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High speed rail development in the United Kingdom of Great Britain and Northern Ireland 2002–2020

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The article presents the development of high-speed rail in Great Britain in the years 2002–2020. The assessment of the development of high-speed rail was preceded by a short description of the country, transport structure and economic development based on basic macroeconomic variables. The collected material also made it possible to determine the trends in shaping the transport intensity of the UK economy on the basis of curves developed using the 6th degree polynomial and the exponential function. In summary, apart from the effects of the development of high-speed rail, development plans and methods of financing are discussed. The article is based on the authors' own thoughts and research as well as on factual sources indicated in the footnotes.

Key words: *UK economy UK, high-speed rail, passenger transport*

1. Introduction

High-speed railways are the most modern and advanced technology for moving passengers inland transport. Their main advantage is the ability to achieve high speeds, usually from over 200 to 300 km/h, which significantly shortens the travel time compared to the time needed to travel the same distance by conventional trains. On the other hand, there is serious competition for high-speed air transport.

High-speed railways require special wagons and locomotives as well as appropriate infrastructure with much larger turning curves, very durable, and strong trackbeds. As a rule, this type of infrastructure is built from scratch, and only in a few cases is the existing infrastructure adapted to the needs of high-speed railways. The operation of high-speed rail requires special trains, railway lines, stations, and separate ticketing systems.

It should be emphasized that the implementation of investments to perform transport using this technology is very capital-intensive. Nevertheless, the required large expenditures for development are compensated by:

- high comfort and short travel time
- huge impact on the economic development of regions and the country
- high level of security and relatively in relation to other branches transport low level of negative impact on the natural environment
- high energy efficiency
- low external costs.

The above-mentioned basic premises determined that transport using this technology is dynamically developing in the rich countries of Europe and Asia.

The research period ended in 2020 in order to eliminate the negative impact on the economy of the effects of the global COVID-19 pandemic. The idea was that the research should be based on the main development trend and not be overshadowed by side causes.

2. General characteristics of the country

The United Kingdom of Great Britain and Northern Ireland is an island country. It is located in the western part of the European continent. Great Britain is comprised of England, Wales, Scotland, and Northern Ireland. The capital of the country is London. The area of the United Kingdom is 242,500 km^2 [46]. Figure 1 shows a map of Great Britain with the country's largest cities marked.

Fig. 1. Map of Great Britain [11]

The UK has experienced relatively minimal demographic change in recent years [48]. In 2020, the population was 67 886 011, an increase of 0.53% over 2019. The population density was 281 people per square kilometer. The average age shows an upward trend – in 2020, it reached 40.5 years. On the other hand, the projected life expectancy is about 81.8 years, with the fertility rate decreasing year by year. In 2020, more than 56 million people, or 83.2% of the UK population, lived in cities. Net migration (i.e. the difference between immigration and emigration) in 2020 amounted to 260,650 people.

3. Economic situation based on macroeconomic variables for the years 2002–2020

Great Britain belongs to the group of highly developed countries. On February 1, 2020, this country ceased to be a member of the European Union. Withdrawal from the EU Brexit caused disruptions in trade with the European Union, which negatively affected the economic situation of Great Britain. In addition, the closure of the British labor market to EU residents resulted in a shortage of qualified employees in many companies. Table 1 presents the basic macroeconomic indicators of the UK economy in the years 2002–2020.

Table 1. Basic macroeconomic indicators of the UK economy in 2002–2020 (annual percentage changes) [29, 43]

Itemization	2002	2003	2004	2005	2006	2007	2008	2009	2010
GDP	2.1	2.7	3.3	1.9	2.6	2.6	–0.1	–5.0	1.9
Private consumption	3.5	2.9	3.4	1.4	2.1	2.2	–0.4	–3.3	0.0
Total investments	3.7	0.4	6.0	3.0	5.4	7.8	–5.0	–15.1	5.0
Employment	72.2	72.4	72.3	72.3	72.2	72.5	72.7	70.6	69.3
Unemployment	5.2	5.0	4.7	4.8	5.5	5.4	5.7	7.6	7.7
Inflation	1.3	1.4	1.3	2.0	2.2	2.0	3.6	2.2	3.3
Public finance balance	–1.7	–3.4	–3.3	–3.4	–3.0	–2.7	–4.2	–3.1	–2.8
The public debt	53.4	52.2	54.7	56.1	55.3	55.6	68.3	81.7	92.8
Current account balance of payments	–2.2	–1.8	–2.3	–2.0	–2.9	–3.4	–4.0	–3.3	–3.1
Export	1.0	1.7	4.9	7.1	12.8	5.6	2.4	–11.3	6.2
Import	4.8	2.0	6.6	6.5	12.1	5.2	–1.2	–12.3	8.7

