Multicriteria analysis of the effectiveness of high-speed rails construction projects: case study of the Czech Republic

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Abstract: *This article seeks to evaluate the effectiveness of planned public construction projects of high-speed rails in the Czech Republic through the application of multicriteria analysis. In line with the nature of the projects, the developed original evaluation methodology places the main emphasis on the potential production of positive effects and on minimizing adverse effects. It includes criteria for integration, relevance, usefulness, stimulation, and sustainability. In this context, article provides synthesized information on the factual focus and geographical and practical context of application of the criteria used, and further on the results of the comparative evaluation of the four main planned high-speed routes. The acquired knowledge is subsequently discussed from the point of view of the most important stakeholders, interpreted through relevant scenarios, i.e. investor, business, and civic scenarios.*

Keywords: *high-speed rail, multicriteria analysis, externalities, optimization scenarios*

Introduction

The construction of high-speed rails (HSR) is undoubtedly one of the significant phenomena in the development of transport infrastructure. This fact is correspondingly considered in the long-term vision of the common transport policy of the European Union (EU) described in the so-called White Paper on Transport (European Commission 2011). In this context, the positive effects of the HSR on increasing the overall competitiveness of the railways are accentuated, combined with an increase in its share at the expense of road motor vehicles and, in part, air transport, with positive effects on sustainability of development (e.g., reducing transport dependence on crude oil, reducing total emissions, and creation of synergetic effects generated by changes in the division of transportation labour). HSRs are currently utilized by 11 of the 27 EU members (Spain, France and Germany have the largest networks) and accordingly form an important part of the TEN-Trans-European transport network, integrating road, rail, water, and air transportation infrastructure. From the point of view of the Czech Republic, it is necessary to mention especially The Orient – East-Mediterranean Corridor (Hamburg – Berlin – Prague – Budapest – Sofia – Athens) and The Baltic – Adriatic Corridor (Gdańsk – Warszaw – Ostrava – Bratislava – Vienna – Ravenna). In addition to the EU, HSRs operate in four other European countries, in five Asian countries (including China, where two-thirds of the world's HSR networks have been built) and one each in North America and Africa. In this respect, it is worth noting that, according to the prevailing opinion, HSR has the highest competitiveness compared to road and air transport for distances between 200 and 600 km (Seidenglanz 2009). Within the Czech Republic, the HSR construction plan was officially presented in 2017 (Ministry of Transport 2017) and subsequently approved by the government (SŽDC 2018). Specifically, it is HSR 1, i.e. Prague – Jihlava – Brno – Ostrava → Katowice, HSR 2, i.e. Brno → Vienna, HSR 3, i.e. Prague – Pilsen → Munich and HSR 4, i.e. Prague – Ústí n. L. → Dresden. The route Prague – Hradec Králové → Wrocław is listed as an alternative and it is not further analysed (Fig. 1).

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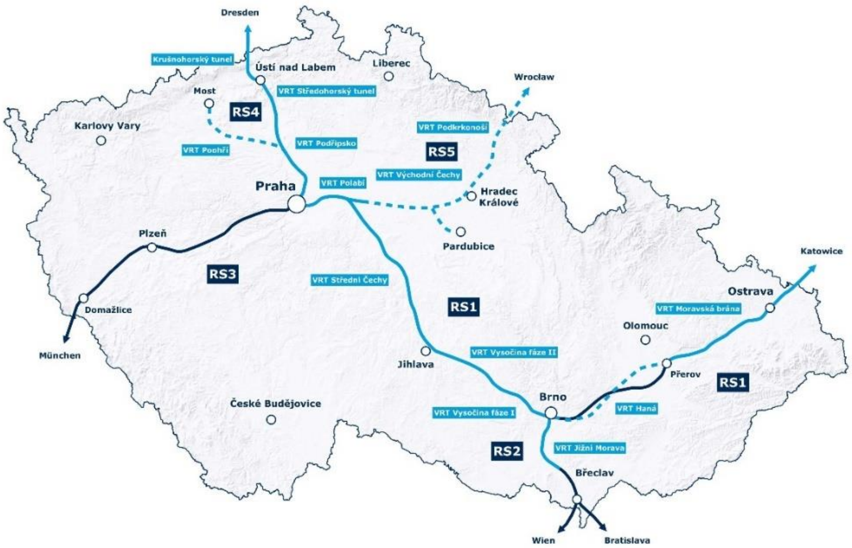

Fig. 1. *Program for the development of HSR in the Czech Republic*

Note: Abbreviation "RS" means Fast Connection which corresponds with HSR route (with lower speed limit of 160 km/h compared to 200 km/h on standard HSR)

Source: Ministry of Transport (2017)

The main goal of this article is the evaluation of the effectiveness of HSR construction in the Czech Republic based on a multi-criteria analysis of the potential impact respectively externalities of this strategic public project on regional development. An activity that positively or negatively affects other entities without having to pay for it or being compensated for it (Samuelson and Nordhaus 1991). Evaluation of these positive or negative impacts has a significant geographical dimension, both from the economic geography (impacts on social systems) and physical geography (impacts on natural systems).

