JOURNAL OF MECHANICAL AND TRANSPORT ENGINEERING
Vol. 68, No. 4 2016
DOI 10.21008/j.2449-920X.2016.68.4.06

Piotr SMOCZYŃSKI*
Adam KADZIŃSKI*
(Date of receipt of the article: 23.09.2016, Date of acceptance of the article for publication: 16.11.2016)

INTRODUCTION TO THE RISK MANAGEMENT IN THE MAINTENANCE OF RAILWAY TRACKS

Risk management is an essential tool for the implementation of safety policy within the framework of safety management systems deployed in all enterprises involved in the management of railway infrastructure and transport operations on the fundamental European Union rail network. The idea of risk management, however, is much younger than the railway system and therefore it is sometimes regarded as an independent supplement to the business of entities related to the railway.

The aim of this article is to present how the processes of the railway track maintenance system can be supported by the language of methods of risk management, in order to be able to better integrate these processes with the safety management system of an infrastructure manager. This work also discusses the requirements for safety management systems and indicates further possible directions of research in the field of risk management methods which support processes of maintenance of railway tracks.

Keywords: railway track, railway track maintenance system, method of risk management, safety management system

1. INTRODUCTION

Damage and/or errors in functioning of elements of a railway system are hazard sources (hazard factors, risk factors) that generate significant risk. Because of that, more and more often, hazard sources are identified on subsequent stages of life of the railway system. On this basis, hazards are formulated. These hazards are associated with users of transport, users of the railway infrastructure and with transportation maintenance systems.

* Poznan University of Technology, Faculty of Machines and Transport.

The impact of activation of hazards on human life and health, on the environment and on technology systems, may be measured in units of risk levels. With the use of risk measures, it is possible to assess the degree of impact which systems and components of railway system have on safety levels of people, on the environment and on the systems themselves. The resulting need to study the system and elements of a railway system justify the need to build and apply models of the concept of their structure, which is based on risk management.

In Poland, the problem of transport risk management was discussed, among others, in the ZEUS project (research project entitled: "Integrated System of Transport Safety 2007-2010"). The project proposed two courses of action [Krystek (ed.) 2009]:

− the adoption of a common terminology and the developement of general principles of integrated risk management in transport,

− the development of detailed procedures, models and risk measures dedicated to highlighted areas of transport (branches of transport: road, rail, air, water and public transport).

Activities within the first course of action have already been completed and their results were presented in a number of studies [Jamroz et al. 2010, Krystek (ed.) 2009, Krystek (ed.) 2010]. The result of these activities was the development of the Trans-Risk – a method of transport risk management, based on the classic method of risk management.

Activities within the second course of action are on different stages of development, depending on the area of transport. The subject literature contains proofs that this second course of action is being implemented. Basing on the concept of the Trans-Risk risk management method, its implementations in the rail transport have been developed [Kadziński 2013, Kadziński 2014, Gill, Kadziński and Smoczyński 2016, Chruzik 2014, Wachnik 2016], as well as implementations in road transport [Jamroz 2011, Szymanek 2012, Szymanek 2014]. Works devoted to risk management organized according to the concept of Trans-Risk concern also public transport and especially tram transport [Kadziński and Gill 2011, Kadziński, Warguła and Gill 2012].

Within the infrastructure of railway system, a classic approach to processes of risk management method was used in the domain of level crossings [Kobaszyńska-Twardowska and Kadziński 2013, Kadziński, Kobaszyńska-Twardowska and Gill 2016]. However, there have not been any attempts to use this approach in context of a track within the infrastructure of the railway system.

The track maintenance system, especially its elements such as diagnosis, preservation, renovations and modernizations, is of interest to the authors of several publications. Bogdaniuk and Towpik [2010] presented the diagnosis of track surface as the basis of making maintenance decisions. As examples, they described practices used in this area by infrastructure managers in a few European countries. They also highlighted the need of the systems thinking approach to the maintenance of the infrastructure. This approach should result, among others, in a free flow of information between the units involved in the execution and supervision of work, materials management and railway traffic management. Because of the large amount of information, according to the authors of the aforementioned work, it is necessary to use complex databases and expert systems which support making decisions related to the maintenance of railway tracks.

The systems, which are used in Poland and which support making decisions related to the maintenance of railway tracks, were described by Sancewicz [2010] and H. and M. Bałuch [2013]. These authors also present the rules for classification of exceedances of permissible deviations for measurable variables of railway track condition. They prove that not all exceedances of deviations require immediate actions. Thus, the knowledge, experience and intuition of diagnosticians are crucial for the choice of actions when such exceedances occur.

