Evaluation of the usefulness and relevance criteria for high-speed railway route construction projects: case study of Czechia

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ABSTRACT The main goal of this article is to assess the effectiveness of the high-speed railway routes construction programme in Czechia according to the criteria of usefulness (with primary links to potential revenues) and relevance (with primary links to potential costs) as integral parts of applying the original methodology of multi-criteria evaluation of public projects within transport infrastructure. The first set of performed analyses focused on observing the development of relevant traffic flows. They were outlined based on data from the movement of mobile phone users and verified through surveys of passenger preferences and other indicators. The second set of analyses was based on an evaluation of relevant external (natural and social conditions) and internal (technical and operational conditions) factors. The practical benefit of these analyses is an evaluation of the position of the planned four routes in terms of the examined criteria. They represent an important basis for setting priorities as a strategic component of managing an investment programme.

KEY WORDS transport – high–speed routes – usefulness – relevance – evaluation

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1. Introduction

Transport policy is an important part of public policy, as evidenced by its inclusion among the common policies of the European Union, which are binding on all Member States, i.e., the institutions of the European Union have "exclusive competences". The long-term vision in this area was described in the White Paper on Transport (European Commission 2011), which lists the main challenges:

- traffic congestion in road transport
- the sustainability of transport, which is too dependent on oil
- negative effects on air quality
- improving the quality of transport infrastructure, which is still unevenly developed.

One important tool for meeting these challenges is considered to be the construction of high-speed rail, which has significant implications for the integration of social structures and their sustainable development. Relevant projects in Czechia are in the preparation stage and the following lines have been set: high-speed rail 1 (Prague–Jihlava–Brno–Přerov–Ostrava–Czechia/Poland border → Katowice), high-speed rail 2 (Brno–Břeclav–Czechia/Austria border → Vienna), high-speed rail 3 (Prague–Pilsen–Domažlice–Czechia/Germany border → Munich), and high-speed rail 4 (Prague–Ústí nad Labem–Czechia/Germany border → Dresden). (Ministry of Transport 2017, 2020) These lines are seen as a promising part of the Trans-European Transport Network integrating EU road, rail, water, and air infrastructure. The following corridors have the strongest direct ties to Czechia:

- The Orient–East-Mediterranean Corridor: Hamburg–Berlin–Dresden–Prague–Brno–Budapest–Timisoara–Sofia–Athens.
- The Baltic–Adriatic Corridor: Gdansk–Warsaw–Katowice–Ostrava–Brno/Bratislava–Vienna–Venetia–Ravenna. Of the other transport corridors, this has the strongest ties to the Czechia.
- The Rhine–Danube Corridor: Strasbourg–Frankfurt/M.–Munich–Vienna–Bratislava–Budapest–Bucharest.

The construction of high-speed rail is a complicated matter, the effectiveness of which – i.e. the degree to which set goals are met – cannot be objectively assessed without a carefully tailored methodological procedure created by independent expert teams. This procedure should be based on a professional vision and not on general proclamations and discussions about parameters and route placements. In this regard, we consider two issues to be crucial: the efficiency of investments and their contributions to regional convergence. In this regard, we consider two crucial issues: the efficiency of investments and their contribution to regional convergence.

Preliminary evaluations of private and public projects usually use a cost–benefit analysis, but its implications are limited by the impossibility of correctly taking into account the production of positive and negative externalities (Bristow, Nellthorp 2000). Externalities arise outside the market and can thus be expressed in monetary terms only through so-called shadow prices (Maibach et al. 2008). This indisputable fact requires, especially in the case of major public projects such as high-speed rail, fundamental attention to be paid to holistically oriented multi-criteria approaches based on non-monetary indicators so as to significantly expand the limited information obtained by applying cost–benefit analysis. In this case, then, the main problem is that the relevant methodological procedures have not been developed to the necessary level and thus do not enable obtaining comparable information (Atalik, Fischer 2002; Albalate, Bel 2012). Logically, this brings us to the question of what the fundamental ability to empirically identify the development impacts of high-speed rail is (Blanquart, Koning 2017). In this context, an original methodology was created for multi-criteria evaluation of infrastructure projects, including the following five criteria: usefulness (an economic component), relevance (a territorial and technical component), stimulation (a regional-development component), integration (a political–administrative component), and sustainability (an environmental component).

