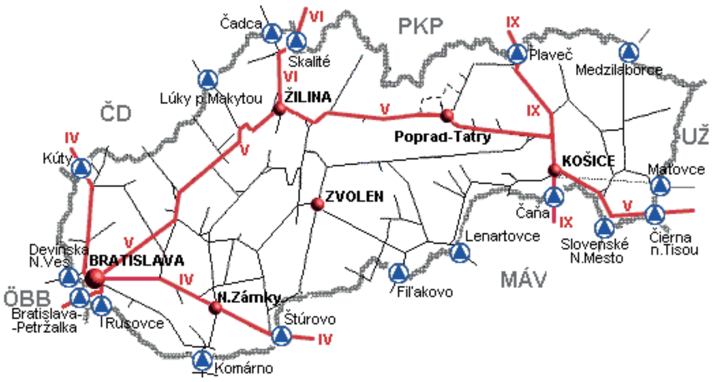

***Figure 3** Pan - European rail corridors [38]*

I_p = percentage expression of static resilience for the reference object.

Six pillars are currently proposed in each area, with the corresponding descriptions, Table 2. To ensure accurate outputs and their application in practice, it is proposed to create at least 30 indicators in each area, which would be characterized in detail. For the purpose of this article, one indicator is assigned to each area for better visualization of the structure of the proposed procedure, which is shown in Table 2.

The above description of selected safety indicators had to be evaluated. In co-operation with the practice, questionnaires were created for security experts, where they were to comment on the overall safety assessment. Based on these findings, the values determined by the experts were averaged. A value in percentage terms of 92 to 100 was determined as an excellent level. A range of 75 to 91 percent was set as a good level. Values below 75 percent were determined to be unsatisfactory. The total level of static resilience is determined by summing up all the assigned quantitative values and their subsequent percentage expression according to Table 3.

Through analysis of available information sources from Slovak Republic, it can be stated that the issue of assessing the static resilience of the rail infrastructure has not yet been addressed and in connection with the issue of resilience, there are no records of its solution, either. In the case of information sources from abroad, it can be stated that the issue of resilience is being actively developed and as regards the solution of the rail infrastructure resilience, several scientific works are devoted to it. This paper is devoted to design of a method for evaluating the static resilience of infrastructure facilities through application of the safety pillars, which are evaluated. As mentionedabove, creation of several indicators is required to ensure application of the proposed procedure. The proposed number of indicators in each area is 30. The next section of the paper presents a case study, which aims to clarify the process of evaluating the static resilience of the chosen reference object.

Table 4 *Evaluation of static resistance of Zilina railway station*

evaluation of static resilience		
pillars	name of the indicator	indicator value
physical safety	unauthorized entry into the premises of the reference object	1
	unauthorized access to the reference object	1
	application of image surveillance systems in a reference object	2
	time for overcoming perimeter protection and approaching the reference object	1
	time of overcoming the mantle protection of the reference object and penetration into the object	1
	time to overcome spatial protection and approach the protected interest	2
fire safety	fire alarm	3
	availability of firefighting equipment directly in the building	2
	smoke and heat removal equipment	3
	level of fire safety	3
	damage to the building due to fire	3
	degree of protection of escape routes	2
environmental safety	periodicity of drainage system inspection	3
	noise pollution	3
	the threat to the building by floods	3
	amount of annual investments aimed at environmental protection	2
	certification of the environmental management system according to the ISO 14001 standard	1
operational safety	creation of environmental reporting	2
	the occurrence of a malfunction of the system for proving identity? check-in	2
	development of security plans	2
	prevention of fault events in the system	3
	development of an analysis aimed at prevention of major accidents	3
	IRS response time to an adverse event	3
	risk of electricity interruption	3
safety and health at work	expertise of employees	3
	handling of hazardous substances	3
	control of the PPE use and control of their condition at the workplace	3
	regular health and safety training	3
	impact of the work environment on the quality of employee health	2
	expertise of employees	3
information security	security of passwords	3
	defining access to information	3
	operating system updates	2
	regular inspections of accession measures	2
	operating system software protection	3
	performing an internal security audit	2
sum of quantitative evaluation of indicators for the reference object		86
the total sum of the quantitative evaluation of the indicators for the reference object		108
percentage expression of the static resilience for the reference object		79.63%

5 Case study

The case study aims to present a method of evaluating the static resilience of buildings located in the sub-sector of the rail infrastructure. In Table 4 are shown the safety pillars, including the individual indicators and the assigned quantitative values on the scale 1 to 3. Table 4 does not describe individual indicators in terms of their scope. The reference object, which was decided to draw attention to and apply the proposed method of the static resilience assessment, is the rail station in Zilina. In Figure 2 is shown the surroundings and the interior of that rail station. The importance lies in the transport of people and goods within the national infrastructure and it is also the most important railway transport node, Figure 3, which is a part of the two pan-European corridors, namely:

- corridor No. V. - Bratislava - Zilina - Cierna n/T - state border Slovakia/Ukraine – Lvov,
- corridor No. VI. - Balt - Warszawa - Zwardon - state border Poland/Slovakia - Cadca - Zilina [36].

