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Main Problems of Railway Cross-Border Transport Between Poland, Germany and Czech Republic

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Abstract: Railway cross-border transport is a special case of railway transport, which, due to the necessity of crossing the state border, raises many difficulties. They result from factors, among which the most important are other power systems, control systems, a variety of regulations regarding traffic management or even problems with communication, resulting from the different languages. These difficulties involve a number of consequences for the fluency and efficiency of transportation, but more importantly, have negative effects on safety. The article describes the main problems of cross-border transport on the example of Poland and two neighbouring countries (Germany and Czech Republic), which are also members of the European Union. For this purpose, in cooperation with the Polish railway undertakings, an analysis was carried out of processes conducted by these in the field of cross-border transport and identifies the main problems in this area. As part of the conducted research, potential solutions and improvements were also proposed. The article focuses solely on the issues of crossing the border and manoeuvring operations at stations close to the German and Czech borders, inasmuch as these processes constitute the largest area of activity of Polish railway undertakings within the framework of rail cross-border transport.

Keywords: railway; cross-border; transport

1. Introduction

Some adopted transport policies pay particular attention to territorial cohesion by means of different models of use and development [1] so as to get sustainable development. While the economic profitability and environmental impact of transport infrastructure were traditionally taken into account, territorial cohesion has now become an integral part of the deployment of new infrastructures or the improvement of existing ones [2].

In this regard, transport networks act as catalysts in unifying spaces [3] and providing structure to the territory, while reflecting the existing imbalance between urban systems and socioeconomic activities [4]. For these reasons they become crucial to the structure of the modern world [5].

This aspect becomes more important when the transport networks join different countries, as a unifying phenomenon within Cross-Border Cooperation (CBC).

Barriers arising in the area of Cross-Border Cooperation are a current and significant problem limiting sustainable development, in particular in the area of Europe and European Union countries. In the Euroregion analysed in this article, they are also discernible and desirable to solve [6]. General problems in the CBC area are also adequate in the area of transport itself, including rail transport (e.g., lack of mutual trust, insufficient knowledge of the partner's language and communication problems, differences in the legal and administrative conditions).

Continuous process of unification and integration of the railway markets of the European Union countries, both in terms of legal requirements and the application of similar organizational and technical

solutions, makes railway cross-border transport a significant and constantly growing share in this market [7–10]. Poland is an example of a country where this type of railway traffic (in the area of passenger and freight transport) is systematically becoming an increasingly important area of activity of railway undertakings and infrastructure managers [11–15]. The biggest area of activity of freight railway undertakings in this regard is to conduct border transport processes. This type of transport consists of carrying out the transport of goods in one country, crossing the border and performing manoeuvring operations at the border station. This article describes this type of transport and the main problems connected with it on the example of Poland and two neighbouring countries—the Federal Republic of Germany and the Czech Republic.

Due to the large number of railway border crossings in the west and south of Poland, and due to the increasing share of this type of transport in the total number of train services, problems related to cross-border transport are becoming more important and more significant. Problems associated with them can be divided into three main groups. The first one concerns technical aspects (various signaling systems, various power systems, various vehicle types). The second one is related to the differences in the documentation (e.g., instructions on traffic and signaling). The third group of problems is related to the use of different languages by train drivers, traffic controllers and other people involved in the transport process [16,17]. These problems can lead to very dangerous situations, which in extreme cases may lead to serious accident, accident or incident.

Currently, in the area of cross-border cooperation between the countries of the European Union, there are solutions, policies and activities to improve and develop it [18–20]. They concern promoting institutional and stakeholders permanent cross-border cooperation in the area of transport in selected parts of Europe (ACROSSEE [21]) or increasing accessibility of transport and reducing differences in this area in individual European countries (SEETAC [21]). Even in the area of railway transport, initiatives such as RETRACK (aimed at increasing the transport of goods between the countries of the Community by rail instead of by road) are noticeable [10]. However, these kinds of initiatives usually have a global scope. They can improve the operation of the entire system, but they do not usually solve local problems related to specific border crossing points. Confirmation of this situation can be found in the area of railway border crossings, where specific problems significantly impede the transport process and can lead to undesirable situations.

Railway border crossings between Poland, the Federal Republic of Germany and the Czech Republic was analyzed in the article in technical and organizational terms. Based on the experience of Polish railway companies as well article describes the most important and most common problems occurring during performing cross-border transport. Additionally, as part of the article, improvements that could be implemented were discussed, which could reduce the current problems and limit their possible effects.