The main goal of this article is to assess the effectiveness of the high-speed railway routes construction programme in Czechia according to the criteria of usefulness (with primary links to potential revenues) and relevance (with primary links to potential costs) as integral parts of applying the original methodology of multi-criteria evaluation of public projects within transport infrastructure. Based on an analysis of previous studies from elsewhere, the following research hypothesis was established: due to the settlement structure characterised by only one established metropolis of supranational importance, achieving efficiency of investments in the construction of high-speed rail seems unlikely in Czechia. This hypothesis corresponds to a detailed investigation carried out on a sample of 14 high-speed rail lines operating in EU countries. According to this report, the specified European efficiency threshold of 25,000 passengers per day was reached on only five routes: Torino–Salerno, Madrid–Barcelona, Berlin–Munich, Paris–Strasbourg, and Munich–Stuttgart (in the section being operated). Only two of them had an average speed above 200 km/h (European Court of Auditors 2018).

In the context of high-speed rail construction, the notion of spatio-temporal convergence is induced by increasing the speed of traffic with positive effects on regional cooperation (Janelle 1968). This issue has long been debated, and a critical view of the role of high-speed rail in regional development has gradually prevailed (Gauthier 1970; Marada, Květoň, Vondráčková 2006). There have been several examples where the construction of high-speed rail has led to an increase in divergence (Saat, Serano 2015). In this regard, we recommend broadening the economic view of the potential benefits of high-speed rail to include impacts on residential attractiveness. It would be best to take a comprehensive approach to the creation of positive externalities, generated in particular by the impacts of high-speed rail on environmental quality, spatial integration, and the selective stimulation of regional development with an emphasis on development axes of national importance (Snieska, Zykiene, Burksaitiene 2019). Within the framework of the corresponding operational measures, harmonisation of the high-speed rail timetable to optimally improve connectivity to other transport modes in the context of door-to-door trips appears to be a promising strategy (Brezina, Knoflacher 2014).

In addition to the results of our own research to date, knowledge gained from other publications and specialised studies in Czechia and elsewhere was used to explain the given topic. In this context, most attention has been focused on the following research themes: analyses and transport demand models with an emphasis on the use of mobile provider data referred to as "big data" (e.g. Bel 1997; Lundqvist, Mattsson 2001), the efficiency and political and economic aspects of high-speed rail construction (Albalate, Bel 2012; Nash 2015), and transnational, regional, and local high-speed rail links (Kim, Sultana, Weber 2018; Viturka, Pařil, Löw 2021).

2. Data and methods

To evaluate both criteria under study, custom methodological procedures were developed emphasising the comprehensiveness of the database with positive implications for determining potential impacts and subsequently prioritising high-speed rail construction. The practical application of the created evaluation models made it possible to identify the ranking of individual planned high-speed rail routes according to selected indicators and subsequently aggregate the achieved results within the relevant criteria.

2.1. Methodology for usefulness

Assessment of the usefulness criterion was based on an analysis of road and rail traffic volumes on corridors directionally corresponding to the planned high-speed rail routes as a fundamental determinant of potential passenger shifts to this new mode of transport. For this purpose, due to the limited predictive power of traditional data sources (e.g. in terms of temporal coverage of differences in demand among university students across the school year), signal data from mobile operators regarding SIM card users' movements within Czechia were used. This data were collected in four 14-day cycles during 2019. The data set is therefore robust and forms the basis for so-called big data containing more structured information (e.g. on SIM card origin or observations of daily, weekly, and seasonal mobility) on several million movements from T-Mobile Czech Republic a.s. In order to verify and refine the predictive power of the big data, so-called small data, focused on a more detailed description of the structure of traffic flows and other relevant characteristics related to passenger behaviour, were used to improve the accuracy of the results. In this context, Figure 1 presents the main data sources.

