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Review of freight high speed railway (HSR)

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The e-commerce market is gaining popularity globally every year. This market also entails the need to deliver the purchased goods at a time that is affordable for the user. One of the solutions is the use of High Speed Railway (HSR) for freight purposes, which is characterized by a relatively low rate of environmental nuisance. Based on the latest available market data and a literature review, an extensive review of the use of HSR, including for cargo transport, has been performed. The article presents an analysis of the demand for express freight transport. The potential and the demand for freight HSR have been demonstrated. The activities and analysis concerning the use of HSR for freight transport were described. Rail freight transport in Poland, Europe and China are characterized. Data on the use of the HSR infrastructure in the world are presented. HSR vehicles use for the transport of goods were presented. The potential and possibilities of using freight HSR in Europe were described. Based on the data, the use of this type of transport seems justified for LDHV shipments when the delivery time is crucial for the user and when the railway infrastructure and rolling stock are properly adapted.

1. Introduction

According to the data of the European Environment Agency from 2022 [12, 25], transport in the EU (European Union) is the only sector in which CO_2 emissions did not decrease comparing to 1990. Moreover, comparing the years 1990 and 2019, the amount of emitted compound increased by 25%. Considering GHG (Green House Gases) emissions in the EU from means of transport, the largest share of emissions come from road transport (71.7%), which mainly consists of emissions from cars (60.6%) and heavy duty trucks (27.1%). This state of affairs is caused by the availability of internal combustion vehicles and the well-developed road infrastructure in Europe [49]. Rail transport has by far the smallest share in GHG emissions in the EU, accounting for 0.4% [12], although it accounts for 8% of passenger and 19% of freight transport in Europe [42]. Despite the lowest share of harmful compounds emission among all means of transport, intensive works are being made in the railway sector to use more efficient propulsion systems [41, 44] and alternative fuels [8, 48], including hydrogen [18, 19, 24, 40] to reduce exhaust emissions [38].

Considering the emission of toxic compounds, such as heavy metals, in the EU-28 countries from non-road transport (air, rail, sea and in-land water transport), the increment factor of the described indicator, dividing into passenger and freight transport, has been growing since 2000 in both cases [25]. However, in the case of passenger transport, this increase is much bigger. In relation to the initial value, the indicator for passenger transport increased by almost 50%. Freight transport contributed to an approximately 10% increase in the emission of harmful compounds during 18 years. All of the above means that the transport of goods by rail has the lowest negative impact on the environment.

Additionally, a continuous increase in the demand for transport is noticeable, including rail transport as one of the most CO_2 emission and energy efficient [4, 29, 55] and cost-effective [31]. An example of a reason why the demand for the implementation of transport services is increasing is the e-commerce market. All over the world there is an increase in the number of transactions taking place via the Internet and online purchases. China is one of the largest representatives of this type of trade. An example is the increase in the express transport services provided in

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this country, where in 2016 the number of transported volumes increased to 31.28 billion, and the revenues from the provision of this type of services increased 10 times since 2008 [58]. In turn, in 2020 "express transported" volume in China already reached the level of 83.4 billion pieces (Fig. 1). This means that the demand for services of this type is not only increasing but is accelerating at a dizzying pace [14, 59]. In order to cover the general demand for express transport of goods, railways are more and more often used, which on many levels can effectively compete with other means of transport.

For this reason, plans, considerations, simulations, optimizations [2, 54], predictions and real solutions for the use of HSR (High Speed Railway) for high speed freight transport [20, 35, 51, 52, 60] have been developed. Including comparative analysis of the use of air transport and HSR [47, 56], as well as the punctuality of express parcels transport by various means of transport [32] and the selection of optimal locations of consolidation centers to reduce GHG [9], mainly on China example. Works related to Freight HSR also include the development of tracking of transported goods [57], intelligent management systems [6], monitoring and calculations related to the rolling stock [3, 16] and issues related to the aerodynamics of HSR vehicles [50].

This paper describes an overview of data on freight transport in Poland, Europe and China. The key HSR railway lines in the world, on which HSR freight trains already run, were also presented, and the number of which will increase in the coming years due to a number of benefits.

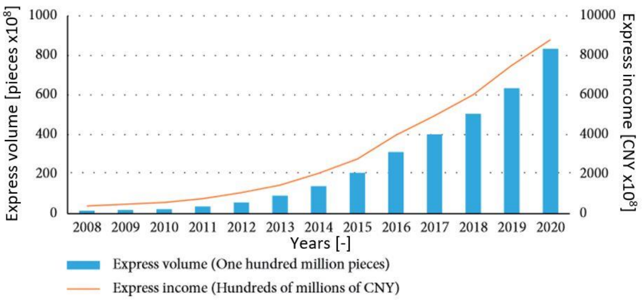

Fig. 1. The volume and income of express delivery during 2008–2020 in China [59]

2. Rail freight transport

2.1. Characteristics of rail freight transport in Poland

In order to correctly illustrate the structure of the rail market in Poland for freight transport, the data for the years 2011-2020 are presented below. The most important indicators are the mass of transported loads (Fig. 2), transport work performed (Fig. 3) and operational work (Fig. 4) [45].

