ARCHIVES OF TRANSPORT *ISSN (print):* *0866-9546*
Volume 44, Issue 4, 2017 ***e-ISSN (online):*** *2300-8830*
DOI: *10.5604/01.3001.0010.5842*

CONCEPTION OF MODERNIZATION OF A LINE SECTION EXAMPLE IN THE CONTEXT OF A FAST RAILWAY CONNECTION

Jerzy Mikulski[1], Karolina Gorzelak[2]
[1,2] University of Economics in Katowice, Katowice, Poland
[1]e-mail: jerzy.mikulski@pstt.eu

Abstract: *For centuries, it is known that people always prefer to accommodate in the region where there is good transportation network. Proper organization of transportation is one of the key elements which influence the dynamics of the World economics system development. Thanks to infrastructure modernization which allows to transfer the goods between engaged parties, it is possible to increase production and commonly to intense exploitation of areas located near this infrastructure among others in industry purposes. With regard to increasing demand for effective and efficient transportation system, there is a real need to improve communication and transportation infrastructure. A chance for this target shall be modern high technologies, which allows running with very high speed and thus also to reduce journey time. For this purpose there were established and is still developing relatively new product – high speed rail which is supposed to revolutionize modern transportation system functioning in the World. The article calls attention on a chance for improving competitiveness of rail freight transportation in Poland thanks to developing high speed rail network. There is underlined also rationality of modernization of the rail line which connect the biggest cities in South part of Poland. The descriptive part of the article refers to the high speed rail system and its development conditions. The research part is a technical feasibility study about section Cracow – Katowice – Wroclaw and possibilities for adopting it to achieve high speed rail line parameters.*

Key words: *high speed rail, HSR, technical study.*

1. Introduction

Proper transportation organization is one of the key elements, which influence the development of economic system functioning in a country. One of the transportation modes which constitutes an integral part of organization of people or goods carriage is rail transportation.

Among the most important characteristic features, which are considered appropriate to invest in modern rolling stock and infrastructure, first of all there should be emphasized low environment impact. The other factor having positive sound is relatively smaller area used for infrastructure building and investment. Next advantage of this mode of transportation is less energy consumption in comparison with other modes.

Polish rail infrastructure, despite it is continuously modernized, it still cannot match technical facilities available in East Europe or Asia. Less than half of all exploited rail lines in Poland are in good or satisfactory condition, but the rest needs comprehensive and complex repairs, restructuring and rebuilding. Bad condition of the infrastructure directly influence transit speed and this have a big impact on achieving competitiveness in transportation.

Short distance journeys are the most popular in Poland. To make that average carriage distance increase there is necessity to establish and operate high speed trains between biggest cities in a country.

2. High Speed Rail

The main objective of each mode of transport is to deliver commodity or passenger in safe and undamaged condition and in possible shortest time. For good and effective management and time optimization the most necessary elements are suitable rolling stock and modern infrastructure together with technical facilities. Thanks to increasing permitted speed on selected section of rail lines rail transportation becomes more and more competitive comparing with others.

High speed rail are recognized as the most significant technology breakthrough in the field of passenger transportation in last years.

The rail lines which can be classified as high speed type are all the lines which have been modernized to parameters allowing running with more than

200 km/h speed and which are exploited by technology advanced rolling stock. On the other hand high speed rail lines can be also those railways which have been built with main intention to be used by high speed trains and which let to drive with more than 300 km/h. In the organization of passengers carriage using HSR resources, the key and necessary for proper functioning of the system is perfect compatibility between all the infrastructure and trains subsystems. This compatibility has a direct influence on services quality, price level, technical possibilities and also safety level (European Parliament and Council Directive, 2008).
Investments project related to rail network development are distinguished mainly by pursuit of travelling comfort and safety growth.