2. Methodology

Currently, between Poland and the Federal Republic of Germany and the Czech Republic, rail traffic is carried out on 19 sections used in border traffic (8 between Poland and Germany, 11 between Poland and the Czech Republic). Individual sections are marked on the map shown in Figure 1.

The border sections differ from each other in terms of operational and technical aspects causing even greater inconvenience due to the need for knowledge of the requirements and regulations for specific sections, both by train drivers as well as people involved in the organization of transport in the structures of the railway undertaking. These differences result primarily from other track layouts of individual railway border crossings and railway traffic control devices installed on them, which makes it necessary to have a precise knowledge of the individual circumstances of individual points.

Detailed information and comparison of individual border sections are presented in Table 1.

Table 1 was developed on the basis of documents called "Local Border Agreement", which were created by infrastructure managers (PKP PLK and DB Netze and PKP PLK and Správa železniční

dopravní cesty respectively) for each border section and which were made available to railway undertakings operating on these sections.

Table 1. Comparison of railway border sections.

Item	Section	Stations	Electrification	Radio Communication	ATP/Signaling Devices	Safety System
Poland—Federal Republic of Germany						
1	Szczecin Główny—Löcknitz	Szczecin Gumieńce	Partially (3 kV DC)	Analogue	Centralized mechanical and relay	SHP
		Löcknitz	No	GSM-R	Combined signalling	PZB
2	Szczecin Główny—Tantow	Szczecin Gumieńce	Partially (3 kV DC)	Analogue	Centralized mechanical and relay	SHP
		Tantow	No	GSM-R	Combined signalling	PZB
3	Kostrzyn—Küstrin-Kietz	Kostrzyn	No	Analogue	Centralized mechanical	n/a
		Küstrin-Kietz	No	Analogue	Combined signalling	PZB
4	Rzepin—Frankfurt (Oder)	Rzepin	Yes (3 kV DC)	Analogue	Computer Ebilock 850	SHP
		Oderbrücke	Yes (3 kV DC, 15 kV AC)	GSM-R	Combined signalling	PZB
5	Tuplice—Forst (Lausitz)	Tuplice	No	Analogue	Centralized mechanical	SHP
		Forst (Lausitz)	No	GSM-R	Electronic	PZB
6	Gubin—Guben	Gubin	No	Analogue	Mechanical manual and centralized	SHP
		Guben	Yes (15 kV AC)	GSM-R and analogue	Light signalling system	PZB
7	Zgorzelec—Görlitz	Zgorzelec	No	Analogue	Light signalling system	SHP
		Görlitz	No	GSM-R	Light signalling system	PZB
8	Węgliniec—Horka	Węgliniec	Yes (3 kV DC)	Analogue	Light signalling system	SHP
		Horka	Yes (15 kV AC)	GSM-R	Light signalling system	PZB
Poland—Czech Republic						
1	Chałupki—Bohumín	Chałupki	Yes (3 kV DC)	Analogue	Relay	SHP
		Bohumín	Yes (3 kV DC)	GSM-R	Electronic	n/a
2	Zebrzydowice—Petrovice u Karvineé	Zebrzydowice	Yes (3 kV DC)	Analogue	Mechanical	SHP
		Petrovice u Karvineé	Yes (3 kV DC)	GSM-R	Hybrid	n/a
3	Międzylesie—Lichkov	Międzylesie	Yes (3 kV DC)	Analogue	Computer	SHP
		Lichkov	Yes (3 kV DC)	Analogue	Electronic	n/a
4	Głuchołazy—Mikulovice	Głuchołazy	No	Analogue	Mechanical manual and centralized	SHP
		Mikulovice	No	Analogue	Electromechanical	n/a
5	Mieroszów—Mezimesti	Mieroszów	No	Analogue	Electromechanical	SHP
		Mezimesti	No	Analogue	Electromechanical manual and centralized	n/a
6	Cieszyn—Česky Tešin	Cieszyn	Yes (3 kV DC)	Analogue	Relay	SHP
		Česky Tešin	Yes (3 kV DC)	GSM-R and analogue	Computer	n/a
7	Głuchołazy—Jindrichov	Głuchołazy	No	Analogue	Electromechanical manual and centralized	SHP
		Jindrichov	No	Analogue	Electronic	n/a
8	Zebrzydowice—Česky Tešin	Zebrzydowice	Yes (3 kV DC)	Analogue	Mechanical	SHP
		Česky Tešin	Yes (3 kV DC)	GSM-R and analogue	Computer	n/a
9	Szklarska Poręba Górna— Harrachov	Szklarska Poręba Górna	Yes (3 kV DC)	Analogue	Relay	SHP
		Harrachov	No	Analogue	Manual	n/a
10	Kamienna Góra—Kralovec	Kamienna Góra	No	Analogue	Electromechanical and mechanical	SHP
		Kralovec	No	Analogue	Manual	n/a
11	Zawidów—Višňová	Zawidów	No	Analogue	Manual	SHP
		Višňová	No	Analogue	Electronic	n/a