Analyzing the data from 2011-2020, it can be seen that 2018 was characterized by the highest values for all three indicators, and years 2017-2019 were the best since 2011. In the case of the mass of transported goods, in 2018 it was 250.3 million tons, where the increase from 2016 was 12.6%. Then there was a decrease in 2019 to a value of 236.4 million tonnes. 2020 was the second least favorable year in the analyzed time period (only 2016 was characterized by a lower value of transported goods – a difference of 1 million tonnes). The decrease in cargo mass after 2018 could have resulted from a change in the structure of the transported groups of goods. With the same length of freight trains, the difference in weight between intermodal and mass trains is completely different. Additionally, drastic decrease in the described indicator in 2020 (–10.8% compared to 2018) was caused also by the outbreak of the COVID-19 virus pandemic, which affected not only the Polish, but also the global rail transport market [28, 46].

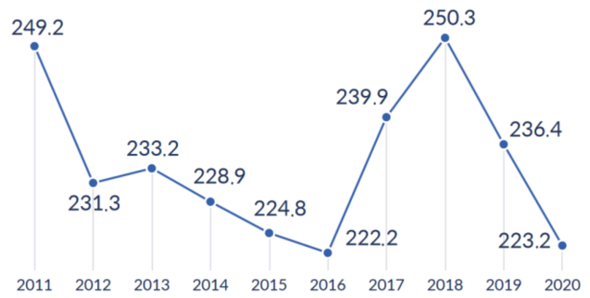

Fig. 2. Mass of cargo in rail freight transport in Poland in 2011-2020 (in million tonnes) [45]

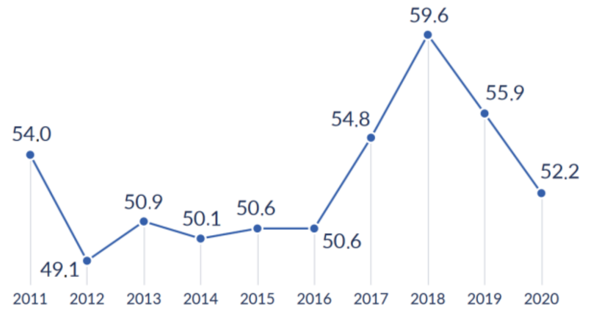

Fig. 3. Transport work performance in rail freight transport in Poland in 2011-2020 (in billion tonne-kilometers) [45]

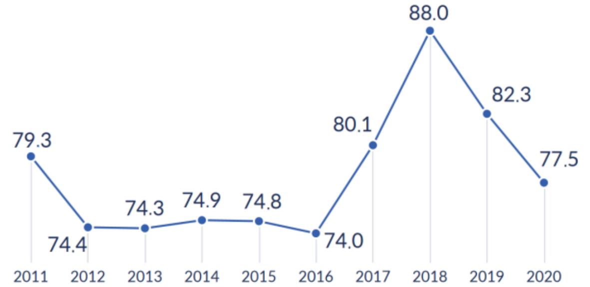

Fig. 4. Operational work in rail freight transport in Poland in 2011-2020 (in million train-kilometers) [45]

Transport work performance in 2011 amounted to 54 billion tkm (tonne-kilometers). Then, in the years 2012-2016, a stabilized situation was noticed, where the annual values were between 49.1 and 50.9 billion tkm. After this period, an increase to the value of 59.6 billion tkm was noticed in 2018 (an increase of 17.8% compared to 2016). From this year, the annual transport work performance has decreased to a value of 52.2 billion tkm in 2020.

The characteristic of the curve for operational work in 2011-2020 in Poland is very similar to the curve for transport work. In this case, the value in 2011 was 79.3 million train-kilometers. In 2012-2016, the value ranged from 74 to 74.9 million train-kilometers. Then, there was a two-year increase in the described index to the value of 88 million train-kilometers, which is the highest in the described time period. From 2018, a decrease to the value of 77.5 million train-kilometers in 2020 is visible.

Figure 5 shows the average speed for rail freight transport in general and for intermodal transport in 2013-2020 in Poland. The average speed for freight transport in 2020 was 25.9 km/h, which is the highest value in the analyzed time period. In the case of intermodal transport, the average speed was 30.3 km/h. This means that this value is one of the lowest during considered period. The lower average speed may result from the terracing of short border sections where the average commercial speed of trains is only 10 km/h. Nevertheless, intermodal transport in Poland is characterized by a higher average transport speed than conventional rail freight transport.

Fig. 5. Average commercial speed of freight trains in general and intermodal trains in Poland in 2013-2020 (km/h) [45]

Figure 6 presents the share of trains carrying out intermodal transport in particular speed ranges. Half of the transports were performed at a speed of less than 30 km/h, and almost 30% of the number of trains were going with an average speed within the range of 30–40 km/h. Only 7.66% of intermodal transports were carried out at speeds greater than 60 km/h.

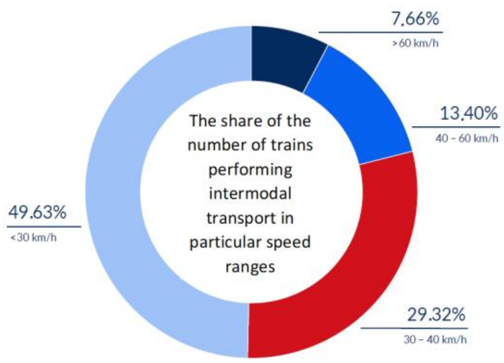

Fig. 6. Share of the number of trains performing intermodal transport in individual speed ranges in 2020 [45]

Figure 7 shows examples of intermodal trains with average speeds between reloading centers in 2020. Maximum and minimum values have been achieved on border routes. The highest speed is on the connection: Frankfurt Oder–Rzepin, where trains between Germany and Poland cover the route at an average speed of 90 km/h. In turn, the lowest value belongs to the connection: Brest–Małaszewicze. The average speed of intermodal trains on the Belarusian–Polish border is 4 km/h. Average speeds of domestic routes are varied and range from 27 km/h on the Gdańsk–Radomsko route to 63 km/h on the Gądki–Dąbrowa Górnicza route.