In this context, it is divided, except for the introduction and conclusion, into three basic parts, the first focuses on theoretical and methodological basis of research, the following one on the outcomes of multicriteria analysis of HSR projects usable for their purposeful and effective planning, and another on presentation of optimization scenarios reflecting the preferences of the most important stakeholder groups.

Theoretical and methodological basis for evaluation of effectiveness of HSR projects

The primary basis of the approach used to evaluate HSR construction projects is their effectiveness, generally understood as the allocation of available resources that will ensure the optimal level of fulfilment of the set objectives while minimizing adverse impacts (e.g. increasing of quality of life or attraction of investments to knowledge economy) or minimizing adverse impacts (e.g. the devastation of the landscape by the extraction of mineral resources or excessive noise and air pollution from traffic). Effectiveness assessment is part of the application of the so called 3E principle, which further includes the evaluation of efficiency and economy, and in interaction with the relevant legislation it represents an important part of a comprehensively oriented system of evaluation for public investment projects. At this point it is worth mentioning P. Drucker's well-known quote "efficiency is doing things right, effectiveness is doing the right things" (Drucker 1993). In this context, it can be stated that the inappropriate selection of an investment project cannot be counteracted by its effective implementation. A typical example is the construction of a new motorway meeting the set financial standards, the aim of which was to encourage the economic development of a lagging region, which, however, was not achieved due to the low competitiveness of local companies (Bray 1992).

For the evaluation of public investment projects with significant impacts on social development, a cost-benefit analysis is often used, which expands the current financial evaluation by assessing the relevant impacts or externalities through so-called shadow prices. However, due to its focus only on monetary indicators, this approach causes a disconnect due to the obvious fact that we cannot objectively express (and therefore not even compare) the benefits arising outside the economy in connection with the effects of natural and social laws. Compared to the evaluation of private projects, this is therefore a much more difficult matter, as public projects are primarily focused on creating positive externalities targeted at diverse user groups. This problem can be solved with the use of multi-criteria analysis of the effectiveness of projects evaluated by means of non-monetary indicators. The developed original methodology for evaluating the effectiveness of transport infrastructure projects includes the following criteria: integration (political and business aspects), relevance (territorial and technical aspects), usefulness (socio-economic aspects), stimulation (development aspects) and sustainability (environmental aspects). Its explanatory power was successfully validated through the evaluation of Czech motorway construction projects (Viturka and Pařil 2015). The acquired experience was also used for professional assessment of HSR construction projects. The experience gained was also used to assess HSR construction projects. The specific evaluation of individual HSR routes is based on evaluating their relative position within individual criteria following the still unfinished selection of their exact location and, thus, the unavailability of the necessary data. In this context, applying this approach can be considered relevant from both a theoretical and a practical point of view.

The following part of this section provides basic information clarifying the factual focus of all five criteria of the analytical model, which are further described in accordance with the above method (more detailed technical and economic information is presented in specialized publications, especially Pařil and Viturka 2020).

The **integration criterion** focuses on the impact of the HSR on the development of integration processes as part of the transformation of social structures arising from the territorial division of labour and other social and political ties of a regular and irregular nature. The driving forces of these processes can generally be considered work interactions at the micro-regional level, production interactions at the interregional level, political-administrative interactions at the macro-regional level, and business interactions at the global level. The presented model of hierarchical arrangement is understood as a dynamic system, where a significant increase in the quality and speed of transport can induce selective shifts of integration processes to a higher hierarchical level. The evaluation of the criterion generally is based on a well-known gravitational model, which effectively captures the generally valid logic of the formation of long-distance transport links (Anderson 1979):

$$G_{ij} = \frac{P_i \ x \ P_j}{d_{ij}}$$

where G_{ij} is the gravitational force, P_{ij} is the settlement residential (population) importance of agglomerations defined as functional urban areas (FUA) and d_{ij} is the distance of FUA (measured along the existing railway routes in the direction to the planned HSRs). The relevant traffic flows are directly proportional to the population size of FUA and indirectly proportional to their mutual distance (Ministry of Transport 2020, OECD 2020).

In this respect, the links to the nearest foreign metropolises, positioned in accordance with the competitiveness of the HSR with air transport within the limit distance of 600 km, were, of course, also considered (Fig. 2). The respective ratio of the number of domestic and interstate railway connections in personal transport was set in accordance with foreign experiences with the so-called border effect at 1:0.2 (Beria 2017). Among the specific questions, it is necessary to consider the prospective use of HSR for freight transport, especially in the direction of Germany (more precisely Bavaria) as the most important trade partner of the Czech Republic.

