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ROLE OF RAILWAY TRANSPORT IN GREEN DEAL 2050 CHALLENGE – SITUATION IN THE CZECH REPUBLIC

ABSTRACT

Motivating people to switch to public transport from using their own car is one of the most important parts on the way to accomplishing the Green Deal 2050 challenge. In the Czech Republic, where the number of passengers was rapidly rising in the pre-pandemic times, individual car transport still offers many more travel benefits than railway lines for most long-distance relations. How to strategically develop the railway infrastructure? Will the planned high-speed railways really be the appropriate solution to this problem in time? Will they satisfy all the different requirements of passengers who are potentially able to switch from car to train?

KEYWORDS

modal split; railway transport; sustainable mobility; gravitation model; service quality.

1. INTRODUCTION

This article is an ongoing output of a long-term project whose goal is to recognise what quality of public transport could motivate passengers to not use individual car transport. A dependence of demand for and quality of public transport will be investigated. Input data will be represented by an origin destination matrix obtained from telephone SIM cards and by quantified quality parameters of public transport.

2. THE ROLE OF RAILWAYS IN SUSTAINABLE MOBILITY

Europe has decided to become a climate-neutral region by 2050 [1]. As is known, transport makes a very significant contribution to the current carbon footprint, and ways to serve population

mobility and freight transport will be a key aspect of meeting the goals set by the Green Deal for Europe.

The transport of both cargo and passengers using motorised means of transport always places a burden on the environment. Ultimately, energy can be saved and pollutants can be avoided through choice of transport mode. Train is an energy-efficient and environmentally friendly method, and modern electric railways even more so. In terms of environmental impact, the railway system performs significantly better than cars, heavy good vehicles or aircraft. Rail transport provides a particularly favourable energy input to transport capacity ratio. In comparison with cars, railways only require around half as much energy for the same passenger transport volume. It is mainly because of low rolling resistance (steel wheel on steel rail instead of rubber tyres on asphalt). Plus, travel in a long distance train is almost three times more energy efficient than air traffic [2]. Detailed comparison is shown in *Figure 1*.

In addition, in some cases railways may be improved compared to the present state, and their standard energy consumption can be further reduced, for example by electrifying lines not yet electrified, expanding the possibilities of braking energy recovery etc.

For the environmental objectives to be achieved at all, railways need to significantly increase their share of the modal split. However, passengers will not start using them just because they are environmentally friendly. What they require is a modern and high-quality mobility product. To reduce the environmental impact of transport, it is necessary to offer railways in the form of an attractive and customer-oriented part of mobility as a service concept [4].

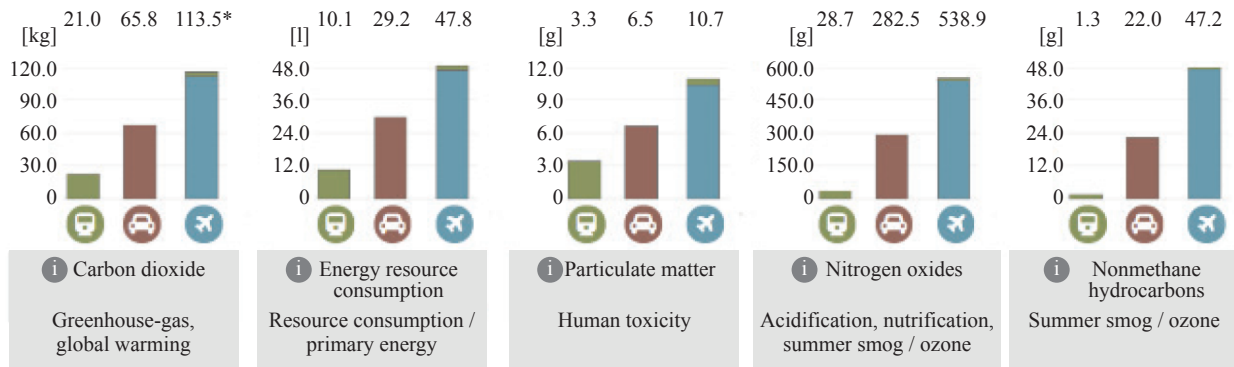


Figure 1 – Comparison of environmental impact of a single passenger journey in the Munich – Berlin route [3]

3. QUALITY MODERN RAILWAY TRANSPORT BRINGS PASSENGERS

For railways to be attractive to passengers and motivate them to make journeys by public transport rather than private cars, railways must meet and exceed the expectations not of passengers who already use them but of those who currently use private cars. This article is primarily concerned with long-distance and interregional transport. The perception of the quality of rail transport from the passenger’s perspective is, of course, somewhat subjective, but several areas can be defined that play a role in deciding whether a passenger chooses to travel by train or by car. General passenger’s perception of quality is indicated in *Figure 2*.

Good practice experiences (French TGV, German ICE, Austrian and Czech Railjet, also Czech “Pendolino” service) show that a successful long-distance railway service has the character of a line (regular interval, same trainsets, same level of quality and service provided on board of each train). These trains have attracted masses of passengers.