3. High Speed Rail – existing resources

Polish infrastructural resources of high speed railways are poor in comparison with total length of HSR lines existing in Poland West neighbours. However, Poland year by year is developing and extending its rail network by new-modernized rail lines, which can be classified as HSR class.
The future of transportation system in Poland became a base for many investigations and researches motivated by defining main purposes and development directions for high speed rail in Poland. The idea of creating HSR network in Poland has been changing its form is successive way, and finally – in the last stage – it focused on the concept of connecting the biggest agglomerations in Poland. The conception of connecting Centralna Magistrala Kolejowa (Central Rail Main Line) with project of "Y" rail line linking Warsaw with Wroclaw and Poznan, met with many positive opinions in the experts community. The project of building rail network with high technical parameters, allowing achieving high speed was already involved in the conception of transeuropean transportation network. According to the assumption of the initial feasibility study of "Y" rail line, transit time for the journey between Warsaw and Wroclaw after placing the line in service could be 1 hour 40 minutes. On the other hand, passengers who travel from Warsaw to Poznan, could reach their destination after 1 hour and 35 minutes. At present, the project of building "Y" rail line is suspended by Ministry of Transport (Siergiejczyk, 2015).

4. Modernization project – rail line Cracow – Katowice – Wroclaw

Territorial and communication cohesion which can be reached by development of fast connections between Polish agglomerations is possible to achieve by implementing modernization and designing works, related to possibility of increasing allowed train speed on the route section linking Cracow with Katowice and Wroclaw. Proper rail infrastructure which meets requirements of technical parameters could become a real competitor for other modes of transportation. Connecting this line to CMK (Central Main Railway Line) and "Y" rail line would be a chance to develop high speed rail network in Poland, and at the same time a chance to increase the role of Polish railways on international transport corridors (Siergiejczyk, 2015).
For the project considerations it was assumed that the railway route Cracow – Katowice – Wroclaw shall be adjusted and modernized to technical parameters of high speed rail. The appropriate infrastructure with the highest technical capability could ensure a growth of competitiveness between railways and other modes of transportation.
Rail line linking Cracow and Wroclaw is located in the territory of four polish voivodships: Małopolskie, Śląskie, Opolskie and Dolnośląskie.
In the train timeline published for 2015/16, passenger trains running between Cracow and Wroclaw operate the line on the route:

- Cracow – Katowice – Opole – Wroclaw – total length 264,6 km
- Cracow – Częstochowa – Opole – Wroclaw – total length 320,1 km.

Figure 1 shows map of proposed high speed rail network in Poland based on new and existing rail lines.
Transit time on investigated route is unsatisfying, taking into consideration the fact that the length of the route is relatively small. Definitely the biggest competitor for railways is road transportation. The capitals of the analysed regions are linked by A4 highway, what slightly increase the advantage of road transportation in terms of communication, but in parallel is become a big obstacle for rail development. Availability of express road or highways makes that rail tariff and also transit time offered by trains should be as attractive to encourage the passengers to change cars for the benefit of trains

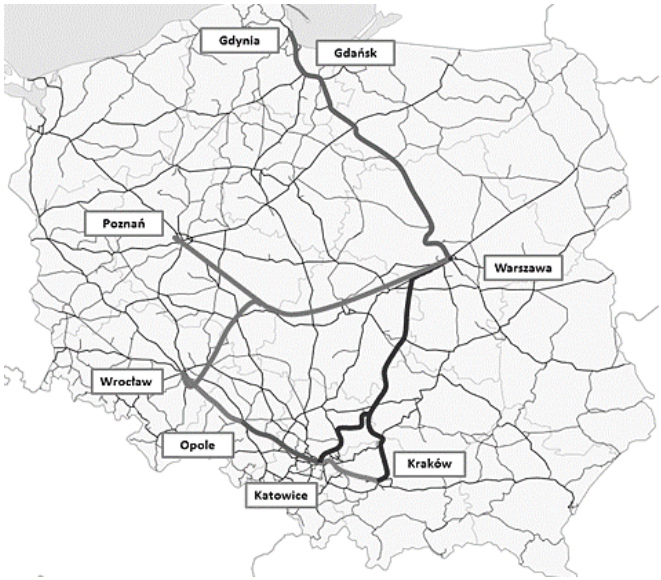

Fig. 1. Proposed matrix of high speed rail connections in Poland

But not only individual transportation stands as a big competitor for railways. It should be remembered that road collective transport, especially buses or tourist coaches also compete for passengers who do not have cars. The route sections where this kind of business is very well developed is route between Cracow and Katowice.

