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Methodology for Processing the Risk Management Plan for Selected Assets of Transport Infrastructure

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To ensure the safety of human society, managers of critical elements of the transport infrastructure need to have a tool to ensure a quality response, because major failures of elements of critical transport infrastructure also mean an impact on the functionality and prosperity of the territory, sometimes even in the long term. Response must be ensured in all aspects: organizational; technical; personal; knowledge; financial and methodological. In accordance with the ISO 31000 standard, a risk management plan for a specific critical item contributes to the preparation of a timely and rapid response at the manager side. We present a methodology for processing the risk management plan for followed items of the transport system with aims to prepare high-quality responses to manage serious risks for selected items and determine clear responsibilities for initiating and implementing a quality response. The methodology has been certified by the Czech Ministry of Transport, and its implementation is currently being prepared. The risk management plans for selected critical elements of transport infrastructure (such as tunnels, bridges, railway stations, airports, and traffic control systems) enable the maintenance of safety at the required level by preventing delayed or inadequate responses to failures or accidents.

Keywords: Risk management plan, transport, critical infrastructure, safety management, legislation.

1. Introduction

Transport consists of an extensive network of transport routes, objects, support systems and means of transport of various kinds and types. The transport network is one of the most important infrastructures ensuring the basic functions of the State, and therefore, the basic needs of humans for their lives (Prochazkova 2012). Therefore, transport infrastructure is included among the critical infrastructure of all developed countries. Transport infrastructure is an open and complex system consisting of many subsystems (subsystems) and many different elements that are linked by a complex network of links and flows of different nature. Subsystems and elements can work separately and together, performing a completely unique task that is remote from the tasks of individual entities.

In order to ensure the safety of human society, the European Union applies the management type of Total Quality Management - TQM (Zairi 1991), according to which the critical transport infrastructure must have safety as the main sign of quality. For this reason, risks need to be managed so that the safety of both, the whole system and its critical items, has a certain level during the operation. As the world is changing dynamically, it is not enough to apply preventive measures in design and construction, but it is also necessary to ensure a high-quality and rapid response to harmful phenomena that were either not considered in the design or were considered only up to a certain size.

To ensure the safety of human society, it is necessary for administrators of critical elements of transport infrastructure to have a tool to ensure quality response, because major failures of critical transport infrastructure elements also have an impact on the functionality and prosperity of the territory, sometimes in the long term. Response must be ensured in all aspects: organizational; technical; human resources; knowledge; financial and methodical. It follows from the complex of these requirements that their ensuring is not trivial and that it is successful only if the response is properly prepared in all aspects.

A risk management plan is a tool for proactive risk management that considers possible interconnections over time and facilitate responses to failures. It is a key output of any risk management (ISO 31 000). Paper shows methodology for processing this plan.

2. Concept of Quality and Safety in EU

In the 19th and early 20th centuries, the bureaucratic system of management according to (Weber 1925) was mainly applied in organizations. The bureaucratic method of management was a necessary condition for the modernization of society, so it gradually spread through the government sector and State organizations to large institutions and companies (Beetham 1996, Weber 1925). Especially in the second half of the twentieth century, quality control methods began to be applied (Zairi 1991).

The Maastricht Treaty 1992, i.e., the founding treaty "Treaty on European Union" establishes a common policy or activities for sustainable and non-inflationary growth respecting, among other things, the environment, a high level of social protection, an increasing standard of housing and quality of life, and economic and social cohesion and solidarity between member States. The Treaty on the European Union from 1992 further sets requirements for individual areas of interest. The latest consolidated version of the Treaty on European Union and the Treaty on the Functioning of the European Union from 2016 continue to impose the obligation to introduce high standards or quality levels and increase them in various areas of public health, the environment, and services of public interest.

The above issue of implementing quality principles becomes even more critical if organizations are tasked with implementing other management systems. In the public sector, it is mainly İSO 14001, OHSAS 18001, but also, for example, information security ISO 27000 or risk management according to ISO 31 000. Risk management with reference to the ISO 31 000 standard is already implemented in the newer revision of the ISO 9001 standard: 2015. When implementing the multiple systems, including the safety management system, the principles of the so-called integrated management system are applied.