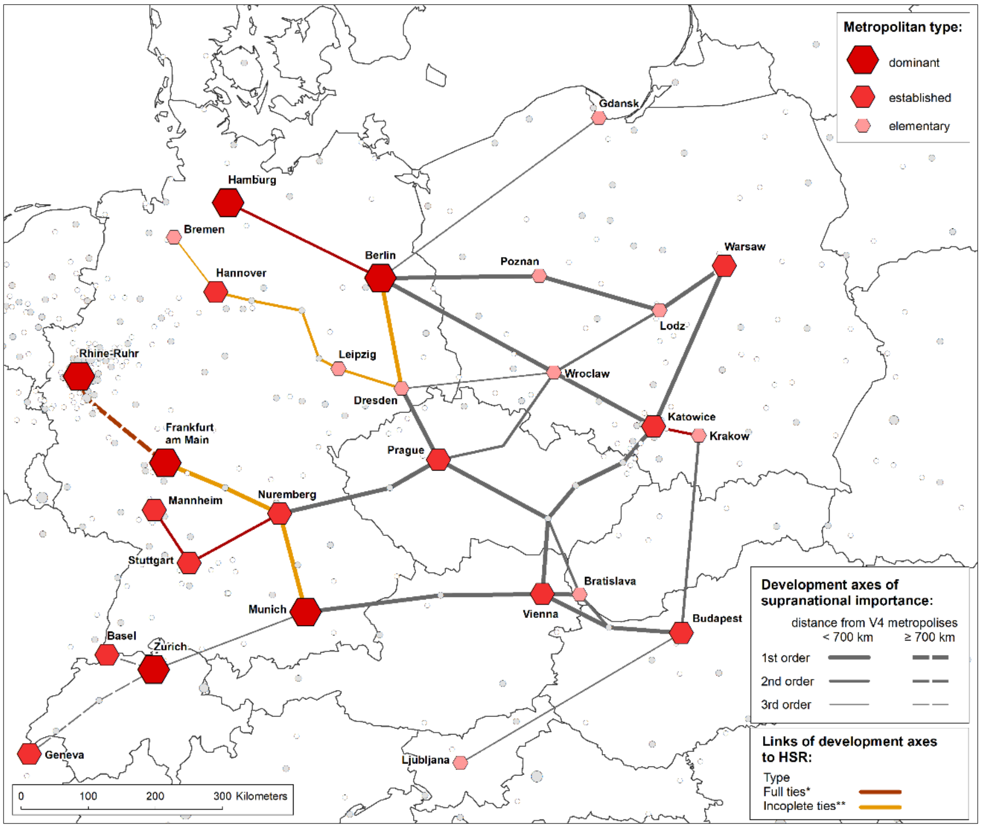

Fig. 2. *The metropolitan system of Central Europe and its links to the operated HSR*
Source: own research

The **relevance criterion** considers key external and internal territorial and technical factors, which are characterized by intensive links to project HSR preparation and implementation and therefore also on construction costs and operational efficiency. The first group of factors reflects the geographical conditions of construction including the natural (landscape structure) and social (urban structure) limits of HSR localization. In the case of landscape structure, the planned routes are evaluated according to the proportion of the standard groups of height fragmentation: plains with the fragmentation of up to 30 m, hilly areas with the fragmentation of 30-150 m, highlands with the fragmentation of 150-300 m and mountains with the fragmentation of 300-600 m (Kudrnovská and Kousal 1971). Specifically, it mainly impacts the radii of track curves with set minimum limits of 6.5 km for passengers and 8.5 km for mixed transport and slopes with set maximum limits of 35 ‰ for passengers and 18 ‰ for mixed transport (Týfa 2007). The consideration of social factors is based on the legitimate goals of spatial planning aimed at optimal land use depending on population density. In this direction, it reaches the highest value of 2.7 thousand inhabitants/km^2 in Prague and the lowest value of 0.6 thousand inhabitants/km^2 in Jihlava. The group of internal factors then clarifies the results of the permeability assessment of existing routes and the perception of potential synergies generated by the construction of the HSR. According to the throughput performance, understood as the basis for estimates of the operational urgency of HSR construction, the existing lines are classified into four groups: group 1 – sections with throughput utilization values below 50%, group 2 – sections with values of 50-74%, group 3 – sections with values of 75-99% and group 4 – sections with values of 100% and more (Čech 2019). The final stage of evaluation of the given criterion then emphasizes the incidence of above-average values of factors with fundamental effects on construction costs (e.g. construction of tunnels).

The **usefulness criterion** deals with an essential component of the assessment of express transport infrastructure construction projects, which is an estimate of the potential economic benefits arising from future demand. In our case, the so-called signal big data of the mobile operator T-Mobile Czech Republic on the movements of SIM cards, between the relevant defined destinations within the planned HSR routes, were used as the basic data source. These data were compared with standard datasets obtained from the traffic census and other sources (e.g. data on rail ticket sales). Based on verified information on the current demand for passenger transport and further the results of questionnaire surveys on the willingness of passengers to switch to HSR taking into account practical foreign experience with their operation, the potential demand was assessed according to individual routes stimulated mainly by travel time savings (see e.g. Tiraschini et. al. 2013, Zhang et. al. 2019).

