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The impact of city public transportation use on the competitiveness between high-speed rail and the car: The example of the Prague – Brno connection

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Abstract: The aim of the paper is to determine how fast the HSR connection in conjunction with public transport between Brno and Prague should be in order to be time-competitive with car use. Brno and Prague are the largest agglomerations in Czechia and, according to the Czech government's plan, the first HSR will be built between them. The competitive speed of high-speed trains is derived from mathematical accessibility models created in GIS. The route planner in Google Maps and control supplementary sources were used as a source of data on the speed of public transport connections and the travel time of cars. The effect of a possible relocation of the main Brno railway station is also considered. The derived optimal competitive speed is slightly higher than the current plans assume.

Keywords: high-speed rail; accessibility model in GIS; modal competition; Prague, Brno, Czechia.

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Introduction and general framework of the analysis

The inadequate railway connection between the two largest cities in Czechia (the Czech Republic) has been a frequently discussed topic for many decades. At present, the high-speed line is starting to be designed. Unfortunately, there are still many uncertainties and unsolved problems, such as the still- unchanged operating model, the problems of the relocated Brno station, or the travel times between the centres of Prague and Brno. This paper compares, based on quantitative GIS models, the travel times of Prague and Brno residents between the two cities, using public transport to and from the station versus using individual automobile transport. The aim is to determine how fast the railway between Prague and Brno should be during peak and off-peak hours to make it faster and more attractive to passengers than a car.

The fast connection of the main agglomerations of the country has a number of positive effects. The commonly known relationship between the quality of accessibility and the

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intensity of labour mobility at the micro-regional level has been demonstrated, e.g., by Hudeček (2011). However, HSR also brings about changes in labour mobility at a higher regional scale, deepening commuting links between even distant agglomerations or promoting suburbanisation in more distant cities, outside expensive agglomerations (for a closer look at the Spanish example, see e.g., Guirao et al., 2018). At the same time, high-quality connections to HSR bring new agglomeration effects to centres (e.g., Ahlfeldt and Feddersen, 2018, in the case of the German cities of Cologne and Frankfurt am Main). A recent overview of the socio-economic impacts of HSR is provided by e.g., Cheng and Chen (2022).

The European Court of Auditors' Special Report No. 19 of 2018 notes that the EU invested €23.7 billion in high-speed rail infrastructure between 2000 and 2018. Despite this expenditure, the European HSR network is still fragmented, with insufficient connectivity. And the report also notes that high-speed lines are being built where they are not needed. This is demonstrated, among other things, by the fact that the average speed of trains is at 45% of the maximum rated speed. Overall, the Report highlights the inefficiency of the costs incurred, which have a long-term ROI (Return On Investment) and are extremely high. For example, the cost per minute of travel saved was up to €369 million (specifically on the Stuttgart–Munich line) and 1 km of high-speed line construction cost an average of €25 million (excluding tunnel sections).

The report also provides a comparison with the Japanese Shinkansen high-speed trains, which are competitive even for travel distances longer than 900 km. In Europe, HSRs are generally competitive for travel distances of 200 to 500 km (Italian case – see Bergantino 2020). For longer journeys there is also the significant competitiveness of air transport, and for shorter journeys individual car transport wins, especially with its flexibility. Although intermodal competitiveness is saturated by a number of factors, a travel time, frequency, and transport costs are the most important (Amparo et al. 2015). In case of car – train competition the pull-to-train factors are possibility to work during the train journey and difficult parking options plus congestions when using car. Private car also provides comfort, privacy, and flexibility (e.g., Braun-Kohlová 2012). In our study, we focus only on travel time, the perception of which is the most important for the mode choice.

It is the high-speed rail link between the two largest agglomerations in Czechia – Brno and Prague – that will be under pressure due to competition from car transport. This will be particularly evident when the entire journey is made by public transport, i.e., when using public transport to get to the station. Due to the relatively slow travel times of public transport, the competitiveness of the connection will be fundamentally dependent on the speed of the HSR service between these cities.