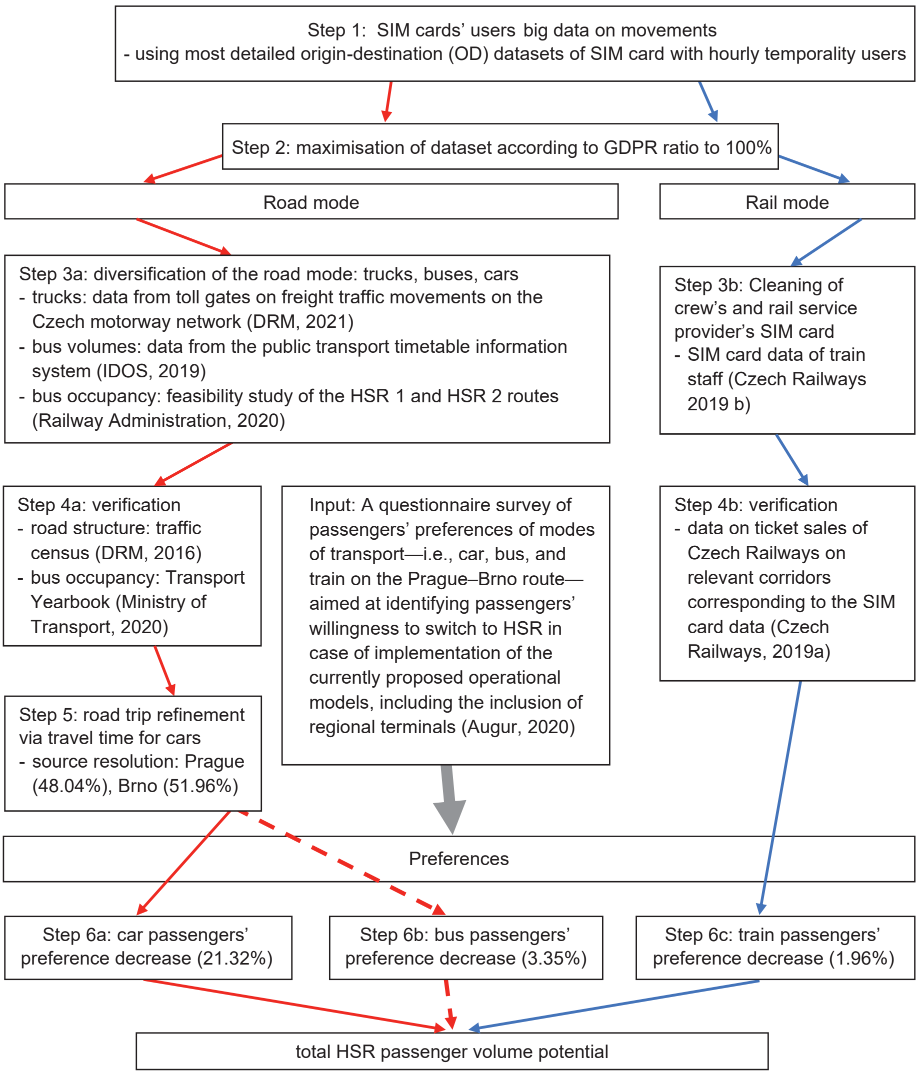

Fig. 1 – Data used in the model. Source: own research.

An important aspect of the data sets provided by mobile operators is the need to meet the requirements of the EU's General Data Protection Regulation (GDPR). In practice, the existence of this measure means that the underlying SIM card data from mobile operators cannot be provided without some degree of aggregation, which implies the need to merge the relevant SIM trajectories into relevant traffic flows. In our case, the individual traffic flows therefore had to contain at least three SIM cards. In terms of the factual orientation of the input data, it is worth mentioning the exclusion of data on SIM card movements related to truck crews – a reflection of the priority focus for Czech high-speed rail on passenger transport (see Road and Motorway Directorate 2021) delivery services, business trips by sales representatives and other trips characterised by many stops and the exclusion of on-board staff in public transport, and the results of the conducted surveys respecting the average occupancy rate of the modes of transport.

2.2. Methodology for relevance

The subsequent evaluation of the relevance criterion was based on an analysis of selected factors with fundamental links to the project preparation and construction implementation of the planned high-speed rail, broadly divided into external and internal factors. The evaluation methodology itself was then based on determining the order of planned routes within individual factors (including the determination of weights reflecting the territorial differentiation of the relevant values) and the subsequent aggregation of the obtained results. The first group of factors reflected the geographical conditions of the construction including natural (landscape structures) and social (urban structures) constraints to the location[1]. The evaluation of these factors on a route-by-route basis, with an emphasis on key characteristics (Kudrnovská, Kousal 1971) and population density, provided important information necessary for objective decision-making on the implementation of these financially demanding engineering projects. As far as the landscape structure is concerned, it can be stated that the discussed routes, by following the directions of conventional railway routes established by historical development, would limit, to some extent, the significant expansion of landscape fragmentation. However, this fragmentation would be strengthened by higher demands regarding

[1] According to the relative height fragmentation, the relief can be divided into relief planes with a segmentation of up to 30 m, hills with a segmentation of 30–150 m, highlands with a segmentation of 150–300 m and rocks with a segmentation of 300–600 m. Population density is closely related to the size of settlements and in the case of Prague it is about 2.7 thousand inhabitants/km², Brno approx. 1.7 thousand inhabitants/km² and in the smallest affected regional town Jihlava then 0,6 thousand inhabitants/km².

technical parameters. In this respect, the main concern is the minimum radii of the track curves, which are 6.5 km for passenger transport and 8.5 km for mixed transport. Other cost factors of particular importance include bridging the valleys of large rivers. In regards to the slope, the limits have been set at 35‰ for passenger transport and 18‰ for mixed passenger and freight transport (Watson 2021). On the basis of expert estimates, it can be stated that routing high-speed rail through a landscape of hills and uplands, which is typical for Czechia, has increased construction costs by about 45% compared to a lowland landscape (Van Hecke et al. 2003).