However, travel speed plays a very important role in making the decision whether the passenger will use a long-distance train or a car ride [5, 6]. It is mainly influenced by infrastructure parameters. Therefore, in this sense, the railway network should be developed by building high-speed lines as well as conventional lines to achieve competitive and systemic travel times between cities [7].

Of course, there is a lot of other factors that influence the demand of public transport. An important part of the total quality is the level of train sets and single carriages. It also includes, for example, operational intervals, ticket prices, reliability of operation, level of on-board services (Wi-Fi, air conditioning, train bistro) and services in stations.

4. SITUATION IN THE CZECH REPUBLIC

Although the Czech Republic has one of the densest railway networks in the world, most of the lines do not meet the requirements of contemporary fast and modern railway transport due to their

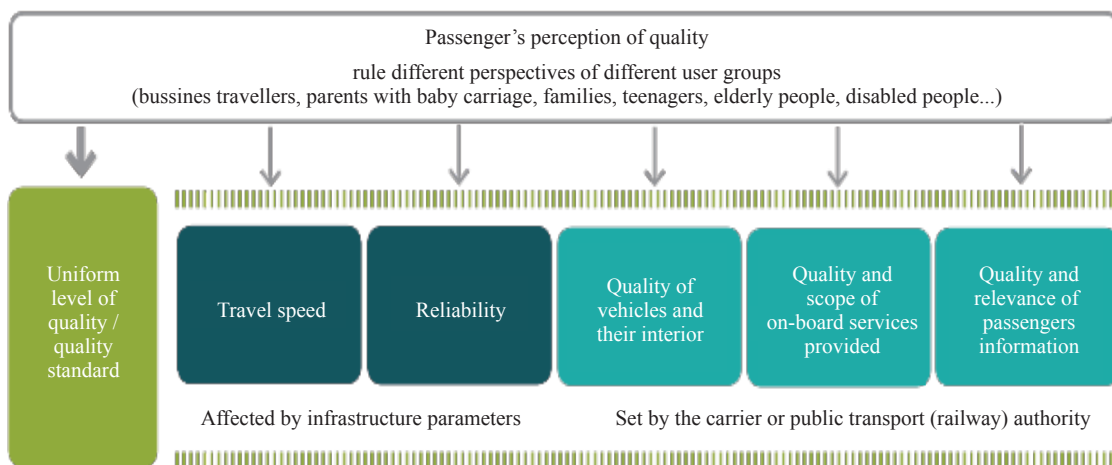


Figure 2 – Passengers' perception of quality of railway services

parameters, especially line speed and state of technology. As a result, more than 70% of rail transport (passenger and freight) is carried out on approximately 30% of the rail network. These are mainly lines that have been upgraded over the past thirty years as part of the so-called rail transit corridor modernisation programme. This typically included renewal of the railway substructure and superstructure, modernisation of stations, increase in line capacity, basic modernisation of signalling equipment and increase in line speed. The map of transit corridors is shown in *Figure 3*.

Generally speaking, the realisation of rail transit corridors modernisation programme (the programme is still ongoing, some sections and key

nodes are not yet complete) created conditions for the development of modern passenger and freight railway transport in Czechia. This programme was financed primarily from various EU funds (up to 80 percent), as well as through loans from the European Investment Bank.

The popularity of passenger rail transport is growing in Czechia. Two segments of passenger rail transport are particularly successful – suburban rail transport as part of regional integrated public transport and long-distance (interregional or interstate) rail transport. Over the last 10 years, the number of passengers has increased by 18%. The development of demand could be seen in *Figure 4*.