Abbreviations: PZB—Punktförmige Zugbeeinflussung—cab signalling and train protection system; SHP—Samoczynne Hamowanie Pociągu—safety device whose task is to ensure the safety of the train; GSM-R—Global System for Mobile Communications–Railway—international wireless communications standard for railways; n/a—no data available.

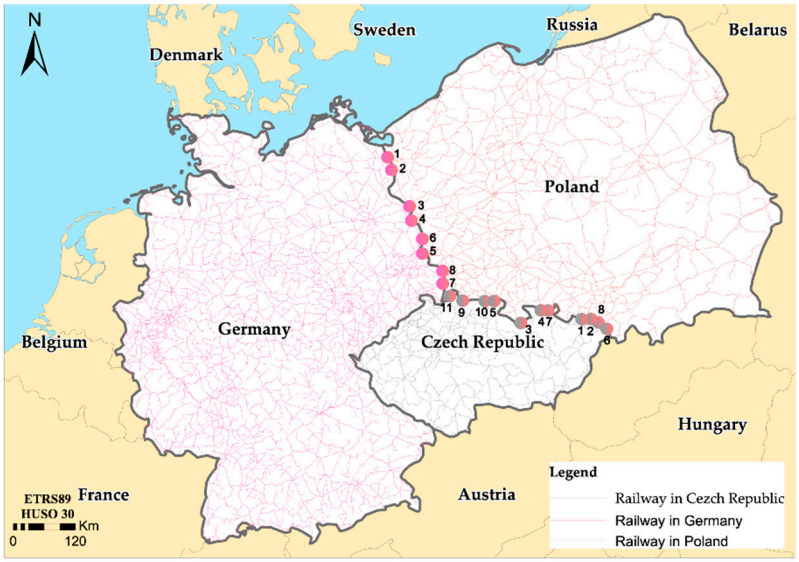

Figure 1. Railway border crossings between Poland and the Federal Republic of Germany and the Czech Republic (numbers in Figure correspond to numbers in Table 1).

There were also analysed data on railway freight cross-border transport between Poland, the Czech Republic and the Federal Republic of Germany, obtained from the President of the Office of Rail Transport (pursuant to [22] railway market regulator in Poland) in the mode of providing access to public information. The data consider the year 2017 (latest available data) and concern all border sections between the countries in question where the movement of at least one train took place. The data is presented divided into three groups, due to the way the border is crossed:

- The train started the route in Poland and finished abroad.
- The train started the route abroad and finished in Poland.
- The train started and finished the route in Poland, during which the border was crossed.

The third of the described ways of crossing the border by a freight train is overall the most common case of transport operations carried out, consisting of a transport service under which goods are transported outside of Poland, followed by manoeuvring operations at a border station. This method is also quite specific because in this case there is no classic transport on the railway tracks of a foreign infrastructure manager (border sections are a special case of rail infrastructure). This is due to the fact of existence two different railway systems at the same time (characterized by different rules of driving traffic, communication with traffic dispatcher, technical aspects, etc., whereby the rules of either infrastructure manager are not fully applicable in these specific areas.

The obtained data regarding this process are presented in Table 2.

To enable the data contained in Table 2 to be referenced to the total number of freight trains, data on the total number of freight trains dispatched in Poland in recent years was also obtained. These data relate only to trains that remained in service within the borders of Poland. In 2017, to which Table 2 applies, it was 381,260 trains, in 2018—393,455, in 2016—360,658 and in 2015—376,716.

Table 2. Number of freight trains crossing railway border crossings in 2017.