The aforementioned literature describes the railway track maintenance system as it has worked for decades. With the increasing role of computer systems, decisions taken by diagnosticians in different parts of the railway network are surely becoming more standardized. However, all works emphasize the role of intuition and experience of people who interpret results of diagnostic tests. Without denying such approach in advance, attention should be paid to several important features of the current situation in the rail transport [Mańka 2014]:

- the change of a railwayman status, a shift from an ethic of service to treating this function as a job,
- lesser number of new workers coming from railway-associated families, in which the profession is passed down from father to son,
- the necessity of hiring and retraining workers from other industries,
- less experienced and more experienced people working together for shorter periods than before, less time to pass the knowledge and good practice,
- an increase in the complexity of the technologies used.

In order to reduce the negative impact of the aforementioned factors, entities operating in the railway system in the European Union (EU) are legally obliged to implement safety management systems which are described in more detail in Chapter 2 of this work. Unfortunately, awareness of the purpose of existence of these systems is low, especially at the lower organizational levels of the national infrastructure manager. This has been confirmed by the publicly available results of checks which has been carried out [Office of Rail… 2016, unpublished].

This state of affairs may partly result from not recognizing connections between the railway track maintenance system and risk management. Even in works directly devoted to risk in operation of railway tracks [Bałuch 2007, Bałuch 2013], risk assessment as a part of risk management methods is rather presented as a tool for finding scenarios of railway accidents, used in the higher organizational levels. People directly involved in diagnostics are only given propositions of participating in additional trainings with the use of case study, so that they can have a better “awareness of hazards” [Bałuch 2007]. Works of authors from outside of Poland also discuss rather a strategic risk and not an operational risk [Podofillini, Zio and Vatn 2006; Ng and Loosemore 2007].

The main aim of this work is – in the light of comments on safety and risk management in the railway system – to identify and describe the activities performed by employees of the infrastructure manager in such a way to show their role in the risk management process and to enable including the results of their work in the safety management system. It is expected, among others, by the Polish National Investigation Body, which, in its report [2015], obliges the infrastructure manager to perform – as a part of the safety management system – successive risk assessments for hazards identified on the basis of the results of checks conducted by diagnosticians. Aditionally, it is required to increase the number of checks of railway track in locations where the risk of hazards might exceed permissible values.

2. SAFETY AND RISK MANAGEMENT IN THE RAILWAY SYSTEM

Safety management systems have been introduced into the European railway system together with the Directive on safety on the Community's railways No 2004/49/EC [29.04.2004]. This directive has introduced also a number of other novelties: Common Safety Indicators (CSI), Common Safety Targets (CST) and Common Safety Methods (CSM). All of these tools are interrelated and are aimed at increasing the level of safety of the railway system of the EU.

The most important of these tools are safety management systems implemented for all infrastructure managers and in railway undertakings. The use of these systems should make it possible to achieve CSTs, and also to meet national requirements and the requirements established at the EU level, resulting from the CSMs and the technical specifications for interoperability (TSI) [Pawlik (ed.) 2015, Smoczyński and Kadziński 2016].

Supervision of safety management systems of infrastructure managers and railway undertakings is a duty of the National Safety Authorities of the Member States of the EU. They issue authorizations and safety certificates – documents, without which it is not allowed to run businessess within the railway system in the EU. In Poland, the role of the safety authority belongs to the President of the Office of Rail Transport. However, his competences are far wider and enable a comprehensive supervision of the Polish part of the railway system in the EU [Smoczyński 2015b, Smoczyński and Kadziński 2015].

Specific requirements on safety management systems deployed for the infrastructure managers and railway undertakings are defined in the EU Commission Regulations: No 1158/2010 [9.12.2010] and No 1169/2010 [10.12.2010] respectively. Both legal acts are largely similar. Their essential parts are the attachments which contain dozens of criteria grouped into chapters. From the point of view of this work's subject, which is risk management, the most important chapters are A-D and M.

The first four chapters of the Regulations No 1158 and 1169 impose an obligation on entities to identify the hazards associated with their current activities, as well as to propose and monitor/evaluate the effectiveness of risk reduction measures. These are the actions, which in fact make up the classic risk management process. The Regulations do not impose any form nor parameters of the risk model used in some procedures of risk assessment; so far, in Polish conditions, the most widely used risk model has been the one related to the FMEA method [PN-EN 60812, Sitarz, Chruzik and Wachnik 2012, Mańka 2014]. Under this model, for each identified hazard the entity determines/quantifies the probability of occurrence of a dangerous situation, the probability of detection of hazard sources and the level of losses which could occur as a result of a dangerous situation. On the basis of the quantified variables, risk is estimated and evaluated. This risk assessment is repeated regularly, usually at least once a year.