Itemization	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GDP	1.7	0.7	1.7	2.8	2.2	1.9	1.9	1.3	1.4	–9.8
Private consumption	0.1	1.8	1.9	2.6	2.3	3.0	3.4	1.1	1.4	–10.5
Total investments	2.0	1.5	2.6	7.5	5.3	4.4	2.8	0.4	1.5	–
Employment	69.3	69.9	70.5	71.9	67.5	74.3	75.0	75.6	76.1	75.4
Unemployment	8.3	7.7	7.1	5.9	4.9	4.8	4.4	4.4	3.8	5.1
Inflation	4.5	2.8	2.6	1.5	0.0	0.7	2.7	2.5	1.8	1.2
Public finance balance	–1.6	–3.2	–4.4	–5.1	–5.3	4.4	4.0	4.0	3.7	3.8
The public debt	106.7	111.0	106.3	116.8	86.9	86.8	86.2	85.7	85.4	94.9
Current account balance of payments	–1.8	–3.5	–-4.9	–4.9	–5.0	–5.4	–3.8	–3.7	–3.1	–3.5
Export	5.6	0.7	1.5	0.5	6.7	-1.3	6.7	–0.1	0.7	–14.7
Import	1.0	3.1	1.4	2.4	4.4	3.8	4.4	–0.6	–0.3	–16.8

In the analyzed period, Great Britain experienced a slowdown in economic growth. The level of GDP in 2008–2009 dropped significantly to as much as –5%. The changes were caused by the global crisis caused by the financial market in the United States. The crisis also had an impact on a drastic drop in other macroeconomic indicators in 2009, such as:

- private consumption –3.3%
- total investments –15.1%
- unemployment 5.7%
- export –11.3%
- imports –12.3%.

Significant drops were also recorded in 2020, when the COVID-19 pandemic contributed to the economic crisis in many countries. As a result, e.g., After the temporary ban on doing business and traveling in the UK, GDP fell by –9.8% and the unemployment rate rose to 5.1%. Like a significant number of countries, the UK has implemented fiscal programs aimed at mitigating the negative effects of the pandemic. The protection of jobs was of particular importance. Thanks to the support in this area, employees received downtime benefits in the amount of 80% of their salary up to a maximum of £2,500. The additional economic losses that occurred were caused not only by domestic actions but also by the global economic slowdown. Table 2 presents the evolution of GDP in billions of dollars in the years 2002–2020.

Table 2. UK GDP in billion USD [42]

Year	GDP
2002	1780
2003	2051
2004	2412
2005	2533
2006	2706
2007	3093
2008	2921
2009	2412
2010	2482
2011	2660
2012	2704
2013	2783
2014	3066
2015	2933
2016	2693
2017	2662
2018	2857
2019	2831
2020	2708

The development of GDP in the analyzed period is presented in Fig. 2 using a sixth-degree polynomial.

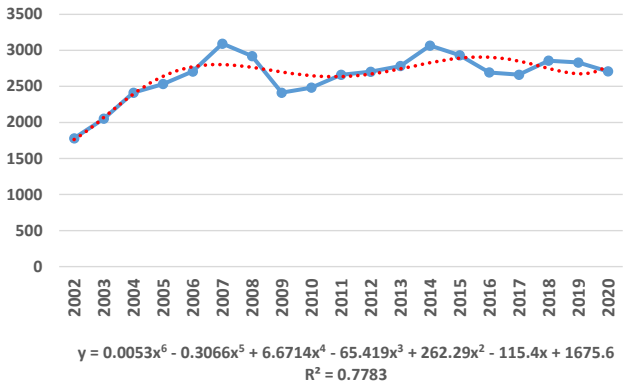

Fig. 2. GDP in the years 2002–2020 using the sixth degree polynomial, in billions (own elaboration based on [42])

Successive slowdown of the UK economy since the referendum on leaving the EU in June 2016 has resulted in a depreciation of the British pound and, consequently, an increase in consumer and producer prices.