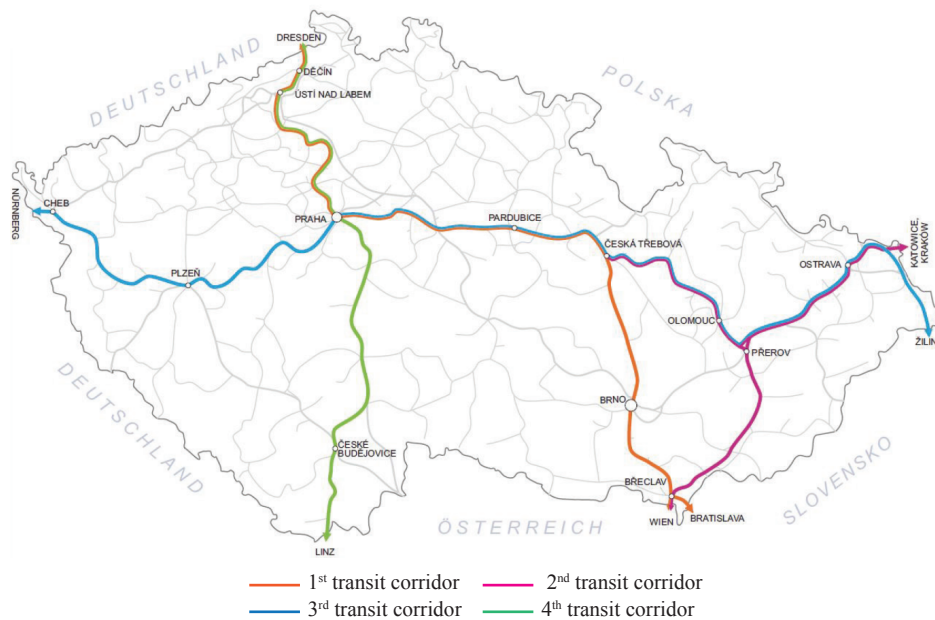


Figure 3 – Map of the Czech rail transit corridors

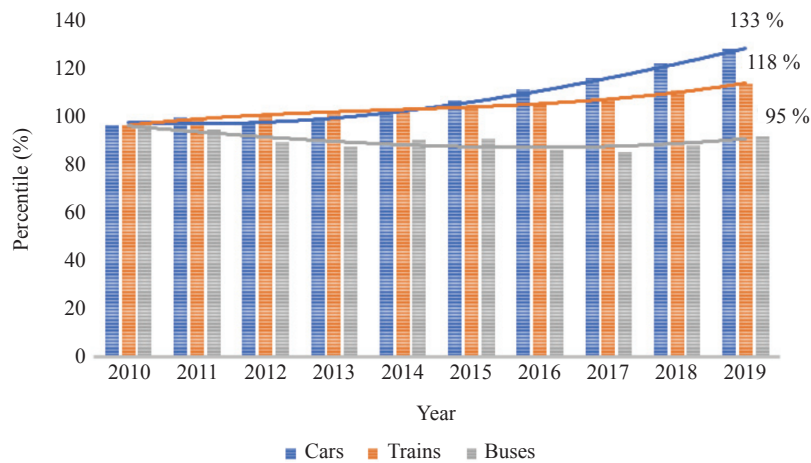


Figure 4 – Trend in number of passenger journeys in the Czech Republic [8]

The medium distance travelled is also on an upward trend, suggesting that long-distance transport is the main driver of railways' success. This positive development is due to several aspects:

- The liberalisation of the rail market and the related emergence of competition have led to an increase in the range and quality of the transport offer.
- Modernised infrastructure has created the conditions for a better and more reliable offer.
- Generally higher perception of environmental aspects and sustainability in society.

However, this development is happening almost exclusively on modernised lines. There is therefore a large disparity in the quality and transport offer across the network.

Before the pandemic, in 2019, the modal split of passenger railway transport in the Czech Republic achieved 9.9%. It is not that bad compared to Austria (12.9%) or Netherlands (11.3%), but the Green Deal challenge requires far better values [9].

4.1 Capacity problems and missing links

As the development of passenger railway transport has been concentrated on corridor lines, the capacity of these lines is practically exhausted, especially in the vicinity of large railway junctions (Prague, Brno). It has become clear that the corridor modernisation programme significantly underestimated the issue of line capacity around these

junctions. For example, nowhere was it planned to increase the number of tracks around these junctions in order to segregate intensive suburban and long-distance rail traffic. Unfortunately, Správa železnic, the Czech railway infrastructure manager, does not publish information on the level of capacity utilisation of the railway infrastructure. However, it is clear that line capacity is or will very soon become a limit to the development of passenger rail transport. Freight transport is operated primarily at the night because almost all the capacity is reserved for passenger transport.

A chronic feature of the development of the railway network and, to a significant extent, of the transport policy, is the neglect of the development of the Prague – Munich and Prague – Linz routes. Bavaria is the Czech Republic's largest trading partner. Although the D5 motorway linking Prague with Nuremberg and Munich was quickly built in the 1990s, there is still no fast, high-capacity railway line of equivalent importance between the Czech Republic and Bavaria. There are even only single-track non-electrified lines. The official development plans promise electrified double-track line Pilsen – Domažlice – Germany with a maximum speed of 200 kmph to be built until 2030. The situation between Prague and Linz is similar. However, it should be noted that even Germany and Austria do not give this connection much priority in their infrastructure planning.

Table 1 – List of Czech-Austrian and Czech-German railway lines (sorted clockwise)

Track number	Track journey	Number of rails	Electrification	Main track
002	Česká Třebová – Brno – Břeclav – Vienna (A)	2	Yes	Yes (corridor 1, 2)
248	Znojmo – Retz (A)	1	Yes	No
199	České Budějovice – České Velenice – Vienna (A)	1	Yes	No
196	České Budějovice – Rybník – Linz (A)	1	Yes	Yes (corridor 4)
183	Klatovy – Bayerisch Eisenstein – Plattling (D)	1	No	No
180	Pilsen – Domažlice – München (D)	1	No	Yes
179	Cheb - Nuremberg (D)	1	No	No
148	Cheb – Aš – Hof (D)	1	No	No
145	Sokolov – Kraslice – Zwotental (D)	1	No	No
142	Karlovy Vary – Johanngeorgenstadt (D)	1	No	No
137	Chomutov – Cranzahl (D)	1	No	No
083	Děčín – Bad Schandau (Dresden, Berlin) – Rumburk	2	Yes	Yes (corridor 1, 4)