The process of risk management is specifically defined to deal with risk of hazardss associated with changes introduced to the railway system in the EU. In this situation, one should refer to the chapter M of Regulations No 1158 and 1169 and its extension in EU Commision Regulation No 402/2013 [30.04.2013, Sowa 2016]. The approach described there relies heavily on the classic method of risk management, but it introduces some important differences that have been shown in Figure 1.

Both the classic method of risk management, as well as the method laid down in Regulation 402, begin with defining of the analyses domain and identification of hazards. In both cases, the phases of response to risk are also identical. A significant difference appears in treatment of the identified hazards. In the classic approach, the risk of each hazard should be estimated in accordance with an accepted risk model. Regulation 402 provides in return the three rules for estimation and evaluation of risk (in the Regulation they are called “the risk acceptance criteria”):

− first of all, the risk may be accepted if the hazard sources are covered by existing codes of practice – documents which describe good practices, such as the European standards. For example, there is no need to estimate the risk of “Possibility of losses incurred by passengers and resulting from injuries caused by the fire of the railroad car” if all materials used in the production of the railroad car meet the standard [EN 45545-2] which specifies the requirements on the properties of flammable materials and components used in rail industry, and the fulfillment of these requirements precludes ocurrence of the aforementioned hazard of the risk level higher than acceptable.

− secondly, there is no need for risk estimation of these hazards, which are the same as those generated in the existing domain/system of reference. For example, there is no need for risk estimation concerning the introduction of a tablet-based system of electronic communication with train drivers if there are available information on acceptable risk of identical hazards generated in the analyses domain/system of a comparable railway company.