4. Characteristics of transport in Great Britain

In 2020, UK transport network length was over 398,000 km, including 3.7 thousand km of motorways. The characteristics of transport in the United Kingdom, broken down by type of infrastructure, are presented in Table 3.

Table 3. Characteristics of transport in Great Britain in 2020 [12]

Type of transport infrastructure	Length (km)
Railway lines	16 377
Roads including:	398 340
highway	3700
main roads	47 480
secondary roads	347 160
Navigable inland waterways	1050
Pipelines	14 355

In the general volume of cargo transport (Table 4), road transport is of dominant importance, with 136 billion tkm of transport performance in 2020. A much lower level in relation to road transport was achieved in the analyzed period by rail transport, reaching 15 billion tkm in 2020.

Table 5 summarizes the total transport performance in the years 2002–2020.

Table 4. Transport performance in Great Britain in 2002–2020 (billion tkm) [9]

A branch of transport	Road	Railway	Water inland	Pipeline*
2002	150	18	0.2	11
2003	152	19	0.2	10
2004	152	20	0.2	11
2005	153	22	0.2	11
2006	152	22	0.2	10
2007	157	21	0.1	10
2008	146	21	0.2	10
2009	125	19	0.2	10
2010	139	19	0.2	10
2011	140	21	0.1	10
2012	143	215	0.2	10
2013	131	23	0.2	10
2014	128	22	0.2	10
2015	143	18	0.2	–
2016	148	17	0.2	–
2017	147	17	0.2	–
2018	152	17	0.2	–
2019	154	17	0.2	–
2020	136	15	0.2	–

Table 5. Total transport performance in 2002–2020 (billion tkm) [9]

Year	Total transport
2002	183.8
2003	186.4
2004	193.0
2005	197.9
2006	201.1
2007	207.5
2008	197.7
2009	177.0
2010	175.7
2011	185.7
2012	190.0
2013	195.0
2014	197.4
2015	171.2
2016	175.2
2017	174.2
2018	179.2
2019	181.2
2020	161.2

The data contained in Table 5 shows that transport performance in the analyzed period shows a downward trend, with some fluctuations.

The development of total transport in the years 2002–2020 was shown using a sixth-degree polynomial (Fig. 3).

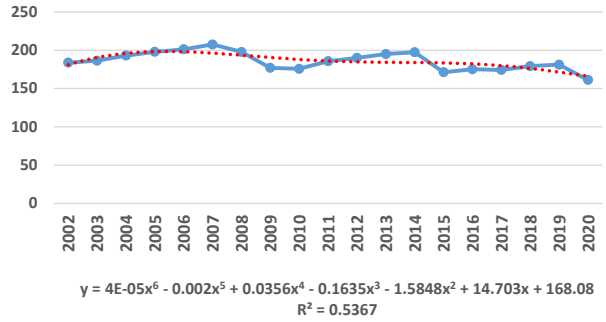

Fig. 3. Total transport in the years 2002–2020 using the sixth degree polynomial (red line), in billion tkm (own elaboration based on [9])

The curves in Fig. 3 are quite uneven. However, the use of this method for research does not seem to be correct due to the low credibility index r^2.

Using data on the GDP and total transport development in Great Britain from 2002 to 2020, the development of transport intensity was examined (Table 6).

Table 6. Transport intensity in the years 2002–2020 [9, 42]

Year	Transport intensity
2002	0.103
2003	0.091
2004	0.080
2005	0.078
2006	0.074
2007	0.067
2008	0.068
2009	0.073
2010	0.071
2011	0.070
2012	0.070
2013	0.070
2014	0.064
2015	0.058
2016	0.065
2017	0.065
2018	0.063
2019	0.064
2020	0.060

The transport intensity determined on the basis of the sixth degree polynomial is presented in Fig. 4.