In case of bus connection linking aforementioned cities, both - start and end points are located in direct neighbourhood of railway station. The competitive advantage of bus carrier over trains communication can be founded in time, frequency and travel price. Table 1 presents comparison including specific features which have an impact on competitiveness of mentioned mode of transportation.

Table 1. Organization of bus and train transportation for route section Cracow - Katowice

Feature	Bus transportation	Train transportation
Average transit time	1 hour 20 minutes	2 hours 4 minutes
Average transport frequency	Each 15 minutes	Each 2 hours 9 minutes
Average normal ticket price	14,00 PLN	13,00 PLN

As Table 1 shows, the main factor which determines passengers preferences regarding choice of mode of transportation is transit time and transport frequency.

Preparing effective feasibility study and technical analyse of modernization works, which are implemented for the purpose of achieving higher train speed is possible and easier to perform by splitting the route into some specific sections.

Therefor the research of the investigated route shall be based on the following rail transportation routes:

- Cracow – Katowice – 76,321 km,
- Katowice – Opole – 97,027 km,
- Opole – Wroclaw – 80,592 km.

Among the factors which have to be considered at first during works connected with renovation and adaptation of infrastructure to allow trains running with high speed, there should be distinguished first of all - the course of the railway line, specification and characteristics of engineering facilities existing on the route, geometrical layout and characteristics of track superstructure (Engelhardt et al., 1995).

4.1. Section Cracow – Katowice – technical analyse

Railway line linking Cracow with Katowice is characterized by quite irregular shape. Analysed section begins to run since railway station Kraków

Główny (Cracow Main Railway Station) which is located in strict city centre. Next the line runs in west direction and near Kraków Mydlniki railway station it branch off two paths - line no. 118 leading to Balice Airport and continuation of the line no. 133 directed to north side. After the station Kraków Business Park the line transitions a curve and runs again in the western direction. In the area of Trzebinia railway station there is a next transition into northern direction, where line 133 combine with line no. 93 which ends its run in Zebrzydowice. Between Balin and Jaworzno Ciężkowice the line clearly change its course in north-west direction. Starting from Jaworzno Szczakowa, the trains which are running to Katowice are operation on 134 railway line, which after level junction in Długoszyn has U letter shape and since Mysłowice railway station trains start operating on 138 line linking Oświęcim and Katowice. Letter U ends its running near level junction named Szabelnia and again is directed to east. Since Katowice Zawodzie railway station trains are operating on magisterial line no 1 Warszawa Centralna – Katowice. The finish point of analysed route section is station Katowice. Figure 2 and table 2 shows detailed course of this route.

The advantage of new-built railway lines which are dedicated to be exploited by ultrafast trains is lack of level crossing within the route. The occurrence of intersections with roadway in rail level on modernized railway line carries the risk for both - rail and road traffic. Therefore, the main activity during designing and planning works connected with line renovation is limiting to minimum the number of level crossings. Within the route section Cracow - Katowice there are in total 36 rail level crossings.

On the lines which can be exploited with not more than 160 km/h speed, it is necessary to reduce number of intersections with roadways in rail level, especially those which are not equipped with proper safety devices like for example boom barriers. Liquidation can be defined among others as replacing them with rail and road bridges. Nevertheless, this solution is firmly connected with engagement of big cash (Kozubek, 2012).