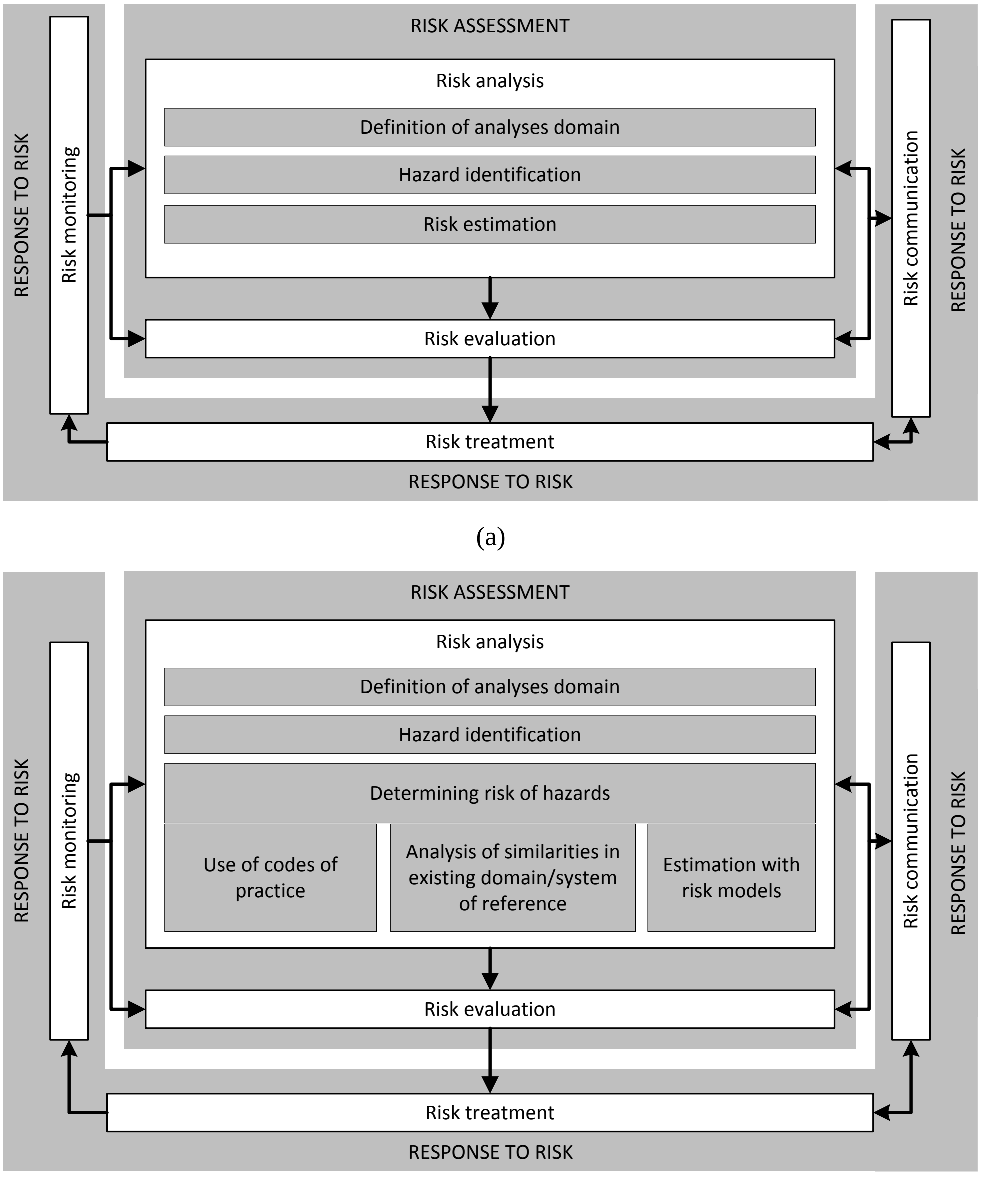

Figure 1. Comparison of (a) the idea of the classic method of risk management with (b) the idea of the method specified in Regulation 402

− thirdly, if the previous rules for determining the risk cannot be used, a risk level must be estimated and evaluated in the so-called explicit way, that is, using the accepted risk model.

In a situation where after the application of the aforementioned rules for the estimation and evaluation of risk, the risk is still unacceptable, the risk treatment must be developed and implemented. This purpose requires other elements of a safety management system, such as management of competences and duties of employees or management of available resources.

3. RAILWAY TRACK MAINTENANCE SUPPORTED BY RISK MANAGEMENT

3.1. Indication of analyses domain

About 95 percent of the railway infrastructure in Poland, more than 18,000 km of railway lines, is managed by PKP Polskie Linie Kolejowe S.A. (Polish Railway Lines, hereinafter called PKP PLK), hence this work describes the system of maintenance of railway tracks only in that entity. Due to the size of the managed railway network, the company is divided into Headquarters and 23 Railway Departments (Zakład Linii Kolejowych), further divided into Operation Sections (Sekcja Eksploatacji). Railway Departments carry out the essential part of the processes within the railway tracks maintenance system, using the results of measurements done by measuring vehicles, performed by the Headquarters of the company [Office of Rail… 2016]. The boundaries of the risk analyses domain related to the operation of railway tracks (within the meaning of risk management methods) result, inter alia, from:

− the boundaries of each Railway Department,
− the boundaries of Operation Sections,
− boundaries of the areas of activity of railway track supervisors.

A precise definition of the analyses domain depends on the rules applied in the Railway Departments. This relates to, for example, the issue of including in one analyses domain both railway station tracks and tracks outside stations, as well as including in the domain both track superstructure and substructure.

3.2. Identification of hazards

Railways have been used and maintained for nearly two hundred years, making it possible to create rich databases and expert systems containing knowledge of the analyses domain which is considered in this work [Sancewicz 2010, Bałuch and

Bałuch 2013]. Valuable information may be obtained also from studies of railway accidents. The ERAIL database was created for this purpose. It contains research reports of all accidents in the EU, which belong to the category of "serious accidents" [Smoczyński 2015].

A key task in identification of hazards in the considered analyses domain is not development of scenarios that lead to undesireable events, but the verification of the size/value of the variables of condition on a specific part of the railway network, in order to determine whether they are hazard sources. The variables of condition are, among others:

- horizontal roughness of a track,
- roughness on the running surface of rail,
- material continuity inside the rail,
- condition of ballast.

The aforementioned variables of condition of the analyses domain actually almost never take the nominal values, because even the new rails are a bit uneven or feature lacks of continuity of the material of which they are build. Any treatment of the variables of condition as hazard sources may depend on the size of deviation of actual sizes/values of these variables from the nominal sizes/values, and on the mutual dependence of some variables.

Identifying hazard sources takes place in the context of diagnostic tests described in internal instructions of the infrastructure manager. In the case of railway track operated within the infrastructure managed by PKP PLK, diagnostic tests are described in the manual of railway track diagnostics Id-8 [PKP... 2005b]. These tests include, among others:

- visual inspection of tracks,
- going by train on the given track in the driver's cab or in the last railroad car,
- technical inspection of railway tracks,
- direct measurements of tracks,
- measurements of tracks with the use of measuring vehicles,
- measurements of shifts of rails of jointless rail tracks,
- defectoscopy,
- visual inspection of turnouts,
- technical inspection of turnouts.