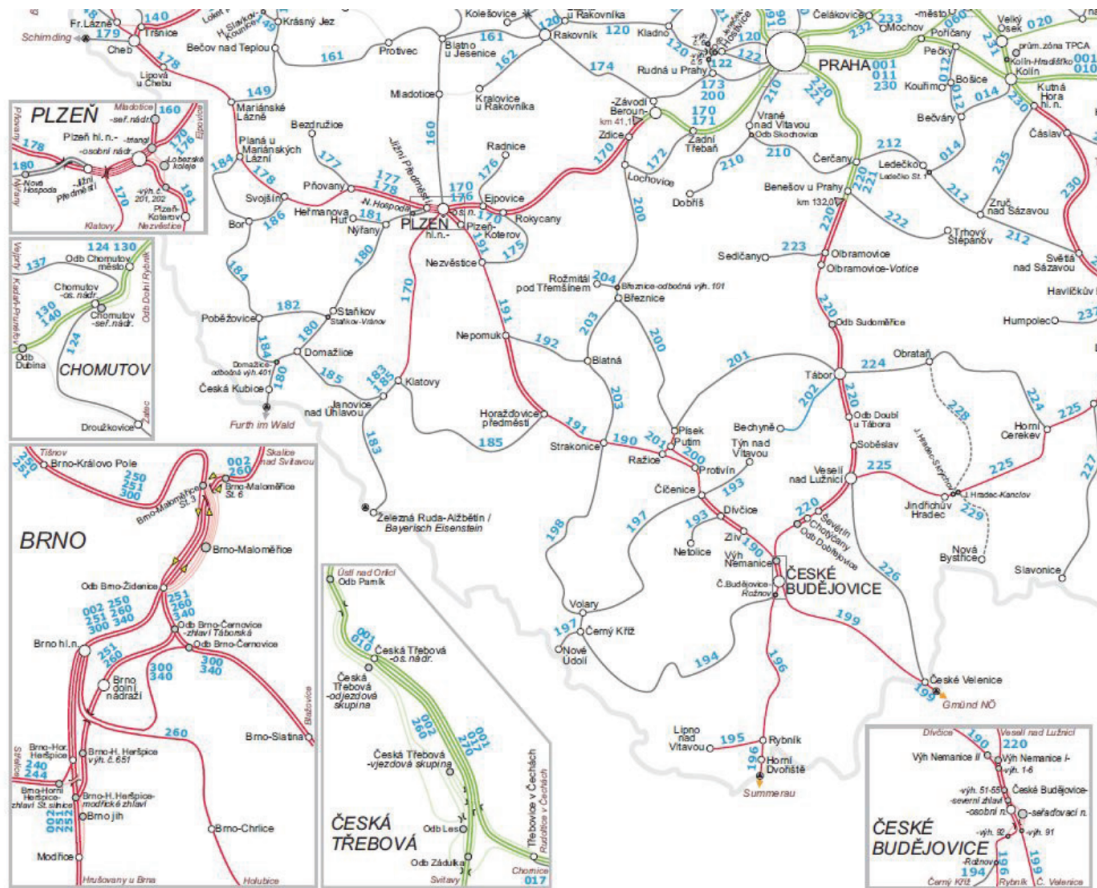


Figure 5 – Map of the southwest of Czech railway network (electrified lines coloured)

The Czech Republic’s train connection with Bavaria and north-western Austria, where the situation is critical, is mapped in Figure 5.

4.2 Inconsistent level of quality

The offer of modern railway long-distance passenger transport in the Czech Republic is limited almost exclusively to corridor lines. However, the level of quality varies considerably. It is logical that the level of quality varies between the different open-access long-distance rail products (e.g. SC Pendolino, RegioJet, LeoExpress). However, the level of quality is significantly different in a number of aspects also for express services operated under a public service obligation, i.e. ordered by the public administration (in the Czech Republic, long-distance transport is governed by the Ministry of Transport of the Czech Republic). The highest standard of services offered in express trains includes, for example, first and second seat class, air conditioning, free unlimited Wi-Fi connection, train restaurant, cinema for children. However, on some lines, for example, there is a systematic lack

of a dining car and related service. There is also an enormous difference in the quality of train sets. The carriages of most of the trains consist of restored vehicles dating back to the last century.

There is no uniform level of quality across the express network. Moreover, the express network basically follows only the corridor lines and does not even serve some major cities (Hradec Králové, Jihlava, Karlovy Vary).

4.3 Travel speed as a key parameter

Travel speed is a key parameter for the competitiveness of passenger rail transport. Achieving a certain travel speed is also a crucial parameter for the design of infrastructure and its line speed.