Item	Border Section	Number of Freight Trains Depending on the Way of Crossing the Border		
		Start in Poland Finish Abroad	**Start Abroad Finish in Poland**	**Start and Finish in Poland (with Crossing the Border)**
1	Bohumin—Chałupki	5046	5599	9067
2	Forst Lausitz—Węgliniec	1737	1790	294
3	Frankfurt—Kunowice	2772	2483	2665
4	Guben—Czerwieńsk	1778	1729	2171
5	Guben—Głogów	6	15	3
6	Kostrzyn—Kustrien-Kietz	685	720	171
7	Rzepin—Oderbruecke	4653	4938	3150
8	Zebrzydowice—Petrovice u Karvine	7701	7804	8616
	Total	24,378	25,078	26,137

3. Results

3.1. Analysis of Operating Parameters of Border Stations

After analysing the Local Border Agreements (data in Table 1), significant discrepancies in the operational conditions of individual railway border sections can be noticed. This applies both to crossings at two different borders and to border sections within one border. Discrepancies concern i.a. the telecommunications system. At all border sections in Poland, analogue radio communication is used, while in almost all German border stations and some Czech stations there is a modern GSM-R communication system. This fact causes obvious difficulties in communication between the train drivers and the train dispatchers because the vehicle crossing the border should be equipped with both systems. A similar situation occurs in the case of the catenary systems, and more specifically the type of power used in it. For Polish-German electrified railway border crossings, carriers crossing the border must contend with two different power systems–Polish based on a direct current of 3 kV and German using alternating current voltage of 15 kV. This fact makes it necessary to use multi-system locomotives whose design allows the use of several kinds of power. Alternatively (which is often happening at the Polish-German borderland), it is necessary to use diesel locomotives that are attached to the train composition by a single-system locomotive that allow the train to move within border stations. Analogously, there are two rail traffic protection systems that require the building of other types of devices on both the railway infrastructure and vehicles side. In the case of Polish border stations, it is the automatic train protection (SHP), while in the case of the German side, the PZB system. Both of these systems operate on a very similar principle and carry out similar functions. They consist of an on-board part mounted on the vehicle and a track-side part (resonant circuit tuned to the appropriate frequency). When the vehicle is over the sensor in the driver's cab, information about that fact is displayed. The driver is obliged to react to the information (pressing the button) thus proving his vigilance. If it does not do this for a certain, short period of time, the automatic braking of the train will be activated, which the driver can no longer control. Resonant circuits are mounted in most important places, for example before railway devices displaying signals about the possibility of driving or not. The Polish system (SHP) uses only one frequency—1000 Hz, and its functionality is limited to one point where the driver's vigilance is checking. The German system (PZB) uses resonators with three frequencies (500 Hz, 1000 Hz, 2000 Hz) that have different functions. The first two are used to warn the driver about the need to reduce the speed, while passing the third type resonator (2000 Hz), without its prior deactivation by displaying a signal allowing to drive, immediately activates emergency braking.

However, these systems are not compatible with each other and require separate infrastructure, and thus locomotive equipment in both systems at the same time. What is important in the documents of the Local Border Agreements regarding the Polish-Czech crossings, we do not find information about the systems built on the Czech side and the resulting requirements for railway undertakings.

3.2. Problems Resulting from the Local Border Agreements

The analysis of the documents of the Local Border Agreements poses many problems. These are extensive documents (some of them consist of even over 200 pages—as in the case of the Chałupki-Bohumin border crossing document), containing a lot of information that is often not systematically arranged. In addition, documents in terms of editing differ from each other making it even more difficult to read and assimilate the information contained in them. In particular, it is visible after comparing Czech and German documents—there is a completely different arrangement of contents (documents on Polish-Czech cross-border are created in both languages at once in a column layout). Even within documents regarding the same border, there are differences in fonts, layout of content, text formatting, etc. An important issue in this respect is the lack of a uniform approach to the description of rail traffic control and signalling systems occurring at individual border stations. This information is extremely important from the point of view of the recipients of documents—employees of infrastructure managers and railway undertakings operating within border stations. This fact causes significant difficulties in obtaining information on elementary issues related to railway traffic on a given station. There are situations where the document does not contain any information about the systems used at all (this is the case of crossing Zgorzelec–Görlitz, Węgliniec–Horka or Guben station). An additional difficulty in this area is the use of non-uniform naming for systems and devices related to the operation and safety of rail traffic, which results, for example, from the use of devices/systems from different manufacturers.

