

## Safety of Rail-Road Crossings at the Hinterland of the Port of Gdynia

M.J. Nowakowski

*Gdynia Maritime University, Gdynia, Poland*

**ABSTRACT:** In order to exploit the possibilities of the Outer Port in the Port of Gdynia, it is necessary to ensure appropriate transport accessibility from the hinterland. Rail transport will play a leading role in this area. In this context, it is important to ensure appropriate technical and operational parameters along the entire length of the Polish part of the TEN-T network. In the immediate vicinity of Gdynia this means the comprehensive modernisation of the railroad line no. 201. The most frequently mentioned parameters include the speed of goods trains, useful lengths of station tracks and permissible axle loads. Far too little attention is paid to the issue of traffic safety at the numerous rail-road crossings located on the line. This is an especially important subject for the residents of areas adjacent to the line, especially in the context of a radical increase in rail traffic.

### 1 CONSTRUCTION OF THE OUTER PORT IN THE PORT OF GDYNIA

The Port of Gdynia is currently the second in Poland in terms of total cargo weight transhipped (after the Port of Gdansk). It is a modern all-in-one port, where the following facilities are located:

- bulk terminals: Aalborg Portland Polska Ltd., Alpetrol Ltd., Baltic Bulk Terminal Ltd., Baltic Grain Terminal Ltd., HES Gdynia Bulk Terminal Sp. z o.o., Koole Tankstorage Gdynia Ltd;
- ro-ro and conventional general cargo terminals operated by OT Port Gdynia Ltd;
- two container terminals located in the Western Port: BCT (Baltic Container Terminal Ltd.) and GCT S.A. (Gdynia Container Terminal S.A.).

Transshipments at the port are steadily increasing and, despite the unfavourable global situation, reached record levels in 2020 (Figures 1 and 2). The response to this growing demand should be the port expansion. It is also necessary due to the rapid

development of competing sea ports in the Baltic and North Sea basin and the forecasts indicating an increase in container throughput in Polish sea ports to a level of approx. 9.5 million TEUs in 2050.

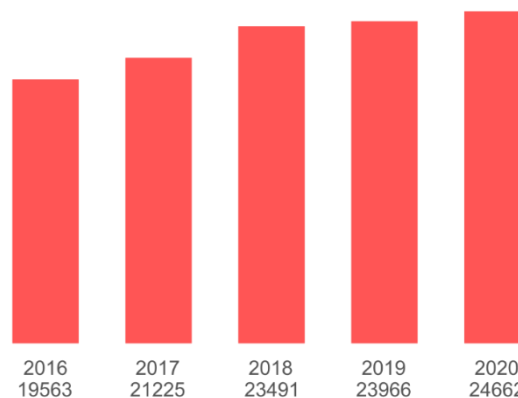


Figure 1. Total transshipments in Port of Gdynia between 2016 and 2020 (in thousand tonnes) [23]

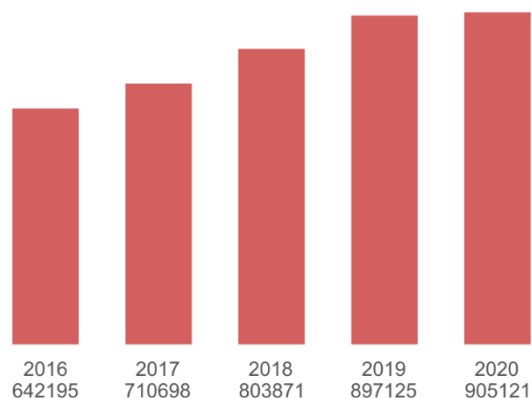


Figure 2. Container transshipments in the Port of Gdynia between 2016 and 2020 (in TEUs) [23]

The existing container terminals have limited handling capacity, and above all – in comparison with the competitive port of Gdansk in this respect – are not able to handle the largest ocean-going vessels. Hence the decision to launch an investment called “Construction of the External Port of the Port of Gdynia”. Since there is no possibility of enlarging the Port of Gdynia towards the land, as it is surrounded by the residential and commercial districts of Gdynia, and the possibilities of acquiring new land around the existing port basins have been practically exhausted, the decision was made to locate the External Port on a new pier built outside the existing Southern Breakwater, in the waters of the Gulf of Gdańsk in the area of the Main Approach Fairway.

The most important functional element located at the new jetty will be a deepwater container terminal capable of handling ocean-going vessels with Baltmax parameters, i.e. up to 430 metres long, 60 metres wide and with a draught of up to 15.5 metres (Figure 3). This will increase the container handling capacity of the Port of Gdynia from the current 1.8 to 4.3 million TEUs [22].