The implementation of safety management systems is required in most modes of transport, and because of its proactive nature, it requires an understanding of quality principles in the context of an integrated management system. Despite this, some state organizations still rely on bureaucratic systems. Introducing new EU standards is becoming increasingly critical in safety management, but it can create issues due to misunderstandings between the two different management principles. Therefore, we present a methodology for processing a risk management plan, which is crucial in addressing this issue.

3. Data and Methods for Safety Management of Critical Transport Elements

Transport infrastructure is an open and complex system consisting of many subsystems (subsystems) and many different elements that are linked by a complex network of links and flows of different nature. Subsystems and elements can work separately and together, performing a completely unique task that is remote from the tasks of individual entities. Interactive complexity and tight connections between elements in a sociotechnical system (Prochazkova 2015) can lead to a critical situation due to systematic failure. Analyses and evaluations of accidents and failures of technical installations (Prochazkova 2015, Prochazkova et al. 2019) show that connecting elements in infrastructures are very vulnerable, often leading to disruption of the services provided by infrastructures to human society.

To obtain data on risks for items of critical transport infrastructure and on response processes to failures, we analyzed following data from transport infrastructure: 283 failures of bridges in the world since 1297 (Prochazka, Prochazkova 2020); 965 failures of road tunnels and 53 case studies in the world since the beginning of the 19th century (Prochazkova, Prochazka 2020); 2511 failures of critical objects on roads (stations / railway stations, intersections, difficult places of roads) in the world since 1815; 1125 failures evaluated for railway stations (Prochazkova, Prochazka 2021a,b); 1917 air accidents of civil aircraft in the world since 1909 (Prochazkova, Prochazka 2021c); and 31 failures of transport management systems worldwide since 2006 (Prochazka, Prochazkova 2022).

4. Risk Management Plan

The risk management plan is drawn up in the form of a table containing: the causes of the risk; a description of the impacts of the risk on public assets and the service provided by the transport infrastructure; the occurrence frequency of failures and the size of the impacts of critical element failures; and ensuring a response, which contains: risk management or at least mitigation measures that are clearly identified. It is a measure. technical; organizational; human resources; methodological, educational and financial, for each action; the organization (or its responsible representative) is identified to provide the response ; and for each action, the person responsible for the correct and timely implementation of the response is indicated. The frequency of occurrence of critical element failures and the size sizes of failure impacts must be determined on the local database of failure causes.

5. Methodology for Processing the Risk Management Plan

The presented methodology is based on generic safety management model for monitored critical elements we introduced in (Prochazkova 2022, Prochazkova et al. 2022a). The model considers the complex open systems in a dynamically changing world, which is influenced both by processes that take place independently of man, and by processes that man creates consciously or unconsciously through his activities and behavior.

Methodology for developing and applying a risk management plan:

- was compiled on the basis of analysis and evaluation of data for response scenarios to failure of followed critical items
- and at formulation of procedures and requirements for ensuring the safety of selected transport infrastructure items they were considered:
  - ***current knowledge contained in renowned professional sources mentioned in works*** (Ale, Papazoglou, Zio 2010, Baraldi, Di Maio, Zio 2020, Beer, Zio 2019, Bérenguer, Grall, Guedes Soares 2011, Briš, Guedes Soares, Martorell 2009, Castanier et al. 2021, Cepin, Bris 2017, Haugen et al. 2018, IPSAM 2012, Leva et al. 2022, Nowakowski et al. 2014, Podofillini et al. 2015, Prochazkova 2015, 2017, Prochazkova et al. 2019, Steenbergen et al. 2013, Walls, Revie, Bedford 2016),
  - ***binding documents*** of the UN, EU, OECD, IAEA and others, the requirements and procedures of which are summarized in works (Prochazkova 2015, 2022, Prochazkova et al. 2022a).

6. Guidance for Developing A Risk Management Plan for A Given Critical Element

The basic function of the State is to ensure the safety of protected assets (interests) of the state and the sustainable development of the State. The State is understood as a unit in which humans, the ruling power and the territory fall under one essence (i.e. the sum of deep properties, relationships and internal laws that determine the main features and tendencies of the development of a given system). The methodology ensures the fulfillment of the basic functions of the state in the field of transport.