Subsequently, Table 4 presents expert estimation and analysis of the internal and external environment values for the indicators set here. Then the values of the indicators are added and the level of resilience of the evaluated reference object is expressed as a percentage. The resilience level is determined according to Table 3, in which the respective levels are defined.

The evaluated reference object within the proposed method of static resilience evaluation reached the total part of the values of indicators 86. Subsequently, the value by mathematical operation according to Equation (2) was expressed as a percentage to 79.63%, which means that the object reached only a good of the resilience level. It follows that the object can withstand and maintain basic functions in the case of adverse events from the external and internal environment. Deficiencies were identified in the system of the building, which may be a potential source of risks that could further affect its resilience and if the preventive measures are not taken, its functioning could be endangered in the future.

6 Results and discussion

The main goal of the article was to present the current results of applied research focused on the rail transport infrastructure resilience. Results of a detailed analysis of the institutional and juridical framework, together with the European Union‘s transport strategy, clearly confirm the current need for research in the areas of green and smart solutions. The EU‘s main goal for sustainable mobility by 2050 is to be climate neutral. In addition to research into the new vehicle propulsion, it is necessary to focus on smart solutions for transportation technology and increase safety with a vision of zero fatalities. This must be facilitated by the newly understood resilience of transport infrastructure [39].

Here is considered the current need to address the resilience of transport and transport infrastructure in a way to be scientifically supported by research articles. Examples from various countries and best practices from the real practice of developed countries are an inspiration for the continuous improvement of the solutions presented here. One of the challenges for the ZSR, as the administrator of the rail infrastructure, is to build a safety/security dispatching center, which would continuously monitor the specified safety and security parameters. The new modern information and communication technologies give a chance for solutions that would measure values of the selected indicators in the real state and show them in clear security maps (GIS applications) using the three traffic light colors; when the state is excellent (green), when there are partial problems (orange) and when there is a big problem (red).

Another result is the solution to challenges posed by the changing security environment - changes in the natural and social environment. Researchers primarily relied on results of the European research projects focusing on the extreme effects of weather on transport [40]. As a part of results of these projects, the new directions were defined how to cope with these extreme weather events [41]. The measures were directed mainly to quality maintenance, monitoring and timely repairs of selected transport facilities.

One can also include, as one of the results, a long-term focus on a comprehensive solution to safety issues [42]. The search for a multidisciplinary and multi-level solution brings effective and comprehensive proposals for the safety pillars with a link to relevant and measurable safety indicators. Security research has been a part of the EU‘s scientific research activities for more than 10 years.

In addition, some countries have conducted their own national security research. The current situation with the Covid-19 virus pandemic in Slovakia documents the need to reconsider the already divided division of science in Slovakia. If the company is to cope with all the similar safety and security challenges in the long term - pandemics, fundamental changes in weather extremes and other safety and security challenges, it is necessary to address scientific projects not only at the transnational but also at the national and even regional and local levels.

7 Conclusions

This article was aimed at approaching the issue of the critical infrastructure and importance of ensuring the functioning of elements included in the critical infrastructure system in the case of the impact of adverse events from the external and internal environment. The aim of the paper was to propose a method of static resilience assessment, which was designed for objects in the rail infrastructure, which can be included in elements of the critical infrastructure. Previous research has pointed to an active solution to the issue of resilience of transport infrastructure, especially abroad. The Slovak Republic does not have any tools that would solve this particular issue. There is a latitude for new ideas and approaches that would move the issue of the resilience assessment forward. The proposed method of the static resilience evaluation represents the initial phase. Ensuring the informative value and the possibility of applying this method in practice requires even more discussions with experts who would be able to eliminate the shortcomings of the proposed method of assessing resilience using the selected pillars and their indicators with a specific description.

The main goal of the researchers is, in cooperation with partners from state institutions, companies and other research institutes, to create a usable application for practice, which will be the basis for the future safety/security dispatching of the Railways of the Slovak Republic.

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