Figure 3. Visualization of the Outer Port in the Port of Gdynia [22]

An increase in transshipment in the port is tantamount to an increase in traffic on its connections with the hinterland. Most of this increase will concern railway transport. This is based on the assumptions included in [35]. They predict, among other things, shifting 30% of road freight transport over distances greater than 300 km to other modes of transport (rail, water transport) by 2030, and 50% of this type of transport by 2050.

In 2018, the 24-hour average number of goods trains arriving at the Port of Gdynia was 21.75 pairs, of which 2.25 pairs concerned traffic towards Wejherowo [14]. As for the projected volumes, they are presented in the document “Development of the Feasibility Study for the task: ‘Improvement of infrastructure of railway access to the Port of Gdynia – Preparatory works’” developed in 2015. The forecasted increase in the amount of reloaded goods, primarily containers, will translate into an increase in the number of goods trains necessary to serve the Gdynia Port station to 109 pairs per day in the perspective of 2045 [9]. An over fivefold increase in the number of trains compared to the present state requires a careful examination of the capacity of the railway lines connecting Gdynia with the hinterland.

## 2 RAILWAY TRANSPORT CORRIDORS IN THE HINTERLAND OF THE PORT OF GDYNIA

The need to connect the newly built port in Gdynia with the hinterland by means of an efficient railway transport was understood already in the interwar period. Therefore, one of the most important infrastructural investments of the Second Republic of Poland was the construction of railway line No. 201, running through Bydgoszcz Leśna, Wierzchucin, Lipowa Tucholska, Koscierzyna, Somonino and Gdynia. It formed part of the so-called Coal Main Line connecting Silesia with the newly established port, bypassing the Free City of Gdansk. After the end of WWII, as a result of the change of national borders and electrification of the railway line No. 131 Chorzów Batory - Tczew, its use for freight transport was marginalised [15]. Goods trains from Silesia to Gdynia started running via Tczew, sharing the Tczew – Gdańsk Główny route with trains running on line no. 9 Warszawa Wschodnia Osobowa – Gdańsk Główny, and further to Gdynia on line no. 202 Gdańsk Główny - Stargard.

Poland’s accession to the European Union was an important impulse for the development of rail connections between Gdynia Port and the hinterland, as a result of which the Gdynia Port station directly serving the port was included in the trans-European TEN-T and AGTC networks [24]. This is a kind of ennoblement, but also a great challenge in terms of technical and operational requirements. For users of rail freight transport, the most important are three basic parameters, the values of which were ultimately defined for the lines included in the network in [5] as follows:

- the minimum road speed for goods trains – 120 km/h;
- goods train length – 750 m;
- acceptable axle loads – 200 kN/axle (221 kN/axle at 100 km/h).

The location of the Port of Gdynia in the system of the Polish part of the TEN-T and AGTC networks is shown in Figure 4. It also includes the names of border stations located on transport corridors used in relations with the Port of Gdynia.



Figure 4. Location of Gdynia in the Polish part of the TEN-T and AGTC networks. Based on [18, 24].

The most important direction for goods transport from the Port of Gdynia is currently the C-E 65 corridor leading south to the border crossings with the Czech Republic (Chałupki and Zebrzydowice) and Slovakia (Zwardoń). The connection is currently provided by a line consisting of three railway lines numbered (in order) 202, 9 and 131. This is one of the best adapted freight railway corridors in Central Europe. The listed main railway lines and their complementary freight bypasses and connectors are fully electrified, double track, suitable for the relevant speeds, axle loads and have the required useful track lengths. The requirements listed in [24] are fulfilled on the route Gdynia Port – Tarnowskie Góry for the destination points in Zebrzydowice and Zwardoń or to the station Herby Nowych in the direction to Chałupki. The remaining part of the route runs through the Upper Silesian Industrial District and the Rybnik Coal District. The dense railway network in the area causes numerous difficulties, primarily associated with obtaining adequate station track lengths and operating speeds. The works carried out and planned will enable the passage of trains with a length of 750 m on the entire Gdynia Port – Zebrzydowice/Chałupki route after 2024.

However, the key problem of the C-E 65 corridor lies right outside the gates of the port of Gdynia. It is the capacity of the Gdynia – Tczew section. The dynamic development of sea ports in Gdańsk and Gdynia goes hand in hand with the development of the Tricity agglomeration. This is associated not only with the development of trade, but also with the growing demand of the population of the Tricity agglomeration for agglomeration and inter-agglomeration transport. The proverbial drop that broke the camel's back was the ill-considered conversion of the Gdańsk-Oliwa station into a passenger station within the project "Modernisation of the E65/C-E65 railway line on the section Warsaw – Gdynia – the area of LCS Gdańsk, LCS Gdynia". As a result, on line 202, which is the backbone of the Tricity transportation system, the critical route Gdańsk Wrzeszcz – Sopot was created, on which, due to the unfavorable location of SBL interlocking semaphores, the train interval is additionally extended by trains stopping at Gdańsk Oliwa station (in practice – by all passenger trains running between Gdańsk and Gdynia