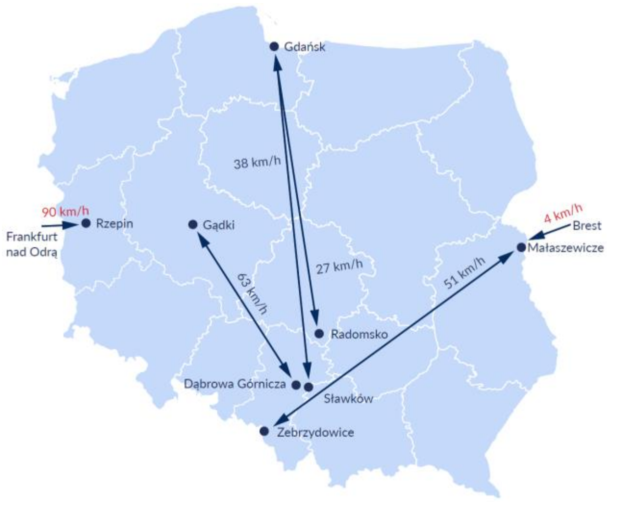

Fig. 7. Examples of intermodal train speed in Poland in 2020 [45]

Intermodal transport in Poland uses a rolling stock consisting mainly of platform wagons, of which there are over 13,000 in Poland. Trailed vehicles are also used for this type of transport to carry containers. In 2020, there were over 5,800 such vehicles. Considering the possibility of achieving the maximum speed of platform wagons for container transport, the speed higher than 100 km/h can only be reached by 23% of wagons (max 120 km/h). The other vehicles are designed for a maximum speed of 100 km/h.

2.2. Characteristics of rail freight transport in Europe

The transport work performance in rail freight transport in Poland against the background of European countries for the years 2010, 2019 and 2020 is presented in Fig. 8 [43]. In Europe, only in Germany in above-mentioned years transport work performance was greater than in Poland. In 2020, Germany was responsible for 30% of the total transport work performance in the European Union, amounting to 108 trillion tkm (twice as much as in Poland – 50 million tkm). In almost all countries, the described indicator increased in 2020 compared to 2010.

One of the indicators in rail freight is the transported mass of goods. In Europe, the leader in this ranking is also Germany. However, when comparing the years 2019 and 2020, it can be stated that the COVID-19 pandemic had a significant impact on the mass of transported loads. Only five EU countries noticed an increase in this indicator. In other cases, declines were noticed. Taking into account the number of transported mass, the most severe situation was related to Germany, where the decrease amounted to 20 million tons year on year, while the relatively largest decrease was recorded in Latvia, where the decrease amounted to 42% (Fig. 9).

Taking into account the characteristics of the goods transported in the EU, the classified goods that were transported in the greatest amount in 2020 were metal ores, which accounted for 12.8% of the total number, taking into account tkm. Coke and refined petroleum products, second in the ranking, accounted for 9.8%. The largest part, however, were goods that can be characterized as: other or not identified (38.2%) (Fig. 10).

In the case of goods counted in tonnes, in this case, classified goods also had the largest share of metal (15.6%). Coal and crude petroleum was second (12.1%), and the third major commodity was coke and refined petroleum (12.1%). As in the case of transport work performance, the products other or not identified constituted the largest part in the summary, as they comprised 1/3 of the share (Fig. 11). One of the solutions used in the transport of goods in Europe is also intermodal transport applied to the so-called LDHV (Low Density High Value) goods [7, 30].

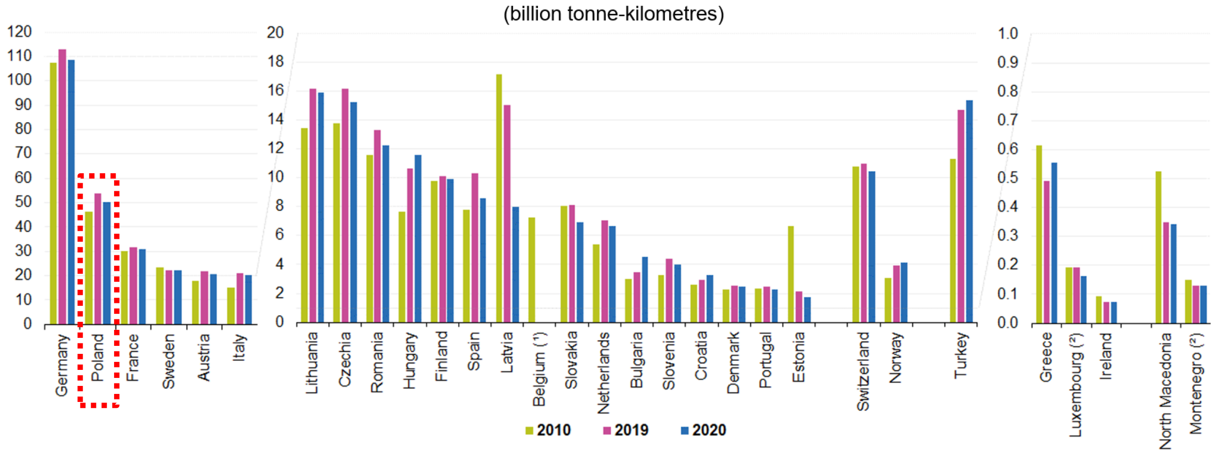

Fig. 8 Rail freight transport for main undertakings, 2010, 2019 and 2020 (billion tonne-kilometres). Countries are ranked based on 2020 data. Cyprus and Malta have no railways. (¹) 2019 and 2020 data not available. (²) 2010 based on quarterly data [43]