In the case of regular rail and bus transport, maximum willingness can be expected, while in the case of car transport, a maximum transfer limit of 15% is usually calculated (Albalate and Bel 2012). The results are refined by modelling national labour relations as the most significant component of regular trips. It reflects the ratio between the increase in income generated by potential commuting to selected regional cities (as main stations on the planned HSR) and the cost of commuting, including lost time costs expressed by a fixed share of revenues where, after the performed analyses as 30% share in the hourly wage at an average speed of 200 km/h. A significantly higher level of net income from commuting compared to the costs incurred is considered a timeless factor in increasing the spatial mobility of the workforce (Taylor 1993). It is also necessary to draw attention to the phenomenon of the so-called induced demand, which foreign experts most often estimated to be between 10 and 20% of the original demand (Feigenbaum 2013). In this context, the distance between HSR stations/terminals is of considerable importance, which in Europe, depending on population density, usually varies between 60 and 80 km/h. The main results of performed analysis are presented in Tab. 1.

Tab. 1. *HSR routes characteristics*

	distance	population	GDP/C (with/without Prague)	travel time conventional/HSR	estimated passengers	travel time savings
HSR1	373	4 019 506	34 631 / 17 963	3:24 / 2:15	8 424	13 977
HSR2	73	793 933	20 000 / 20 000	0:30 / 0:30	636	0
HSR3	165	2 613 674	42 970 / 18 500	1:20 / 1:00	2 141	391
HSR4	100	2 379 226	45 211 / 15 100	1:12 / 0:30	2 319	2 173

Source: own research

The **stimulation criterion** is based on the own original theory of integrated and sustainable regional development (Viturka 2011). The basic component of this theory is the quality of the business environment/QBE, which is evaluated using 16 factors (involving 105 primary variables) divided into groups of business, labour, infrastructure, regional, price, and environmental factors taking into account the results of international surveys of investment companies' preferences operating in the processing industry and higher market services (Viturka 2011). In this regard, the potential impacts of HSR construction on the level of administrative districts of municipalities with extended powers (MEC) were assessed. The first elementary level of evaluation is focused on the perception of future changes in the values of the relevant quality factor of roads and railways. In this regard, however, it is necessary to respect the fact that this infrastructure factor is only one of the moderate significant factors of QBE and therefore it is not possible to objectively assess the causal links between HSR localization and economic growth (e.g. Benoit, Koning, Bahoken et al. 2016, Blanquart and Koning 2017). The second level of evaluation is based on the premise that the induced changes reflect the achieved level of QBE of the affected MEC microregions. From a general point of view, this level predetermines their position within the systems of precisely development centres and axes specified based on positive deviations of QBE from the theoretically relevant values which are derived from the population size of microregions.

For evaluating the dependence between QBE values and MEC population size, a following power function appears optimal:

$$y = 7{,}1411x^{-0{,}2211}$$

where *y* is corresponding with QBE and *x* with MEC population size.

This fact confirms the dominant role of the most important agglomerations in economic development. On this basis, in contrast to traditional theories (e.g. Perroux's theory of growth poles), it is possible to precisely define the position of urban centres as poles of development integrating space through development axes of national Type A and regional Type B importance (Fig. 3). In practice, these systems have long functioned as the main channels for expanding positive "spread effects", which were confirmed based on unemployment rate and housing construction intensity indicators. It logically follows that the territorially corresponding localization of HSR generates the greatest stimulation effects. The used approach can be considered a unique example of a theoretically grounded methodology for evaluating the stimulation of regional development through the construction of express transport infrastructure.