Table 2. Cracow – Katowice detailed route course including division into sections between main railway stations

Line number	Route section between railway stations	Distance
133	Kraków Główny – Kraków Towarowy	2,255 km
133	Kraków Towarowy –Kraków Mydlniki	6,041 km
133	Kraków Mydlniki – Zabierzów	4,471 km
133	Zabierzów – Rudawa	5,881 km
133	Rudawa – Krzeszowice	6,537 km
133	Krzeszowice – Dulowa	8,308 km
133	Dulowa – Trzebinia	6,587 km
133	Trzebinia – Jaworzno Ciężkowice	9,228 km
133	Jaworzno Ciężk. – Jaworzno Szczakowa	4,853 km
134	Jaworzno Szczakowa – Sosnowiec Jęzor	7,258 km
134	Sosnowiec Jęzor – Mysłowice	7,020 km
138	Mysłowice – Katowice Zawodzie	5,157 km
1	Katowice Zawodzie – Katowice	2,725 km
		76,321 km

Decision regarding removal of nominated level crossing should rely among others on maximally allowed train speed on the railway route section. Figure 3 shows map of level crossings existing on a route Cracow – Katowice and permitted speed on each rail line.

Over the greater part of the analysed route, trains can operate with 90 km/h speed. To change actual situation, means to increase permitted speed to minimum 160 km/h on the railways route Kraków Główny (Cracow Main Station) – Jaworzno Szczakowa, it is necessary to remove level crossings on this section, where the most difficult part including almost 10 level crossings is Krzeszowice – Dulowa railway line section.

Fig. 2. Cracow – Katowice railway line course

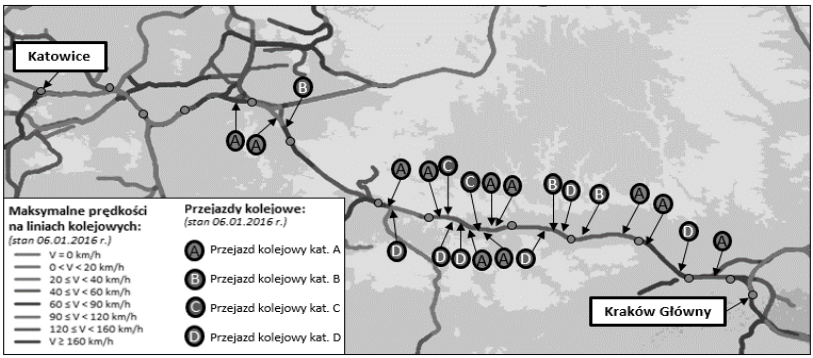

Fig. 3. Permitted speed and level crossings on the route Cracow – Katowice

.

At first, elimination shall refer to level crossings classified as category D, so all those which are not equipped with boom barriers and safety systems and those existing on the route between railways stations Jaworzno Szczakowa and Mydlniki. In case if elimination of any level crossing is connected with engagement of big and disproportionate capital or is impossible to arrange it from operational point of view, then on this level crossing trains should slow down and run with accordingly adjusted and legally regulated speed.

According to the ordinance of the Minister of Infrastructure and Development dated on 20th October 2015, on the level crossings classified to category A and B, the trains can run with maximal speed 160 km/h and for level crossings type C and D allowed speed oscillates around 140 km/ h and 120 km/h (accordingly). Taking into consideration the large number of level crossings on analysed railway route, most of them shall be liquidated to ensure sufficient flow, and in the same time – to allow running with higher speed.

An important railway infrastructure element are also bridges and viaducts, where modernization and adaptation works to gain high speed rail parameters is significantly difficult. Within the railway route section Cracow – Katowice there are 47 engineering facilities like bridges and rail viaducts. Each of this facilities before adaptation works need careful carrying capacity and underground stability expertizes.

The surface and its characteristics is one of the main points to prepare rail line modernization plan. For high speed rail this surface should comply with the requirements for its strength and resistance to external forces. On the whole route distance which is exploited by rolling stock running with high speed it is recommended to use heavy padded sleepers and railway tracks with adequate resistance. In those points where there are still wooden sleepers it is necessary to replace it into padded ones and also to replace old railway tracks with those which have wider and higher construction and also higher resistance to abrasion and cracking(Karaś & Krasnowski, 2012).