Procedure of safety management system SMS-PW-01 "Maintenance of the railway line in technical and organizational efficiency" oblige diagnosticians of PKP PLK to use all the gathered information about the sizes/values of the variables of the condition of the considered analyses domain. In some cases it is sufficient to consider each variable separately, for example, when the permissible size/value of the variable of condition has been exceeded, track twist becomes a hazard source. Often, however, to formulate the hazard, there must be a coincidence, or in other words: simultaneous occurrence of some sizes/values of the variables of condition in the analyses domain.

This issue was discussed, inter alia, in [Bałuch and Bałuch 2013, p. 120]. The authors point out that due to the large number of variables of condition, examination of their interrelations and impact on the ability to formulate hazards is virtually impossible. Under the assumptions made by the authors, the number of possible coincidences was estimated at $5.63 \cdot 10^{15}$, and analyzing them would take tens of millions of years.

The solution to this problem adopted in the diagnostics of railway track – in addition to the use of expert systems – is the calculation of synthetic indicators which enable the assessment of mutual influence of variables of condition of a geometric character. In the network managed by PKP PLK, there are two such indicators in use. The indicator of track status J is a function of the standard deviations of sizes/values of variables of condition and does not depend on the maximum speed limit on the track, which is the analyses domain [PKP... 2005c]:

$$J = \frac{\sigma_z + \sigma_y + \sigma_w + 0{,}5\sigma_e}{3{,}5} \tag{1}$$

where:

σ_z – the standard deviation of the size/value of a variable of track condition, the variable being the size of vertical roughnesses of the railway track,

σ_y – the standard deviation of the size/value of a variable of track condition, the variable being the size of horizontal roughnesses of the railway track,

σ_w – the standard deviation of the size/value of a variable of track condition, the variable being the size of the railway track twist,

σ_e – the standard deviation of the size/value of a variable of track condition, the variable being the track gauge,

Unlike the J indicator, the value of a five-parameter defectiveness W_5 depends on the values of permissible deviations, which in turn depend on the speed on a given section of the railway line. For each of the measurable variables of condition, the defectiveness indicator W is determined by the equation [PKP... 2005c]:

$$W = \frac{n_p}{n} \tag{2}$$

where:

n_p – number of signals that exceed permissible deviations on the analysed section,

n – number of signals on the analysed section.

The following equation is used to calculate the indicator of five-parameter defectiveness W_5 [PKP... 2005c]:

$$W_5 = 1 - (1 - W_e) \cdot (1 - W_g) \cdot (1 - W_w) \cdot (1 - W_z) \cdot (1 - W_y) \tag{3}$$

where:

W_e – value of the track gauge defectiveness indicator,

W_g – value of the track’s superelevation’s defectiveness indicator,

W_w – value of the track twist's defectiveness indicator,
W_z – the arithmetic mean value of the defectiveness of vertical roughnesses measured for the left and right rail,
W_y – the arithmetic mean value of the defectiveness of horizontal roughnesses measured for the left and right rail,

The obtained values of synthetic indicators make it easier to make right decisions about the treatment of the sizes/values of some variables of condition as hazard sources.

3.3. The use of codes of practice

The managers of the railway infrastructure, in their internal instructions, set out the standard way of interpretation of the collected results of diagnostic tests. The application of these guidelines enables making a decision to treat variables of condition as hazard sources. Codes of practice used by PKP PLK were collected in the instruction Id-1 [PKP... 2005a].

In the case of variables of condition related to geometry of the track, the infrastructure manager has developed a set of permissible deviations, some of which are presented in Table 1. For example, according to this table, the variables of condition such as "track gauge" and "difference in height of the rail heads" can not be considered as hazard sources if the analyses domain is a track of a maximum train speed of 70 km/h, gauge of 1444 mm (+9 mm) and the difference in height of rails of 20 mm.

Table 1

A list of permissible deviations of basic variables of track condition for manual measurements [PKP... 2005a, app. 13, tab. 2]

Speed [km/h]	The difference in the nominal track gauge [mm]	The difference in height of the rail heads [mm]
160	+6 –4	8
140	+8 –5	12
120	+9 –7	12
100	+10 –7	15
80	+10 –8	20
70	+12 –8	20
60	+15 –8	21
50	+17 –8	25

Using this type of codes of practice requires knowledge of the principles of their development described, among others, by Sancewicz [2010]. Permissible deviations of variables of condition contained in the aforementioned codes of practice can be divided into three groups:

− deviations which are the criterion of smoothness of train running, used in practice for most of the variables of condition,

− deviations which are the criterion of track degradation; exceeding these deviations results in rapid degradation of the track surface,

− deviations which are the criterion of safety; exceeding these deviations results in a significant increase of risk of some hazards.