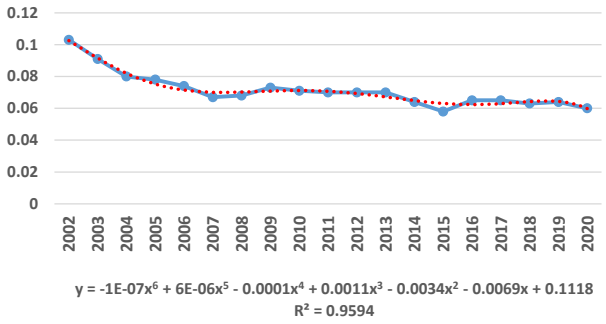

Fig. 4. Transport intensity in the years 2002–2020 (polynomial – red line)

The polynomial curves illustrating the transport intensity in the analyzed period are systematically decreasing. This means that the economy's transport needs are reduced. The credibility of the conducted research is fully confirmed by the high r^2 index, which is close to one.

The transport intensity calculated using the exponential function is presented in Fig. 5.

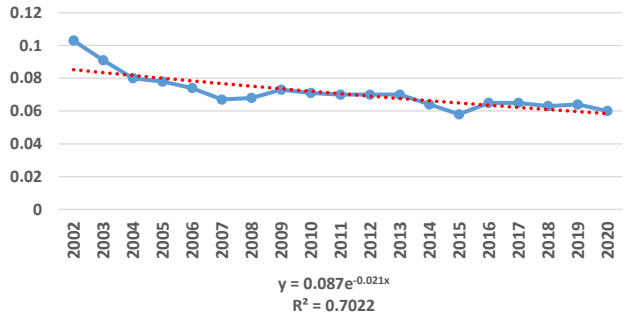

Fig. 5. Transport intensity in the years 2002–2020 (exponential function – red line)

The downward curves indicate a favorable trend in the level of transport intensity. This means the development of modern technologies in the economy of the United Kingdom of Great Britain and the decreasing share of transport costs in economic development. However, this method's transport intensity analysis does not seem useful in research due to the too low credibility index r^2.

5. High-speed railways in the UK

5.1. Development of high-speed rail

Great Britain has a long history of railway development. Concepts of building high-speed rail appeared at the end of the 20th century. The development stages of high-speed rail in Great Britain are presented in Table 7. It contains a synthetic summary of individual stages determining the current shape of high-speed rail.

Table 7. Development stages of high-speed rail in the UK by 2020 [19–21, 27, 45]

Year	Development stages
1970s	Start of investment in high-speed trains – the first Class InterCity125 (HST) train
1990s	Commencement of construction of the first high-speed line, High Speed 1
2003	Opening of the first part of the High Speed 1 line
2007	The opening of the second part of the High Speed 1 line (London St Pancras)
2009	Announcement of plans to develop high-speed lines in the UK
2010	Announcement of the route of the new high-speed line High Speed 2
2012	The government's decision to build the High Speed 2 line London–Birmingham–Manchester–Leeds
2017	Signing of contracts for the first engineering part of High Speed 2
2020	Commencement of construction of the first stage of High Speed 2

In the UK, the criterion for high-speed rail is the maximum speed that trains can reach. High-speed railway lines should be connected with other railway lines, creating one integrated national network [15].

We are dealing with high-speed rail if it is possible for trains to travel at a maximum speed of 200 km/h and 300 km/h on a specially built line (HS 1).

There is only one high-speed line in the country, High Speed 1 (HS1) London – the Channel Tunnel, which allows you to travel at a maximum speed of 300 km/h. In addition, there are four lines modernized and adapted to service high-speed trains with a maximum speed of 200 km/h:

– East Coast mainline
– West Coast mainline
– Great Western Main Line
– Midland Main Line [44].

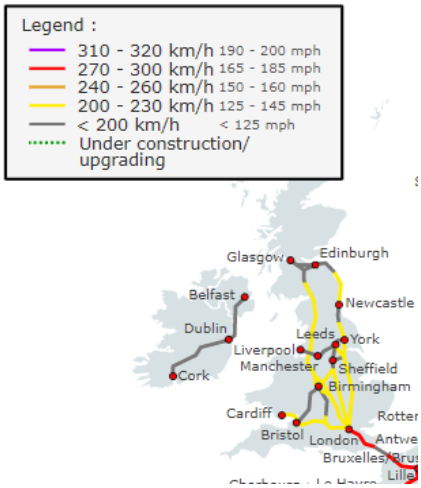

Fig. 6. Map of high-speed lines in Great Britain in 2016 [17]

By 2020, high-speed rail transport in Great Britain was served by ten carriers [47]:

– Avanti West Coast
– CrossCountry
– East Midlands Railway
– Eurostar
– Grand Central
– Great Western Railway
– Hull Trains
– London North Eastern Railway
– Southeastern
– TransPennine Express.