on line 202) [10]. The analyses presented in [10, 11] show that currently the main railway corridor of the Pomeranian conurbation on the section Gdańsk Główny – Gdynia Główna is characterised by completely exhausted or depleting capacity. Additional traffic from the port of Gdynia forecasted in the perspective of 2045 will not be able to be handled by this section. This has resulted in renewed interest in line no. 201 as an alternative route connecting Gdynia with the hinterland by rail. Currently, the project "Works on the alternative transport route Bydgoszcz – Tricity" is being implemented, which assumes, among others, upgrading the 201 line to double-track along its entire length, its electrification and adaptation to the requirements defined in [24]. When the works are completed, railway lines 201 and 131 will form the core of the connection between the Port of Gdynia station and the southern border of Poland.

An alternative connection to the Czech Republic is provided by a corridor connecting Gdynia with the Międzyzlesie-Lichkov border crossing. The initial section of the route runs together with the corridor to Chałupki/Zebrzydowice/Zwardoń, i.e. via lines 201 and 131. At the Inowrocław railway junction the route deviates to the south-west and via line 353 runs through Gniezno to the Kobylnica station and then via line 394 to the Poznań-Franowo station. After passing through Poznań railway junction the route leads from Luboń along line 271 to Wrocław-Popowice station and further through Brochów and Lamowice to Międzyzlesie.

Currently, the Gdynia Port – Międzyzlesie corridor has full TEN-T and AGTC network parameters only in the sections to Inowrocław (without line no. 201) and on line no. 271 from Luboń to Wrocław-Popowice. Travel on the remaining part of the route encounters numerous operational restrictions. In the section Inowrocław – Gniezno – Poznań Franowo there is a train speed limit of 70-100 km/h. The final section of the corridor, from Wrocław to Międzyzlesie, permits the passage of trains with a maximum length of 640 metres. The investment works in progress will allow trains of a length of 750 metres to run from 2028 [16, 30].

Access from Gdynia to the Terespol-Brest border crossing is via the main corridors of the TEN-T network: railway line no. 9 (corridor C-E 65) to the Warsaw railway junction and further via railway line no. 2 (corridor C-E 20). Railway line no. 9 is a double track and electrified main line, upgraded to TEN-T network parameters, connecting Tri-City with the capital city. Railway line no. 2 is also a fully modernised double track and electrified railway line running from Warsaw to the border with Belarus and further towards Moscow via Brest and Minsk. It is the direct entrance to Poland of the China-Europe Silk Road.

The corridor almost along its entire length has full TEN-T and AGTC network parameters, except for the Tczew and Warsaw railway junction. A weak point of the entire corridor is the heavy passenger traffic and the lack of an alternative route from Gdynia to Terespol, bypassing the Tricity cross-city line. Additionally, investments carried out under the National Railway Programme do not envisage the

elimination of the onerous restriction of train length to 650 m in the area of the Warsaw railway junction [16, 30]. This will not be possible until after 2028.

The last of the corridors presented in Figure 4 leading from Gdynia to the border crossing in Kuźnica Białostocka is an alternative to connecting Gdynia with the China-Europe Silk Road. The core of the route is railway line No. 9, which can be used to reach Warsaw. Then, via connecting passages, through the Warszawa Wschodnia Towarowa station and railway line no. 449, one can reach railway line no. 6, which runs to Kuźnica Białostocka itself. Alternatively, you can exit at Iława from line no. 9 on line no. 353 to Korsze and continue on line no. 38 to Białystok, where you join up with line no. 6.

The corridor to the border crossing Kuźnica Białostocka has full TEN-T and AGTC network parameters only on railway line no. 9. On the remaining lines there are operating difficulties in the form of lowered axle loads, useful station track length below 700 metres and parts of lines in single-track standard. In addition, most lines are heavily laden with passenger traffic, which affects the capacity of the lines, especially in the sections near the agglomeration. The most important investment in this direction included in the National Railway Programme is the project for modernisation and construction of Rail Baltica [16, 30], which is tangential to the corridor in question in the section Elk – Białystok. Equally important is the modernization and electrification of railway line no. 38 in section Korsze – Ełk. However, all these investments will not enable 750 m long train traffic on the whole route from Gdynia to Kuźnica Białostocka.

The current status of operational restrictions on these TEN-T corridors is shown in Figure 5.