Czech Republic today

In order to accurately describe the current situation in the Czech Republic, we have selected the twenty-two largest Czech cities, where 32% of the country’s total population live, and analysed all interconnections between them using rail transport

Table 2 – List of twenty-two largest Czech cities [10]

No.	City/Town	Population	Region	Corridor line (its number)
1	Prague	1 324 277	Praha	Yes (1, 3, 4)
2	Brno	381 346	Jihomoravský	Yes (1)
3	Ostrava	287 968	Moravskoslezský	Yes (3, 4)
4	Pilsen	174 842	Plzeňský	Yes (3)
5	Liberec	104 802	Liberecký	No
6	Olomouc	100 663	Olomoucký	Yes (2, 3)
7	České Budějovice	94 463	Jihočeský	Yes (4)
8	Hradec Králové	92 939	Královéhradecký	No
9	Ústí nad Labem	92 716	Ústecký	Yes (1, 4)
10	Pardubice	91 727	Pardubický	Yes (1, 3)
11	Zlín	74 935	Zlínský	No
12	Havířov	71 200	Moravskoslezský	No
13	Kladno	69 337	Středočeský	No
14	Most	66 034	Ústecký	No
15	Opava	56 450	Moravskoslezský	No
16	Frýdek-Místek	55 557	Moravskoslezský	No
17	Karviná	52 128	Moravskoslezský	Yes (3)
18	Jihlava	51 216	Vysočina	No
19	Teplice	49 731	Ústecký	No
20	Chomutov	48 635	Ústecký	No
21	Děčín	48 594	Ústecký	Yes (1, 4)
22	Karlovy Vary	48 479	Karlovarský	No

and individual car transport. This selection, including all cities that are the administrative centres of Czech regions, is shown in Table 2.

Note that most of these cities are not connected by lines that were parts of the rail corridor modernisation programme.

A total of 231 routes were analysed. With the help of the digital road map and railway timetables, all intercity distances, travel times, travel speeds and operating intervals (only for railway lines) were obtained, and every pair of connections was compared (car vs. train).

Currently (i.e. in 2021), the travel speed of rail transport is higher than the travel speed of individual car transport one in only 20 of 231 analysed routes (8,7%). The average travel speed of trains

Table 3 – Comparison in years

Size	2021	2050
Ratio of routes realized faster by train [%]	9	52
Average travel speed of trains [kmph]	47	84
Average travel speed of cars [kmph]	67	74
Average train operation interval [min]	86	61
Average number of train transfers	0.93	0.79

is only 47 kmph but cars achieve 67 kmph. The complete summary statistics of this comparison are shown in Table 3.

The connections between Prague (the capital city and the largest passenger rail hub in the country) and other major cities is shown in Figure 6.

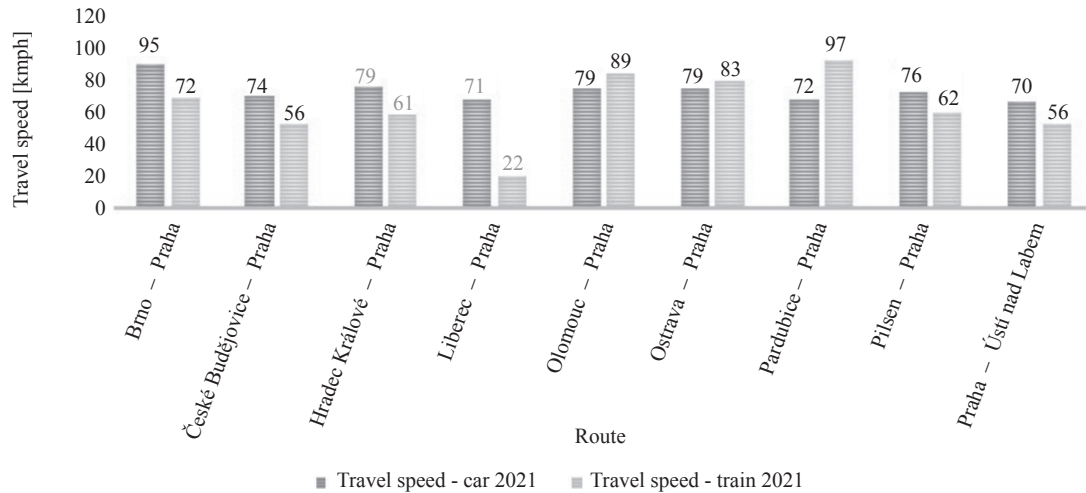


Figure 6 – Comparison of travel speed in 2021

Routes marked with a black number are parts of corridor lines. It is evident that even on the reconstructed corridor lines, the travel speeds achieved are not higher than those of road transport.

Czech Republic – projected 2050

The Czech Republic is currently preparing to implement a programme for the construction of high-speed lines with an expected completion in 2045. The programme promises three new complexes of high-speed tracks dimensioned for the speeds of 200 to 350 kmph. Many of the conventional lines should be modernised too, for example, Prague – Liberec or Pilsen – Domažlice – Germany (Munich). In order to see how this programme

will change the competitiveness of railway services (in terms of travel speed), we have carried out the same analysis for the 2050 model. The year 2050 was chosen because it is the year in which the goals of the Green Deal are to be accomplished [11].

The model includes the completion of all planned high-speed lines and planned upgrades to conventional lines. At the same time, the planned development of the motorway network is also included in the model calculation.

In 2050, the travel speed of rail transport is higher than the travel speed of individual car transport one in 119 of 231 analysed routes (51.5%).