5.2. Types of operated high-speed trains

The high-speed trains used in Great Britain mostly belong to the so-called ROSCOs (rolling stock leasing companies), i.e. associations of rolling stock leasing companies [34] that rent rolling stock to operators of high-speed lines. The offer is dominated by three private companies: Angel Trains, Eversholt Rail Group and Porterbrook Leasing Company Ltd [23]. Table 8 shows the types of high-speed trains in operation in the UK until 2020. The list also includes information on the operators of the given trains, the number of trains in use, along with information on the number of wagons in a given train. The year of entry into service of a given type of train and its maximum speed, as

well as the operational speed achieved on British tracks are also given.

Table 8. Types of operated high-speed trains [47]

Name	Operator	No. of sets	No. of wagons in the set	Max speed km/h	Max operating speed km/h	Year of com-mission-ing
Class IC125	Cross Country, East Midlands Railway, Grand Central	80	9 or 10	200	200	1976
Class IC225	London North Eastern Rail-way	thirty	10	225	200	1989
Class 180 Adelante	Grand Central, Hull Trains	14	5	200	200	2000
Class 220 Voyager	cross country	34	4	200	200	2001
Class 221 Super Voyager	Cross Country, Avanti West Coast	44	4 or 5	200	200	2002
Cass 222 Meridian	East Midlands Railway, Hull Trains	27	4.5 or 7	200	200	2004
Class 390	Avanti West Coast	56	9	225	200	2002
Class 395 Javelin	Southwestern	29	6	225	225	2009
Class 800	Great Western Railway, London North Eastern Rail-way	46	5	200	200	2017
Class 800	Great Western Railway, London North Eastern Rail-way	34	9	200	200	2017
Class 801	London North Eastern Rail-way	12	5	200	200	2018
Class 801	London North Eastern Rail-way	thirty	9	200	200	2018
Class 802	TransPennine Express, Hull Trains, Great Western Railway,	22	5	200	200	2018
Class 802	Great Western Railway	14	9	200	200	2018
Class 374 e320	Eurostar	17	16	320	300	2015

The official UK system for naming train types is British Rail Class + number. Selected high-speed trains operating passenger services in Great Britain are presented below.

British Rail Class 800 Intercity Express Train or Azuma is a type of diesel multiple units built by the Japanese company Hitachi based on the Hitachi A-train project [5]. It was put into operation on British tracks in 2017. This type of train uses electric motors powered by overhead electrical wires and diesel generators at the same time, enabling transport on non-electrified tracks. It is operated in five- or nine-carriage trains and its maximum speed is 200 km/h [47]. These trains operate on Great Western Railway and London North Eastern Railway routes. Currently, most of the 300-kilometre route requires the use of internal combustion engines (with a maximum speed of 200 km/h). The trains comply with British Railway Group standards and Technical Specifications for Interoperability (TSI). The appearance of the Class 800 trainset is shown in Fig. 7.

Fig. 7. British Rail Class 800 Azuma train [22]

British Rail Class 395 " Javelin " (Fig. 8) is a Hitachi-built dual-voltage electric multiple unit (EMU) for high-speed commuter services on the High Speed 1 (HS1) and London–Kent Line [41]. Entirely manufactured in Japan, the train, which is part of the Hitachi AT300 family, is a six-car vehicle. Each six-car unit can work together to form a 12-car train (the joining process is automated and takes less than 60 seconds). The train's top speed is 140 mph (225 km/h) with 25 kV AC overhead electrification on High Speed 1 (HS1) and 100 mph (160 km/h) on 750 V DC third rail on conventional lines. The fleet was ordered in June 2005 and entered service in 2009 and is now operated by Southeastern. The trains comply with British Railway Group (RGS) standards and Technical Specifications for Interoperability (TSI). The name " Javelin " refers to the Olympic Javelin service Shuttle, which was the transport offer during the Olympic Games in London in 2012.