An undoubted obstacle for railway undertakings operating trains within border stations is also the multitude and diversity of systems found in various infrastructure managers. This is not only about the above-mentioned different power systems, radio communication or rail traffic safety, but also about difficulties caused by the use of mechanical signalling in addition to light signalling (as in the case of Głuchołazy and Kamienna Góra stations), other loading gauges (e.g., G-2 UIC–Oder and A PN-69/K-02057–Rzepin), or the simultaneous use of analogue radio and GSM-R (Guben).

In addition, the provisions in the Local Border Agreements directly related to safety may be worrying. For example, we find information: "Irregularities in the operation of rail border traffic should be immediately assessed and adequately solved" (Local Border Agreement of Szczecin Główny—Löcknitz border crossing) or "Problems encountered while conducting traffic on a section operated in border traffic must be immediately analysed and eliminated by both parties" (Local Border Agreement of Węgliniec–Horka border crossing) or "The local border agreement should be immediately supplemented with appropriate regulations if necessary" (Local Border Agreement of Kostrzyn—Küstrin-Kietz border crossing). The very ambiguous form of these provisions means that there are not really indicated units/persons responsible for performing the relevant activities, which were also not indicated in the documents. It is not difficult to guess that in the vast majority of cases when there is no railway accident in the strict sense, all kinds of dangers and potentially accidental situations remain unrecognized. This is due to the fact that in accordance with the applicable law all serious accidents, accidents and incidents (of which the detailed catalog is contained in the relevant documents) must be reported to the National Safety Authority and National Investigation Body. Other situations that did not lead to the above events must be recorded and analyzed by railway undertakings, without the obligation to report them. Unfortunately, such a state may give rise to abuse and intentional concealment of dangerous situations. A definitely better solution in this respect would be to indicate detailed, systemic actions that should be taken by appropriate organizational units or employees of the infrastructure manager and railway undertaking at the time of undesirable situations.

3.3. The Main Problems from Railway Undertakings Point of View

In order to identify the most important and most common problems faced by railway undertakings during transport at border stations, three Polish rail companies were contacted. Selected undertakings specialize in railway freight transport in Poland but they also operate trains which crossing borders with Germany and Czech Republic. In all cases, conversations were held with company management

and a selected group of several train drivers to obtain information on the most common and significant difficulties for cross-border transport. As a result of discussions and analyses, a number of irregularities were found that significantly affect the correctness of the processes carried out during border traffic. It should be borne in mind that errors and problems described in the further part of the article have been identified as part of the collaboration with several railway undertakings and should not be treated as a source of common and general incompatibilities occurring during the transport process. On the other hand, they may indicate problematic areas important for infrastructure managers, which are potential for improvement, in which the introduction of specific corrective and preventive actions could have a significant impact on improving the safety and quality of services.

One of the significant problems reported by railway undertakings is the non-adaptation of the provisions of the Local Border Agreements to the actual conditions prevailing during the operation of border stations. The consequence of this is the non-compliance of carriers with certain provisions of these documents. An example here can be the use of the GSM-R communication system. In accordance with the provisions of the Local Border Agreement, a train driver operating a locomotive equipped with this system should activate it at the moment of commuting to the indicator informing about the need to switch the communication system. In fact, due to the necessity of a later stop of the vehicle due to the change of the power supply system (3 kV DC–15 kV AC), usually the GSM-R system is activated just at this moment. This is not the most advantageous solution, because it can be misleading traffic dispatcher who may not be aware of the lack of contact with the train drivers by radiotelephone. Among other things, for this reason, Polish train drivers crossing the German side contact the traffic dispatcher using a mobile phone. Often they do not even know the principles of GSM-R system operation, because they simply do not need it—it is not used by them, if their role ends only on bringing the train for the station on the German side.

A completely different problem is moving in the border traffic of single-system vehicles (one type of power system) and not equipped with the GSM-R system. This type of locomotive is not allowed on foreign infrastructure based on this method of communication. In connection with the above, there is often a situation in which the train must to drive another locomotive with a diesel engine. This causes some inconvenience to the train drivers, because the locomotive is deprived of external power while waiting. A locomotive without external power does not have the option of switching on the heating system, which forces train drivers to wait in the cabin, where the temperature is far from comfortable.

