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THE COMPLEX REQUIREMENT MODEL FOR THE DEFENCE PREPARATION OF THE RAILWAY INFRASTRUCTURE

A VASÚTI INFRASTRUKTÚRA KOMPLEX VÉDELMI CÉLÚ FELKÉSZÍTÉSÉNEK KÖVETELMÉNYMODELLJE

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Abstract

The military security of Hungary requires that the tasks of defence preparations to be fully accomplished. It is possible only with properly functioning systems. In order to implement rail transport tasks, it is necessary to ensure the operation of this sub-sector and, within this context, the preparation of this sub-sector for defence purposes, i.e., to define the current tasks that must be carried out as part of defence preparation in order to maintain the sub-sector's functional ability. In this article, I present the requirement model I have developed to be able to define these tasks.

Keywords: national defence, defence preparation, railway transport, requirement model, military logistics

Absztrakt

Magyarország katonai biztonsága megköveteli, hogy az ennek érdekében végzett feladatok maradéktalanul teljesíthetők legyenek. Ez csak megfelelően működő rendszerekkel lehetséges. A vasúti szállítási feladatok végrehajthatóságához szükséges az alágazat működésének biztosítása, ennek keretében pedig a szektor védelmi célú felkészítése, vagyis meg kell határozni, hogy melyek azok a jelenkori feladatok, amelyeket a védelmi felkészítés keretében el kell végezni a szektor működőképességének fenntartásához. A cikkben a feladatok meghatározásához általam megalkotott követelménymodellt mutatom be.

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Kulcsszavak: országvédelem, védelmi célú felkészítés, vasúti közlekedés, követelménymodell, katonai logisztika

Introduction

Transport networks are the main arteries of a country because of their vast extent. This is also fully true for railway transport. The standard gauge (1435 mm) used over most of the continent allows trains to run from England to Greece and from the Mediterranean to the North Sea. Artificial obstacles (e.g., different track gauges, different traction voltage) are now easily overcome by modern technology (e.g., gauge-changing wagons, multi-current traction vehicles), so it is fair to say that railway transport plays a major role in Europe's economy as a mode of passenger and freight transport.

As part of the transport system, railway transport contributes to the military defence of a country. The movement and transport requirements of the army is one of the priority aspects of the defence of the country, which needs an undisturbedly operating transport system. The military movements and transportation (M&T) requirements are over the control of the military logistic support system. The military logistic support is responsible to full fil the material, medical, transport and accommodation needs of military units.[2] In the field of logistics, the M&T support organizations are responsible for the management of this functional area. M&T support is the set of activities carried out by military and civilian transport agencies and units to meet military transport needs and to maintain uninterrupted transport flows at home or in foreign territory based on a coherent concept and plan.[3]

When a disturbance occurs in the transportation system, it is blocks, the transport process, and the movements cannot be executed in the planned way. This could lead to the disruption of the transport system. The substitution of railway transport by other sub-sectors is possible, but this could lead to congestion in other modes of transport, both for passenger and freight. The resulting congestion can cause significant damage to the world economy, as it was seen in the case of the stuck

2 Szászi Gábor: Katonai logisztika; In: Lakatos Péter (szerk.): Logisztika a közszolgálatban, Dialóg Campus Kiadó, Budapest, 2018, pp. 165-216.

3 Magyar Honvédség Közlekedési Támogatás Doktrína; Magyar Honvédség Közlekedési Főnökség, Budapest, 2005, p. 12, point 101.

cargo ship in the Suez Canal.[4] It is, therefore, necessary to protect railway infrastructure to ensure the sustainability of transport and the whole economy.

Therefore, it is of both military and societal interest to include the strengthening of the defence capabilities and to prepare it for emergencies. Moreover, the success of the fight against terrorism requires coordinated government action and the strengthening of the system.

In general, the shared civil-military use of transport systems requires an adequate level of protection that can ensure their use both in normal conditions and under the circumstances of an emergency period or their replacement in the event of disruption as well. Indeed, the availability of transport networks as a means of satisfying military logistical processes is essential for the defence of a country or even for responding to crises.

The transport infrastructure of a country has many elements that not only meet the mobility needs of a country but also cover the trafficking within and even between continents. It is quite natural that not all the elements of a network can or should be considered as elements to be protected. Since the spread of terrorism, the way in which potential risks of critical infrastructures can be calculated and analysed has expanded.[5] The definition of risks must take into account the threat, the vulnerability of components of the whole system or element and the expected consequences of the eventual occurrence of an incident.

It is also necessary to identify which elements of the transportation infrastructure are critical network elements whose protection should be given higher priority.

Almost all public and common perceptions assume that critical infrastructures are those high-value elements and subsystems whose failure, linked to an extreme event, could result in the loss of life, economic disadvantage, material damage and disruption of the daily life of society and the public administration. It is also important to see that there

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4 Russon, Mary-Ann: The cost of the Suez Canal blockage; BBC, 2021. 03. 29., online: https://www.bbc.com/news/business-56559073 (downloaded: 25. 04. 2021.)

5 Ronyecz Lilla: Létfontosságú rendszerek és létesítmények védelmével kapcsolatos kockázatelemzési módszertan szakirodalmának bemutatása; Védelem Tudomány, 3:3, 2018, pp. 112-132.

can be interdependencies between the functions of different infrastructures, as the condition of one infrastructure can affect the condition of another or be linked to the condition of another.[6]

The definition of critical infrastructure protection states that it is protecting vital network elements from attack and damage, essentially caused by intentional human actions. The protection also needs to be extended against natural hazards, which can disrupt the operation of supply chains. From a military point of view, the protection of critical network elements is necessary to be able to maintain the country's defence capability.

We can only perform the protection of the critical infrastructure in a right way if the method implemented is the foresight, not the reaction. Thinking in advance means always a real advantage. We need critical infrastructure protection in the military sector as well, and it means the tasks to defend the properly functioning systems. The Host Nation Support and the RSOM[7] tasks need a functioning transport system. The M&T is defined as a part of the military logistics support system. In this context, to prepare the sector for defence purposes means to define the current tasks that must be accomplished to maintain the sector's ability to operating well.