The highest costs are naturally associated with overcoming mountain ridges and urban limits through the construction of tunnels. The main output of this stage was a preliminary evaluation of the planned high-speed rails, which has an indicative character due to the still unfinished approval process for their final location. However, an analytical assessment of the planned routes according to an urban planning perspective showed that the most significant construction obstacles with proportional costs can be expected in urban agglomerations, where it is necessary to respect a number of legal measures and standards aimed at protecting the population from negative effects of high-speed rail on the quality of the urban environment. The group of internal factors includes the factor of using the throughput capacity of existing routes as the basic foundation for a qualified assessment of the operational value of high-speed rail construction and the subsequent perception of synergistic effects generated by transferring part of express passenger transport from existing conventional routes and the subsequent release of their capacity for the development of other passenger and especially freight transport (with positive impacts on the operability and speed of rail transport). According to capacity utilisation, the sections of the Czech railways are divided into four groups: Group 1 – sections with utilisation below 50%, Group 2 – sections with utilisation of 50–74%, Group 3 – sections with utilisation of 75–99%, and Group 4 – sections with utilisation of 100% and more. The final stage of the assessment was a synthesis of the findings obtained as an important source of information for setting construction priorities, where, to counteract the distorting effects of the different lengths of the planned routes, emphasis was placed on the incidence of above-average values for selected factors with significant effects on the cost (and usually length) of the construction.

3. Research results

This section presents the results of the evaluation of the proposed high-speed rail routes according to the criteria specified above. In the first subsection, the applied methodology emphasised the potential impacts of the selected factors on potential revenues, and in the second subsection on the potential construction costs of the proposed routes.

3.1. Results on usefulness

The data sets produced enabled the quantification of primary potential traffic flows related to the planned routes that, in line with the generally limited predictive power of future societal development, were processed using variant scenarios labelled as minimum, average, and maximum variants. The practical interpretation of the achieved results emphasised the prospective savings in travel time between the regional cities concerned: Prague, Brno, Ostrava, Pilsen, Ústí and Labem, Jihlava, and Olomouc (connected to the high-speed rail via the nearby Přerov railway junction). As part of the usefulness criterion, extensive origin–destination data sets on rail and road transport mobility, up to the level of designated municipalities (393 municipalities in total), were collected to obtain the highest level of spatial and temporal detail. In this context, it was necessary to consider the fact that a rigorous application of the GDPR would reduce the actual passenger numbers to 65.45%. This problem could be solved operationally by calibrating to a level of 100%. Using the example of the busiest Prague–Brno connection, the calibration methodology from T-Mobile recorded more than 99% compliance compared to the uncalibrated data respecting the GDPR ratio.

The following tables present the observed organised values of the intensity of traffic flows between Czech metropolitan areas for the most important routes, Brno–Prague and Ostrava–Brno, in variations that only take big data into account and variations that also take small data into account (Table 1). These data came mainly from surveys differentiated by the main modes, which capture the extent to which potential passengers were willing to switch to high-speed rail in future. The calculations performed differentiated between the respective traffic flows implemented by rail, bus, truck, and car transport and special road transport comprising delivery and business travellers (SRT). For broader reference, it is worth

Table 1 – Traffic flow structure on the route Prague–Brno

Mode	Rail			Road					Total	PT2HSR
Category	Pass	Crew	∑	Cars	Bus	Trucks	SRT	∑	∑	∑
big data	4,409	522	4,931	7,316	1,937	3,686	7,996	20,935	25,865	13,662
small data	4,323	-	4,323	5,756	1,872	—	—	7,628	—	11,951

Pass – Passengers; PT2HSR – Potential transfer to high-speed rail
Source: SIM card big data, IDOS (2019), own research.

noting that in 2019 the share of rail transport in total inland passenger transport was around 3.6%, the share of bus transport was 6.6%, the share of IAT including SRT was 48.4%, and the complementary share of local public transport was 41.3% (Ministry of Transport 2020). These data provide important information on the differences in preferences for different mode type groups and metropolitan significance and the resulting maximum values of potential passenger transfer to each high-speed rail route (the primary source of the trip was distinguished by its start time, where trips starting between 0:00 and 12:00 were considered to be trips from the source metropolitan area, while trips between 13:00 and 24:00 were considered to be return trips).

