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MANAGEMENT OF THE CRITICAL INFRASTRUCTURE USED FOR THE TRANSPORT OF FOSSIL RAW MATERIALS – A CASE STUDY

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Purpose: The occurrence of mining damage has a huge impact on the quality and safety of railway infrastructure. Damage to the railway infrastructure due to mining damage may result in the need to temporarily close the railway line, reduce capacity and thus cause disruptions in the supply of goods and services in part of the value chain requiring non-standard actions. Due to the occurrence of mining damage, there is also a need to increase funds for infrastructure maintenance.
Design/methodology/approach: Railway infrastructure is a kind of critical infrastructure and its elements are subject to special protection. In order to prevent threats and minimize their effects, risk assessment should be carried out systematically and control mechanisms should be introduced in order to increase the security and quality of services provided.
Findings: Analyzing the scope of activities of Jastrzębska Spółka Kolejowa sp. z o.o. numerous potential hazards have been noted. The risk may result from deterioration of the quality of railway infrastructure, railway event, incident, potentially dangerous situation, but also loss of human life. Taking into account the location of railway infrastructure in mining areas, ensuring its required quality is a huge challenge for its manager due to the intensity of mining damage.
Originality/value: The article includes, among others, an analysis and risk assessment and presents control mechanisms to increase the security and quality of services provided by JSK sp. z o.o. In the article, this problem was looked at prognostically.

Keywords: critical infrastructure, threat, risk, railway accidents, management.

1. Introduction

The present dynamisation of society significantly increases the standards of human life. Improvement of the life's quality, creation of a friendly space, scientific and technical progress contributed to an increase in the sense of security. Each of the aforementioned aspects is seen as obvious and widely available. By analysing the arising relationships between key state sectors and possible threats, we can observe how easily the security and existence of the society can be upset. Infrastructures that are part of individual state sectors and have an impact on the proper functioning of the state, economy and society should be subject to special protection.

The concept of Critical Infrastructure (CI), which is important from the point of view of modern society, was introduced and discussed in the Act of 26 April 2007 on crisis management in which the CI is: "systems and their functionally related facilities including civil structures, devices, installations, services essential for the security of the state and its citizens, and for ensuring the efficient functioning of public administration bodies, as well as institutions and entrepreneurs"(Act of 26 April 2007…).

It can be concluded that in the situation of determining the infrastructure as critical, it is all about additional enhancement of the importance of infrastructure without which modern societies and innovative entrepreneurs cannot function.

The critical infrastructure includes, among others, the energy supply system, energy sources, fuels and transport systems (Milewski, 2016, pp. 99-115).

Threats which critical infrastructure is exposed to may be local but also global. There is a reference in the Crisis Management Act to the infrastructure located on the territory of the European Union, under the concept of European Critical Infrastructure (ECI), according to which: "a disturbance or destruction would significantly affect two or more Member States" (Act of 26 April 2007…). Thus, threats to one critical infrastructure may impact and affect other related critical infrastructures in a procedural and social manner.

The transport network has been used for years to transfer people and goods for a fee from point A to point B using an appropriate means of transport. The development and security of the economy largely depend on transport. The area of transport infrastructure is classified as the economic infrastructure which, among others, includes road, rail, air and sea transport. Due to its universality, the technological process of transport is exposed to numerous threats. The very stage of preparing the selected means of transport and loading it is complicated and involves a risk that may affect the timeliness of deliveries (Grabowski, 2019, pp. 183-193; Kolano, 2018, pp. 229-237).

Railway infrastructure is a kind of critical infrastructure in the context of making it available to railway carriers that perform the shipment of, among others, hard coal, from which coke is obtained in the combustion process, which as the basic raw material used in the production of steel is one of the strategic raw materials for the European metallurgy. Thus, the coking coal market has a global dimension and is crucial for the steel industry. Based on an assessment of the risks of deficit, supply and economic importance, coking coal was included in the EU list of critical raw materials. This raw material is obtained in several countries. The leaders of coking coal suppliers in the world are located in Asia and Australia, while in Europe the largest producer is Jastrzębska Spółka Węglowa (JSW S.A.), which covers approximately 25% of the EU demand, the remaining part, i.e. approximately 40 million tons per year, is imported by the European Union (https://www.jsw.pl/ raportroczny/…). Railway transport is inextricably linked to the functioning of mining plants and coking coal producers. Railway activity is considered to be the last stage of their production cycle. JSW S.A. uses for the transport of coking coal, among others, the railway infrastructure whose authorised manager is Jastrzębska Spółka Kolejowa Sp. z o.o. (JSK), part of the JSW S.A. capital group (https://www.jsw.pl/raportroczny/…).