The need for the requirement model

The two basic elements of defence preparedness will be defined in the following paragraph. They can be derived from the interpretation of the transport tasks related to the defence preparedness of the country, as it is pointed out in the Hungarian Forces Transport Support Doctrine (hereinafter referred to simply as ‘Doctrine’).[8] The maintenance of the infrastructure network and the provision of the necessary capacities imply the maintenance of the operational capability of the railway network, i.e., the network must be able to perform the transport tasks. This capability is to be facilitated by the implementation of the specialised tasks of transport support, which further narrow down the scope of the

[6] Lévai Zsolt: A vasúti szektor védelmi lehetőségei terrorakciók ellen; Közlekedéstudományi Szemle, 69:5, 2019, pp. 50-71., DOI: 10.24228/KTSZ.2019.5.5

[7] Reception, Staging, Onward Movement

[8] Magyar Honvédség Közlekedési Támogatás Doktrína; Magyar Honvédség Közlekedési Főnökség, Budapest, 2005, pp. 16-17., point 111.

task of defence preparation. On the one hand, the Doctrine itself defines the task of preparation as the preparation of transport infrastructures to military operational requirements.[9] On the other hand, it defines the task of technical protection as the maintenance of the operational capability of transport infrastructures. A functioning transport system is essential to ensure the protection and supply of the population.

The methods of maintaining this functionality are therefore examined below, starting with the definitions of the concepts of robustness, resilience, and vulnerability.

According to the article of Carlson and Doyle, (technical) robustness is defined as the persistence of certain system properties despite changes in the behaviour or environment of the components.[10] This indicates that the system is not sensitive to disturbances. However, the authors further decompose the issue of robustness into "robust but fragile" and "complex" systems. A "robust but fragile" system is resistant to certain changes, but only to predetermined ones, i.e., it cannot respond adequately to unexpected events, whereas a "complex" system can. The authors introduce the notion of "highly optimised tolerance", where "tolerance" emphasises that robustness in complex systems is a finite "quantity" that must be designed and protected. And "highly optimised" emphasises that this can be achieved by highly structured and individually designed or improved configurations. Systems designed in this way, are characterised by internal complexity and apparently simple robust external behaviour. The designed robustness provides barriers to failures, thus ensuring complexity.

The concept of railway resilience is defined by Evnika Grass in her thesis as follows: "A railway system is resilient if it is prepared for unexpected events with extreme impacts. It can react to these events in such a way that the basic functions of the system are maintained and (the system) returns to its initial state after a predetermined time interval".[11]

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9 Magyar Honvédség Közlekedési Támogatás Doktrína; Magyar Honvédség Közlekedési Főnökség, Budapest, 2005, pp. 16-17., point 111.

10 Carlson, J. M. – Doyle, John: Complexity and robustness; Proceedings of the National Academy of Sciences of the United States of America, 99:1, 2002, pp. 2538-2545., DOI: 10.1073/pnas.012582499

11 Grass, Evnika: Bewertung von Resilienz im Schienenverkehr; Eingereichte Abschlussarbeit zur Erlangung des Grades Master of Arts im Studiengang Verkehr und Logistik, Karl-Scharfenberg-Fakultät der Ostfalia Hochschule für angewandte Wissenschaften, Wolfenbüttel, Deutschland, 2018, p. 19.

Military aspects should also be taken into account when determining resilience. One of the factors of national defence preparedness is the resilience of transport systems to damage. The transport system must be at all times capable of performing military movement and transport tasks from a defence perspective. This is particularly true for tasks during emergency periods. These conditions must also be taken into account when defining railway resilience.

In engineering terms, vulnerability means the inability of a structure (e.g., an element of railway infrastructure) to withstand the forces generated by a given threat.[12] However, this theory ignores human activity. According to Perrow's article, the complex-systems approach argues that vulnerability is created by built-in hazards in the human-technology interface, in cooperation with today's interconnected systems.[13] The authors of a study on vulnerability management describe that the relationship between vulnerability and improvements can be bidirectional:[14]

- on the one hand, developments can increase vulnerability (for example, through the construction of high-speed railway lines);
- on the other hand, development can reduce vulnerability (through advances in science and technology to address threats).

It means that railway infrastructure can be considered to be operational if it is resilient, able to respond to unexpected events, and has a low vulnerability, i.e., if it operates as a complex system.[15] It is, therefore, necessary to examine the vulnerability of the railway infrastructure and the extent to which it can react to an unexpected event (e.g., a flood or a terrorist attack) in such a way that the system's resilience reaches the level defined in the Doctrine. It is necessary to develop a model (a set of procedures) to ensure that the railway transport sub-sector remains operational.

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12 Strandh, Veronica: Exploring vulnerabilities in preparedness – rail bound traffic and terrorist attacks; Journal of Transport Security; 2017/10, pp. 45-62., DOI: 10.1007/sl2198-017-0178-5

13 Perrow, Charles: The next catastrophe: reducing our vulnerabilities to natural, industrial and terrorist disasters; 2007, online: https://www.microsoft.com/en-us/research/video/the-next-catastrophe-reducing-our-vulnerabilities-to-natural-industrial-and-terrorist-disasters/ (viewed 05. 05. 2023)

14 Manandhar, Rejina – McEntire, David A.: Disasters, Development and Resilience: Exploring the Need for Comprehensive Vulnerability Management; In: Kapucu, Naim – Liou, Kuotsai T. (editors): Disaster and Development Examining Global Issues and Cases (Environmental Hazards), 2014th Edition, Springer International Publishing AG, Cham, Switzerland, 2014, pp. 19-38.

15 "complex system" according to Carlson – Doyle

General description of the model

The model should ensure the railway transport sub-sector to be operated as a complex system in the means of robustness as its resilience would be at its highest and the protection preparedness would reach the value defined in the Doctrine.[16] The complexity (robustness) of preparedness for protection should therefore be based firstly on the protection of the railway infrastructure, secondly on the response to disruption and thirdly on the minimisation of vulnerability, i.e., reduced vulnerability through improvements. If the protection of the system is adequate, its vulnerability is low, which also increases robustness. In addition, robustness can also be facilitated by the availability of efficient resources and reserves to achieve an adequate response, and by technical solutions that increase resilience. If the system is robust, and resources and reserves are available, it can respond adequately to disturbances, unexpected events will not hinder the system's ability to operate, and its resilience will be at its highest. The efficiency of resources can also be facilitated by cooperation between the actors in the sector.

In this context, the preparation of transport systems for complex protection is a set of activities to maintain operability and to provide substitutes by making the system robust, which will result in the highest resilience and the lowest vulnerability.

Components of the model

Based on the previous chapter and the European Union (EU) Green Paper,[17] the three pillars of preparedness for protection in the operational model are:

- the sustainability of the operability of railway infrastructures;
- the substitutability of railway lines if the operability of a railway line cannot be ensured;
- and the minimisation of vulnerability.