Fig. 8. British Rail Class 395 Javelin train [4]

British Rail Class 374, also referred to as Eurostar e320, is a type of passenger electric train [3]. The trains, owned by Eurostar International Limited, are sixteen-car versions of the Siemens Velaro. Each set is 390.2 m (1,280 ft) long. With a traction power of 16,000 kW, the train reaches a maximum speed of 320 km/h [39], but on the UK line, the

speed does not exceed 300 km/h. These trains have been carrying out passenger transport on the High Speed 1 line through the Channel Tunnel since 2015. They have been designed and built based on very strict standards and design requirements that are set for rolling stock used for transport in tunnels. The trains comply with the technical specifications for interoperability (TSI). The Class 374 e320 kit is shown in Fig. 9.

Fig. 9. British Rail Class 374 e320 train [28]

6. State and development prospects of high speed networks

As previously mentioned, the High Speed 1 (HS1) line carries international passenger traffic between the UK and mainland Europe via the Eurotunnel and domestic passenger traffic to and from Kent and East London stations. The construction of the High Speed 1 line was divided into two stages. The first one ended in 2003, and the line was fully commissioned on November 14, 2007. On the HS1 line, which is 109 kilometers long, trains move at a speed of up to 300 km/h [16]. Services are provided by Eurostar and Southeastern. It is the first fully high-speed line in the UK. Its course is presented in Fig. 10.

Fig. 10. Route of the High Speed 1 line [18]

Although the HS1 infrastructure is still relatively new, it needs upgrading work as it ages. Planned modernization works in the next five years include [32]:

– renewal of elevators and, escalators and walkways at stations
– renovation of the track ballast along a 30-kilometer section of HS1
– replacement of all 13 emergency power supply systems (UPS) in signal rooms.

As of 2020, construction is underway on a second high-speed rail line, High Speed 2 (HS2), which will link London to major cities in the north of the country. The assumed speed on the 400 km (250 mi) long HS2 will be 360 km/h and will significantly reduce journey times to Scotland. High Speed 2 is designed and built to be the most sustainable high-speed rail network in the world. Trains running on HS2 will be powered by zero-CO_2 energy, offering a cleaner alternative to long-haul car journeys and domestic flights [24].

It was originally assumed that the construction of the line would take place in three phases (Fig. 12) [24]:

– Phase 1 – covering the London–Fradley section in the West Midlands (under construction) – approx. 225 km of route, of which over 100 km are tunnels
– Phase 2a – covering the section from Fradley in the West Midlands to Crewe in Cheshire, with services joining the existing rail network at Crewe, creating direct links to destinations including Liverpool, Manchester, Preston, Carlisle and Glasgow
– Phase 2b – Crewe to Manchester and West Midlands to Leeds.

Phase 1 requires the construction of 225 km (140 miles) of new high-speed rail track, four new stations and two new depots. Part of the route will run through a 103 km (64 miles) tunnel and four shorter tunnels. In addition, the route will include 50 railway viaducts, including the longest in the UK at 3.4 km (2 miles), Colne Valley (Figure 11). Phase 2a includes the construction of four new stations, 17 viaducts, 65 bridges and two tunnels. Both phase 1 and phase 2a are expected to be commissioned in 2029–2033 [25].

Fig. 11. Visualization of the Colne Valley viaduct as part of the HS2 project, which is to be the longest railway bridge in Great Britain [24]

In 2021, phase 2b was reviewed by the government as part of the Integrated Railway Plan, which consequently led to a reduction in the construction of new high-speed railway

tracks (Fig. 12) [26]. The main premise for the revision of the plans was the assessment of the Office for Infrastructure Projects Infrastructure Projects Authority (IPA), which assessed the probability of achieving the objectives and tasks set out in phase 2b negatively in terms of their implementation within the set deadline and within the allocated budget [7].

Fig. 12. Currently planned route of HS2 [2]

As a result of the changes made, the north-east section, which will run from Birmingham to Nottingham, has been greatly shortened. The Birmingham to Leeds leg of the HS2 was abandoned, and the construction of the Northern line Powerhouse Rail (NPR) was to link Manchester and Leeds.