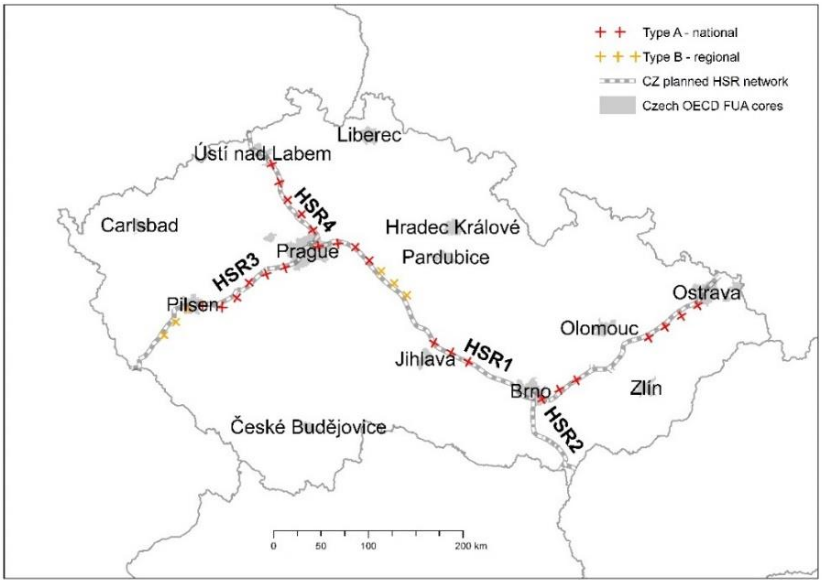

Fig. 3. *HSR and development axes*
Source: own research

The **sustainability criterion** is primarily focused on potential conflicts between the planned HSR routes and the protection of the most important ecosystems represented by the European Natura 2000 system and the national territorial systems of ecological stability of the landscape/TSES of supra-regional significance (see Tab. 2). Early identification of these territorial conflicts makes it possible to prevent the negative effects on landscape fragmentation as a characteristic accompanying phenomenon of linear structures that is associated with a non-negligible decline in the biodiversity of ecosystems. The Natura 2000 system includes the most valuable habitats of European importance, divided into Special areas of conservation/SAC (Council Directive 92/43/EEC) and the so-called Bird Areas/ Special protection areas/SPA (Council Directive 2009/147/EC). The main components of the TSES system are biocentres (BCE) and biocorridors (BCO). These systems have been assigned the following significance statuses weights in accordance with their hierarchical position: Natura 2000 – significance 1, supra-regional TSES – significance 2. Another important problem associated with HSR is the noise burden, which manifests approximately up to 500 meters from the centre of the railway bodies (Sarikavak and Boxall 2019).

The number of people prospectively endangered by noise was estimated at about 500 thousand population (CSO 2020, Corine 2018). To this end, it is worth noting that according to Czech legislation, the night-time permissible limit for outdoor noise is at the level of 50 dB, but the recommended WHO limit is only 40 dB. The solution to this problem is closely connected with the system optimization of the territorial coexistence of natural and urban construction factors, and for this reason it is part of both sustainability criterion and the relevance criterion. On the other hand, it is necessary to recall the clearly positive aspect of HSR operation, which is the production of zero greenhouse gas emissions, as an increasingly important component of horizontal and vertical circulation of the atmosphere. Overall, it can be concluded that HSR is the least environmentally harmful mode of transport (European Commission 2019).

Tab. 2. *HSR conflicts with environmental protection infrastructure*

Protection system/ HSR route	SPA	SAC	EECONET	TSES supraregional biocorridors	TSES supraregional biocentres	**Total conflicts**
	Absolute total impacts					
HSR1	4	4	4	4	4	**20**
HSR2	2	1	1	1	1	**6**
HSR3	1	1	2	3	3	**10**
HSR4	2	3	3	2	2	**12**
	Relative impacts (weighted by route length)					
HSR1	2	1	2	1	2	**8**
HSR2	4	4	3	2	1	**14**
HSR3	1	2	1	2	4	**10**
HSR4	3	3	3	4	3	**16**

Source: own research

Main outcomes of multicriteria analysis according to individual HSR routes

The second part of this section presents the results of the multicriteria evaluation of the planned HSR routes according to the criteria described above.

The Tab. 3 shows that the first group with overall above-average values includes the longest HSR 1, i.e. Prague – Brno – Ostrava – Czech Republic/Polish border (a total of 438 km within the existing railway lines) with the best location with an average rating of 1.8, followed by the HSR 3 route, i.e. Prague – Pilsen – Czech Republic/Germany border, with an average rating of 2.0. The second group with overall below-average values includes the route HSR 4 Prague – Ústí n. L. – Czech Republic/Germany border with an average rating of 2.8, followed by the shortest route HSR2 Brno – Czech Republic/Austrian border (total 65 km along the existing railway line) with an average rating of 3.4. The identified order of planned routes represents one of the bases for objective determination of long-term strategic priorities of HSR construction. This is a necessary measure for preventing recurrence of long-term problems associated with construction of transport infrastructure generated in the Czech Republic, especially serious shortcomings in the building law as well as bad project management. In this context, the achieved results of the evaluation according to individual HSR routes and set criteria are further summarized, with emphasis on the synthesis of findings.

The overall assessment of effectiveness of projects is procedurally based on the application of the well-known statistical method of a simple sum of orders, where the final order P_c is the non-weighted aggregation of partial orders P_d, gained within the individual criteria systematically described above. The ranking of the given project within the relevant set of investigated projects represents synthetic, and to some extent timeless, information for a qualified assessment of the effectiveness of its potential implementation in comparison with the remaining projects (see Tab. 3). The corresponding procedure can be simply written as follows:

$$P_c = \sum_{i=l}^{n} P_d$$

Tab. 3. *Order of the proposed HSR according to selected criteria and overall order*

HSR	criterion					sum	overall
	integration	relevance	usefulness	stimulation	sustainability	order	ranking
HSR1	1	1	1	2	4	9	1
HSR2	4	3	4	4	2	17	4
HSR3	3	2	3	1	1	10	2
HSR4	2	4	2	3	3	14	3