[16] Magyar Honvédség Közlekedési Támogatás Doktrína; Magyar Honvédség Közlekedési Főnökség, Budapest, 2005, p. 20., point 201

[17] European Commission: Green paper on a European Programme for Critical Infrastructure Protection COM (2005) 576 final; Brussels, 2005, online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52005DC0576&from=EN (downloaded: 19. 03. 2023)

These three pillars ensure that the sub-sector can respond adequately to unforeseen events, i.e., the complexity of preparedness for security. To be able to reach **the sustainability of the operability** of railway infrastructure, it is necessary to examine:

- the resilience of the tracks;
- the operation of the railway safety devices as a key element of transport safety and hence of operational reliability;
- traffic management, as it must be possible to maintain the performance of railway operations in the event of a disruption;
- the system of capacity allocation to ensure that the necessary capacity is available.

The issue of substitutability is primarily a matter of railway geography studies. Due to the topography, railway lines are affected by the geographical environment. For this reason, it is essential to examine substitutability from a geographical point of view.Military geography deals with the military aspect of geography. As defined in the 2019 edition of the Encyclopaedia of Military Sciences, "military geography" is an interdisciplinary field of military and geographical sciences, divided into general, regional, and sectoral fields.[18] Defence geography seeks answers to the relationship between the geographical environment and the threats to the region.[19] Geographical studies must therefore answer the question that which railway lines can be used to carry traffic when other lines are out of service and which other sub-sectors should be involved to meet transport needs. According to the findings of a joint study by the KTI Hungarian Institute for Transport Sciences and Logistics Non-Profit Limited Liability Company and the University of Public Services, Faculty of Military Sciences and Officer Training, the following key points of the current rail infrastructure in Hungary in terms of substitution:[20]

- main river bridges and tunnels;
- railway network of Budapest;
- integration of other transport sub-sectors.

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18 Siposné Kecskeméthy Kálra: Katonaföldrajz; In: Krajnc Zoltán (főszerk.): Hadtudományi Lexikon, Új kötet, Dialóg Campus Kiadó, Budapest, 2019,

19 Siposné Kecskeméthy Kálra: Védelemföldrajz; In: Krajnc Zoltán (főszerk.): Hadtudományi Lexikon, Új kötet, Dialóg Campus Kiadó, Budapest, 2019,

20 KTI Magyar Közlekedéstudományi és Logisztikai Intézet Nonprofit Kft. – Nemzeti Közszolgálati Egyetem Hadtudományi és Honvédtisztképző Kar: A vasúti infrastruktúra fejlesztés és a kritikus infrastruktúra védelem kapcsolata; tanulmány, megrendelő: Innovációs és Technológiai Minisztérium, Témaszám: 3140-903-2-9, Budapest, 2020, 79 p.

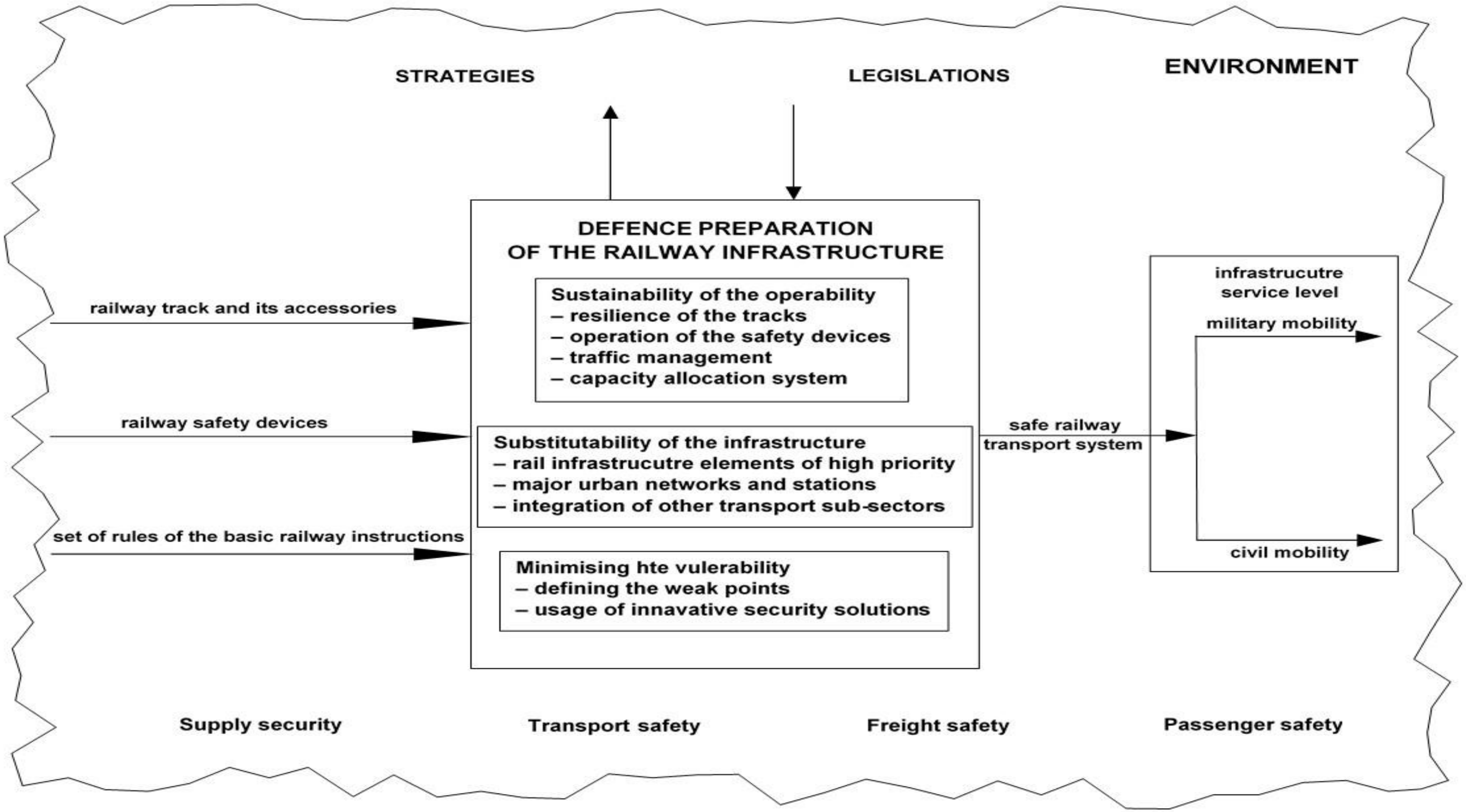

Figure 1. The complex requirement model for the defence preparation of the railway infrastructure (source: edited by the author)

Consequently, the issue of substitutability indicates the following investigations:

- railway elements of high priority;
- major urban railway networks and stations;
- substitutability with other transport sub-sectors.