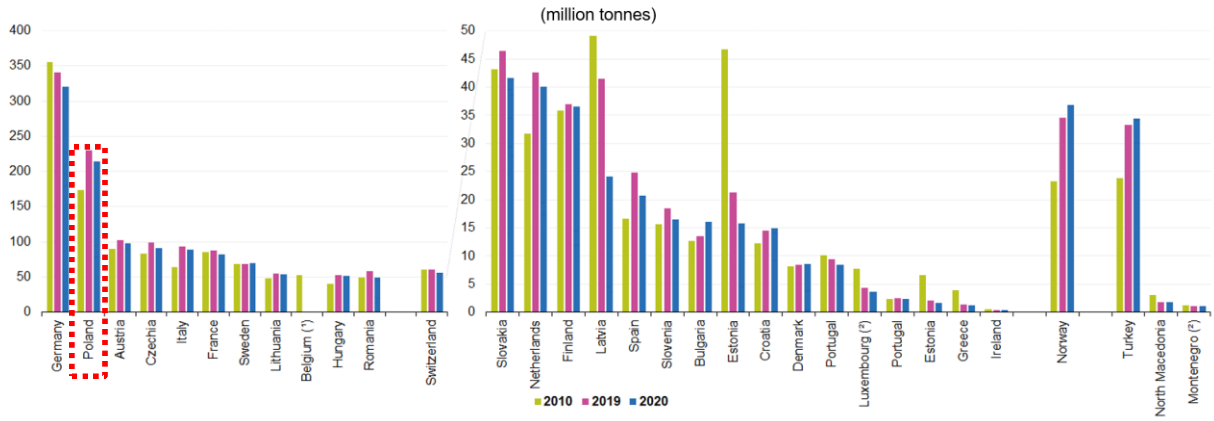

Fig. 9. Rail freight transport for main undertakings, 2010, 2019 and 2020 (million tonnes). Countries are ranked based on 2020 data. Cyprus and Malta have no railways. (¹) 2019 and 2020 data not available.(²) 2010 based on quarterly data [43]

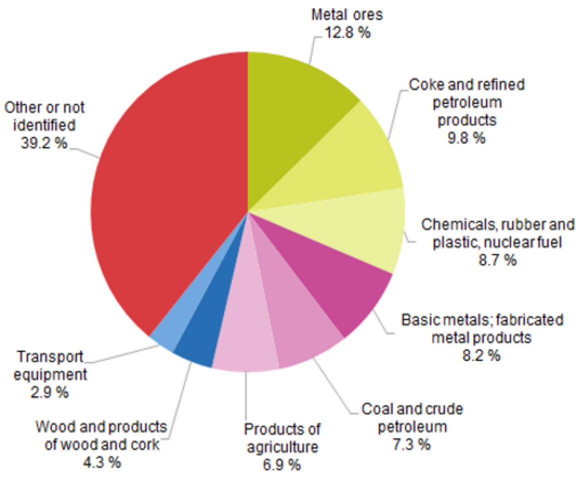

Fig. 10. Rail freight transport by type of goods for main undertakings, EU, 2020. Share based on tonne-kilometres [43]

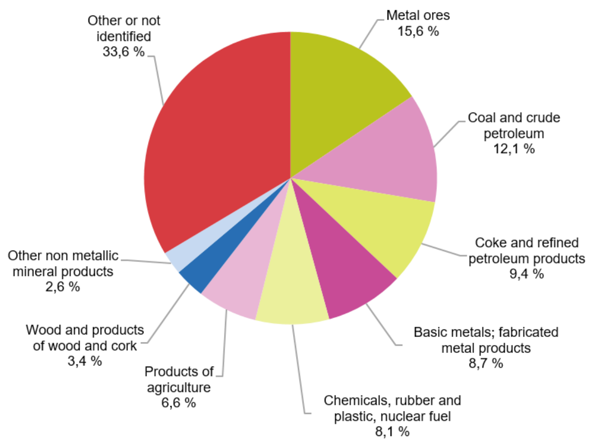

Fig. 11. Rail freight transport by type of goods for main undertakings, EU, 2020. Share based on tonnes [43]

3. High Speed Railway

High speed railway is a form of transport that is gaining more popularity all over the world every year [33]. Thanks to this form of transport, including more and more easier access to high speed communication for ordinary passengers, the possibilities of daily commuting of employees from distant regions to the place of employment increase significantly [17]. Every year, multi-million investments are made to expand the railway network adapted to moving at high speeds. According to UIC (International Union of Railways) [5] data, there are 20 countries in the world that have high speed railways, and the total length of HSR lines in the world is 56,130 km.