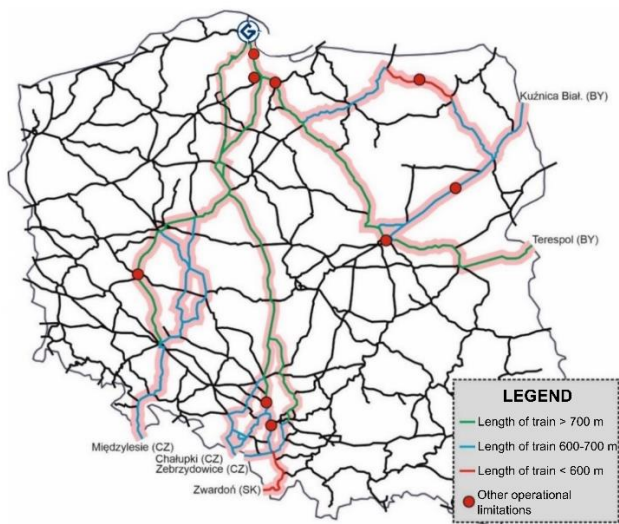


Figure 5. Map of operational restrictions on the analysed corridors — as of 12.2019 [14]

### 3 MODERNISATION OF HINTERLAND RAIL TRANSPORT AS A CONDITION FOR THE DEVELOPMENT OF THE PORT OF GDYNIA

Operational parameters presented in [5] influence the capacity of a railway line, which comes down to the number of trains running on the line per day and their weight [3]. The factors determining the weight of trains are permissible axle loads (limiting the weight of a wagon) and the usable length of station tracks, which translates directly into the maximum length of a train and, consequently, the number of wagons in its composition. The maximum number of trains of a given type per day is influenced by the operational speeds of trains, types of junctions encountered on route and station tracks and the train control system. Adaptation of lines included in the TEN-T/AGTC network to the postulates of [5] therefore means the necessity of carrying out specific investment activities in the rail transport infrastructure.

The most costly is usually to adapt the line to increased train speeds. This usually requires adjustment of the line's geometric layout in horizontal alignment to a various extent (depending on the existing parameters of the line). In extreme cases, it is necessary to relocate a section of the line, changing its course in the field. In such cases, procedures typical for construction of a new railway road (including purchase of land) are applied. Apart from the routes, the layouts of stations and traffic posts will also require modernisation, with the replacement of turnouts and new alignment of turnout routes as a rule. For example, each double slip switch located in the main tracks will have to be replaced with a pair of ordinary turnouts (a slip switch allows travel at a maximum speed of 100 km/h on the straight track).

The adaptation of the line to the new, longer length of the goods train is also a significant interference in the track systems of the stations, where at least one additional main track must have a length enabling the entry of such a train [27, 28, 32]. This should be treated as an absolute minimum solution and the aim should be to have a situation where the longest train can be accommodated by any auxiliary main track. The lengthening of the station layout forces the occupation of adjacent land and is often hampered by adjacent pre-station arches.

Adapting a line to the new, higher axle loads requires an analysis of the substructure strength and its reinforcement, as well as the selection of the appropriate superstructure standard - type of rails, sleepers, fasteners, ballast of the appropriate grade and of a specified minimum thickness under the sleepers. This often involves the replacement of the entire superstructure of the track and station tracks. The total thickness of the superstructure is then increased, which requires the reconstruction of level crossings along the entire length of the line and adjusting the road profile at the crossing to the new rail head profile. Larger axle loads also require checking the load capacity of all railway bridges and viaducts along the entire length of the line and, if necessary, reinforcing or rebuilding them.

All the above-mentioned activities occur in the context of an investment of key importance to the efficient functioning of the External Port of Gdynia -



the modernisation of the railway line no. 201. The implemented project “Works on the alternative transport route Bydgoszcz – Tricity” assumes, among other things

- upgrading the line to double-track over its entire length;
- raising the maximum speed to 160 km/h for passenger trains and to 120 km/h for goods trains;
- electrification of lines;
- modernisation of traffic control equipment.

At present, the 201 line has a local character and the traffic on it is characterised by the intensity of a dozen or so pairs of trains per day (except for the Glinicz - Gdynia Główna section, where it increased to 32–52 pairs of trains per day after launching the PKM line). This is practically exclusively passenger traffic [9]. An increase in traffic generated by Gdynia Port station to 109 train pairs per day in 2045 and operational limitations on lines no. 9 and 202 will necessitate redirecting approx. 80% of this value to line no. 201, which means an increase in freight traffic to 90 train pairs per day. Such a dramatic increase in freight traffic will mean that the line, which is currently used by an average of 20 pairs of trains per day (mostly railbuses), will not only change its character, but will also have a considerable impact on the environment in which it runs.