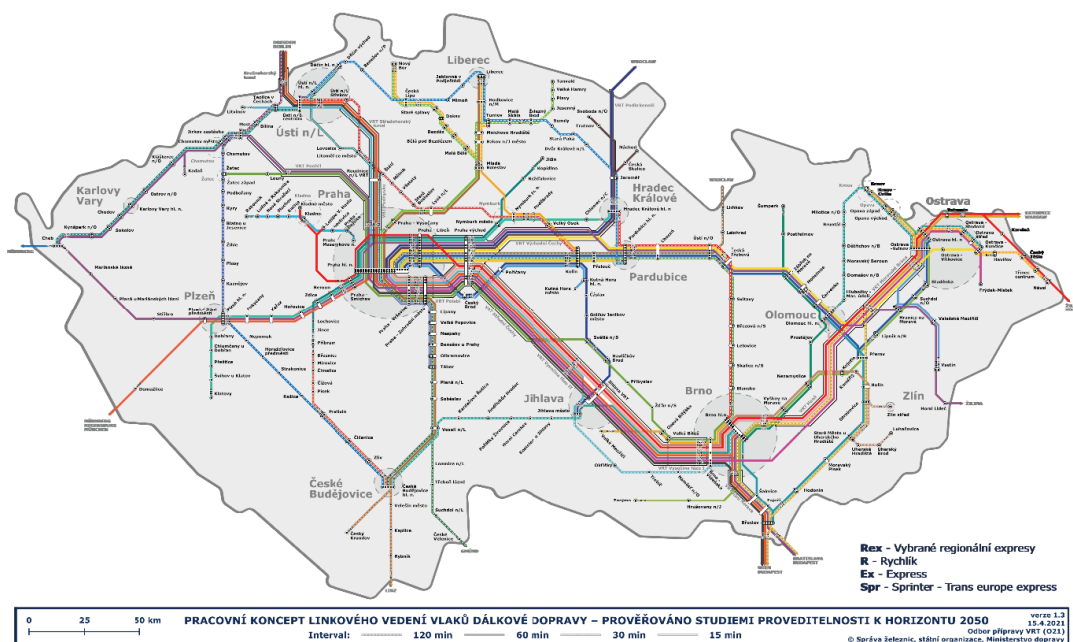


Figure 7 – Map of railway lines in 2050

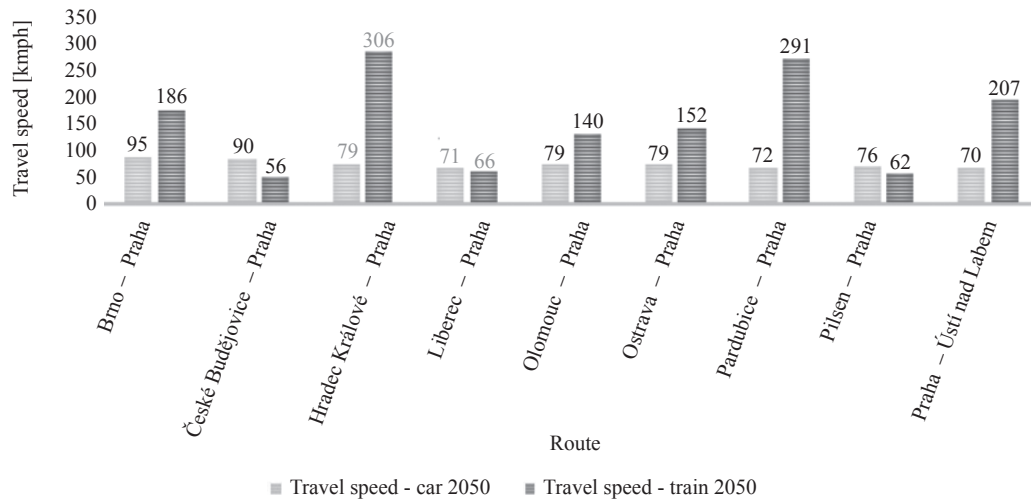


Figure 8 – Comparison of travel speed in 2050

Average travel speed of trains is only 47 kmph, but cars achieve 67 kmph. The summary statistics of this comparison are shown in *Table 3*.

The connections between Prague (the capital city and the largest passenger rail hub in the country) and other major cities is shown in *Figure 8*.

The biggest improvement will be perceptible in routes coming from Prague. Unfortunately, the situation in cities that do not lie on the corridors or new high-speed tracks will be almost the same.

We can look forward to some extreme improvements. For example, there are some routes where the train will be three or four times faster than car, with major improvements to the operation interval (*Table 4*).