A base factors determining definition of allowable speed are geometric parameters of bends – mostly its radius, cant level, and also transition types. For trains running with speed of 200 km/h all the railway turnouts should be equipped with the movable frog points. When mentioning about replacing sleepers it is necessary also to mention about the base layer. It is recommended to replenish its losses on those sections, which needs it (Zboiński & Woźnica,2010). In addition to this, the whole railway route between Cracow and Katowice should be equipped with ERTMS level 2 control system and suitable electric traction. Due to high risk connected with running with very high speed it is also necessary to separate railway tracks territory from the rest area and to build noise barriers along it. Such action allows to minimize the risk of collision with wild animals and prevents from people movement in this area. Significantly difficult railway sections to be fenced by noise barriers are city centres due to high urbanization of this areas, and consequently minimal possibilities of dealing with lands, what has direct impact on necessity of decreasing allowable speed on those route sections (Siergiejczyk & Gago, 2014).

For railway route between Cracow and Katowice the areas near which tracks fencing from other land is

significantly important and needs verification of existing safety equipment are:

- since railway station Kraków Główny (Cracow Main Railway Station) to 65km of the line number 133 – highly urbanized area (Cracow city centre),
- in the nearest area of Zabierzów (km 56-58 of the 133 line) – city buildings, necessity of decreasing the train speed,
- in the area of Krzeszowice railway station (km 44 – 45 of the 133 line) – city buildings, necessity of decreasing the train speed,
- in the area of Jaworzno Szczakowa railway station (km 15 – 18 of the 133 line) – city buildings, necessity of decreasing the train speed,
- since Mysłowice railway station to Katowice railway station – very highly urbanized area (Silesia Agglomeration)
- Renovation works consisting in bends correction are connected with necessity of grounds purchasing, what can be difficult especially near:
- Tenczyński Park Krajobrazowy (Landscape Park),
- Puszcza Dulowska (Forest),
- Las Sławków (Forest).

The condition for placing high speed traffic into passenger rail services is also reduction or elimination of freight transportation on the line. The analysed railway section is exploited by freight trains, so this traffic should be limited or transferred to another line, via Skawina, Brzeźnica, Oświęcim and Imielin.

Figure 4 shows a map with proposal of permitted peed on the route Cracow – Katowice, assuming implementation of above described solutions.

Table 3 shows estimated transit time on each route section on the railway line between Cracow and Katowice. Calculation is made based on simplified method (Poznański & Żebrak, 2012).

Transit time presented in table 3 is counted based on technical parameters of trans series no ED250, including start-up acceleration equal 0,49 m/s^2 and braking deceleration equal 0,6 m/s^2.

According to the results coming from the calculation, transit time of a train from Cracow to Katowice, assuming running with maximum speed 200 km/h could be 39 minutes, so in comparison with current timetable it would be 68% shorter.