The railway line, connecting the territory along its course, must at the same time secure the functioning of local transport running across its course. Such interaction with the environment is provided by – among others – road-rail-road crossings. Their influence on the costs and final effects of modernisation of railway lines has been underestimated several times in the past in Poland. This was, among others, the case during consecutive modernizations of railway line no. 3 Warszawa Zachodnia – Kunowice [3] and during the modernization of railway line no. 9 Warszawa Wschodnia - Gdańsk Główny to the speed of 200 km/h [19]. In the first case, resignation from the reconstruction of crossings into collision-free two-level crossings effectively limited the operating speed on the line despite its favourable geometrical parameters in this respect. In the second case, delays in the construction of collision-free crossings increased the travel time of Pendolino trains on the route from Warsaw to Gdańsk by several minutes.

#### 4 RAIL-ROAD CROSSINGS AT THE BACK OF THE PORT OF GDYNIA

##### 4.1 Traffic safety at rail-road crossings

A rail-road crossing is, according to the definitions given in [26, 33], a single level crossing of a railway line or siding with a public road. If the public road is intended only for pedestrian traffic, we are dealing with a crossing. The basic task of rail-road crossings is to enable road traffic participants to safely cross the railway line.

Article 25 of the law [21] stipulates the absolute priority of a rail vehicle at a rail-road crossing, while Article 28 defines the duties of a road traffic participant, formulating them as follows: “The driver

of a vehicle, when approaching a railway crossing and when passing through a crossing, is obliged to exercise particular care. Before entering the track, he is obliged to check whether a rail vehicle is approaching and to take appropriate precautions ...”. This provision and the fact that the braking distance of a train is an order of magnitude longer than the braking distance of a car (see [7, 12]) force installation of the majority of safety devices and markings only on the road side in order to warn road users of an approaching train. From the railway line side, only the W 6a and W 6b indicators are installed and – in justified cases – crossing warning boards informing about the efficiency of road traffic protection devices at the crossing [13].

Crossings are categorised according to the safety features used on them. The best secured category A crossings are those operated by a qualified worker and equipped with a horn that closes the whole width of the carriageway. At the opposite end are category D crossings, which do not have any protective devices apart from “Stop” and “St. Andrew’s Cross” road signs. The criteria according to which a crossing is qualified to a given category are the number of tracks on the crossing, traffic product, train speed and visibility conditions [26].

The number of crossings and rail-road crossings on the PKP network has been systematically decreasing for several years. Currently (beginning of 2021) there are 13936 such crossings (including 482 crossings, i.e. category E and 850 non-public crossings - category F), which means a decrease by 4189 in relation to the year 2000 [1]. To this should be added the so-called “wild” crossings, the number of which – according to the data of the General Headquarters of the SOK – in 2019 was 44150 [31]. Unfortunately, these are the places where most accidents occur on the railway network, involving hundreds of victims. This can be traced to the summary presented in Table 1.

Table 1. Casualties at rail-road crossings of all categories and illegal crossings 2015-2019. Based on [31]

Location	Fatal casualties					Seriously injured				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Rail-road crossing	55	48	42	49	60	41	39	29	33	22
Illegal crossing	168	119	127	140	98	57	44	48	37	42

What escapes common attention is the fact that mass crossing of tracks in unauthorised places causes significant losses in the ballast, which violates the conditions of stability of the contactless track in these places and may cause a railway disaster. Figure 6 shows an unauthorised crossing on the Reda – Hel line less than a year after the main track repair. The lack of ballast from the front of the sleepers is clearly visible, which in this case – in the horizontal curve of the contactless track – poses a danger of buckling.

Accidents at places designed for crossing railway lines (at crossings and rail-road crossings) occur irrespective of the category of the crossing, as shown in Table 2. They are most often caused by the mistakes of road users – disregarding the “Stop” sign and red

lights, driving under falling horns, slaloming around closed semicrossings and driving on the tracks when there is no room to exit the crossing.



Figure 6. Defects in the ballast at an illegal track crossing

Table 2. Accidents at crossings of all categories 2015-2019. Based on [31]

Category	Number of accidents				
	2015	2016	2017	2018	2019
A	17	15	14	7	13
B	20	19	23	27	19
C	36	26	27	40	27
D	123	147	141	132	126
E	7	5	9	9	9
F	5	0	0	0	0
<b>Total</b>	<b>208</b>	<b>212</b>	<b>214</b>	<b>215</b>	<b>199</b>

Despite numerous activities carried out by the President of UTK, the infrastructure manager, the Railway Guard and the Police, accidents at rail-road crossings constitute a major part of all railway accidents (Figure 7). It should be noted that the influence of railway sector entities on minimising risk at these places is limited. Their role is limited to equipping crossings with modern protection and warning devices for drivers, installing systems to record violations of laws by road traffic participants and building collision-free (two-level) crossings.