Minimising vulnerability means identifying the “soft targets” (i.e., easily accessible to terrorists and not protected) of the system and preparing them against the threat of terrorism.

Vulnerabilities in themselves do not cause damage to the system, but if discovered by those who wish to commit malicious acts, they can cause damage to the system through targeted attacks. Researchers have periodically highlighted the fact that individual networks show a high degree of robustness against accidental failures but appear to be particularly vulnerable to targeted attacks.[21]

In addition, damage can be caused by natural effects, which are difficult to prevent, but can be reduced by appropriate technical security.

The structure of the model is presented in Figure 1. The inputs to the model are the elements of the railway transport infrastructure. The output is a secure railway transport system and the military and civilian mobility that can be achieved by it. The environment of the model, including national defence requirements, is the legislative and policy framework defining the defence preparedness framework and the various security elements that can be achieved through the operation of the model, which affect the system, and which are affected by the system itself (e.g., through increasingly advanced defence technologies).

The operational environment of the requirement model

The way the model is being operated is defined by legislation and strategies and describes the preparation of railway infrastructure for complex protection purposes. The infrastructure is used by both passen-

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[21] Berche, B. – von Feber, C. – Holovatch, T. – Holovatch, Yu.: Resilience of public transport networks against attacks; The European Physical Journal B, 71, 2009, pp. 125-137. DOI: 10.1140/epjb/e2009-00291-3

ger and freight trains, so the protection also affects the users of the infrastructure, i.e., the people (passengers) and goods, as well as the security of the supply chains through transport and freight. The interaction between the model and its environment is indicated by the vertical arrows on the figure 1.

Legislative framework

When assessing the legislative environment for security preparedness, we must start with the general principles of security. According to Article G) (2) of the Fundamental Law of Hungary, the country shall protect its citizens.[22] This action is embodied primarily in national defence. According to the Law on National Defence of Hungary, the country relies primarily on its own strength to maintain its national defence capability.[23] An adequate level of national defence capability can be maintained by preparing the national economy for defence. The National Security Strategy adopted in 2020, states that preparing the national economy for defence guarantees the security of the country.[24] The National Military Strategy published in 2021, defines the organisation of defence preparedness as a government responsibility through national and international cooperation and resilience capabilities.[25] According to the Resolution on the Principles of the Security and Defence Policy of the Republic of Hungary adopted by the Parliament in 1998, the national economy must be able to provide the economic basis necessary to achieve the security and defence policy objectives.[26] Whereas the railway subsector is an important link between the various players in the national economy, and therefore, as part of the national economy, it is necessary to prepare the sub-sector for defence purposes in order to enable the national economy to fulfil its role as set out in the Parliamentary Resolution. The Act on the Coordination of Defence and Security Measures also lays down rules for the performance of this task.[27]

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22 Magyarország Alaptörvénye (2011. április 25.)

23 2011. évi CXIII. törvény a honvédelemtől és a Magyar Honvédségről, valamint a különleges jogrendben bevezethető intézkedésekről

24 1163/2020. (IV. 21.) Kormányhatározat Magyarország Nemzeti Biztonsági Stratégiájáról

25 1393/2021 (VI. 24.) Kormányhatározat Magyarország Nemzeti Katonai Stratégiájáról

26 94/1998. (XII. 29.) OGY határozat a Magyar Köztársaság biztonság- és védelempolitikájának alapelveiről

27 2021. évi XCIII. törvény a védelmi és biztonsági intézkedések összehangolásáról

Indirectly, the Act CLXXXIII of 2005 on railway transport also establishes the need to protect the sector.[28] The definition of “common security objectives” in the interpretative part of the act states that such objectives must be formulated for the specific risks associated with unauthorised persons on railway elements. In my understanding, this is to build rail security against terrorism.

The National Cyber Security Strategy provides the legislative basis for protecting against the threats that will emerge in cyberspace that dominates the 21st century. The operation of Information Technology (IT) systems in the railway sector is also becoming common, and their operation is a prerequisite for the functioning of the country. The cyber defence strategy,[29] complementing with the network and information systems security strategy[30] therefore stipulate that Hungary must have effective prevention, detection, management, response, and recovery capabilities against attacks in cyberspace. Based on this strategic point, it can be deduced that there is a need to develop a preventive capability against cyber threats to the IT systems of the railway transport sub-sector. This is equivalent to preparing IT systems for defence.

The railway sector is considered part of the military transport system, due to the military mobility and transport tasks that are performed on it. Consequently, it is also necessary to interpret the sector's preparation for military defence. In 1997, István Duchaj defined the tasks of preparation for defence purposes in his definition of transport insurance.[31] This is supplemented by the Doctrine of Transportation Support, according to which ‘preparation for defence purposes’ means preparation for the military defence of the country on the one hand and for the performance of tasks arising from allied obligations on the other.[32] This is also confirmed by the Decree of the Ministry of National Development.[33] The preparation of the transport system is part of the preparation of the transportation support system, which is part of the military logistics support system. Preparation must be carried out in the

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[28] 2005. évi CLXXXIII. törvény a vasúti közlekedésről

[29] 1139/2013. (III. 21.) Korm. határozat Magyarország Nemzeti Kibervédelmi Stratégiájáról

[30] 1838/2018. (XII. 28.) Korm. határozat Magyarország hálózati és információs rendszerek biztonságára vonatkozó Stratégiájáról

[31] Duchaj István: A katonai közlekedési rendszer felkészítéséről; Hadtudomány – A Magyar Hadtudományi Társaság folyóirata, 7:2, 1997, pp. 114-120.

[32] Magyar Honvédség Közlekedési Támogatás Doktrína; Magyar Honvédség Közlekedési Főnökség, Budapest, 2005, pp. 22-24. point 204

[33] 22/2014. (IV. 18.) NFM rendelet a közlekedési és energetikai szervek honvédelmi feladatairól

normal period in order to ensure that the system is able to fully perform the necessary tasks in an emergency period. Therefore, the Doctrine defines the specialised transport tasks for the preparation of the country for defence purposes as follows:

- be able to redeploy Hungarian Forces and allied troops to threatened areas during the deployment;
- be ready to decentralise central stocks, to implement continuous resupply;
- to return the damaged equipment during combat operations;
- maintain transport systems and sectors operational, repair destruction and war damage;
- meet the transport needs of the country and the national economy with unchanged efficiency;
- meet the transport needs of the population in terms of supply and evacuation.