JSK makes its railroad lines and sidings available to licensed railway carriers. In order to maintain traffic continuity, it also cooperates with other Railway Administrators. Due to the imposed duties on the management of the railway infrastructure, it gradually improves the safety and quality of the railway infrastructure through its ongoing maintenance, repairs, modernisation and new investments. Based on the risk analysis, its manager introduces modern systems ensuring technical consistency (https://www.jsk.pl/oferta/…). Threats that may affect the safety and continuity of rail traffic are divided into three categories:

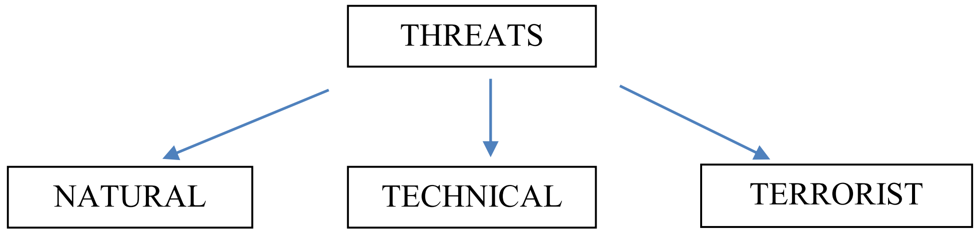

Figure 1. Threats that may affect the safety and continuity of rail traffic.

Source: https://phavi.umcs.pl/…

Further in the paper the following are discussed:

- risk assessment developed on the basis of the FMEA method,
- railway accidents, incidents and potentially dangerous situations that took place in 2016-2021 in the company's railway infrastructure,
- preventive measures taken and their impact on the safety and continuity of rail traffic at Jastrzębska Spółka Kolejowa Sp. z o.o. (JSK),
- damage to the railway infrastructure as a result of mining damage.

2. Risk Assessment

Currently, great emphasis is placed on the quality of the services provided. In order to be able to efficiently manage the critical infrastructure, which is the railway infrastructure, by ensuring safety and continuity of traffic, railway infrastructure managers are obliged to:

- conduct risk analyses,
- identify threats,
- control identified threats,

- keep records of threats,
- introduce preventive measures aimed at increasing the safety of rail traffic and related activities.

Different methods and techniques are used to perform a risk assessment. These methods can be divided into qualitative, quantitative and qualitative-quantitative. Qualitative methods are elected more often due to their simplicity in application and the smaller amount of required data. The methods that are mainly used for risk assessment in railway transport are:

- FTA – Fault Tree Analysis,
- ETA – Event Tree Analysis,
- FMEA – Failure Mode and Effect Analysis,
- HAZOP – Hazard and Operability Study,
- COSO II – Corporate Risk Management – an integrated framework prepared by the Committee of Sponsoring Organizations of the Tradeway Commission,
- Checklist,
- Brainstorm (Jacyna, Szaciłło, 2017, pp. 163-178).

Among the aforementioned methods for risk assessment, the most commonly used is FMEA. This method belongs to the qualitative modes. It is based on determining all risks that can occur in a given process in order to prevent them or minimise the losses incurred in the event of risk. FMEA is based on the determination of cause and effect relationships for a given threat. The resulting list of hazards should be systematically monitored, it must be completed with necessary changes and supplemented with new identified threats, which will allow to increase safety (Garlikowska, Gondek, 2019, pp. 10-16; Jacyna, Szaciłło, 2017, pp. 163-178).

In 2021, the risk assessment of the JSK's railway infrastructure was updated. Twelve risk groups were distinguished to which a total of 281 identified threats were assigned. Each threat is attributed with:

- possible consequences,
- existing measures of supervision,
- probability of occurrence (P) in a range from 1 to 10, where 1 means 'rare' and 10 'frequent' occurrence,
- possibility of its detection (W) in a range from 1 to 10, where 1 means 'easy' and 10 means 'difficult' to detect,
- effects (S) on a scale from 1 to 10, where 1 means 'insignificant' and 10 'catastrophic',
- critical identification (R) calculated on the basis of the following formula (1) (Register of FMEA threats…)

$$R = P*W*S \quad (1)$$

The table below contains five threats with the highest critical identification factor. The level of risk for the following hazards is unacceptable (R > 150), therefore measures should be taken to eliminate or reduce their effects.