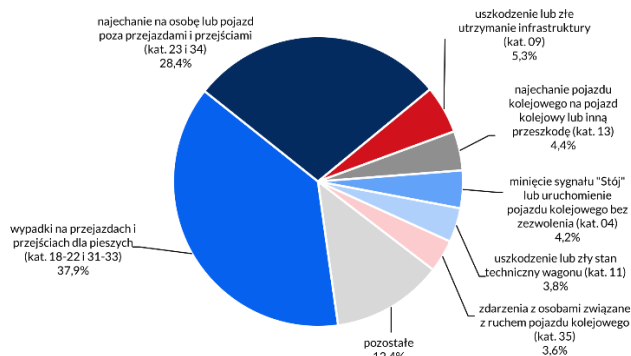


Figure 7. Percentage of rail accidents in 2019 by category [31]

Accidents at rail-road crossings are commonly thought of as a collision between a heavy, multi-tonne train and a passenger car, which is clearly associated

with casualties among road users only. However, changes in the structure of road and rail traffic have led to an increasing number of heavy road vehicles with trailers being driven on the roads, and to an increasing number of relatively light rail buses appearing on rail lines, especially local ones. As a result, a new category of accident has been observed: collisions between a light train and a heavy road vehicle. In such situations, casualties also occur among the train passengers, and the material losses include a premium-class train set that is sent for costly repairs or a totaled rail bus. One of the most tragic accidents of its kind occurred in Spain at Masalfasar station in November 1976. There, a passenger train from Barcelona collided with a lorry loaded with steel girders at a crossing. After the collision, the train pushed a trailer with girders in front of it for several hundred metres, destroying residential buildings located along the track. Fourteen people were killed and 21 injured [4].

It should be stressed that the only measure that will eliminate the risk of an accident at a rail-road crossing is its removal or replacement with a collision-free (two-level) crossing. This is an expensive solution, but the only one that is 100% effective. This is confirmed by the fact that despite modernization works at crossings and educational campaigns such as 'Safe crossing' or 'Railway ABC campaign', the number of fatalities remains at a constant level of about 50 people per year and the number of seriously injured people – about 30 people/year. Sweden's experience in implementing the Vision Zero Initiative in road traffic has encouraged some countries to promote the same vision for rail-road crossings. In Australia, the State Government of Victoria, as part of the Level Crossing Removal Project (LXRP) plan, decided to convert 75 crossings located in the Melbourne metropolitan area into collision-free crossings [17]. The most frequently cited benefits of this solution are improved traffic safety, reduced congestion and increased rail capacity. In Europe, a similar approach was implemented in Spain, restrictively limiting the possibility of leaving single level crossings in the case of railway projects [8]. This has been reflected in the relevant legislation.

Activities carried out in Poland to improve safety at railway and road crossings are not unequivocally positive. This was shown in the report of the Supreme Chamber of Control where only the activities of the President of UTK were assessed positively (however indicating their low importance) while the activities of the infrastructure manager, road managers and the Police were assessed negatively [2]. The report also points to a significant inconsistency in activities aimed at improving safety at crossings. On the one hand, there is a tendency to install modern safety devices on crossings, which relates to their reclassification from category D to B and C, while on the other hand regulations have been introduced which make it difficult to change this category. This refers to the basic parameter for the categorisation of crossings, i.e. the traffic product, whose threshold values were significantly increased in 2015 [26, 29]. This is presented in Table 3. These changes, made against the opinion of the President of UTK and in many cases making it practically impossible to reclassify D category crossings to a higher (better protected)

category, should be clearly assessed as savings made by the infrastructure manager at the expense of traffic safety.

Table 3. Changes in the threshold values of the product of traffic, qualifying a rail-road crossing into a given category. Based on [26, 29]

Category	Value of the product of traffic classifying the rail-road crossing into a given category	
	Based on Dz.U. 1996	Based on Dz.U. 2015
B	≥ 50000	≥ 150000
C	<20000; 50000)	<60000; 150000>
D	< 20000	< 60000

#### 4.2 Rail-road crossings on line 201

Information on the number and categories of rail-road crossings located on the transport corridors leading to the Port of Gdynia is presented in Table 4. This summary does not fully reflect the situation on the aforementioned corridors due to the fact that the density of crossings on their particular parts is highly diversified.