Safety elements

The operation of the requirement model ensures the operability of the system through complexity, and thus the operation of the train and the possibility of performing shunting movements. The safe railway transport system, as a result of the operation of the model, also has an impact on other safety elements. Such safety elements are:

- supply chain security (through the ability to carry out transport operations);
- traffic safety (by avoiding accidents);
- freight safety (by reducing damage to goods);
- passenger safety (by reducing attacks on passengers).

At the same time, the development of these security elements also has an impact on the effectiveness of preparedness for security, for example by transport security.

Elements of the railway infrastructure

To prepare transport systems for protection, as an input element of the requirement model, it is necessary to know the exact structure of the sub-sector to be protected. The infrastructure of the railway sector, as defined by the EU, includes tracks, sidings, engineering facilities (e.g. bridges), associated station infrastructure (e.g. platforms), and safety and security equipment.[34] These elements can be grouped as follows:

- railway track and its accessories;
- railway safety devices;
- set of rules of the basic railway instructions.

Railway track and its accessories

The railway track can be basically divided into two parts:

- the open lines and
- stations.

The area of stations is defined by the position of the entrance signals. According to these, the area of a station is the area between the entrance signals at the two ends (for terminals, entrance signals are only placed in one direction). The definition of the open line is also linked to the entrance signals at the stations. An open line is a section of line between two adjacent station areas (entrance signals).

Railway track accessories include facilities that do not fall into the previous categories but are necessary to maintain railway operations. Typical examples are the overhead system (traction current pylon, contact wire, catenaries, etc.) and associated facilities such as the electrical substation which supplies traction current to the overhead system.

Safety devices

Railway safety devices are technical elements of the railway infrastructure designed to prevent accidents and hazards and to control the movement of trains. They can be:

- station safety devices;
- inter-station protection devices;
- level crossing protection devices;
- on-board equipment.

[34] Directive 2008/57/EC of the European Parliament and of the Council of 17 June 2008 on the interoperability of the rail system within the Community; Brussels, 2008, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0057&from=HU (downloaded: 19. 03. 2023.)

They play a very important role in railway safety. This is because their malfunctioning can lead to serious accidents and as listed above, they are present in all areas of railway transport so the possible consequences of their malfunctioning must be understood throughout the whole network.

However, it should also be stressed that railway safety devices basically work on the fail-safe principle, i.e. when a fault occurs, the system is put into a safer state, so that a major problem can be avoided (usually a speed reduction or stopping).[35]

From the definition of safety devices, it can therefore be seen that they are the infrastructure elements that are most important for the safety of railway transport. In this case, the purpose of deliberate compromise is to disrupt their operation and thereby cause accidents. This can be achieved by violating the fail-safe principle, i.e. the occurrence of a failure does not result in a safer condition. For older devices, this means the elimination of physical dependencies, for modern devices it is clearly an IT attack. Disabling physical dependencies is a time-consuming and difficult task (e.g., cutting a steel cable off for a switch, while natural effects can cause physical damage to equipment (e.g., a rock avalanche). A more serious problem is the damage to the IT systems, which, with few exceptions (e.g., water ingress), may be a deliberate human act. This activity leads to the operational domain of cyberterrorism. Here, there is no need to physically damage the equipment, but rather to interfere with the operating software. This can result in the issuing of false traffic commands to be executed by railway staff, or in the communication between systems being compromised. In both cases, fatal accidents can occur. For all these reasons, the whole range of safety equipment must be involved in security preparation.

Set of rules of the basic railway instructions

Train movements and the control of shunting are based on signals. The signals that can be used in railway traffic and the rules for their interpretation are set out in Signalling Instruction F.1,[36] and the rules for traffic management are set out in Traffic Instruction F.2. of the Hungarian State Railways (MÁV Zrt.).[37] The workflow is basically carried

[35] Tokody Dániel: Intelligens vasúti informatikai és biztonsági rendszerek fejlesztése; Doktori (PhD) értekezés, Óbudai Egyetem Biztonságtudományi Doktori Iskola, Budapest, 2020, DOI: 10.23715/SDA.2021.2.4, pp. 19-20.

[36] MÁV Zrt. F. 1. sz. Jelzési Utasítás

[37] MÁV Zrt. F. 2. sz. Forgalmi Utasítás és Függelékei

out in accordance with these two instructions, which means that compliance with the rules of the basic instructions is vital for the clear running of the railway. In examining the system of rules of the basic instructions, it is necessary to consider the system of objectives on which they are based and the rules for giving and interpreting instructions that can be derived from the system of objectives as a framework for the proper management of railway traffic in the context of preparing for defence.

The pillars of the requirement model

Sustainability of the viability of railway infrastructure

The sustainability of railway functionality, which is one of the pillars of the requirement model, is essentially the ability to run trains and carry out shunting movements. The ability to perform these movements requires a railway track with sufficient resistance, a reliable safety system, traffic management and adequate capacity allocation to establish the timetables on which the railway traffic is based.

Railway track resistance

One of the main requirements for the resilience of the railway track is the robustness of the system, i.e. its ability to withstand disturbances. The factors that contribute to robustness, as defined in the chapter *"General description of the model"*, in achieving the resilience of the railway track can be assessed as follows.

Responsiveness is based on promptness. If there are defects (for whatever reason) in the tracks, it can disrupt railway traffic, so the first priority is to correct these defects. This depends on the extent and location of the fault. In a high-impact event, the extent of the damage to the railway track is likely to be greater and the time needed to repair the damage may be increased by the difficulty of accessing the site (e.g. a bridge collapse). Until the final repair of the railway track, temporary solutions are often used, which are quicker to install and allow traffic to flow at a lower capacity. In other cases, the damage to the track requires traffic to be diverted or replaced (by buses, ships, etc.).

Effective resources not only mean the availability of human and mechanical power to maintain (restart) operations but also need to include a system of preparation. Part of the preparation of railway transport for defence purposes is the efficient allocation of railway resources to carry out the necessary tasks. This may include risk analyses, situation studies and emergency plans. The efficient allocation of resources is supported by appropriate communication. It may be necessary to establish notification arrangements and emergency communication with customers. The communication of detours and replacement options is required as the loss of critical infrastructure elements is of high priority. The key issue in emergency communication is to ensure that the passengers have all relevant information and can make travel decisions accordingly. To achieve this, sensitive devices and communication channels need to be identified and robust risk management rules need to be established and applied.