In the guidance, there were used the following terms:

- Critical infrastructure elements are elements that are determined by cross-cutting and sectoral criteria pursuant to Government Regulation No. 432/2010 Coll., on criteria for determining critical infrastructure elements, as amended.
- Selected element of critical transport infrastructure, hereinafter referred to as the "critical element", is an element of critical infrastructure in the transport infrastructure according to above mentioned regulation and is related to the safety of services that the critical transport infrastructure performs for the State, i.e. the inhabitants of the Czech Republic.
- Risk management plan is defined in Chapter 4.
- All Hazard Approach (EU 2012, FEMA 1996) refers to an approach in which all harmful phenomena that can significantly damage a critical element are considered,

namely external, internal, organizational, human errors.

- Hazard is an inherent property of a harmful phenomenon that is determined by the process that produces it (Prochazkova 2015). It is a set of maximum impacts of a harmful phenomenon that can be expected in a given place for a specified time interval with a probability equal to a specified value. According to norms and standards, it is usually determined by the size of the disaster, which will occur with a probability greater than or equal to 0.05, considering account the frequency distribution for a time interval of one hundred years. In technical practice, threat refers to the normative size of the disaster at a specified level of credibility (centennial, millennial, etc.). For the purposes of practice, it is expressed by a set of impacts on protected assets.
- Risk is the probable magnitude of damage, loss and harm to protected assets that corresponds to a threat that is normatively determined. In technical practice in quantitative risk analysis used in strategic management, the risk is equal to the magnitude of losses, damages and harm to protected assets at the normative magnitude of the harmful phenomenon normed per unit of territory and unit of time (usually 1 year); integral risk is based on the systemic concept of a critical element and includes losses, damages and detriments caused by the connections between elements and components of a critical element. It is the overall risk of an object or process that is understood as a system. Risk management is the management of a set of anthropogenic measures and activities so that damage and loss to assets is below a set level; usually set levels — ALARP and ALARA (Prochazkova et al 2020).
- Risk management is the planning, organizing, allocating of work tasks, and controlling an organization's resources to minimize loss, damage, injury, or death caused by various harmful phenomena likely to occur. The task of risk management is, therefore, to find an optimal way to reduce the assessed risks to the required socially acceptable level or to maintain them at that level (Prochazkova 2015); the integral safety of a critical element is an essential characteristic of the quality of a critical element. It is the result of the application of anthropogenic measures and includes not only the protection of a critical element, but also its reliability and functionality so that it does not endanger itself and its surroundings. Critical element safety (Prochazkova 2017, Prochazkova, Prochazka, Kertis 2022, Prochazkova et al. 2019) addresses issues relating to material, technology, construction, construction, operation, personnel, task organization, education, finance, and law in such a way that: ensure required processes that bring profit and competitiveness to a critical element; ensure tasks that ensure the fulfilment of the basic functions of the State in the field of transport; and at the same time, they suppressed the processes that bring damage and loss to the critical element.
- Administrator of a critical element is the operator of a critical element designated by the director by the administrator of the competent public authority – in the Czech Republic, these are: Road and Motorway Directorate; Railway Administration; and the Air Traffic Directorate.
- Public authority entrusted with supervising the safety of a given critical element is a body designated by legislation issued by the Ministry of Transport.

Sources of risk that have so far caused the failure of the critical elements of interest, which have been derived by detailed research, are described in chapter 4 above. Since each site has different tectonic, geological, geophysical, geographical, meteorological and other conditions (Prochazkova et al. 2019), some sources of risk are more or less typical for it. In addition, everything changes over time, with the result that the limits ensuring the safety of the element specified in the design are exceeded with certain changes in conditions (Prochazkova et al. 2019), leading to an accident or failure of the element; In addition, there is an effect of aging of material, structures, bonds and flows of elements.

The safety of the monitored items of critical transport infrastructure (critical elements) is ensured by optimal risk management targeting all harmful phenomena that may cause the critical element to fail at a given location identified according to the procedures (Prochazkova 2015). Risk management is a continuous and iterative process.

The basis of the risk management of a critical element is the risk register (Zairi 1991) and the manager's organizational structure for the critical element (Prochazkova 2017). The risk register shall be divided into: list of non-current/resolved risks ; a list of risks requiring the most attention, as the risks in question change over time; and a list of outdated/resolved risks that must be regularly checked due to the dynamic development of the world.