Table 4. Rail-road crossings by category on individual TEN-T corridors leading from Gdynia Port station. Based on [18]

TEN-T Corridor	Number of rail-road crossings of a given category					Total
	A	B	C	D	E	
Gdynia – Chałupki	72	28	40	192	8	<b>340</b>
Gdynia – Zebrzydowice	76	30	36	188	11	<b>341</b>
Gdynia – Zwardoń	85	44	51	212	22	<b>414</b>
Gdynia – Międzyzlesie	74	106	24	99	12	<b>315</b>
Gdynia – Terespol	36	78	0	1	4	<b>119</b>

The most favourable situation is on the route to Terespol, where line no. 9 is practically devoid of crossings except for short sections that were not adjusted to 200 km/h during the last modernisation. The two largest clusters of crossings are near Rybno Pomorskie (8 crossings between km 166.476 and 184.439) and the crossing over Narew near Modlin (6 crossings between km.41.258 and 49.840). On the entire line no. 9 there are only 22 crossings, the remaining 89 are located between Warsaw and Terespol. The situation is also good on the route to Międzyzlesie, where category C and D crossings were removed from the section between Gniezno and Poznan-Kobylnica during the last modernisation.

However, the most interesting is the initial fragment of the corridor, common for the relations to Chałupki, Zebrzydowice, Zwardoń, and Międzyzlesie, running on the line no. 201. There are 105 crossings and rail-road crossings (as of January 2021), the structure of which is shown in Table 5. Implementation of the project "Works on the alternative transport route Bydgoszcz – Tricity" means the reconstruction of 40 category D and C rail-road crossings into category B crossings and removal of the remaining ones. This raises an understandable controversy among the residents of municipalities adjacent to the investment, for whom even the

temporary elimination of crossings for the duration of the works often means the isolation of two parts of the city and a significant extension of daily mandatory travel. Local authorities are not interested in the construction of two-level crossings, because if they are constructed as road viaducts or pedestrian bridges over the railway tracks, the obligation of further maintenance of such facilities falls on local governments, which results from the provisions of [20]. There are also situations, when the administrator of the railway line informs about the need to preserve the crossing, but in the light of the law (§6-12 of the regulations [25, 26]) this is not possible, because the crossing is not located on a public road. A case, which is unique in Poland, is when the owner of a private plot of land cedes it to a municipality in order to leave a rail-road crossing located there [34].

Table 5. Rail-road crossings on the railway line No. 201 by category – as at 01.2021 [1]

Category A	Category B	Category C	Category D	Category E
12	4	8	77	4

To learn more about the needs and possibilities of reconstruction of rail-road crossings on the line no. 201, an on-site inspection was conducted on its section between the passenger station Bładzim-Dworzec at km 63.325 and the crossing within county road no. 1027C between the villages Zielonka and Cekcyn at km 75.608, where there are 11 public rail-road crossings. Particular attention was paid to maintaining visibility triangles at the studied crossings as the most important condition for road traffic safety. The results are not optimistic: the front of the train from the required distance is visible only at one of the investigated D category crossings. At the remaining crossings the lack of visibility occurs in at least one triangle, with an average value of 3 unobserved triangles. It should be noted that according to [26], for an intersection angle of not less than 60° and the correct distance of the "St. Andrew's Cross" sign from the outermost rail at the crossing (i.e. 5.00 m), the distance L in the 5 m and 10 m triangles from which the front of the oncoming train should be visible for a speed of 120 km/h is 660.00 m. This means that at four of the crossings tested this value is greater than the distance between the adjacent crossings.

When considering – in the perspective of 2045 – the necessity of upgrading the category or converting the analyzed crossings to collision-free crossings only due to the existing regulations, the available information on the volume and structure of railway traffic and road traffic volume was analyzed. This information is important for calculating the product of traffic and the daily traffic closing time at the crossing.

As mentioned, the line currently carries only passenger traffic. The traffic forecast for 2045 made in [9] predicts an increase in passenger traffic to the level of 28 pairs of trains per day. To this should be added the previously assumed freight traffic volume of 90 train pairs. This gives a total of 118 pairs of trains per day, i.e. an increase of 102 pairs compared to the current traffic.



The planned increase of the maximum train speed on the line No. 201 to 160 km/h requires, according to [26], reclassification of category D crossings to at least category B. At these crossings it is required to meet visibility conditions for 5 m triangles. Assuming  $V_{max}=160$  km/h for the calculations and taking into account the extension of the second track with the distance between track axles equal to 4.00 m we obtain (while maintaining the other design conditions) the value of  $L=1040.00$  m. It is greater than the distance between adjacent crossings for five out of 10 analyzed cases.

Information about the volume and structure of rail traffic and the volume of road traffic shall be relevant for the calculation of the traffic product and the daily traffic closure time at the crossing for the passage of trains.

Of the crossings visited, only one – 201 064 565 – lies at the intersection with a provincial road (DW240) for which results of traffic volume surveys performed by the General Directorate for National Roads and Motorways (GDDKiA) as part of the General Traffic Measurement are available. The last measurement for which results are available was performed in 2015 [6]. The average 24-hour traffic volume SDR was then 6570. Forecasting the increase in traffic volume according to the principles presented in [37] in Appendices 2 and 3, the value SRD=11027 was obtained for the year 2045. According to [26], this value qualifies the crossing to be reconstructed as a collision-free intersection. The most favourable option at this location is to build a road overpass along the DW240 road. There is space in the area to construct a temporary diversion and crossing for the duration of the project.