Redundancy is an indicator of the degree of substitutability. This requires finance and human resources and reserves. The necessary reserve resources are the uncommitted rolling stock and staff, and the railway infrastructure reserves are the available (uncommitted) capacities of the railway lines. However, the reserve resources of rolling stock and staff are decentralised, so that reserve capacities are also needed to transport where they are needed. In most cases, the use of reserves can only be achieved at the cost of increased performance and additional costs, and it is, therefore, necessary to have adequate finance (reserve) resources available to be able to use them.

Technical solutions that increase the resistance of the railway infrastructure can help to maintain operability.[38] These can be solutions that increase the rigidity of the used materials, thanks to today's advanced manufacturing technology, and make individual joints more durable. Safety features (e.g. fusible links) in various installations can briefly disrupt operations, but their role is to prevent major problems from occurring. These elements are usually easily replaceable.

The importance of the operation of safety devices

In any transport system, the traffic flow must be managed. In the railway transport sub-sector, control operations are carried out by both people and machines. In addition to human activity, traffic management operations can be carried out by operating safety devices. Failures in the operation of the safety devices can have a major impact on

[38] Szászi Gábor: A vasúti infrastruktúrával szemben támasztott újszerű védelmi követelmények kutatása, a továbbfejlesztés feltételrendszerének vizsgálata; Doktori (PhD) értekezés, Nemzeti Közszolgálati Egyetem Katonai Műszaki Doktori Iskola, Budapest, 2013, DOI: 10.17625/NKE.2014.028, p. 79.

the operability of the railway infrastructure and in most cases can only be replaced by human intervention. The lower capacity of the human replacement may lead to a reduction in service quality.

Ensuring redundancy, as defined in the resilience assessment, is the most difficult due to the significant difference between machine and human action times and the human factor reduces the level of safety that can be achieved. In many cases, building in machine redundancy is costly. Therefore, the importance of the proper functioning of the safety devices is most evident in the highly technical and operational safety.

In order to achieve this, the design of fuse protection systems must be based on technical elements with a sufficiently long service life to guarantee technical safety and hence operational safety. The main requirements to be met when designing the equipment include the following:[39]

- the standard position of the signals shall, except in specific cases to avoid accidents, be a signal not to proceed;
- a fault in the equipment must not cause an immediate risk of an accident;
- the safety devices are mutually controlling, and high-reliability devices must be used for parts which cannot be checked;
- a backup power supply system must be used to increase operational safety.

According to the principles of railway safety equipment, when a fault occurs, the commands are always changed in the direction of safety, i.e., lower speed or stopping (for example, a green light burns out, resulting in yellow or red light, which is more worrying than green). The existence of a red light giving the stop command at any time is solved by duplicating the red-light bulb, by installing a so-called red backup circuit, so that the red light can be triggered on the signal if the original circuit fails. This is a typical case of the required redundancy.

The Role of traffic management in Maintaining Operability

During traffic management, the essential objective is to ensure that trains run, and shunting movements are carried out without accidents. This is essential to ensure the sustainability of the operation, as incidents coming from accidents can cause the disruption of infrastructure

[39] Lévai Zsolt: Közlekedésbiztonság; egyetemi jegyzet, Dialóg Campus Kiadó, Budapest, 2019, ISBN 978-963-531-012-8, p. 113.

elements, which in turn can affect the operation. As a rule, all aspects of railway work are planned in advance: train movements or shunting, inter-station movements or station duties, and passenger or freight trains. This planned work is a major constraint for railway staff, but it is also one of the key elements to accident-free and regular transport. If the technology is known and respected, any incidents that may occur can be detected immediately and the railway staff can react. Traffic management is a multi-stage system, and all traffic operations must be authorised and monitored. In addition, the work of station staff is supervised and managed.

A good level of traffic management is a key element of traffic safety, as traffic must be maintained also in the case of disruptions. In this case, trains cannot run according to the timetable but must be dispatched in a specific order using the available capacity, which may cause delays.

Capacity Allocation System

Capacity allocation basically determines the time schedule for the usage of railway infrastructure based on the rules of the basic instructions, i.e., it establishes a link between the input elements of the requirements model.

Increasing the robustness of the railway transport sub-sector can also be enhanced by an efficient allocation of available reserves. This requires an understanding of the network's congestion and capacity reserves, which can be determined based on the previous paragraph and are primarily the main potential solution to the substitutability problems.

The capacity determined by the technical parameters must be distributed among the users (usually railway undertakings) and reserve capacity must be maintained to cope with disturbances. Therefore, in principle, all trains on a railway line require a capacity share, which is given to the access holder in the form of a training path (slot) and reflected in the timetable. With very few exceptions, trains are operated on the basis of a pre-established timetable.

Due to their technical configuration, railway lines have limited throughput capacity and therefore train paths have to be managed by the infrastructure manager. Their tasks are laid down in legislation, primarily in acts on railway transport and in other government and ministerial decrees. The ministerial Decree on the detailed rules for open access to the railway infrastructure network[40] states that only 80% of the available capacity may be allocated to form reserve capacity. Capacity allocation is based on UIC[41] regulations.[42]

The above-mentioned legislation further specifies that the spare capacity may be used primarily to serve disaster management and national defence needs related to emergency events. Free capacity may be used to create train paths, for example for diverted trains, but the parameters of a new slot (e.g., speed, axle load, traction voltage, etc.) may not always correspond to the original train paths. This can also lead to a reduction in service quality.

There may be exceptional circumstances where certain trains need to be operated immediately (e.g. emergency services following an accident). It is of course possible to request an immediate train path, but the time taken to prepare a timetable on this basis is 60 minutes, and in such cases, it must be ensured that the train can be put into service as soon as possible and operated without a timetable.

When adequate reserve capacity is available, the capacity allocation body is expected to monitor the utilisation of the railway infrastructure on an ongoing basis and to take and propose measures to eliminate the higher-than-expected capacity utilisation on overcrowded infrastructure sections.

During defence preparation, military transport capacities need to be assessed in two situations: in the normal period: free of conflicts and emergencies, and in the emergency period. The transport tasks in the normal period do not require priority for military transport, but the availability of free line capacity does. This requires a sufficient number of slots for military transport trains. In principle, the annual train paths ordered for passenger trains take precedence over freight trains and hence over the capacity share ordered for military transport. With the introduction of an emergency period, the first order of priority will be no longer valid, and priority will be given to trains more important for national security (i.e. less capacity will be available for passenger trains),

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[40] 55/2015. (IX. 30.) NFM rendelet a vasúti pályahálózathoz történő nyílt hozzáférés részletes szabályairól

[41] UIC – Union International des Chemins de fer (International Union of Railways)

[42] Union International des Chemins de fer: Capacity (UIC Code R 406); Paris, France, 2013, pp. 29-34.

but military trains will only be allowed to run up to the maximum capacity of the lines.