The country with the most extensive HSR is China. It is a world leader in this area with 38,283 km of lines. For comparison, the second country in the world with the longest HSR line is Spain with 3,487 km, which is over 11 times less than China. Asian countries with HSR lines are also Japan (3,041 km) and South Korea (893 km). Considering such an extensive infrastructure, especially in China, HSR in Asia accounts for 75% of the total length of HSR in the world. In Europe there is 21% of the total length of the HSR in the world (11,819 km), in the Middle East it is less than 2.1% (1,173), in North America (USA) 1.3% (735 km), and the rest of the lines (186 km) are located in Africa, more precisely in Morocco (Fig. 12).

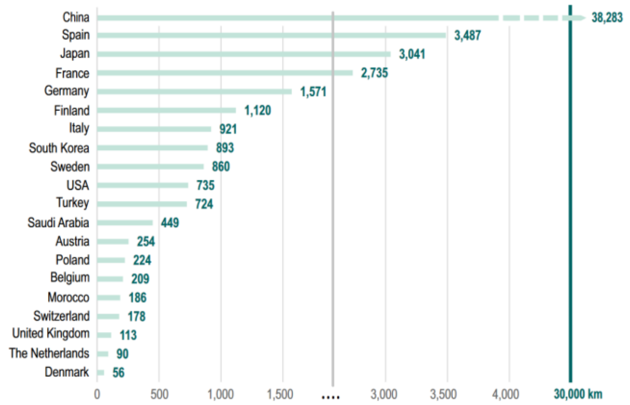

Fig. 12. Length of the high speed railway network in commercial operation by country [5]

Currently, the HSR line in the world is being expanded and according to the available data, 22,562 km of the line are under construction. This means that after the completion of construction, the network of HSR lines in the world will be 40% longer than today. The largest part of the expansion takes place in Asia, where 16,515 km of HSR lines are currently under construction. 3,079 km of lines are built in the Middle East, 2,405 km in Europe and 563 km of lines in North America.

It is worth noting that since 1990, when the total length of the HSR lines in the world was 2,767 km, the length of this type of lines has increased 155 times. One of the main reasons was the launch of intensive operations in China, where, among others, in 2008, the fastest railway route in the world those days, Beijing–Tianjin, was put into use with a maximum speed of 350 km/h. So far, it is still the fastest railway line in the world. Countries with the fastest railway lines having a maximum speed limit of 320 km/h are Japan, France and Morocco (Fig. 13).

Due to the length of the HSR lines, China is in first place. However, taking into account the density of the HSR network, the index of HSR lines per km^2 of the country, China is 8th in the ranking (3.989 m/km^2). This is due to the enormous area of the country and a significantly developed infrastructure, especially in the east of the country. South Korea has the densest HSR line (8.911 m/km^2), while Japan is in second place (8.045 m/km^2). European countries with the highest density index are Spain (6.892 m/km^2) and Belgium (6.846 m/km^2). Among the countries with HSR, the lowest value of the described index are countries outside Asia and Europe, i.e. Morocco (0.417 m/km^2), Saudi Arabia (0.209 m/km^2) and the USA (0.075 m/km^2) (Fig. 14). Figure 15 and Fig. 16 show the HSR network in Asia and in Europe, respectively.

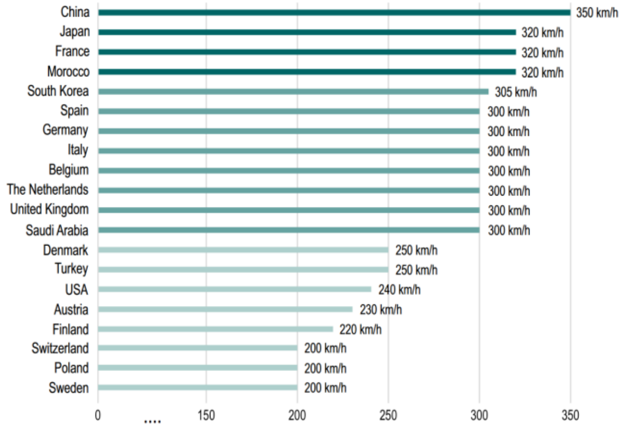

Fig. 13. Maximum speed of high-speed rail network by country (2020) [5]

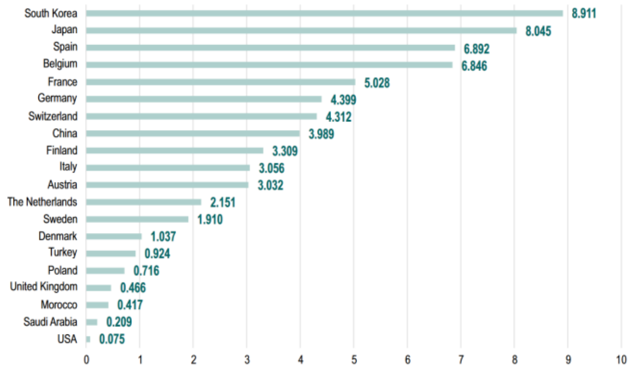

Fig. 14. Density of the high-speed network in 2020 (meters of high-speed lines/country area in km^2 [5]