The results of the surveys carried out for rail and bus show a very low proportion of passengers who were not willing to switch to high-speed rail under any circumstances and therefore preferred lower travel costs to lower travel times (the average values were 1.9% for train and 3.3% for bus). Significantly lower willingness to switch to high-speed rail was found in the case of passengers using cars, where the observed proportions of passengers refusing to switch were 31.4% for the Brno–Prague direction and 10.4% for the opposite direction of Prague–Brno. In the context of significantly different values within the two directions for car transport, it can be hypothesised that the willingness to accept changes was inversely proportional to existing differences in the value status or economic prosperity of both metropolitan centres. On the basis of the above data, it can be concluded that the most significant transfers of passengers to the planned high-speed rail would be linked to the most important mode of transport: car transport. (In this context, it is worth mentioning that in many countries with a different inland transport structure that includes air transport, unlike Czechia, such as France, the development of a high-speed rail network has also meant a significant shift of passengers away from this mode of transport.) The individual inter-regional sessions were derived from the inter-regional transport volumes (Ministry of Transport 2020) and coefficients were applied to these sessions based on comparing the session between Prague and Brno with the traffic obtained from this session in the signalling SIM card big data. The shift from train and bus transport is reflected in the Public Transport variant. For shifts from cars, we used the maximum potential of 15% (Albalate, Bel 2012; Feigenbaum, 2013) from car volumes excluding SRT. The shift from trains, buses, and even cars is shown in Modal Shift variant (Table 2). The last Theoretical variant calculated the maximum achievable train volumes from the Transport Yearbook (Ministry of Transport 2020) increased by a shift from buses and cars. However, this last variant assumed a shift from all inter-regional train passengers to high-speed rail, which is only achievable theoretically. Table 2 shows the results for the relevant connections between all regional centres affected by the planned high-speed rail network. The cells relevant for calculating the shift to high-speed rail 1 are in italic and highlighted in grey.

Table 2 – Selected inter-regional linkages and their potential for high-speed rail (in thousands of persons / year) – "modal shift" variant

Origin/destination	Prague	Jihlava	Brno	Olomouc	Ostrava	Plzeň	Ústí/L.
Prague	×	*273*	*1,040*	1,095	*1,113*	783	858
Jihlava	*297*	×	*488*	*13*	*14*	*10*	*9*
Brno	*1,085*	*526*	×	399	*414*	*20*	*22*
Olomouc	1,137	*14*	415	×	680	17	12
Ostrava	*1,160*	*15*	*424*	689	×	*20*	*10*
Plzeň	833	*10*	*21*	17	*21*	×	20
Ústí/L.	935	*9*	*25*	12	*11*	22	×

Note: The cells relevant for calculating the shift to high-speed rail 1 are in italic and highlighted in grey. Assumes transfer of all potential passengers from rail and bus passengers and 15% passengers shifted from the car (Albalate, Bel 2012).
Source: Transport Yearbook (2020), SIM card Big Data, own research.

Table 3 – Potential time savings generated by high-speed rail (in hours/trip)

Regional centre		Prague	Jihlava	Brno	Olomouc	Ostrava	Plzeň	Ústí/L.
		Travel time savings high-speed rail to conventional train						
Prague	*Travel time savings high-speed rail to road*	×	1.32	1.45	0.78	1.53	0.00	0.68
Jihlava		0.27	×	1.28	2.55	3.02	2.02	2.32
Brno		1.13	0.30	×	0.75	1.35	2.40	2.82
Olomouc		1.05	1.75	0.25	×	0.20	0.93	1.73
Ostrava		1.67	2.52	0.80	0.20	×	1.70	2.52
Plzeň		0.02	2.22	3.13	3.75	4.60	×	1.75
Ústí/L.		0.57	2.28	3.20	3.90	4.88	2.08	×

Source: Czech Railways (2021a, 2021b), Maps.google (2021), own research

Table 4 shows that only in the Theoretical variant (the maximum variant) did the potential traffic volumes on the planned high-speed rail routes generally reach the European efficiency threshold (European Court of Auditors 2018). The corresponding population information derived from functional urban areas (Eurostat 2021) shows the population minimum for a sufficient number of passengers is about 7 million inhabitants in the relevant urban area. In our case, however, the highest number related to high-speed rail 1 was only 3.8 million inhabitants, meaning 54% of this value. In this context, it can therefore be concluded that this threshold is unlikely to be reached. From a purely economic point of view, the plan to build an high-speed rail network in Czechia appears to be inefficient overall and its potential benefits can thus be expected to appear more within the incentive and sustainability criteria. In this context, it is necessary to mention also the border effect, the reduction in the intensity of cross-border versus inland traffic flows in passenger transport, where the ratio of the intensity of domestic and international