Other main problem in the area of border transport is the question of communication resulting from the use of other languages. This problem looks different in the case of the Polish-German and Polish-Czech borders. In the first case, it often happens that train drivers do not know German at all, but only a few key phrases enabling communication at a very elementary level. This type of solution works well when the transport process runs smoothly (there are no unexpected events, unplanned stops, rolling stock or infrastructure failures, etc.). Complications begin when difficulties arise. In the case of the Polish-Czech border, there is a slightly different problem. Since both languages belong to the group of Slavic languages, communication between employees of the railway undertakings and infrastructure manager seems to be easier. In reality, however, the similarity of these two languages results in the use of a specific mix of Polish and Czech, which is not really any of them. Experienced train drivers and train dispatchers have much smaller problems with this, while the work of people with less experience can lead to misunderstandings and misinterpretations of the provided information. It should be noted that the use of this type of communication is inconsistent with the requirements of the Local Border Agreements and it is natural that it can lead to dangerous situations regarding the flow of information.

4. Discussion, Conclusions and Future Research Directions

The area of rail cross-border transport is a constantly growing, important market segment, especially in the case of the European Union, almost completely uniform in terms of legislation, and the requirements related to crossing the border are kept to a minimum. This is primarily due to the

implementation of the second (2004) and third (2007) railway packages, which were group of European Union legislation which promote common standards and open access, working towards an integrated European railway area. In particular, this was due to implementation of directive 2004/49/EC and directive 2007/59/EC. Simplification and harmonization of border crossing regulations is, of course, desirable and necessary in order to enable economic development and trade. However, it should be realized that the lack of proper supervision and too liberal regulations may lead to undesirable situations in which the level of safety may be alarmingly lowered. The analysis carried out under this article allows to conclude that issues related to the crossing of the Polish-Czech and Polish-German border by railway freight undertakings are subject to certain threats and cause problems, which in consequence may lead to undesirable events. Often the signals and information coming directly from railway market participants regarding problems in border traffic are disturbing. It would be advisable to consider the possibility of introducing systemic, general and comprehensive, yet simple and understandable solutions, compliance with which would guarantee safe transport. It is understood that technical problems, such as different power supply or signalling systems, are not possible to solve in a quick and cost-free way, nevertheless the analysis carried out indicates that a number of problems are related to communication, which with a little good will of both parties, could be solved or it would be possible to limit their possible effects.

The main conclusion resulting from the conducted analysis is that it is necessary to consider the possibility of updating the Local Border Agreements in order to unify, simplify and delete unnecessary records. According to the authors, it is possible to reduce the scope of these documents, leaving only the most important and necessary information. It would also be appropriate to ensure a unified form, regardless of the border which the document concern, which would guarantee exactly the same distribution and scope of content. Undoubtedly, this solution would contribute to better understanding the documents by railway employees, and thus to their correct application. For example, in case of use technical devices/systems from different manufacturers it seems that the proper solution would be to introduce a requirement to describe issues related to traffic control and signalling in the form of a short table, identical for each border crossing, in which only specific phrases and names could be used. This procedure could have a significant positive impact on the ability to quickly and accurately obtain information on important issues of rail traffic operation. Secondly, it is necessary to consider the possibility of increasing the enforcement of provisions contained in the Local Border Agreements. Currently, knowledge of the content of these documents is practically not verified in any way and very often railway employees rely on their experience, not on specific guidelines on the operating rules of a specific railway border crossing. Furthermore, it is hard to be optimistic about the dead letters in documents. An example here may be the information that railway undertakings operating trains at border stations should develop instructions for their train drivers in moving along the border sections. Although this provision from the point of view of rail safety is desirable, and the instructions in question would certainly improve its level, it unfortunately is not reflected in reality, because the vast majority of carriers do not develop such documents. Thirdly, it is advisable to organize meetings with all interested parties in order to identify threats and problems related to the railway cross-border transport and to counteract them. Such meetings of railway undertakings with infrastructure managers would undoubtedly have a positive impact on information exchange and safety. Rail companies contacted by the authors express a big interest to participate in such initiatives.

The most important direction of further research will be the analysis of subsequent railway border crossings in Central and Eastern Europe, in view of the difficulties encountered while crossing the borders. Particularly interesting in this respect may be the case of countries outside the European Union, especially the countries that were part of the Soviet Union (for example, Belarus, Ukraine) because apart from the problems mentioned in the article there is also the issue of different track gauges (1435 mm–1520 mm) causing the necessity of applying technical or spatial planning solutions to overcome this barrier.

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