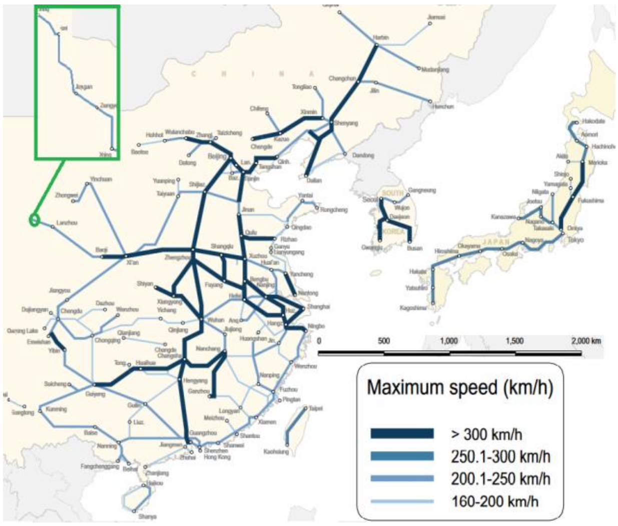

Fig. 15. Japan, South Korea and China Railway High-Speed (CRH) lines [5]

Fig. 16. High-speed railway lines in Europe [5]

4. Freight high speed trains

Rail transport using HSR was designed with passenger transport in mind. This is also confirmed by statistics, which say, among other things, that in China in 2020, despite the COVID pandemic, 2,357.7 million passengers used these services, and in Japan – 354.6 million passengers. This means that this type of transport has become a generally accessible form of transport for passengers. Due to the fast travel time, this type of railway has a significant potential for the transport of goods. The use of HSR for freight services is not only a plan, but is already being implemented on certain sections of the railway lines. Examples of the use of HSR in freight transport are presented below.

4.1. ETR.500 M-01 rail vehicle

The world's first high speed freight line was put into operation on November 7, 2018 by the Italian operator Mercitalia Fast (Gruppo FS Italiane). The line connects the Maddaloni-Marcianise terminal in Caserta with the Bologna Interport (approx. 550 km) (Fig. 17), one of the most important logistics hubs in northern Italy [36, 37]. Trains used for this operations (Fig. 18) are specially modernized and designed to transport time-sensitive products for customers such as couriers, logistics operators, manufacturers, distributors and developers.

Fig. 17. Italian high speed rail route used for freight transport [36]

Fig. 18. The Italian high speed freight train ETR M-01 Fast, a modernized version of the ETR 500 vehicle [39]

Fig. 19. Scheme of the internal division of each wagon with 17 boxes designed to put the containers on wheels and to mark the 12 wagons in the M01 train [22]

Fig. 20. Freight space in one of the wagons of the ETR M-01 Fast train by Mercitalia [36]

For this special and innovative service, the ETR 500 multiple unit rail vehicle (currently classified as ETR M-01 Fast) was used, consisting of two multi-system drive units – E.404.514, E.404.516, and 12 passenger units. Adaptation of passenger units for freight transport was made in workshops in Vicenza and Voghera. The air conditioning system and 220 volt static transducers for passenger services and electrical sockets have been removed. This operation had to be performed to compensate for 3.6 tons of ballast in order to maintain stability. The wagons (units) are equipped with a fire suppression system compliant with the TSI 2014 specification by means of two fire extinguishers and special ceiling smoke detectors. Each vehicle also has two cameras connected to a screen in the driver's cab. The lighting is made of neon tubes placed on the ceiling alongside the vehicle.

The transport capacity of the modernized vehicle is equal to 18 road semi-trailers or two Boeing 747 airplanes. The cargo space is divided into 12 sections, called wagons after modernization. Each wagon has 17 load spaces (boxes) called "racks" and numbered in ascending order from 1 to 17 (Fig. 19). In total, in one wagon there is space for 60 containers with dimensions of 71×80×180 cm (Fig. 20).

One container takes up a space of about 1 m^3 and it is possible to transport up to 250 kg of goods in it. The shipping unit is designed for easy and quick loading and unloading due to the use of wheels (Fig. 21).

Fig. 21. Loading of containers on wheels to the high speed freight train ETR M-01 Fast [34]

In terminals, the loading and unloading of wheeled containers is carried out by means of 12 removable platforms that connect the warehouse dock with the level of the train floor. The operations are therefore only performed through one door (Fig. 22). The use of such a solution allows to maintain 17 tons of load per axle, which is a value required on high speed lines.

Fig. 22. Loading platform in the ETR M-01 Fast vehicle [34]

The yellow tubular structures are a frame for securing the containers and allow the containers to be fastened with special belts (Fig. 23). The standard load capacity is 7 tons per wagon, however, in the case of transporting heavier goods, it is possible to remove/adjust the ballast.

Fig. 23. Containers in the cargo area secured with belts and prepared for transport [36]

The train runs between the Maddaloni-Marcianise terminal (Caserta near Naples) and Bologna Interporto in 3 h and 20 minutes (average speed 180 km/h). A truck covers the same route in about 6–7 hours. Although the vehicle is adapted to a maximum speed of 300 km/h, it was decided to limit the driving speed of the ETR.500 M-01 to 250 km/h. Data on the ETR 500 train and the modernized version of the ETR.500 M-01 are presented in Table 1.

Mercitalia estimates that its new service could remove nearly 9,000 trucks from the heavily congested A1 motorway, which would reduce carbon dioxide emissions to the atmosphere by around 80% compared to road transport.

4.2. Fuxing CR400BF

The Chinese State-owned Rolling Stock Manufacturer – CRRC – provided transportation services for the Double 11 Shopping Festival 2020 from November 1 to November 20, 2020, it was a worldwide online shopping festival. In order to improve operational efficiency, the Chinese National Rail Administration has allowed the CRRC to convert Fuxing CR400BF trains (Fig. 24) from passenger to freight trains, ensuring that trains can be completely converted back [15].