Source: own research

Here are the detailed results according to relevant routes:

a) **HSR 1**: This route will prospectively connect all Czech biggest cities, i.e. Prague (the only Czech metropolis of supranational importance) with Brno and Ostrava as secondary metropolises and from an international point of view also with the Polish HSR network in the direction of Katowice. It occupies the best position according to the integration criterion (the share of national gravitational interactions is about 68%) and further in the criterion of relevance and usefulness. Regarding the criterion of relevance, it is necessary to mention highly above-average figures of capacity utilization of current lines (especially in the Ostrava part of the route) together with high potential synergy effects. These effects are associated with the transfer of a significant part of express passenger transport from the existing Prague – Česká Třebová – Brno line to HSR and consequent potential use of freed up capacity for the development of conventional transport. The performed analyses confirmed that the route has the greatest potential for demand and therefore has, of course, the best position according to the usefulness criterion. The daily number of transported passengers who should be transferred to the HSR from existing rail and bus routes and car transport/CT was estimated at about 7.1 thousand per day. In terms of work attractiveness of the relevant regional centres (supplemented by selected railway junctions Přerov and Břeclav), determined based on the indicator of marginal labour force mobility when commuting revenues equal commuting costs of course Prague shows the highest value, followed by Brno, Pilsen, and Ostrava with approximately three-, six- and ten-times lower attractiveness. To this end, it is worth noting that the necessary consensus has not yet been reached in assessing the cost of lost time (Batarce et al. 2016). The route logically also appears well positioned within the stimulus criterion, where thanks to its construction there will be a more significant increase in the level of the factor of roads and railways quality in the case of Jihlava (+ 16%; within the total QBE scope, it is however only 1.3%) and Brno (+ 13.5%), which is followed by the most important railway junctions, i.e. Prague (+ 8%) and Ostrava (+ 8.5%). The route also occupies an above-average position in terms of stimulus effects generated by its socio-economic ties to the developed Czech-Moravian and East Bohemian development axis of national importance and to a lesser extent to the partially developed East Moravian development axis of national importance (the position of this axis further weakens the Central Moravian axis of national importance which is also associated with the negative population development of the regional city of Ostrava). The route than took the worst position in the case of the sustainability criterion, where almost half of all potential conflicts with legally anchored nature protection were found: SAC (13 cases), SPA (2 cases), BCE (3 cases) and BCO (9 cases).

b) **HSR 2:** This shortest route will connect Brno with Břeclav and subsequently with the fast-growing Austrian capital, Vienna. Since no other significant Czech settlement agglomeration is located on it, it ranks last within the integration criterion. In the case of the criterion of relevance, it has a slightly below average position (despite favourable values of landscape and to some extent also urban limits and correspondingly lower construction costs) due to having the lowest values of capacity utilization and therefore low potential for prospective creation of synergetic operational effects. As for the usefulness criterion, in accordance with the expected weak potential demand, it ranks last again. The total number of passengers who will transfer to it from the directionally corresponding railway and bus routes and CT was estimated at 0.6 thousand per day. Due to its particular "connecting" nature, this route is characterized by the weakest position within the stimulus criterion, where, however, in the distant future certain development incentives generated by ties to Vienna can be expected with positive effects on improving QBE and partly the quality of social environment (residential attractiveness). Regarding the last sustainability criterion, the position of the route can be assessed as favourable (second best position) with the following number of potential conflicts: SAC (4 cases), SPA (1 case), BCE (1 case) and BCO (2 cases).

c) **HSR 3**: This route prospectively connects Prague with Pilsen and will continue to connect to the German railway network in the direction of the dynamically developing Bavarian metropolis of Munich. Within the integration criterion, it has a slightly below-average position (the share of national interactions is about 64%). From a broader geographical point of view, however, its importance logically increases with the improvement of accessibility to the core area of European development known as the "blue banana" including Munich, located on the Rhine - Danube Corridor. As for the criterion of relevance, the route occupies the second best position, which is based on favourable values of landscape parameters and above-average potential synergetic effects (a significant problem, is however the route tracing through the inner city of Prague and the densely populated Berounka river valley, which will need to be addressed through tunnel construction). According to the criterion of usefulness, corresponding to the results of potential demand analysis, the route occupies a slightly below-average ranking, while the prospective number of passengers transferred from the existing railway and bus routes and CT was estimated at 2.1 thousand passengers per day (the Pilsen agglomeration shows 5.5 times lower value of work attractiveness than Prague). In terms of the stimulation factor, the route holds the best position, which confirms the expected significant improvement in the quality factor of roads and railways by about

10%, with positive impacts on the development of the regional city of Pilsen associated with the positive spread effects. This progression is supported by the below-average unemployment rate and the above-average rate of housing construction recorded along the developed West Bohemian development axis of national importance and the related development axis of regional importance, as well as deepening cross-border ties with Bavaria (given almost a quarter of the Czech Republic's total foreign trade turnover is with Germany). The route also occupies the best position according to the sustainability criterion, with where the following number of potential conflicts: SAC three cases, for SPA no case, BCE one case and BCO four cases.