Table 1.
Threats with the highest critical identification factor (Register of FMEA threats…)

Item	Threat	Possible consequences	P	W	S	R
1	No licence for a road-rail vehicle driver	Railway accident	8	4	5	160
2	Conducting periodic instructions during the epidemic threat	Exposing employees to loss of health and life	9	2	10	180
3	Mining damage	Destruction of railway infrastructure, railway accident	9	3	7	189
4	Admission of a road-rail vehicle without technical efficiency certificate	Railway accident	8	5	5	200
5	Epidemic threat	Threat to health and life of employees, limitation or suspension of business activities	6	5	10	300

The most common possible consequences after the threat include:

- railway accidents,
- railway incidents,
- damage to the railway infrastructure,
- material losses,
- reduction of throughput,
- limitation to trafficability performance,
- incorrect performance of tasks,
- suspension of traffic (Register of FMEA threats…).

The presented data show how important it is to assess the risk and the need to introduce solutions aimed at eliminating threats and reducing their effects. Railway infrastructure is exposed to a large number of identified threats. The railway infrastructure manager is obliged to take actions aimed at their elimination, which is a huge challenge due to the area of the infrastructure selected for analysis. To be able to meet the challenge, it is important that the manager constantly analyses and updates the risk assessment list. During this assessment, different methods should be used to verify the risks more accurately. It should be remembered that none of the methods used for risk assessment will guarantee the total elimination of threats, but will only improve the process of the organisation's functioning and will influence the improvement of safety.

2.1. Railway accidents, incidents and potentially dangerous situations

Railway accidents, incidents and potentially dangerous situations resulting from undesirable hazards have a significant impact on the deterioration of the company's safety. Jastrzębska Spółka Kolejowa has developed the R3 instruction on dealing with serious accidents and incidents in railway transport. Within this document, information can be found who to notify about the accident, who can conduct an investigation, how to conduct an investigation and what to do after an investigation is finished. The information about all railway events, incidents and potentially dangerous situations in the period from 2016 to 2021 is gathered in the charts below. It can be observed that the number of railway accidents and incidents is gradually decreasing but is still high. Railway carriers are responsible for the direct cause, over 90%, of all accidents occurring in the company's railway infrastructure in the analysed period (Register of potentially…; Register of accidents…).

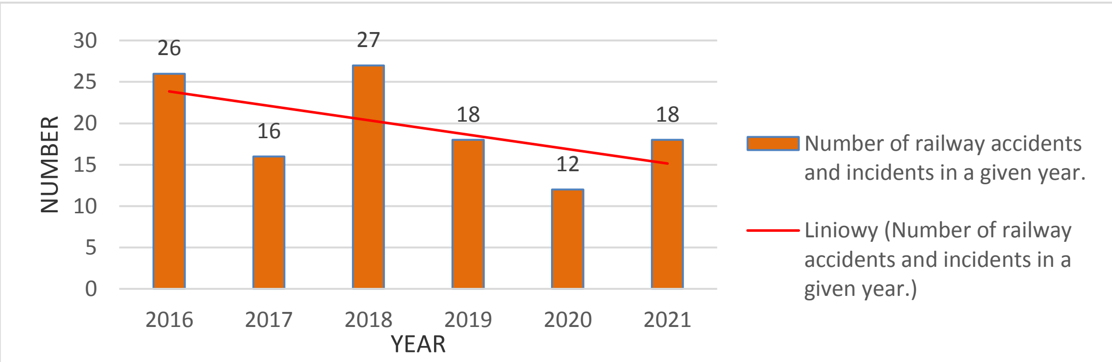

Figure 2. Number of railway accidents and incidents recorded in years 2016-2021.