The questions of substitutability

The second pillar of the requirement model is the substitutability of the railway infrastructure when the operability of a particular railway line cannot be guaranteed. The fastest way to restart traffic after damage and destruction of lines is to use bypasses.

For this reason, it is useful to examine the transferability of the concept of a railway line to other lines, i.e. redundant lines. The basic concept of a graph-theoretic model defining redundancy was developed and published by Bence Tóth.[43] According to the model, certain stations are the vertices of the graph, while the open line and other stations are the edges of the graph. The stations should be distinguished according to their function. There are stations from which several railway lines originate, i.e. branch stations or connecting stations (nodes), and there are stations which are located on only one railway line, i.e. intermediate stations. The nodes are the vertices of the graph, the intermediate stations are located along the same edge and are therefore of no importance to the model. It should be noted, however, that they are of course of importance from a railway operational point of view, since if one edge of the graph is damaged, traffic can be maintained up to that station, so that traffic on the whole edge does not have to be restricted.

The redundancy test described above is suitable for determining railway detours. Two aspects are involved in the selection of alternative routes:[44]

- the impact of the detour on journey times;
- the impact of the detour on the path length.

Both methods include a capacity analysis of the detours in terms of whether the traffic to be diverted can be accommodated on the alternative route. If not, it may be necessary to divert railway traffic to another sub-sector, and ultimately to restrict it.

[43] Tóth Bence: Állomások és állomásközök zavarának gráfelméleti alapú vizsgálata a magyarországi vasúthálózaton; Hadmérnök, 12:4, 2017, pp. 52-66.

[44] Tóth Bence: Menetidő- és menetvonalhossz növekedés gráfelméleti alapú vizsgálata a magyarországi vasúthálózaton állomások és állomásközök zavara esetén; Hadmérnök, 13:1, 2018, pp. 118-132.

For the methods to be applicable, it is necessary to determine whether all sections containing critical infrastructure elements can be substituted, i.e. whether detours are available. Such sections may contain a high-priority facility (e.g. tunnel) or be lines in major cities.

The issue of substitutability is therefore mainly relevant in the case of damaged lines, where the damaged element may take longer to repair and where replacement or diversionary action is necessary until the repair or the installation of the provisory is completed. This in the vast majority of cases increases journey times, i.e. trains do not run according to the pre-announced timetable. The resulting delays will in any case lead to a reduction in service quality. Substitution by other transport sub-sectors requires further investigation.

Vulnerability assessment of the railway transport sub-sector

The third pillar of the requirement model is to minimise the vulnerability of the railway transport system. Accordingly, in this section, I will examine the vulnerabilities of the railway infrastructure and its exposure to terrorist threats, with a special focus on open lines and stations.

The railway network of a country is made up of a myriad of elements, among which it is necessary to identify the ones most vulnerable to damage. The lines, with few exceptions, run on the surface and thus the whole infrastructure can be affected by natural hazards. From this point of view, it is not possible to identify priority elements, but to identify vulnerable sections as weak points based on the redundancy analysis, and substitutability parameters defined in the previous point, because disruptions to these sections are capable of causing significant disruption to network traffic.

Of course, not all disturbances on the railway network in Hungary can be interpreted as disturbances of the system as a whole. However, there are dedicated railway lines which are the main arteries of the European railway network and as such are part of the TEN-T.[45] Damage and failure of these types of lines can cause the greatest disruption to the functioning of the sub-sector, so resilience lies primarily in maintaining the viability of TEN-T railway lines. In addition, there are lines which are not a priority in themselves, but they provide the operation of another subsector through the trains running on them (e.g.: a railway line to a power station).

[45] TEN-T – Trans European Network-Transport

Another starting point for identifying vulnerabilities is deliberate human actions. The persons or organisations that want to attack the railway lines also look for the points where terrorist acts are most easily committed. The feasibility of planned actions depends on the nature of the targets. The greatest number of victims can be taken where there are many people at the same time and where it is easier to carry out the attack. The study of Jennifer Hesterman defines persons and things that can be attacked and are not defended as "soft targets".[46] The EU has further refined the notion of a 'soft target'. These are attackable places with difficulties to defend, and attacks are likely to result in significant casualties.[47] The definition fits precisely some elements of transport infrastructure. Large train stations and terminals can be easily attacked, difficult to defend and crowded at the same time, meaning that casualties can be high. It can therefore be concluded that transport targets are "soft targets" for terrorists and therefore suitable locations for their operations.

Because of the "soft" nature of the system, the preparation for security must include protection against terrorism: specific tests must be carried out to ensure that the system is sufficiently resistant to terrorism.

Output elements of the requirement model

The outputs of the requirement model are a safe railway transport system and feasible military and civilian mobility with an adequate level of railway infrastructure service.

Feasibility of a safe railway transport system

Security can be achieved primarily through the application of appropriate security methods. Operational sustainability studies have shown that compliance with safety rules and railway instructions can increase security, but specific protection against malicious acts is also needed.

[46] Hesterman, Jennifer: Soft Targets; In: Fagel, Michael J. – Hesterman, Jennifer (editors): Soft Targets and Crisis Management: What Emergency Planners and Security Professionals Need to Know, Routledge, New York, USA, 2017

[47] Communication from the Commission to the European Parliament, the European Council and the Council: Fourth progress report towards an effective and genuine Security Union COM(2017) 41 final; Brussels, 2017, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017DC0041&rid=9 (downloaded: 19. 03. 2023.)

The task of security preparedness is therefore to identify innovative security solutions that can greatly enhance the security of the railway transport sub-sector, both on the infrastructure and service side.

In addition, the robustness and resilience of railway systems will help to ensure security. Addressing the issues of substitution of the preparedness for protection will increase the redundancy of the system and create sufficient reserve capacity to deal with the necessary diversions. Increasing resilience can be achieved by enhancing technical and operational security. Rapid response requires a clear definition of the roles of the actors in the sector and the exploitation of the potential for cooperation between them.

Military and civil mobility

Provided that the sub-sectors' operational capability ensures that military transport and mobility tasks can be carried out, military mobility can be met in terms of both strategic, warfare and operational mobility. However, this requires a much higher degree of serviceability (even via detours) than substitution with another sub-sector. Therefore, innovative security solutions to maintain operability will play a major role in enabling military mobility.