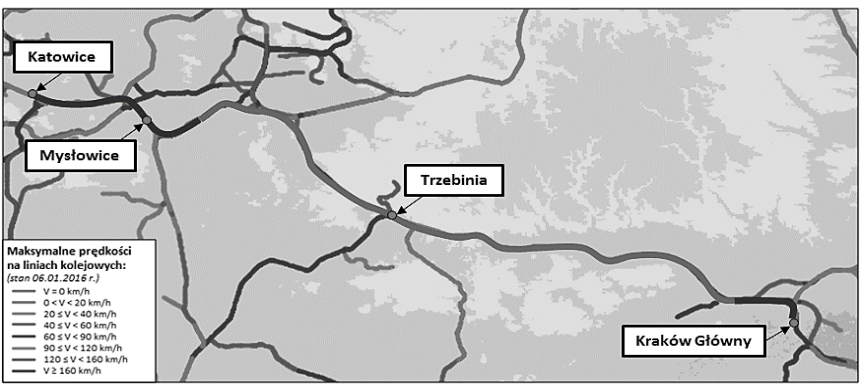

Fig. 4. Map of proposed maximal speed on a route Cracow – Katowice

Table 3. Transit time on a route Cracow – Katowice for proposed train speed

Section	MAX speed	Distance	Time			
			Start-up	Regular	Braking	Total
Kraków Główny - Kraków Mydlniki	70 km/h	6 978 m	19,84 s	358,87 s	0,00 s	6 min
Kraków Mydlniki - Trzebinia	200 km/h	31 588 m	23,95 s	568,58 s	46,30 s	11 min
Trzebinia Station - stop	-	-	-	60,00 s		1 min
Trzebinia - Mysłowice	180 km/h	27 735 m	51,02 s	554,70 s	41,67 s	11 min
Mysłowice Station - stop	-	-	-	60,00 s		1 min
Mysłowice - Katowice	70 km/h	10 020 m	19,84 s	515,31 s	16,20 s	9 min
		76 321 m				**39 min**

4.2. Cracow – Wroclaw route modernization – summary

Without any doubt, placing high speed trains into services what may result as good communication links by rail between main cities in South Poland is rational and reasonable investment project, but on the other hand it is connected with engagement of big cash.

Rail infrastructure modernization works, which aim is to improve rail passenger traffic, shall also take into account freight transportation needs. The research should also include rail passenger traffic of those trains which cannot be exploited with 200 km/h speed. An important thing is to limit those trains frequency and replacing them with express trains. Special attention should be paid to investigation of possibilities for procedure of overtaking manoeuvre on another railway stations which are not subject to train stop.

Table 4 shows summary of transit time of express train on a route Cracow – Katowice – Wroclaw. As can be seen from table 4, the average train speed on the whole route between Cracow and Wroclaw after infrastructure modernization works can oscillate around 130 km/h. This result is comparable with average train speed on CMK (Central Railway Line).

So far, low demand on rain passenger transportation on a route Cracow – Katowice – Wroclaw was determined mainly by transit time, which, according to train timeline valid for period 2015/16, was 288 minutes. Car transit time between capital of Małopolska and Dolny Śląsk region is approximately 2,75 hour (165 minutes). If it is possible to renovate the infrastructure to gain suitable technical parameters and meet other requirements related to introduce passenger trains speed in the range of 180-200 km/h, thus the person who will choose train as mode of transportation, will arrive to Wroclaw 41 minutes earlier than person who decide to travel by car.

5. Conclusion

One of the main assumptions of European Transport Policy is to change structure of transport sector up to 2020, for benefits to rail transportation based on high speed rail network. The role of rail transportation in the World is definitely increasing year by year, what is determined mostly by the scale of the problem of air pollution generated by cars, what is directly connected with the necessity of searching for the alternative solutions to meet people's expectations regarding transportation system.

Table 4. Summary of transit time on a route Cracow – Katowice - Wroclaw

Route section	Max speed	Distance	Time			
			Start-up	Regular	Braking	Total
Kraków Główny - Kraków Mydlniki	70 km/h	6 978 m	19,84 s	358,87 s	0,00 s	6 min
Kraków Mydlniki - Trzebinia	200 km/h	31 588 m	23,95 s	568,58 s	46,30 s	11 min
Trzebinia station - stop	-	-		60,00 s		1 min
Trzebinia - Mysłowice	180 km/h	27 735 m	51,02 s	554,70 s	41,67 s	11 min
Mysłowice station - stop	-			60,00 s		1 min
Mysłowice - Katowice	70 km/h	10 020 m	19,84 s	515,31 s	16,20 s	9 min
Katowice station - stop				60,00 s		1 min
Katowice - Gliwice	120 km/h	26 719 m	34,01 s	801,57 s	27,78 s	14 min
Gliwice station - stop				60,00 s		1 min
Technical reserve after 103 km				180,00 s		3 min
Gliwice - Pyskowice	90 km/h	11 097 m	25,51 s	443,88 s	0,00 s	8 min
Pyskowice - Strzelce Opolskie	200 km/h	26 821 m	56,69 s	482,78 s	46,30 s	10 min
Strzelce Opolskie station - stop				60,00 s		1 min
Strzelce Opolskie - Opole	200 km/h	32 390 m	56,69 s	583,02 s	46,30 s	11 min
Opole Główne station - stop				60,00 s		1 min
Opole Główne - Opole Zachodnie	100 km/h	2 763 m	28,34 s	99,47 s	0,00 s	2 min
Opole Zachodnie - Święta Katarzyna	200 km/h	68 889 m	14,17 s	1240,00 s	46,30 s	22 min
Święta Katarzyna - Wrocław Główny	120 km/h	8 938 m	0,00 s	268,14 s	27,78 s	5 min
Technical reserve after 151 km				360,00 s		6 min
		253 938 m				**124 min**