Source: Register of accidents…

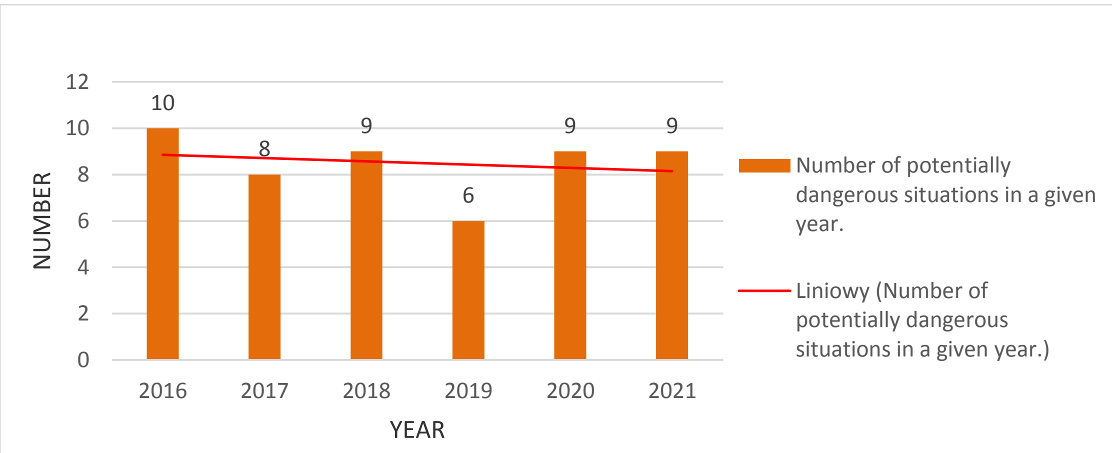

Figure 3. Potentially dangerous situations recorded in years 2016-2021.

Source: Register of potentially…

The railway accident of B09 category of 8 December 2020 on one of the tracks of the JSK railroad line brought the greatest effects of the threat in the analysed period. On that day, three carriages of the train from Pawłowice Górnicze to Kraków NH derailed. According to the findings of the railway commission, the direct cause of the accident was a cant deficiency and excessive track gauge. The original cause of the accident was the excessive degradation of the track surface caused by the sharp increase in traffic in a short period of time. During the investigation, numerous irregularities were found during the visual inspection and measurements of the freight wagon, which had an indirect impact on the cause of the accident. The track where the wagons were derailed was closed for over half a year. The removal of the effects of the derailment continues up to this day. Currently, the cost of the derailment has been estimated at around one million zlotys. Considering the scale of the effects of the derailment of wagons, appropriate preventive measures should be taken. Following the risk assessment, the following preventive conclusions were made:

- controlling and providing information in situations of a significant increase in transport on the lines and its sections,
- increasing the frequency of track and turnout measurements,
- the occurrence should be included in the company's information bulletin on railway accidents,
- the accident should be discussed in periodic trainings for employees (Protokół Ustaleń Końcowych…).

Figure 4. On-site inspection of B09 accident. The first derailed wagon.

Source: Protokół Ustaleń Końcowych…

Figure 5. On-site inspection of B09 accident. The second derailed wagon.

Source: Protokół Ustaleń Końcowych…

2.2. Damage to the railway infrastructure as a result of mining damage

Mining damage has a huge impact on the quality and safety of the railway infrastructure. The activities of Jastrzębska Spółka Kolejowa are conducted in active mining areas, therefore they are exposed to coping with numerous effects of mining damage. On the basis of the risk assessment, a risk sheet has been developed in which the probability of damage to railway infrastructure elements (such as: railway surfaces, control stations, buildings and structures) as a result of subsidence is assessed. In the area of the company's operations, an increased intensity of rock mass movement is recorded, as a result of which elements of the railway infrastructure are destroyed. Typical damage for individual groups of railway structures:

a) railway surface - buckling, uplifting, crimping and breaking rail joints; degradation of sleepers, base plates and rail bonds; distortion of turnout geometry,
b) control stations - mainly diagonal cracks; horizontal cracks in the ceilings, side walls; sinkholes under the facility,
c) other structures (bridges, viaducts, culverts, embankments, electro-traction power supply devices as well as security and traffic control devices) - excessive and non-uniform slopes, formation of funnels over culverts, expansion gap openings, flooded outlet heads, displacement of bearing parts, stresses of central anchor ropes, cracked foundation heads; tilts of railway signals, overhead power masts, overhead transmission lines, displacement of supports, breaking cable and communication routes through excessive straining of cables.

Hence, the occurrence of risk in the area of the company's operations in the coming quarters is almost certain, therefore the weight of probability is assessed at 5 points on a scale of 1 to 5, where 1 means ‘rare’ and 5 ‘common’ (Risk Sheet…).