Table 4 – Potential Time Savings of Planned high-speed rail Routes

HSR	Passengers (thousands of persons / year)			Time savings (hours a year)			Rank
	Public transport	Modal shift	Theoretical	Public transport	Modal shift	Theoretical	
HSR1	*5,889*	*7,064*	*10,792*	7,930	12,146	16,362	1
HSR2	495*	522*	835*	0	0	0	4
HSR3	1,496	1,795	2,742	231	338	444	3
HSR4	1,621	1,945	2,970	1,218	1,893	2,567	2

Note: HSR – high-speed rail. High-speed rail Route 2 calculates potential passenger transfers between Brno and Břeclav with the data on commuting based on Census (Czech Statistical Office 2011). Time savings on the Brno–Břeclav route do not occur in the Czech Railways operating model and the journey time remains constant at 30 minutes.
Source: Ministry of Transport (2020), own research.

rail transport in Czechia was set at 1:0.2 after analyses (Pařil, Viturka 2020). Table 3 shows the potential time savings associated with building high-speed rail compared to an existing road connection. These savings can be considered a decisive factor in increasing the competitiveness of long-distance rail transport.

In addition to the information given in Table 3, it is worth noting that the typical distance required to reach the maximum speed of a high-speed train of 300 km/h (which is currently estimated based on the longest route, high-speed rail 1) is around 20 km, with about 6 km required for a stop. In order to meet, from an operational and technical point of view, the completely logical requirement that the maximum speed be used for at least 2/3 of the running time, then the smallest appropriate distance between stops would have to be around 100 km. From this, it can be concluded that a closer distance between stops generates negative effects on the overall efficiency of high-speed rail operations.

From the standpoint of prospective time savings, the results of the analyses presented in Table 4 showed that by far the greatest potential was available on high-speed rail 1 Prague–Brno–Ostrava and the least potential was on the shortest line, high-speed rail 2.

3.2. Results on relevance

In the case of the relevance criterion, the evaluation results attained for the individual high-speed rail lines, considering the links to the current rail network, are further presented according to the selected factors and in accordance with their ranking. The planned high-speed rail 1 route corresponds in direction to the railway lines Prague–Kolín–Havlíčkův Brod–Brno–Přerov–Ostrava, which are electrified and, except for the expected branch line to the regional town of Jihlava and the Brno–Přerov section, double-tracked. For further analysis, it is appropriate to divide the route into Brno and Ostrava sections. In the Brno section, approximately 2/3 of the line passes through uplands and, in accordance with the nature of the landscape, is characterised by a slightly higher-than-average slope (the highest gradient observed is close to 15‰). Its routing through the urbanised areas of the metropolitan regions of Prague and Brno appears to be a much more serious problem (potential conflicts with existing land uses, noise abatement measures, and more). In this respect, the connection to Brno is particularly important in connection to the planned construction of the new central railway station, with respect to its options for placement (in the north or south). The existing routes included all of the aforementioned capacity utilisation groups, and the corresponding average value was 1.7. According to the mentioned considerations, and furthermore the distribution of traffic flows, the optimal use of high-speed rail appeared to be for passenger services only. In this context, significant synergistic effects can be expected from the transfer of a substantial part of fast passenger transport from the existing Brno–Česká Třebová–Prague line. In the case of the Ostrava section, the planned high-speed rail route essentially follows historical routes passing through a flat landscape and the very low slope of the landscape naturally corresponds to this fact. The greatest limitations on the options for surface routing, to protect the quality of the residential environment, can be expected in the densely populated metropolitan region of Ostrava. In terms of the capacity utilisation of the routes, the three sections had values well above average and the calculated average value was 3.1 (the total group value for both sections was 2.3). As in the previous case, we considered the optimal use of high-speed rail to be only for passenger transport, where we could again expect synergistic effects generated by the transfer of a significant part of fast passenger transport from the existing Ostrava–Česká Třebová–Prague line associated with more efficient use of the freed capacity for freight transport.

The planned high-speed rail 2 route corresponds to the Brno–Břeclav electrified double-track railway line. It passes through a flat landscape and, in line with the nature of the landscape, is characterised by a very low slope (generally not exceeding 1‰) with positive effects on construction costs. In terms of the geographical conditions for construction, protecting the population from negative impacts on the quality of the residential environment is therefore of crucial importance. The capacity utilization for the existing route was below 75% and the corresponding group average was 1.6 (the lowest value among the routes assessed). Based on the strong link to the previous route, the use of the planned high-speed rail for passenger traffic only, especially in the direction of Vienna, could be considered relevant (in the case of the planned connecting Austrian section, a mixed-use option for passenger and cross-border freight traffic also appeared to be beneficial due to the connection of a significant transit freight route in the direction of Břeclav–Ostrava).