Due to the dynamic evolution of the world, the risk registers for the critical element of interest must be reviewed at regular intervals and necessarily must be reviewed after each major failure of a critical element. The clearly defined organizational structure of the critical element manager shall include: chain of competences; communication structure; a management framework according to which risk management and decision-making processes take place according to the requirements of TQM management, which apply in the European Union, i.e. also in the Czech Republic. For risk management to be effective, the tool manager must be part of the management system, both standards, procedures, guidelines, policies and others, and continuous qualified risk management (Prochazkova 2017, 2022, Prochazkova, Prochazka, Kertis 2022, Prochazkova et al. 2019). Risk management must be carried out at all stages of the critical element's life (siting, design, construction, operation, reconstruction and disposal).

The procedure for establishing a risk management plan is:

1. Create a scheme of the critical element and its surroundings and mark important objects which can threaten the critical element.
2. Identify sources of harmful phenomena that can lead to the failure of a critical element using the crisis plan of the region and the crisis plan of the municipality with extended powers, which is required by the Crisis Act, and consider the causes of organizational accidents, i.e. the quality of management of the critical element. ***Causes of organizational accidents include***: the State does not have: a strategic safety management program; clearly defined responsibilities at each level of critical element management and public administration; and legislation clearly imposing the obligations on the owner (legal guardian) and public administration in the field of safety; the critical element manager (legal quardian) does not have in control: established safety as an essential quality characteristic; the exact safety documentation in the form of a safety report (Prochazkova 2015); an organizational structure with clear safety responsibilities; security documentation containing a crisis preparedness plan; the obligation to carry out safety checks on all elements and components, their connections and the whole; a clear obligation to maintain a safety culture; a clear obligation to have a financial reserve for maintenance and repairs; a defined obligation to cooperate with public administration in response to failures; and the state administration system does not designate a public administration body that performs proper professional supervision in full and direct responsibility over the safety of a critical element. *For example, in the Czech Republic* (Prochazkova, Prochazka, Kertis 2022), the causes of risks in the Czech Republic are:
   - ***external:*** beyond design natural disasters; accident (fire, explosion, leakage of dangerous substances) of technical objects or equipment in the vicinity of a critical element; failure of external infrastructures that are needed to operate a critical element; coercive actions; terrorist attack; and war;
   - ***internal:*** unsettled deficiencies in design, construction and construction; accidents (fire, explosion, leakage of dangerous substances) of internal technical installations; failure of internal infrastructures that are needed to operate a critical element; operating rules are absent or imprecise; the mode of operation is not in accordance with the design and the state of operation; poor-quality maintenance; poor-quality technical inspections; OSH and environmental regulations are not complied with; staff lack quality education, training and motivation, or are overburdened; lack of staff; and insufficient physical or cyber protection of a critical element;
   - ***and human errors***, both in traffic and people management, as well as in specific work tasks.
3. Evaluate the frequency of occurrence and size of failure of the relevant critical element

according to the data in the previous paragraph.

4. Prepare a response plan, i.e. a hierarchical set of measures to be implemented by the administrator of a critical element in the event of a critical element failure and ensure them in terms of organizational, technical, personnel, knowledge and finance, and identify a human responsible for the implementation of the response. In addition, it is necessary:
   - ***align the response plan in question with the crisis preparedness plan*** that the administrator of the critical element prepares according to the Crisis Act (Act No. 240/2000 Coll.);
   - ***for harmful phenomena*** listed above that do not fall under the Crisis Act, to process its own response with the help of its own organizational rules that respect the requirements of TQM and ISO 9000 series standards, and technical forces and resources own or from a sector subordinate to the Ministry of Transport;
   - and ***in case of necessity of cooperation with the Integrated Rescue System, public administration or other organizations*** (e.g. a large fire, extensive mechanical disturbance, major accident with dangerous substances, cyber-attack, etc.), prepare and discuss in advance a response cooperation plan.
5. Prepare your own risk management plan, i.e. fill in a table, the models of which are in the work (Prochazkova, Prochazka, Kertis 2022).
6. When drawing up the risk management plan, the manager should identify potential conflicts that may arise in response, and agree in advance on their resolution, in particular in the area of competences and responsibilities with the rescue system or the relevant crisis authority.
7. Since the failure of critical elements is in most cases caused by a combination of several harmful phenomena that occur in a short time interval (Prochazka, Prochazkova 2020, 2022, Procházková 2015, 2017, Prochazkova, Prochazka 2020, 2021 a, b, c), it is necessary to regularly or after each major failure to assess the degree of integral risk and according to the assessment of its degree, to take / not to take measures. Tools and instructions for integral risk assessment are prepared and published, i.e. publicly available: bridges (Prochazka, Prochazkova 2020); tunnels (Prochazkova, Prochazka 2020); railway stations and stations Prochazkova, Prochazka 2021a,b); airports (Prochazkova, Prochazka 2021c); and traffic control systems (Prochazka, Prochazkova 2021).