d) **HSR 4**: This route will connect Prague and Ústí n. L. and then with the German HSR network in the direction of Dresden and the capital city of Berlin as the largest Central European metropolis. Accordingly, it has a slightly above-average position within the integration criterion (the share of national interactions is only about 21%). However, in terms of relevance, the route has the worst position due to strong landscape limitations precluding its placement through the Elbe river valley, which creates the need to build long tunnels under the Ore Mountains and Central Bohemian Highlands with significant impacts on construction costs (expected synergy effects associated with these routes, planned even for freight transport, can compensate for these negative effects in a very limited way). According to the analyses, on the other hand, a relatively strong prospective demand for passenger transport can be expected and within the utility criterion, where this route has a slightly above-average position (the expected number of passengers moving from the relevant rail and bus routes and CT is 2.4 thousand passengers per day). Within the stimulation factor, the route ranks third, while in the case of the regional city, i.e. Ústí n. L., a more significant strengthening of the quality factor of roads and railways can be expected (+ 13%) with positive impacts on the creation and spread of development effects along the only partially developed North Bohemian axis of national importance. According to the results of the sustainability criterion evaluation, the route was assigned the second worst ranking, with the following number of potential conflicts (reaching almost a quarter of their total amount): SAC 6 cases, SPA 2 cases, BCE 2 cases and BCO 4 cases.

Optimization scenarios

The above findings can be prospectively used to effectively support the spread of development effects from the main settlement centres along the individual routes of the HSR to their wider surroundings, complemented by other regular and irregular interactions with adequate relations to the development of regions and cities. In this context, optimization scenarios were developed based on the perception of key interests of the main stakeholder groups (interest groups) emphasizing the identification of potential development effects as well as potential conflicts of interest. The methodological concept of creating optimization scenarios is of course not uniform, they are usually understood as internally consistent images of the future based on selected sets of interconnected factors and phenomena of a qualitative and quantitative nature. The basis for creating these scenarios should then be to define what we know about future developments, i.e., presentation of information on development trends on the one hand, and specifications of what we do not know, i.e. identifying key uncertainties associated with the future on the other hand (Schoemaker 2018). In our case, the scenarios emphasize the application of the project methodology, and in this spirit logically follow the results of the multicriteria analysis presented above. In accordance with the factual focus of the examined transport projects, the following three basic scenarios were defined:

A) The **investor scenario** reflects the interests of the primary stakeholders represented by investors and railway operators, emphasizing increased competitiveness through the construction of HSR routes while targeting the criteria of relevance and usefulness. In this regard, we consider it particularly beneficial to support the creation of synergistic effects based on the general assumption that the resulting effect of systemically interconnected components is greater than the sum of the isolated effects of individual components. In this respect, it is mainly a functional interconnection of high-speed and conventional rail transport, where the transfer of express passenger to HSR, in addition to the desired increase in its quality, frees up the capacity of the directionally corresponding backbone conventional lines. This has positive impacts on operational ability and efficiency within the remaining traditional system of passenger and especially cargo railway transportation (which has a subordinate position within the traditional system of the right of way of train movement, which exacerbates its competitive disadvantages compared to road freight transport). The greatest synergy effects can be expected in the case of planned HSR 1 and 3. Regarding potential conflicts of interest, it is necessary to mention in the first place the problem of segmentation of landscapes and urban units by construction of HSR, whose serious negative effects on natural and residential environment can be mitigated preventively through costly technical measures such as the construction of tunnels and notches and wildlife crossing. Of course, this problem most concerns the positioning of routes through the largest urban agglomerations Prague, as well as Brno, Ostrava, and Pilsen. In this context, it is worth noting that with the backdrop of accelerating global climate change, the public interest in protecting the biodiversity of the landscape is becoming increasingly important as one of the most essential mitigation measures.

B) The **business scenario** reflects the interests of stakeholders represented by business entities emphasizing the improvement of the business environment quality and thus the investment attractiveness in terms of integration and stimulation criteria. In this regard, it is necessary to mention in particular the possibility of using HSR for effective expansion of labour markets generated by knowledge industries of the secondary and tertiary sectors located in the affected regional centres (penetration and dissemination of innovations generally follows a hierarchical pattern). In justified cases, their use for freight transport, motivated by the continuous expansion of trade markets and production cooperation within global production chains, can also be considered. According to the declared EU target, 30% of freight transport over 300 km should be shifted from road to rail and water transport by 2030 (European Commission 2011). From a long-term perspective, we consider that the activation of the development potential of the HSRs is determined especially by their geographic location due to the historically constituted system of development poles and axes of national importance as major concentrations of demand. In this context, however, the question arises as to whether the described effects do not conflict with the fulfilment of convergence principle as a priority of the European Union's Economic, Social and Territorial Cohesion Policy (European Union 2021). The expansion of the spheres of influence of dominant settlement centres can lead to conflicting situations caused by the removal of the most qualified part of the workforce from economically less developed regions, which of course undermines their economic development (in the next phases, however, thanks to the dissemination of knowledge with positive effects on their investment attractiveness, the economy may be modernized and a new, more progressive stage of their development may begin). However, it is clear that a successful solution to these problems will not be possible without systemic connection links with national and regional policy.