Civil mobility means the scheduled running of trains, which also requires accident and fault-free operation and the necessary protection solutions and improvements to achieve this.

It is therefore of paramount importance that protection solutions are brought to the planning phase of infrastructure investments so that they can be built in at the construction stage and thus be able to protect the infrastructure from the outset.

Railway infrastructure service level for military and civil mobility

Service level is a quality parameter for railway transport, which measures the adequacy of the provided services. In relation to the infrastructure, it is the value of the quality characteristics resulting from its use that must be examined in the first instance. The most characteristic parameter of the usage of infrastructure is timetable adherence or enforceability, i.e. the level of the generated delays. The timetable is a representation of the service offered for passenger transport. Passengers can use the timetable information to decide whether or not to use a particular service. One of the most basic decision points is the extent to which the availability of the rail service matches individual travel needs.[48] Passengers plan their journeys based on the published timetable (print or online), and therefore adherence to the timetable is a quality characteristic of rail passenger services and can be understood as part of the quality of rail passenger services. Similarly, the system of connections at railway stations can also be understood as a quality measure. This is particularly true of the symmetrical connection of the integrated interval timetable structure.[49] The delays can lead to loss and thus the disintegration of the connections, so that the journey previously planned by the passenger cannot be realised, which in all cases means a reduction in service quality in the eyes of the passenger.

In freight transport, the timetable is not as tight as in passenger transport. The main concern is to meet the transport deadline, which can be measured in hours and days so that freight train operators do not generally require that trains run to the minute. However, as explained in the analysis of the capacity allocation system, a timetable is drawn up for each freight train, because the complexity of railway transport requires that all parts of it should be coordinated, and this coordination is ensured by the timetable. To meet the deadlines, it is essential that freight trains run close to the timetable. Significant delays increase the time spent by each freight wagon (both loaded and empty) in the train, thus reducing the reusability of the wagon.[50] The lack of capacity due to the increase in turnaround time and the low regularity of freight trains led to a reduction in the quality of service for freight.

It can therefore be concluded that service level, i.e., adherence to timetables, is an important quality factor for customers and railway undertakings as well. In many cases, the solutions proposed in the context of preparing for defence are not able to ensure that services are operated according to the timetable, i.e., that they meet the declared service level. It can be seen without any specific proof that a reduction

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48 Lévai Zsolt – Molnár Balázs: Vasút és turizmus: lehetséges válaszok a globális klímaváltozás kihívásaira; In: Albert Tóth Attila – Happ Éva – Printz-Markó Erzsébet – Kupi Marcell – Török Nikolett (szerk.): Multidiszciplinaritás a turizmusban: X. Nemzetközi Turizmus Konferencia (Tanulmánykötet); Széchenyi István Egyetem, Győr, 2020, pp. 81-98.

49 Kormányos László: Az integrált vasúti személyszállítási szolgáltatásrendszer feltételeinek kidolgozása; Doktori (PhD) értekezés, Budapesti Műszaki és Gazdaságtudományi Egyetem, Közlekedési Tudomány Doktori Program, Budapest, 2009, pp. 43-46.

50 Schváb Zoltán – Lévai Zsolt: A vasúti árufuvarozás versenyképességének javítása az árufuvarozási folyosók fejlesztésével; In: Duleba Szabolcs (főszerk.): Logisztikai évkönyv 2022, pp. 172-183, Magyar Logisztikai Egyesület, Budapest, 2021, DOI: 10.23717/LOGEVK.2022.16

in throughput on busy lines will lead to delays, but maintaining operational capacity cannot mean ensuring maximum capacity, because this would mean the protection of the whole railway system from any failure, but it does not exist. The questions to be answered in the context of preparedness for defence are: what could be the value of the loss of capacity and what is the minimum capacity that must be guaranteed in order to remain operational?

To answer these questions, we need to return to the method of capacity allocation. In a normal period, it is in everyone's interest that the planned journey or transport could be carried out, i.e., that the planned capacity reduction be as small as possible. The capacity utilisation planned in the timetable cannot always be achieved because of possible major bottlenecks, i.e., the reduced capacity is not always sufficient to carry the scheduled traffic on the railway line. Reducing the extent of planned capacity reductions can be achieved by increasing the resilience of the railway infrastructure. It is therefore necessary to investigate methods and solutions to make the railway track more resilient to possible damage and disruption.

Even under the changed conditions for making capacity available when a special legal regime is introduced, preferred trains can only run up to the maximum available capacity. Therefore, in the event of a special legal regime, the level of service will be determined by the military trains that need to be operated. This is not primarily a question of scheduled services but of the successful operation of the trains themselves using the available capacity.

Conclusions

To achieve adequate transport and security safety of the railway transport system, it is necessary to prepare the sector for security purposes. In this paper, I have examined the system of preparedness for defence of railway infrastructures. The analysis was carried out on the basis of my requirement model for railway transport infrastructure preparedness for defence.

Legislation and the strategies and international conventions enacted in the operational framework of the model state that the aim of preparedness for defence is to maintain the capability of national defence, which requires the continued viability of the national economy. Based on the operating principle of the requirement model, it can be stated that preparedness for defence can only be adequately considered if the railway infrastructure can be understood as a complex system in terms of its operational capability, i.e., if it can react to unexpected impacts. I have defined the basic pillars of this system as ensuring the functionality of the railway infrastructure and, in the event of its failure, the substitutability of railway lines and the minimisation of vulnerability.

The findings and results of the investigation to be able to develop the model have demonstrated that the preparation of railway infrastructure for defence purposes can be considered effective if military and civilian mobility can be achieved on a secure railway transport system, which requires a sufficiently high level of railway infrastructure services.

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34. 2011. évi CXIII. törvény a honvédelemtől és a Magyar Honvédségről, valamint a különleges jogrendben bevezethető intézkedésekről
35. 1139/2013. (III. 21.) Korm. határozat Magyarország Nemzeti Kibervédelmi Stratégiájáról
36. 22/2014. (IV. 18.) NFM rendelet a közlekedési és energetikai szervek honvédelmi feladatairól
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38. 1838/2018. (XII. 28.) Korm. határozat Magyarország hálózati és információs rendszerek biztonságára vonatkozó Stratégiájáról
39. 1163/2020. (IV. 21.) Korm. határozat Magyarország Nemzeti Biztonsági Stratégiájáról

40. 2021. évi XCIII. törvény a védelmi és biztonsági intézkedések összehangolásáról
41. 1393/2021 (VI. 24.) Korm. határozat Magyarország Nemzeti Katonai Stratégiájáról