Examples of risk management plans are in (Prochazkova, Prochazka, Kertis 2022). The methodology for drawing up a risk management plan was also developed in the form of a legal regulation that is in harmony with the Czech legislation rules. Experts appreciated their usefulness, the Ministry of Transport certified it (Prochazkova et al. 2022b) and recommended to the Legislative Council of the Government to issue it in the form of a legal regulation.

For practice in the Czech Republic, we have created, in addition to the professional form of the methodology, a legal form that is linked to the legal system of the Czech Republic. The methodology has been certified by the Ministry of Transport and its implementation is being prepared (MD 2022) .

7. Conclusion

The data in the works (Prochazkova et al. 2022 a, b) describing the impacts of default and the response to the failure of the monitored items show that, in addition to direct losses on public assets due to the failure of critical elements, it is necessary to consider, from the point of view of the costs of human society, expenditure on: implementation of the response (wear or destruction of equipment, consumption of materials, finances for response personnel, settlement of secondary damages, i.e. damage caused by the response); remediation of the territory; treatment of the injured; compensation to victims; and compensation for survivors.

Major failures of critical transport infrastructure elements also have an impact on the functionality and prosperity of the territory, sometimes in the long term. A swift quality response is needed to reduce the impact and, in particular, the costs of restoring recoverable public assets (Prochazkova 2017, Prochazkova et al. 2019).

Response must be ensured in all aspects: organizational; technical; human resources; knowledge; financial and methodical. It follows from the complex of these requirements that reinsurance is not trivial and that it is successful only if it is properly prepared. It is the preparation of a timely and rapid response that is ensured by a risk management plan for a specific critical item. Therefore, the application of this tool in the area of critical infrastructure, i.e. for monitored critical items of critical transport infrastructure, is important.

In conclusion, risk management plans for selected (critical) elements of critical transport infrastructure (tunnels, bridges, railway stations, airports and traffic control systems) make it possible to maintain the safety of transport infrastructure at the required level, because they avert the occurrence of delayed or poor response to failures or accidents. The expert statements and verification of two plans in practice (CVUT 2022) show that establishment of specific plans shall ensure:

- proactivity (appreciation of the magnitude and frequency of impacts of serious risks, preparation and provision of solutions when they are implemented in all important aspects)
- and timely and correct execution of the response (thorough processing of the organization of the implementation of the response, including personal responsibility in advance at rest).

Response preparation is very important because the world is changing dynamically and sudden changes in conditions cause the limits of objects belonging to critical infrastructure set in designs to be exceeded and the object fails or crashes (Prochazkova et al. 2019), which has unacceptable immediate impacts not only on public assets (lives, health and safety of people, property, well-being, environment, other critical objects and critical infrastructure), but also unacceptable long-term impacts on the development of the entire region caused by economic losses that cause unemployment, civil unrest and crime.

The risk management plan for selected transport infrastructure elements (tunnels; bridges; railway stations and stations; airports; and traffic control systems) shall ensure: preparation of a high-quality response to manage serious risks that must be expected by the administrator of the monitored element of critical transport infrastructure in the given locality; ad by assigning responsibilities, possible delays in starting the response. By this it will contribute to:

- ensure the interoperability of transport systems, transport routes and technical means of transport routes,
- ensure the sustainability of public service provision,
- improve the quality of transport systems and networks for the development and competitiveness of regions,
- improve the quality of the transport system for regional development and the living conditions of the population,
- to match the needs of economic development, natural resources and waste recycling in the development of transport systems and networks,
- reduce the global climate impacts of transport and reducing pollutant emissions in places with heavy traffic congestion,
- reduce the environmental impact of transport and increasing the efficiency of the transport system,
- ensure solutions for sustainable transport services for regions and cities with a link to the supply of retail and wholesale zones, including city centers, and reverse logistics considering the principles of the smart city concept.

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