Table 4 – List of very fast train routes

Route	Travel time [min]		Travel speed [kmph]		Air distance [km]	Ratio	Operation interval [min]
	Car	Train	Car	Train			
Pardubice – Prague	81	20	72	291	97	0.25	12
Hradec Králové – Prague	77	20	79	306	102	0.26	30
Brno – Jihlava	56	15	83	308	77	0.27	60
Olomouc – Ostrava	62	20	75	231	77	0.32	60
Prague – Ústí n/L.	59	20	70	207	69	0.34	20

Table 5 – List of routes among three biggest cities

Route	Travel time [min]		Travel speed [kmph]		Air distance [km]	Ratio	Operation interval [min]
	Car	Train	Car	Train			
Brno – Ostrava	102	40	81	207	138	0.39	30
Brno – Prague	118	60	95	186	186	0.51	10
Ostrava – Prague	211	110	79	152	278	0.52	30

Table 6 – List of the slowest train routes

Route	Travel time [min]		Travel speed [kmph]		Air distance [km]	Ratio	Operation interval [min]
	Car	Train	Car	Train	Together	Train/car	Train
Karlovy Vary – Kladno	57	158	94	34	89	0.36	60
Hradec Králové – Liberec	57	149	87	33	83	0.38	120
Frýdek-Místek – Zlín	80	208	53	20	71	0.38	120
Chomutov – Kladno	40	97	90	37	60	0.41	60
Frýdek-Místek – Karviná	31	75	46	19	24	0.41	60
Kladno – Pilsen	64	138	64	30	68	0.46	60
Děčín – Kladno	79	168	54	25	71	0.47	60
České Budějovice – Kladno	103	213	77	37	133	0.48	60

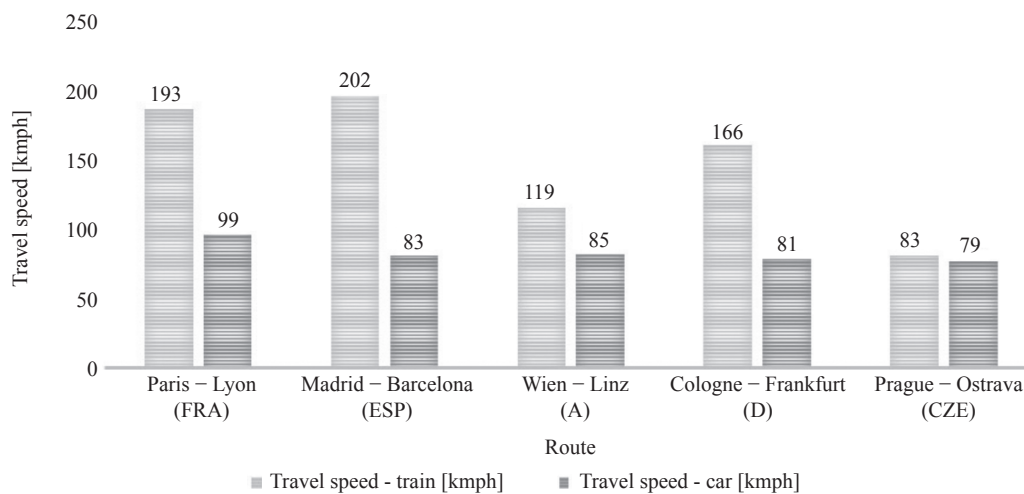


Figure 9 – Comparison of travel speed of western European rails in 2022

examples of functional high-speed railway lines with large differences between car and train travel speed. The comparison is shown in Figure 9.

At first glance, it is obvious that travel speeds of western railways are much higher than in the Czech Republic.

Dependence of travel speed and gravity model

As indicated above, primarily the biggest cities are connected by modernised transit corridors. However, let us find out how well are the smaller cities connected. As a key parameter for this research, the principle of the gravity model was used:

$$gravity\ model = G = k_1 \cdot \frac{(p_1 \cdot p_2)}{l_{1,2}} \tag{1}$$

where:

- k_1 – weighting coefficient 0.0001
- p_1, p_2 – population of two measured cities
- $l_{1,2}$ – air distance between cities [km]

In the next step, the difference of travel speeds of cars and trains from the target year 2050 was multiplied by the gravity model. The equation is shown below:

$$rationing\ of\ speed = (v_{train} - v_{car}) \cdot G \cdot k_2 \tag{2}$$

where:

- k_2 – weighting coefficient 0.01
- v – speeds of individual types of transport in 2050 [kmph]
- G – gravity model

The multiplication of the gravity model and the difference of travel speeds gives a specific result, which can be used to compare the relations on the basis of their importance. As the gravity model indicates, importance is determined by size of the cities and their mutual air distance.

Simply, the result of the equation is a dimensionless number that shows the future dependence of competitiveness of public transport on the size of

Table 7 – Most negative results from gravity model

Relation	Gravity	Rationing of speed
Karlovy Vary – Prague	57 321	-13 221
Brno – Zlín	37 600	-12 807
Liberec – Prague	157 712	-8 440
Děčín – Prague	82 502	-7 188
České Budějovice – Prague	100 883	-7 033
Hradec Králové – Liberec	11 735	-6 331
Frýdek-Místek – Havířov	32 964	-5 045
Havířov – Karviná	30 929	-5 037
Hradec Králové – Olomouc	7 606	-3 797

Table 8 – Most positive results from gravitation model

Relation	Gravity	Rationing of speed
Pardubice – Prague	125 229	274 437
Hradec Králové – Prague	120 664	273 327
Brno – Prague	271 510	248 224
Prague – Ústí nad Labem	177 944	243 482
Brno – Ostrava	79 576	100 126
Ostrava – Prague	137 176	99 568
Most – Prague	121 455	94 174
Pilsen – Prague	275 642	67 357
Olomouc – Ostrava	37 646	58 911

the cities. We could see how much the modernisation of railway infrastructure is focused on the biggest cities. In case of a negative result, the individual car transport is faster in a chosen relation. In the opposite case, the railway public transport is faster.