The occurrence of infrastructure destruction due to mining damage may cause the necessity to temporarily close the railway line, limit capacity, and as a result make disruptions in the shipment of goods and services in part of the value chain demanding non-standard actions.

In connection with the occurrence of mining damage, there is also a need to increase funds to maintain infrastructure. Due to the amount of losses oscillating in the range from PLN 3 to 30 million incurred as a result of mining damage, the effects of primary risk have been assigned with a weight of 3 on a scale from 1 to 5, where 1 means ‘insignificant effects’ below PLN 300 thousand per year and 5 means ‘catastrophic effects’ above PLN 100 million (Risk Sheet…).

By multiplying the probability weight with the primary risk effects, the risk significance value is determined to be 15. Current mechanisms that have been implemented in order to supervise the risk involve:

- conducting inspections and monitoring damaged areas,
- introducing speed limits in selected sections,
- obtaining information from mining corporations on land subsidence forecasts in periods not shorter than 3 months,
- introducing transport systems eliminating the number of devices, buildings and railway structures exposed to mining damage.

Due to limitations in implementation, the current inspection mechanism is given a weight of 3 points on a scale from 1 to 5. The reduction in the rating is also caused by the possibility of improving the inspection mechanism including the implementation of additional inspection mechanisms and measures aimed at minimising the risk (Risk Sheet…).

On the basis of the model presented below (Table 2), the value of the residual risk is defined at a weight of 9.

Table 2.
Residual risk assessment (Risk Sheet...)

25	Primary risk value	25	20	15	10	5
20		20	16	12	8	4
16		16	12,8	9,6	6,4	3,2
15		15	12	9	6	3
12		12	9,6	7,2	4,8	2,4
10		10	8	6	4	2
9		9	7,2	5,4	3,6	1,8
8		8	6,4	4,8	3,2	1,6
6		6	4,8	3,6	2,4	1,2
5		5	4	3	2	1

Cont. table 2.

4	4	3,2	2,4	1,6	0,8
3	3	2,4	1,8	1,2	0,6
2	2	1,6	1,2	0,8	0,4
1	1	0,8	0,6	0,4	0,2
	Evaluation of inspection mechanisms				
	1	2	3	4	5

In order to improve the current inspection mechanism, a "Technical and economic study for the optimization of transport and its reliability by rail transport from JSW sidings" has been commissioned. The aforementioned data is presented in the Risk Sheet (Table 3).

Table 3.
Risk sheet of damage to the railway infrastructure as a result of mining damage (Risk Sheet…)

Risk Sheet		
Name of risk	**Damage to the railway infrastructure as a result of mining damage**	
Definition of risk	Risk of damage to railway infrastructure elements such as the track surface, control stations, buildings and structures (bridges, viaducts, culverts, embankments, electric traction power equipment, and security and traffic control devices) as a result of mining damage.	
Significance of primary risk	Probability	5
	Effect	3
	Significance according to the formula	**15**
Assessment of current inspection mechanisms	Assessment	3
	Justification	A risk management plan has been defined and implemented. Inspection and risk minimisation measures have been implemented and are in operation. There are limited possibilities to improve inspection mechanisms.
Residual risk value	According to the model	**9,0**
Type of reaction to risk	Monitoring inspection mechanisms	
Current action plan	Action plan in the event of mining damage, the "Technical and economic study of the optimisation of transport and its reliability by rail transport from JSW sidings" has been developed	
	Status:	In progress
Category	Operating activities	
Area	Logistics (storage, transport, distribution)	

Summary

JSK's railway infrastructure creates conditions for the operation of mining plants and coking coal producers. Railway transport is involved in the process of creating value and constitutes an added value in the trade exchange of fossil raw materials including raw materials recognised as strategic or critical due to their importance in the European economic area. Considering the aforementioned, railway infrastructure is a kind of critical infrastructure and its elements are subject to special protection. In order to prevent threats and minimize their effects, it is necessary to systematically assess the risk and introduce inspection mechanisms in order to increase the safety and quality of the services provided. While analysing the scope of the company's operations, numerous possible threats are recorded. The occurrence of threat may result, among others, in deterioration of the quality of railway infrastructure, railway accident, incident, potentially dangerous situation, but also the loss of the most valuable human life. Taking into account the location of the railway infrastructure, ensuring its required quality is a huge challenge for the manager due to the intensity of mining damages. In order to prevent or reduce the effects of mining damage, the issue should be considered with a prognostic approach.

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