C) The **civic (residential) scenario** reflects the interests of stakeholders represented by citizens and non-profit institutions, placing the main emphasis on improving the quality of the social environment, and thus increasing residential attractiveness in terms of the integration and sustainability criteria. In this respect, it is possible to expect positive impacts induced by the transfer of passengers from road transport to HSR, generated by the offered benefits (speed, comfort, safety, or seamless transport to the centres of urban agglomerations). These impacts concern both regular trips (commuting to work and school, especially colleges) and non-regular trips (tourist trips, cultural activities, and visits). The secondary benefits of HSR, produced due to the primary electric traction, by significantly lower emissions compared to competing modes of transport can also be considered a significant advantage (in this respect, important transfers of passengers from frequented airlines connecting Prague with Munich Vienna and Berlin can be expected). In this regard it is necessary to mention the negative effects caused by potential conflicting factors created by the already mentioned segmentation of landscape and urban areas, accompanied by other controversial phenomena associated mainly with noise generation, forced changes in land ownership, and creation of urban barriers. In addition to standard technical solutions, non-traditional solutions associated with the increasingly supported construction of the so-called ecological infrastructure are offered to resolve these conflicts. This includes, e.g., the construction of biocorridors along selected sections of the HSR with positive effects on the ecological stability of the landscape. These examples can be purposefully complemented by other evidence based specific measures relating to the advancement of the global public interest in the fight against climate change.

From a practical point of view, the created scenarios provide a methodological basis for a constructive reflection of the relevant interests of the main stakeholders regarding the planned construction of the HSR as an important tool for maximizing future benefits and minimizing possible conflicts. In this regard, it is useful to draw attention to the common interests of the investor and business scenario in reducing transport's dependence on oil and increasing the residential attractiveness of the affected regions as an increasingly important localization factor of knowledge-intensive industries. Regarding the management of the implementation of the planned HSR routes, the following combinations of scenarios can be recommended within the optimization of relevant plans and taking into account the development of the main influencing factors, including their significance sequence: HSR 1 – investor, business and civic scenario; HSR 2 – civic, investor and business scenario; HSR 3 – business, investor and civic scenario; HSR 4 – civic, business and investor scenario (the above recommendations are rather symbolic due to serious uncertainties regarding future developments).

Conclusions

The construction of the HSR is a very complicated project, the effectiveness of which cannot be assessed without a comprehensive strategy developed by independent expert teams based on a professionally formulated vision and not on general political proclamations and defined parameters of planned routes (McNaughton 2017). From a practical point of view, the emphasis is on finding the optimal combination of costs and benefits with geographical and technical conditions of construction and with positive impacts on the competitiveness of rail transport in the context of sustainable development. A holistic view with an emphasis on spatial and environmental aspects of social development is gradually being promoted. According to a report by the European Court of Auditors containing the results of a survey of 14 HSRs in EU countries, ensuring the profitability of HSR operations requires a daily transport of around 25,000 passengers per day, i.e., about 9 million passengers a year. Only five of these lines meet this threshold, and on only two of them did the average speed exceed 200 km/hr. (European Court of Auditors 2018). From this it can be deduced that decisions on HSR construction projects were often based on incomplete or incorrect information. In addition, experience shows that the costly construction of express transport infrastructure has only limited links to economic development (Körner 2015). According to the results of analyses of planned HSR construction projects in the Czech Republic, the potential figures of daily traffic on the busiest HSR 1 connecting the largest Czech settlement agglomerations would reach approximately 8.4 thousand passengers per day within the average variant, i.e. approximately 34% of the above profitability limit. In this respect, we can only state that achieving profitability is unlikely and accordingly it is necessary to pay close attention to savings (e.g. situating a part of the HSR on existing railways) or rejecting inefficient and politically motivated proposals (e.g., construction of redundant terminals) and system-based support for the creation of positive externalities. On the other hand HSR are considered to be the least environmentally burdensome mode of transport (European Commission 2019), which also demonstrates their important contribution to addressing the main issues set out in the White Paper on Transport (see introductory section). From the point of view of project implementation, gradual changes in the basic paradigm of human civilization towards sustainable development will undoubtedly play an important role, which will logically be reflected in public budget priorities (see e.g. the commitment under the Green Deal to reduce emissions by 2030 by at least 55% compared to 1990 approved by the European Parliament). In this context, the prospects for the further development of the HSR appear to be favourable. In addition to increasing the competitiveness of railway transport, the leading general benefits of the construction of HSR in the Czech Republic consist mainly of supporting its integration (with an emphasis on the EU Cohesion Policy), improving the quality of life and sustainability development. Practical approaches are increasingly coming to the fore, within the framework of which spatially oriented multicriteria (and therefore also multidisciplinary) analyses are increasingly being applied, which can also be effectively used for finding compromises between relevant preferences of the main stakeholders.

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