On November 1, 2020, the Fuxing CR400BF-3087 high speed train, the first to convert to a freight electric multiple unit, took off with 40 tons of packages and crates from Beijing and Tianjin shipped to the Double 11 Shopping Festival (Fig. 25). Friction belts and pulley systems were temporarily used on the train and on the platform, not only to prevent damage to the floor and packaging, but also to improve loading efficiency. The train reached the Hankou railway station in Wuhan in five hours, traveling over 1,100 km between Beijing and Wuhan. Carrying out the transport proves the feasibility of the service.

Table 1. Technical data of the ETR 500 and ETR.500 M-01 units [21, 36]

	ETR 500 (passenger)	ETR.500 M-01 (modernized freight)
Producer	Trevi (Alstom, Bombardier, AnsaldoBreda consortium)	
Production	30 complete multiple units + 60 drive units (for 1st generation single system sets)	1
Number in use	59 passenger multiple units	1
System	drive unit + 11 intermediate units + drive unit (originally-2004, 2011-present) drive unit + 12 intermediate units + drive unit (2004-2010) drive unit + 8 intermediate units + drive unit (ETR 500 F, Turin-Milan)	drive unit + 12 intermediate units + drive unit
Carrier	FS/Trenitalia	Mercitalia Rail
Maximum speed	360 km/h	250 km/h (limited for safety reasons) 300 km/h (no limits)
Continuous power	2 × 4400 kW	
Number and type of motors	8 asynchronous electric motors	
Mass	598 t	
Gauge	1435 mm	
Transport capacity	575 passengers	from 7 t to 10.6 t – per intermediate unit

Table 2 presents the most important data concerning the CRRC Electric Multiple Unit (EMU) – the Fuxing CR400BF vehicle. The vehicle is adapted to travel at a speed of 420 km/h, but the usable speed is 350 km/h.

The Fuxing CR400BF high-speed train is characterized by the ability to carry out high speed journeys, punctuality, safety and with environmental protection, which corresponds to the modern requirements of the large-scale transport and logistics sector. According to the CRRC, in the future, the company will continue to research the EMU rapid delivery service [26].

Fig. 24. CR400BF train at Beijing South station [23]

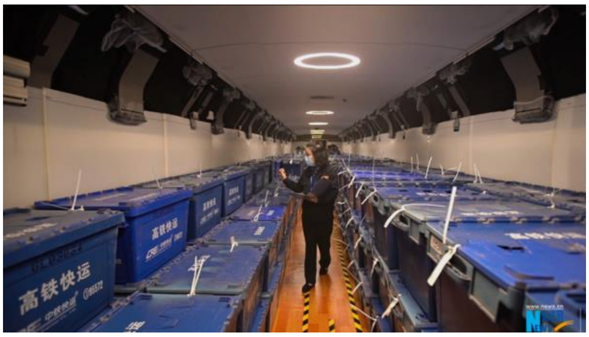

Fig. 25. Load space of the CR400BF high speed train adapted to the freight transport [26]

Table. 2. Technical data of the CR400BF vehicle [13]

Fuxing CR400BF		
Producer	CRRC Changchun Railway Vehicles Co., Ltd.	[–]
Production	2016-present	[years]
System	8 units (4 drive units, 4 driven units)	[–]
Maximum speed	420	[km/h]
Usable speed	350	[km/h]
Traction power	10 140	[kW]
Electric motors	YQ-625 3 Phase AC Induction Motor (Zhuzhou CRRC Times Electric)	[–]
Number and type of motors	8 asynchronous electric motors	[pcs]
Width	3 360	[mm]
Height	4 050	[mm]
Length	211	[m]
Gauge	1 435	[mm]
Axle load	< 17	[t]
Type of traction	25/50 AC from overhead power lines	[kV/Hz]
Traction system	Water cooled Inverter control IGBT-VVVF (Zhuzhou CRRC Times Electric)	[–]

4.3. China's first high-speed freight train

A new generation of high speed freight trains that can carry up to 110 tons of goods rolled off the production line in Tangshan, Hebei Province in northern China (Fig. 26). The new trains, developed by CRRC Tangshan Co Ltd, a part of China Railway Rolling Stock Corp, the country's largest rolling stock producer in terms of production volume, can travel at a maximum speed of 350 km/h [10, 27, 53].

Fig. 26. Chinese high speed freight train in a production hall [11]

Equipped with eight units, the EMU is also characterized by an increased ability to adapt to weather changes. The vehicle can operate in temperatures from –25°C to 40°C. Unlike air and road transport, the high speed freight train is less exposed to the elements, such as heavy rain and strong winds. Train is able to cover 1,500 km distance in five hours [11].

A high speed freight train uses technologies such as big data analysis, Beidou satellite navigation systems, virtual information storage in the cloud, ultra-wide range solutions, precise weight control of transported goods and advanced algorithms for intelligent storage goods and load distribution in the cargo space. These systems are also helpful in working procedures such as accurate identification and positioning of cargo during cargo loading and unloading operations. Each wagon has a pair of loading doors 2.9 m wide, which means those train cargo doors have the largest degree of opening in the world (Fig. 27).

Fig. 27. Loading door – 2.9 m wide [11]

In the cargo spaces is designed floor system with built-in conveyors (Fig. 28), which automatically distribute the goods on the vehicle (Fig. 29). Filling the cargo space with transport units thanks to this system reaches the level of 85% (Fig. 30). The system used is similar to that used in transport aircraft.