Only deviations of track twist are defined and used as the criterion of safety, as they are most restrictive for this variable of condition. Exceeding deviations which are the criterion of smoothness of train running – in principle – does not have any impact on safety, but only on passengers' comfort. This means that such an exceedance does not necessarily result in the need to reduce the speed limit. However, estimation and evaluation of risk of hazards generated by the given hazard source is to be treated with rules other than the existing codes of practice (Fig. 1).

A similar approach was introduced in 2015 also to the other codes of practice of PKP PLK. The amended text of the instruction Id-1 says that the boundary lines of the durability of the track elements and the criteria for removing these elements from the track are not mandatory, but are only an auxiliary indication for skilled diagnosticians.

3.4. The use of reference systems

Expert systems used to search the analyses domain are also used to estimate and evaluate the risk of hazards generated by the identified hazard sources. From the point of view of risk management, information included in expert systems can be regarded as an domain/system of reference for the analyses domain. Expert systems currently implemented in PKP PLK enable, among other things, to determine the permissible axle loads and speed on the basis of the information about the structural elements of railway tracks and the type and condition of soil below the railway track.

In some cases of risk evaluation, diagnosticians use their own experience and historical data. An example of such a situation is described in one of the protocols [Office of Rail... 2016]. At one railway line, constructors used concrete sleepers, which had been designed to sustain the track gauge of 3 mm less than the nominal value. According to the statement of the infrastructure manager, it was meant to be a way to reduce sway. In reality, the value of that narrowing was even higher in many places, reaching up to 9 mm, and so it was larger than the permissible deviations for the speed of trains on that line. Knowing, however, that this track gauge would not change dramatically during the use of the railway line and that there are no large gradients in the gauge, the decision was made to accept the risk generated by the hazard source related to the variable of condition – “track gauge”.

In the aforementioned situation, the National Safety Authority questioned the decision of the infrastructure manager, because it was not documented in any way. Written justification for the chosen risk estimation and evaluation rule based on the reference domains/systems not only makes it easy to find the persons responsible for the decision taken, but also contributes to its better argumentation.

3.5. Risk treatment

The use of codes of practice and reference systems increases awareness of the level of risk of hazards generated in a given analyses domain. If this level, according to diagnostician of the infrastructure manager, is too high, he should propose risk reduction measures, which should be next implemented by the Operation Sections.

The choice of risk reduction measures falls within the competence of the infrastructure manager and is in no way imposed by the regulations. In the instruction Id-1, as a part of risk reduction measures, there is a requirement of changing the conditions of use of railway tracks by:

- limiting the permissible axle load and the loading gauge,
- introducing the speed limit,
- the exclusion of certain types of carriages, for example, dangerous goods.

In fact, diagnosticians often define also additional tasks to do, especially replacement of some of the railway track elements, tightening the screws, tamping the railway track, etc. The actual implementation of the proposed proceedings of dealing with the risk is relatively easily verifiable and is often the subject of control for the National Safety Authority. In all the cited protocols of controls carried out for the first four months of 2016 in the area of operation of the Poznan branch of the National Safety Authority, it was found that the infrastructure manager does not implement risk reduction measures [Office of Rail… 2016, unpublished].

4. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

On the basis of the developed and presented description of the actual processes within the system of maintenance of railway tracks in PKP PLK, it can be stated that they are supported by the processes which are a part of the risk management method set out in the relevant EU Regulation No 402/2013. Therefore, it is expected that further research on the relation of the track maintenance system and risk management methods will have a positive impact on their integration, which will contribute to a greater consistency of safety management systems and improve their effectiveness in the implementation of the objectives of the safety policy. For this purpose, the authors of this work suggest to:

− describe each type of research conducted in track diagnostics in terms of their usage in the process of management of risk of hazards related to the maintenance of the railway infrastructure. In particular, it is necessary to develop a process of description of variables of condition; such process would make it possible to write down the formal conditions for the treatment of these variables as hazard sources in order to use codes of practice,

− develop a tool for supervising the application of the rule of domain/system of reference in the process of management of risk of hazards related to the maintenance of railway tracks,

− examine the reasons for the use of rules for determining and measuring risk explicitly, used for certain hazards related to the maintenance of railway tracks,

− specify the interface between risk management carried out under a railway track maintenance system and risk management related to the activities of the infrastructure manager.

REFERENCES

Bałuch H., 2007, Ryzyko w eksploatacji nawierzchni kolejowej, Problemy Kolejnictwa, No. 145, p. 5–28.