The planned high-speed rail 3 route corresponds in direction with the Prague–Pilsen electrified double-track railway line and the connected Pilsen–Domažlice non-electrified single-track line. The route runs mainly through a hilly relief to Pilsen and further to the border with Germany, where it passes through border mountains. In this case, the routing through the Prague municipal area and the impossibility of parallel routing with the existing line in the Prague–Beroun section due to the densely populated river valley (associated with the practically unsolvable problem of an abnormal increase in noise pollution) can be identified as significant problems. The proposed technical measure is the construction of an approximately 25 km tunnel. The gradient of the existing lines was relatively low, except for the border section, where it exceeded 10‰. Regarding the permeability of existing lines, 75% was exceeded only on short sections near Prague and the border with Germany. The average group value for capacity utilisation was 1.9. It seemed optimal to use the planned line for passenger and freight transport. Such usage can significantly increase competitiveness with road transport (in Germany, for example, the average speed of rail freight transport on selected high-speed rail routes, which for operational reasons is carried out only during night hours, is around 120 km/h).

The planned high-speed rail 4 route largely follows the current Prague–Ústí nad Labem electrified double-track railway line, which runs almost its entire length through the valley of the Vltava and Elbe rivers and thus has very favourable gradient parameters. As far as the construction of high-speed rail is concerned, however, it is necessary to solve the problem of unsatisfactory spatial parameters in the deeply incised Elbe valley stretching from Lovosice to Pirna in Germany, which preclude the implementation of a parallel route with the old route. The proposed solution is the construction of tunnels under the affected mountain ranges (the approximately 26km international Ore Mountains Tunnel). It is obvious that due to the enormous construction costs, the specific cost of building 1 km of this route would be the highest of all of the planned routes (this fact should be considered when setting construction priorities). In line with the geographical characteristics, the 75% capacity utilisation threshold was not exceeded on any section of the existing route; the calculated average value was 2.0. From an operational point of view, the priority seemed to be passenger transport (although the planned tunnel can also be assumed to be used for freight transport).

Based on a synthesis of the obtained knowledge, the identified high-speed rail routes were ranked reflecting the intensity of the limiting effect of external and then internal factors and their overall ranking according to the examined relevance criterion (Table 5). In the case of identical rankings, landscape limits were prioritised under natural factors and urban limits were prioritised under the overall ranking of external factors, which usually have a decisive influence on the cost of development. A similar approach was taken in the case of internal factors,

Table 5 – Ranking of planned high-speed rail routes

External factors		Internal factors		Overall ranking
Natural limits	Urban limits	Capacity utilisation	Synergistic effects	
Route 2	Route 2	Route 1	Route 1	Route 1
Route 3	Route 4	Route 4	Route 3	Route 3
Route 1	Route 3	Route 3	Route 4	Route 2
Route 4	Route 1	Route 2	Route 2	Route 4

Source: own research.

where the potential introduction of synergies with branching system linkages to rail transport development were prioritised. The comparative position of the planned routes within the internal factors was then considered more relevant for the final aggregation of the assessment.

Table 5 shows that, overall, the longest high-speed rail 1 which had the best position within both internal factors, but on the other hand showed the highest urban limits of development. Second place went to the longest route, high-speed rail 3, due to its relatively low landscape constraints and above-average synergistic effects as well as the lowest level of positional differences across the factors examined. The next shortest route, high-speed rail 2, was characterised by major differences in its position within the external factors (best position) and within the internal factors (worst position) and the corresponding highest level of positional differentiation. high-speed rail 4 showed the worst position with the highest level of landscape limits and a lower level of synergies.

5. Conclusion

The final synthesis of the evaluation of the usefulness and relevance criteria as integral parts of the concept of a multi-criteria project evaluation provided valuable information on the potential effectiveness of high-speed rail construction in Czechia as one of the key national projects related to the construction of a single European transport area. Table 6 presents the findings on the relative positions of the planned routes.

In line with expectations (and the preference of Czech Railways), high-speed rail 1, connecting the three largest urban agglomerations in Czechia, had the best overall position, followed by high-speed rail 3 connecting these agglomerations with the EU core (including the three most important foreign trade regions for Czechia: the German Länder Bavaria, Baden-Württemberg, and Hesse), high-speed rail 4 via Dresden to Berlin and then to the port of Hamburg, and high-speed rail 2 as a “connecting” route between the Czech and Austrian high-speed rail networks.