Fig. 28. Automatic floor conveyor system for cargo [1]

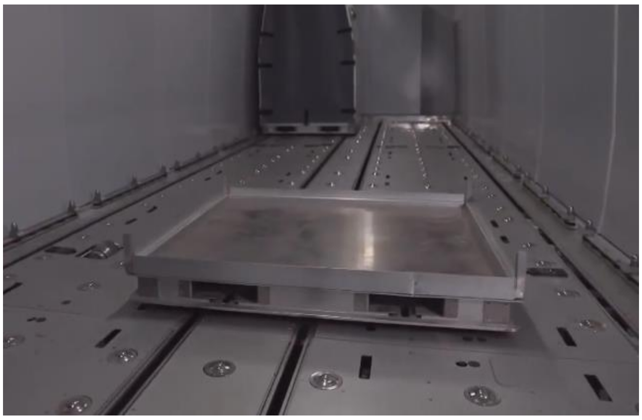

Fig. 29. Platform for automatic distribution of transported goods in the cargo space [1]

High speed freight trains meet the demand for high speed freight transport over medium and long distances ranging from 600 km to 1,500 km. This type of train has significant advantages such as transport on time, high frequency of goods handling, low transport costs and operational capability regardless of the weather.

The front end of the high speed freight train uses the bionic structure of the Chinese sturgeon (fish) skeleton, which increases the slimness of the front of the vehicle. The results of the wind tunnel tests showed that the shape and design of the vehicle nose are very advanced and significantly reduce the running resistance compared to the existing models (Fig. 31).

Fig. 30. Loading space with transport units [1]

China is seeking to increase its global competitiveness in the rail sector by expanding rail networks with a wider range and higher speeds. The Chinese rail operator China State Railway Group plans to build 200,000 km of railroads by the end of 2035, and big part of this will be HSR. All cities over 200,000 residents will be connected to the rail network by 2035, and cities larger than 500,000 will have access to the HSR network [14]. It means that such express vehicles will be more and more needed.

5. Summary

The transport of goods, especially express transport, becomes a determinant of modern trade and enables the efficient development of the economy. The rapid development of the e-commerce department, which makes online trading possible, contributed significantly. Ordinary users have the opportunity to buy or sell items that reach the recipient in record time. Meeting such demanding time standards is extremely complicated and requires the involvement of a well-developed transport infrastructure. On the other hand, the use of a high speed means of transport generates significant costs. This means that in some cases express transport may not be an effective solution.

Fig. 31. First, specially designed Chinese high speed freight train [11]

The examples presented in the article show, despite the increased costs, a significant increase in the popularity of express freight transportation. For this reason, the use of HSR – classified as the top of the most expensive form of rail transport, until recently reserved only for passengers – becomes an interesting prospect with great potential for the implementation in freight transport.

The most developed country in this area is China, which, having the longest HSR network in the world, is intensively working on express freight transport. The solutions of the high speed passenger train Fuxing CR400BF were developed, which, after being adapted to the transport of goods, became a cargo vehicle.

A special EMU vehicle is the recently developed by CRRC Tangshan Co Ltd. It is unique because it is the world's first rail vehicle designed from the beginning for freight transport at speeds of up to 350 km/h. The vehicle also has an automated cargo space, which significantly contributes to increasing the efficiency of the transport. It seems that China, planning huge investments related to the expansion of the HSR network, will increasingly look for solutions in freight transport using HSR.

In the case of Europe, a fairly well-developed HSR network is used so far for passenger transport. The exception is the solution in Italy, where the carrier Mercitalia Fast adapted the Italian high speed train called ETR M-01 Fast for freight transport. The vehicle regularly running on a high speed route with a length of over 500 km is intended for the so-called LDHV shipments and is an advantageous alternative to other modes of transport.

Mercitalia Fast uses the HSR line dedicated to passenger transport and runs through two important transport terminals. Interporto Bologna, one of the largest intermodal logistics hubs in Europe, is home to more than 120 industrial and freight logistics companies and three rail terminals. Interporto Maddaloni-Marcianise, near Caserta is big terminal 30 km from Naples. Due to the location of the terminals and the HSR line connecting them, it was decided to use the HSR train for the transport of goods.

The reasons for the lack of use of HSR in Europe on a larger scale are mainly financial reasons, as well as the nature of the goods transported. In the EU, rail transport mainly transports goods with large dimensions and weight. Such goods do not require transport at high speeds, which is confirmed, inter alia, by the average transport speed of freight trains in Poland (the second country in Europe in terms of rail freight transport work performed) of 25 km/h.

In the event of an increased demand for express freight, the railway infrastructure in European countries with HSR is well-adapted. Therefore, it seems necessary to establish regular long-distance connections while maintaining the profitability of transport. Additionally, the development of logistics centers adapted to this type of transport would be needed.

Such created line for freight HSR would be used for the transport of light goods inside the country due to the small number of connections of the HSR network between countries. An alternative to international connections for the transport of freight HSR would be international connections with a reduced average shipping speed, with only sectional increased speeds.

Nomenclature

CRH	china railway high-speed
EMU	electric multiple unit
ERTMS	European rail traffic management system
EU	European Union
GHG	green house gases
HSR	high speed train
LDHV	low density high value
UIC	international union of railways
tkm	tonne-kilometers

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