Bałuch H., 2013, Zagrożenia w nawierzchni kolejowej – badania i przeciwdziałanie, Problemy Kolejnictwa, No. 158, p. 89–110.

Bałuch H., Bałuch M., 2013, Determinanty prędkości pociągów – układ geometryczny i wady toru, Instytut Kolejnictwa, Warszawa.

Bogdaniuk B., Towpik K., 2010, Budowa, modernizacja i naprawy dróg kolejowych, PKP Polskie Linie Kolejowe, Warszawa.

Chruzik K., 2014, Zarządzanie bezpieczeństwem w transporcie kolejowym, Wyd. Instytutu Technologii i Eksploatacji PIB w Radomiu, Radom.

Commission Implementing Regulation (EU) No. 402/2013 of 30 April 2013 on the common safety method for risk evaluation and assessment and repealing Regulation (EC) No. 352/2009.

Commision Regulation (EU) No. 1158/2010 of 9 December 2010 on a common safety method for assessing conformity with the requirements for obtaining railway safety.

Commission Regulation (EU) No. 1169/2010 of 10 December 2010 on a common safety method for assessing conformity with the requirements for obtaining a railway safety authorisation.

Directive 2004/49/EC of the European Parliament and of the Council of 29 April 2004 on safety on the Community's railways and amending Council Directive 95/18/EC on the licensing of railway undertakings and Directive 2001/14/EC on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification (Railway Safety Directive).

EN 45545-2 Railway applications – Fire protection on railway vehicles – Part 2: Requirements for fire behaviour of materials and components.

EN 60812 Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA).

Gill A., Kadziński A., Smoczyński P., 2016, Zrozumieć zarządzanie ryzykiem zagrożeń, In: Proceedings of Zrozumieć zarządzanie ryzykiem – ZZR'2016, Politechnika Poznańska, Poznań, electronic version.

Jamroz K., 2011, Metoda zarządzania ryzykiem w inżynierii drogowej, Wyd. Politechniki Gdańskiej, Gdańsk.

Jamroz K., Kadziński A., Chruzik K., Szymanek A., Gucma L., Skorupski J., 2010, Trans-Risk – an integrated method for risk management in transport, Journal of KONBiN, No. 1 (13), 2010, Wyd. ITWL, Warszawa, p. 209–220.

Kadziński A., 2013, Studium wybranych aspektów niezawodności systemów oraz obiektów pojazdów szynowych, Wyd. Politechniki Poznańskiej, Poznań.

Kadziński A., 2014, Zarządzanie ryzykiem zagrożeń na stanowiskach pracy, In: Lewicki L. (ed.), Sadłowska-Wrzesińska J. (ed.), Istotne aspekty bhp, Wyższa Szkoła Logistyki, Poznań, p. 149–195.

Kadziński A., Gill A., 2011, Koncepcja implementacji metody TRANS-RISK do zarządzania ryzykiem w komunikacji tramwajowej, Logistyka, No. 3, CD, p. 1053–1064.

Kadziński A., Kobaszyńska-Twardowska A., Gill A., 2016, The concept of method and models for risk management of hazards generated at railway crossings, Proceedings of 20th International Scientific Conference Transport Means.

Kadziński A., Warguła J., Gill A., 2012, Szacownie i wartościowanie ryzyka zagrożeń związanych z odcinkiem szybkiego tramwaju na poznańskiej sieci tramwajowej, Logistyka, No. 3, CD, p. 939–948.

Kobaszyńska-Twardowska A., Kadziński A., 2013, The Model of Railway Crossings as Areas of Analyses of Hazard Risk Management, Logistics and Transport, Vol. 18, No. 2, p. 85–91.

Krystek R. (ed.), 2009, Zintegrowany system bezpieczeństwa transportu (part 2), WKŁ, Warszawa.

Krystek R. (ed.), 2010, Zintegrowany system bezpieczeństwa transportu (part 3), WKŁ, Warszawa.

Mańka A., 2014, Analiza ryzyka w transporcie szynowym – metoda FMEA i dobre praktyki jej stosowania, Logistyka, No. 6, CD, p. 7058–7067.

Ng A., Loosemore M., 2007, Risk allocation in the private provision of public infrastructure, Vol. 25, Issue 1, p. 66–76.

Office of Rail Transport, 2016, Infrastructure manager supervision protocols, Poznań.

Pawlik M. (ed.), 2015, Interoperacyjność systemu kolei Unii Europejskiej – infrastruktura, sterowanie, energia, tabor, Kolejowa Oficyna Wydawnicza, Warszawa.