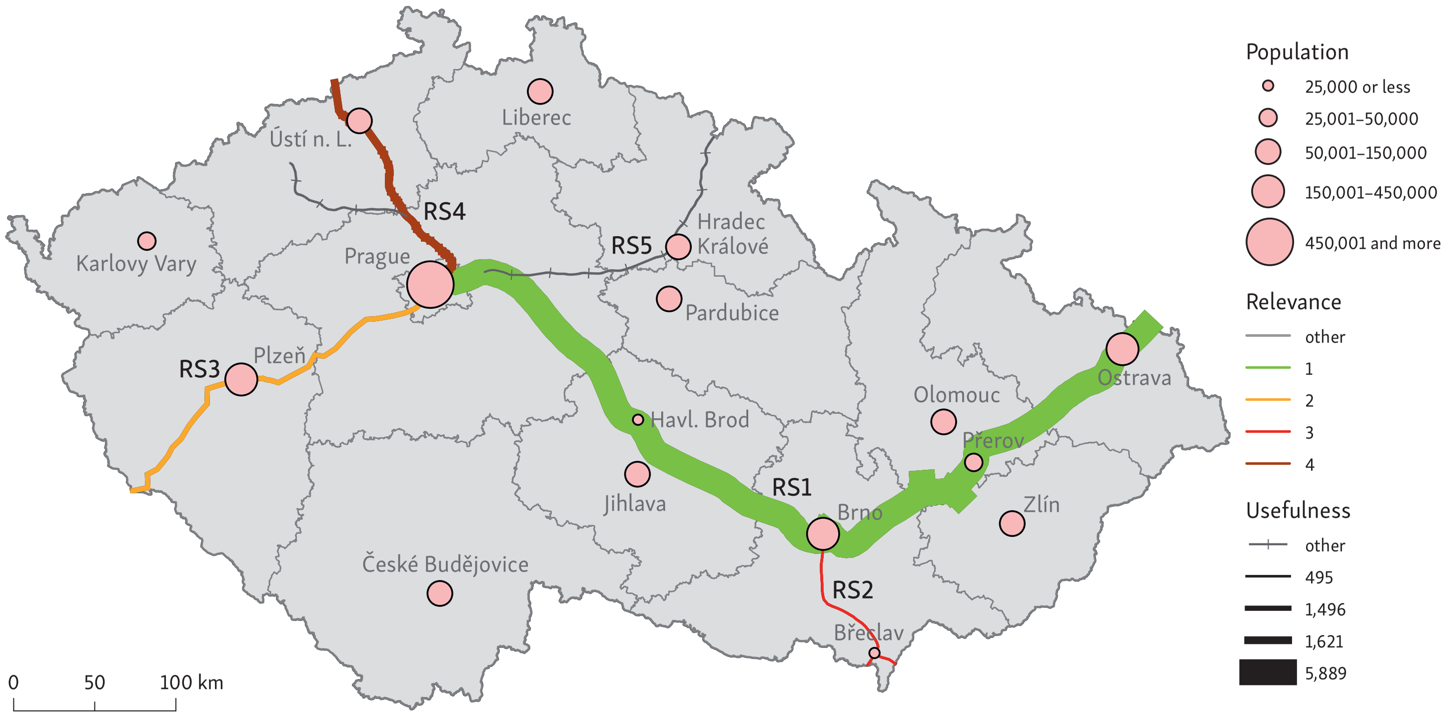

Fig. 2 – Usefulness and relevance criteria evaluation of the planned high-speed rail. The abbreviation RS (fast connection) is an alternative designation of the planned high-speed rail routes by Czech Railway Administration which reflects its expected lower speed parameters (the discussed alternative route RS5 and turns from the route RS4 to the city of most is also included). Source: own research.

Table 6 – Ranking of high-speed rail routes

Usefulness	Relevance	Total
HSR 1	HSR 3	HSR 1
HSR 4	HSR 1	HSR 3
HSR 3	HSR 2	HSR 4
HSR 2	HSR 4	HSR 2

Note: HSR – high-speed rail
Source: own research.

Figure 2 offers basic information on the geographical location and position of the planned high-speed rail routes according to the examined criteria.

From a practical point of view, the achieved results provide useful data that can be used for finding the optimal combination of speed and cost parameters for planned high-speed rail routes with spatial and technical conditions for their construction with a primary emphasis on the creation of positive externalities and a reduction of negative externalities. The application of this approach corresponds to the accepted hypothesis of the insufficient effectiveness of the planned high-speed rail. The use of data from SIM cards seems to be a suitable tool for determining relevant changes in traffic behaviour induced by increasing the competitiveness of rail transport through the construction of a high-speed rail network. However, it remains to be stated that in the preparations so far the issues discussed above (despite positive foreign experiences) have not yet received sufficient attention. This obvious fact should, in our opinion, lead to fundamental innovations in the preparation of large investment projects within transport infrastructure construction and, where appropriate, considered in policy decision-making (especially in the less developed countries of Central and Eastern Europe).

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