To changes compensate, there are plans to upgrade and extend the Transpennine Main Railway line between Manchester, Leeds and York. The Midland line will also be upgraded Main Line between London St Pancras, East Midlands and Sheffield, as well as the East Coast Main Line, where train speeds will be improved [13].

Rail journeys (it is estimated) that approx. increase throughput. Critics of this decision have highlighted the need to include the northern part of the country in the high-speed rail system to boost economic development in this part of the UK, while supporters believe that upgrading existing infrastructure and reopening old lines faster will bring more benefits to more people for much less financial outlays, ensuring sustainable local transport without interfering with the natural environment [40]. It should be noted that discussions on the final shape of phase 2b are still ongoing, so the current concept of its implementation may still change.

7. Methods of financing high-speed railways

After the Second World War, most of the British railway network and trains were managed by the transport company British Rail [36]. For several decades, the company was the main national rail operator in the United Kingdom. The privatization process, which started in the 1990s, resulted in Great Britain resigning from having a state-owned carrier [8], and the possibility of providing transport services was made available to private companies on a franchise basis [35]. Currently, the entire infrastructure is owned and managed by the state manager – Network Rail [32].

British railways, including high-speed rail [24], are financed from several sources. The first is the revenues of carriers operating in the country, which are allocated, among others, to the maintenance of rolling stock and personnel [37]. Part of the funding for maintenance and upgrades to tracks, stations, tunnels and bridges comes from Network Rail. The railway is also financed by the UK government, which spent 6.5 billion pounds on rail transport in 2019–2020 [37]. To a small extent, funds also come from private companies.

The HS1 line is operated by a wholly owned subsidiary of Network Rail, Network Rail High Speed (NRHS) [33]. The construction cost of HS 1 amounted to EUR 7.61 billion, including EUR 2.78 billion in stage 1 and EUR 4.83 billion in stage 2. The investment was financed from a subsidy:

- government (EUR 4.68 billion)
- private companies (EUR 2.93 billion) under the PPP program (private–public–partnership) [14].

High speed 2 is financed from the state budget. The executive non-departmental public body for the line is HS2 Ltd, sponsored by the Department of Transport. The total budget allocated to the construction of HS2 (2019 prices) is:

- for phase 1 – £44.6 bn, including £9.6 bn for contingencies
- for phase 2 – 5.2–7.2 billion pounds.

8. Organization of traffic and comfort of transit

There are two classes on trains in the UK – First Class and Standard Class. Reservation is also possible. All new trains are equipped with displays and automatic communication systems to inform passengers about the route. Power points for chargers and laptops as well as on-board Wi-Fi are also standard equipment [31].

Information on the current traffic organization can be checked on the carriers' websites and at railway stations. National Rail is a network of railway connections, which includes about twenty carriers associated with the Association of Railway Transport Companies (ATOC) [1]. Visit nationalrail.co.uk for travel details and on-board amenities. Passengers can buy tickets at railway stations and via the Internet. Carriers offer many discounts if the ticket is bought in advance and special promotional offers on selected journeys [31]. National Rail also offers special train cards – National Railcards and Regional Railcards, thanks to which it is possible to travel cheaper by rail in Great Britain [31].

9. Summary – benefits of high-speed rail transport

The operation and development of high-speed rail contributes to the improvement of the quality of rail services and economic, regional and environmental development. The advantages resulting from the development of high-speed rail include [10]:

- creation of new jobs (from the planning stage and construction to the operation of high-speed lines)

- development of the regions through which this line runs [6]
- improving connections between cities and smaller towns
- reducing train travel times, which encourages more people to travel by train and thus relieves congestion in cities
- freeing up capacity on existing lines to increase the provision of local commuter services and shift many freight services from road to rail [38]
- reduction of CO_2 emissions, which helps to prevent climate change.

The biggest source of carbon emissions in the UK is transport. The government's commitment to bring all greenhouse gas emissions to net zero by 2050 will help deliver the HS2 high-speed rail, which trains will be powered by zero-carbon energy, offering a cleaner alternative to long-haul car journeys and domestic flights [30].

The benefits of high-speed rail operation mean that despite the constant growth and significant costs of building and maintaining high-speed lines, countries have decided to develop this type of rail transport.

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