PKP Polskie Linie Kolejowe S.A., 2005a, Id-1 (D-1) Warunki techniczne utrzymywania nawierzchni na liniach kolejowych, Warszawa

PKP Polskie Linie Kolejowe S.A., 2005b, Instrukcja diagnostyki nawierzchni kolejowej Id-8, Warszawa.

PKP Polskie Linie Kolejowe S.A., 2005c, Instrukcja o dokonywaniu pomiarów, badań i oceny stanu torów Id-14 (D-75), Warszawa.

Podofillini L., Zio E., Vatn J., 2006, Risk-informed optimisation of railway tracks inspection and maintenance procedures, Reliability Engineering & System Safety, Vol. 91, Issue 1, p. 20–35.

Polish National Investigation Body, 2015, Raport nr PKBWK/1/2015 z badania wypadku kat. B10 zaistniałego w dniu 31 sierpnia 2014 r. o godz. 16:17 na szlaku Kraków Prokocim PrC – Kraków Płaszów KPa, Warszawa.

Sancewicz S., 2010, Nawierzchnia kolejowa, PKP Polskie Linie Kolejowe, Warszawa.

Sitarz M., Chruzik K., Wachnik R., 2012, Aplication of RAMS and FMEA methods in safety management system of railway transport, Journal of KONBiN, Vol. 24, No. 4.

Smoczyński P., 2015a, Database of railway accidents in the European Union, Journal of Mechanical and Transport Engineering, Vol. 67, No. 2, p. 37–50.

Smoczyński P., 2015b, European legislation related to supervision of railway system and its implementation in Poland, Logistyka, No. 3, CD, p. 4466–4475.

Smoczyński P., Kadziński A., 2015, Instytucje nadzorujące system kolejowy Unii Europejskiej wzdłuż projektowanej linii kolei dużych prędkości Rail Baltica, Logistyka, No. 3, CD, p. 4476–4486.

Smoczyński P., Kadziński A., 2016, Wymagania dotyczące wprowadzania do obrotu składników interoperacyjności na przykładzie szyny kolejowej, Pojazdy Szynowe, No. 2, p. 13–23.

Sowa A., 2016, Analiza poprawności użycia wybranych pojęć w rozporządzeniu wykonawczym UE nr 402/2013 dotyczącym transportu kolejowego, In: Proceedings of XXII Scientific Conference „Pojazdy szynowe 2016", Bydgoszcz – Gniew, electronic version.

Szymanek A., 2012, Teoria i metodologia zarządzania ryzykiem w ruchu drogowym, Wyd. Politechniki Radomskiej, Radom.

Szymanek A., 2014, Rozwój standardów zarządzania ryzykiem w transporcie drogowym, Logistyka, No. 3, CD, p. 6158–6191.

Wachnik R., 2016, System zarządzania utrzymaniem pojazdów kolejowych, jako narzędzie do monitorowania bezpieczeństwa, Uniwersytet Technologiczno-Humanistyczny im. Kazimierza Pułaskiego w Radomiu, Wydział Transportu i Elektrotechniki, PhD thesis, Radom.

WPROWADZENIE DO ZARZĄDZANIA RYZYKIEM ZAGROŻEŃ ZWIĄZANYCH Z UTRZYMANIEM NAWIERZCHNI KOLEJOWEJ

Streszczenie

Zarządzanie ryzykiem zagrożeń jest podstawowym narzędziem realizacji polityki bezpieczeństwa w ramach systemów zarządzania bezpieczeństwem, wdrożonych we wszystkich przedsiębiorstwach zajmujących się zarządzaniem infrastrukturą kolejową oraz wykonywaniem przewozów na zasadniczej sieci kolejowej Unii Europejskiej. Idea zarządzania ryzykiem zagrożeń jest jednak znacznie młodsza od systemu kolejowego i przez to traktowana niekiedy jako niezależny dodatek do działalności podmiotów kolejowych.

Celem artykułu jest zaprezentowanie, w jaki sposób procesy w systemie utrzymania nawierzchni kolejowej można wspomagać językiem metod zarządzania ryzykiem zagrożeń, aby móc je lepiej zintegrować z systemem zarządzania bezpieczeństwem zarządcy infrastruktury. Omówiono także wymagania dotyczące systemów zarządzania bezpieczeństwem oraz wskazano dalsze możliwe kierunki prac badawczych w zakresie metod zarządzania ryzykiem zagrożeń wspomagających procesy utrzymania nawierzchni kolejowej.

Słowa kluczowe: nawierzchnia kolejowa, system utrzymania nawierzchni kolejowej, metoda zarządzania ryzykiem zagrożeń, system zarządzania bezpieczeństwem