Traffic forecast for 2045 made in [9] predicts an increase in passenger traffic to the level of 28 pairs of trains per day. To this should be added the previously assumed goods traffic volume of 90 pairs of trains. This gives a total of 118 pairs of trains per day (an increase of 102 pairs compared to the current traffic). When analysing the crossing closure time necessary for trains to pass, the crossing equipment and traffic structure should be taken into account. For the calculations it was assumed:

- length of goods trains 750 m;
- average length of passenger trains (assuming 50% of traffic is handled by multiple units) 300 m;
- equipping category A crossings with semi-autonomous crossing systems;
- retrofitting of category B crossings with automatic crossing systems with traffic signals and horns to close the traffic in the direction of entry and exit from the crossing;

Assuming time norms according to [26, 36], the minimum crossing closure times necessary per day to allow rail traffic with the projected volume for the year 2045 were determined. The results obtained are:

- 09 h 48 min. 44 sec. for category A;
- 05 h 21 min. 16 sec. for category B;

These values do not formally qualify the crossings for conversion to collision-free crossings, however they must be taken into account in the case of A category station crossings. In these locations the train speeds may be considerably lower than those

assumed for the calculations, which will result in the daily crossing closure time exceeding 12 hours. According to [25, 26], this is the basis for conversion to a two-level crossing.

The 201 067 899 category D rail-road crossing enables crossing from the forest car park in the Wierzchlas settlement, located on the western side of the track, to the Leon Wyczółkowski Forest Reserve of Old Polish Yew, located on the opposite side of the line. A pedestrian bridge over the tracks could be built in this place instead of the crossing. Crossing 201 063 932 should be rebuilt in the same way.

The vicinity of the recently removed 201 074 756 crossing on county road 1028C looks interesting. On satellite maps at kilometre 74.539 (217 m before the existing crossing, on the opposite side of the Zielonka Pomorska passenger stop) one can clearly see the preserved road embankments which are the remains of the former viaduct over the railway line. This viaduct was probably destroyed during the war. It seems to be a good time to rebuild it and eliminate the crossing at km 74.756. A sketch of the proposed solution is presented in Figure 8.



Figure 8. Proposal to replace the decommissioned 201 074 756 rail-road crossing with a rebuilt road viaduct at the Zielonka Pomorska passenger stop and to restore the historical alignment of the 1028C county road

Taking into account “Vision Zero” on the analysed fragment of the line no. 201, it is possible to propose reconstruction of two crossings into pedestrian bridges over the tracks, construction of four road viaducts, one crossing under the tracks and elimination of the remaining four crossings. The reconstruction of one road viaduct should also be included.

## 5 SUMMARY

The routes of most railway lines in Poland were laid out in the 19th and first half of the 20th centuries. By now, the surroundings of these lines have undergone significant changes: the settlements adjacent to the lines have become denser and the network of road links of various categories that connects them has expanded. The natural tendency to use the shortest possible route has resulted in an increasing number of rail-road crossings on the railway lines. These crossings, often located with distances between each



other much shorter than recommended by regulations, pose a great threat to traffic safety and pose a significant economic and social problem when modernising railway lines.

For years there has been a conviction in Poland that it is possible to increase safety at crossings by installing more modern safety devices, in particular by upgrading category D crossings to category B and C crossings. Statistics contradict this view. The accident rate, which relates the number of accidents at crossings of a given category to the total number of such crossings in the period 2013-2019, was highest at category D crossings only three times (in 2016, 2017 and 2019), in other years the infamous winner of the classification was the category C crossing. What is equally important, the analogous competition between category D and B crossings gives a result of 4:3. This authorises the conclusion that the mass conversion of D to B crossings planned for the modernisation of the 201 line will not reduce the number of accidents.

The only safe way of intersecting a railway line with a motor road, by which the "Vision Zero" can be achieved, is a collision-free crossing. Modernization of lines belonging to TEN-T corridors to the standards presented in [5] is a good opportunity to convert crossings to two-level crossings. This should be legally sanctioned. As traffic safety and the reduction of external transport costs are in the focus of attention of the European institutions and "Vision Zero" is a very high-profile topic, with a suitably careful application there should be no problems in obtaining additional EU funds for this purpose. Delaying the reconstruction until the regulatory criteria are met at the crossings will necessitate the introduction of temporary train speed restrictions for the duration of the works. This will cause a decrease in the commercial speed of trains and as a result – the capacity of the line no. 201.

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