It is estimated that high speed trains generate circa 14 times less pollution (mostly in relation to CO_2) than cars and 15 times less pollution than planes counting per one passenger.

Among the wide range of advantages of rail transportation it should be mentioned also smaller usage of territory and also economics advantages such as regional development of the areas where high speed railway line is located. European experience shows that building high speed rail network influenced increasing of tourism development and also the level of employment in the society. Building of HSR network has significant influence on tourism increasing and employment level development.

50 years after establishing the first railway line where trains could run with 200 km/h speed, the technological progress allowed to settle the world record of speed of trains running on railways tracks which is 574,8 km/h. This results in the face of infrastructure judgement and also possibilities of financing such kind of project, seems to be impossible to gain in Polish realities. Polish technical resources allows now only to run with maximum speed of 200 km/h. PKP PLK S.A. (Polish National Railways) gradually replace their rolling stock with newer EMU (Electric Multiple Units) produced by Italian and also native factories, which unfortunately cannot be fully exploited because of the old and insufficient rail infrastructure condition.

All of the decisions connected with building of high speed rail system in each country shall be supported and preceded by deep and detailed effectiveness analyses of the investment. The biggest barrier for countries which want to develop railways on theirs territory is very high cost of infrastructure investments. The chance for improvement regarding extension of railway network in Poland can be found in several EU's investment financing programs in the provision of rail transportation development. Till end of 2023 year PKP PLK S.A. is planning to spend almost 67 billion zloty, which are located in the company's investment portfolio. The main assumption is to intense the investment process, costs reduction and also modification of the technical resources process maintenance.

References

[1] ENGELHARDT, J., WARDACKI, W., ZALEWSKI, P., 1995. *Transport Kolejowy – organizacja, gospodarowanie, zarządzanie.* Warszawa: Kolejowa Oficyna Wydawnicza.

[2] EUROPEAN PARLIAMENT AND COUNCIL DIRECTIVE 2008/57/WE of 17 June 2008 r. on the interoperability of the rail system within the Community, The Official Journal of the European Union from 18.07.2008, L191, p. 25.

[3] KARAŚ, S., KRASNOWSKI, A., 2012 High speed rail - the current challenge to Polish rail transport, *Journal of KONES*, 19(3), pp. 203-212.

[4] KOZUBEK, P. R., 2012. *Efektywność inwestycji infrastrukturalnych w transporcie kolejowym*. Kielce: Wydawnictwo Politechniki Świętokrzyskiej.

[5] POZNAŃSKI, J., ŻEBRAK, D. 2012 Zastosowanie metody obliczeń uproszczonych do wyznaczania czasu jazdy pociągu na szlaku. Warszawa. Zeszyty Naukowe Politechniki Warszawskiej, seria Transport, 87, pp. 69-83.

[6] SIERGIEJCZYK, M. (ed.), 2015. *Koleje Dużych Prędkości w Polsce*. Warszawa: Instytut Kolejnictwa.

[7] SIERGIEJCZYK, M., GAGO, S. 2014. Safety and security, availability and certification of the GSM-R network for ETCS purposes. *Archives of Transport System Telematics*, 7(1), pp. 45-49.

[8] ZBOIŃSKI, K., WOŹNICA, P. 2010 Optimisation of the railway transition curves' shape with use of vehicle-track dynamical model. *Archives of Transport*, 22(3), pp. 387-407.