When we focus on the extremes, the table showing the worst relations looks as *Table 7*.

The reason why these routes are placed at the end of the list is mainly that the concerned railway tracks were built in the 19th century, and since then they have not and will not be significantly modernised for a higher speed.

On the other side, let us show a table with the most positive results (*Table 8*).

All these railway tracks placed at the top of the list will be parts of the high-speed track lines or at least will be sufficiently modernised.

5. CONCLUSION

After an exceedingly long stagnation (practically from the 1960s until the first decade of the 21st century), the railways in the Czech Republic

have been revived, and it can be seen that, if the conditions are right, they can offer a competitive modern service that passengers like to use. This is an important conclusion, as it confirms that if the public administration creates the conditions for the development of passenger rail transport in a strategically correct and sufficiently generous way, there is a great potential for increasing the share of rail transport in the modal split, and that is essential to meet the Green Deal goals.

As seen in the tables in the previous chapter, the largest rationings of speed are held only by relations connecting the most populated cities linked by the transit corridor. Cities that are not located on these modernised corridors are positioned substantially lower in the result table. However, it is quite surprising that even in the table showing the worst results, some of the most important connections could be found (Prague – České Budějovice, Prague – Liberec). These are the routes where the road infrastructure is significantly better than railway infrastructure, but also the ones that depreciate the whole public transport system.

Currently, the development of railway transport in the Czech Republic is limited by wrong strategic decisions made in the relatively recent past:

- The development of railway infrastructure was limited to railway corridors instead of being systematically oriented towards connecting the largest and most important cities in the country.
- The scope of modernisation was too small. There have been no significant upgrades in terms of capacity or signalling.
- Instead of setting the line speed based on the competitive travel speed in each route, a fixed limit of 160 kmph was chosen. However, even this limit has not been reached on a significant part of the corridor lines after the reconstruction.

These poor strategic decisions could have been avoided. Both the principles of the integral timetable and the good practice examples of the network approach to rail transport were well known in the 1990s when these strategic decisions were made.

Rail transport and increasing its modal share will play a crucial role in meeting the targets set by the Green Deal. The Czech Republic must therefore systematically develop fast, modern and high-quality railways.

"Transport accounts for a quarter of the EU's greenhouse gases and its share is still growing. To achieve the climate neutrality, transport emissions need to be reduced by 90% by 2050. Both road, air, rail and waterborne transport must contribute to this reduction. Achieving sustainable transport means prioritising users and obtaining them more affordable, accessible, healthier and cleaner alternatives to the means of transport to which they are currently accustomed." [1]

Our analysis has confirmed that the planned construction of high-speed lines and modernisation of existing lines will make rail transport in the Czech Republic significantly more competitive with road transport than at present. However, rail transport will still be speed-competitive on only about half of the selected routes. Little consolation can be taken from the fact that this half includes all the largest cities except Pilsen, which is senselessly excluded from the high-speed system. Equally alarming, however, is the long-unresolved connection with European cities such as Munich, Nuremberg or Linz in Austria. These three cities with several million inhabitants represent an immense potential for connection to the high-speed system. Unfortunately, the Czech plans so far completely ignore these traditional trading partners and tourist destinations.

Overall, the 2050 route plan, however ambitious and developmental, is still quite inadequate. The railway transport simply needs to offer even better-quality connections between at least all our selected settlements, so that the incentive for the passenger hesitating between individual and public transport is clearly on the side of the public transport.

The Green Deal is an opportunity to catch up with these internal debts of the Czech infrastructure in relation to its European neighbours, but this opportunity must be grasped well. In this particular case, it means not relying entirely on the 2050 plan, but developing rail lines on a much larger scale and building the railway system in the Czech Republic in a conceptual and systematic way.

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port Sciences (EPTS), the scientific chair chose the best-presented papers for publishing in extended form in the journal *Promet – Traffic&Transportation*.

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ROLE ŽELEZNIČNÍ DOPRAVY VE VÝZVĚ GREEN DEAL 2050 – SITUACE V ČESKU

ABSTRAKT

Motivování lidí k užívání hromadné dopravy namísto jejich vlastních vozidel je jedna z nejdůležitějších částí cesty vedoucí ke splnění výzvy Green Deal 2050. Na příkladu Česka, kde v časech před pandemií počet cestujících strmě stoupal, ve většině dálkových relací individuální automobilová doprava stále nabízí daleko více jízdních benefitů než železniční linky. Jak strategicky rozvíjet železniční infrastrukturu? Budou plánované vysokorychlostní tratě skutečně vhodným řešením tohoto problému včas? Uspokojí také veškeré rozdílné požadavky cestujících, kteří jsou potenciálně ochotni přeseďlat z auta do vlaku?

KLÍČOVÁ SLOVA

modal-split; železniční doprava; udržitelná mobilita; gravitační model; kvalita služeb.

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