1. Methodology for determining journey times

At the outset of the analysis, it is important to highlight the difference in terms that are often misused. Riding time represents the net time a passenger spends on a transport vehicle. In contrast, travel time includes all the time a passenger spends travelling from A to B, i.e., on the journey. The travel time of the whole transport chain in the case of travelling from Prague to Brno (and vice versa) can be expressed as follows (Fig. 1):

Figure 1. Transport chain diagram for travel time by public transport and by car

Individual automobile transport:

Arrival at the vehicle + car driving + (traffic complications) + parking time at the destination + walking time at the destination

Public transport:

Arriving at public transport + waiting for a connection + riding public transport to the station + waiting for a train connection + riding the main means of transport (HSR) + waiting for a public transport connection from the station + riding public transport to a stop near the destination + walking to the destination + (traffic complications may also occur at all stages)

At first glance, it is already evident that the transport chain is more complicated in public transport, with passengers having to change between several different connections, for which they have to wait for varying lengths of time at transfers. The number of connections and modes of transport used increases the likelihood of traffic complications and places great demands on the speed and reliability of the main (long-distance) means of transport. The high-speed train, in our case, therefore, needs to be adequately fast to compensate for the entire transport chain of public transport and to offer more attractive travel times than a car. In the specific case of the Prague–Brno connection, the question is therefore what travel time should a high-speed train between Prague and Brno have if it is to be competitive with the car?

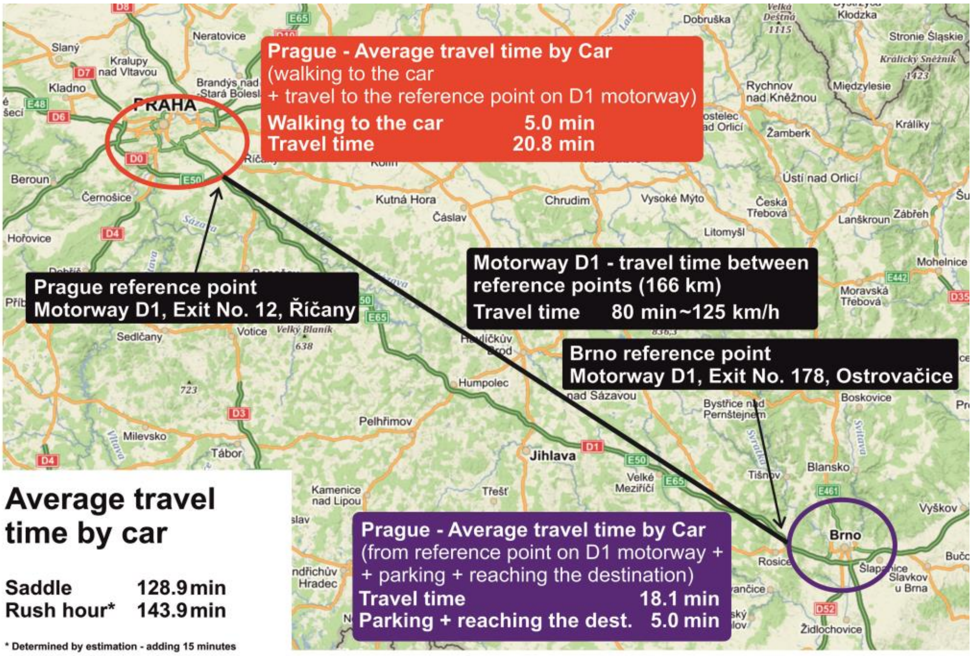
1.1 Travel time by individual automobile transport

First, we determine the average travel time by car. The journey by car (in the direction of Brno) is divided into 3 main stages – travelling by car through Prague to the D1 motorway (we have chosen exit 12 Říčany as the reference point), then travelling along the D1 motorway, and finally reaching Brno (from the reference point at exit 178 Ostrovačice). Driving time in peak hours was estimated by adding 15 minutes to the driving time in the saddle. The estimate does not reflect contingencies and constraints on the route. Also arbitrarily, a flat commute time to the vehicle and from the vehicle to the destination was set at 5 minutes. The average travel time within Prague and Brno was determined using an area availability analysis using data from Google Maps' route planner. The travel times were weighted by the number of residents registered at the address points (CSO records) to reflect the distribution of the population in Prague and Brno in the resulting accessibility time value. The resulting average travel time through Prague and Brno to the respective reference points on the D1 motorway was therefore calculated in the model according to the following formula:

$$\text{Average travel time} = \frac{\Sigma(\text{sum. of people in the house * travel time})}{\text{sum. of people in the city}}$$

The speed of movement on the D1 motorway between the reference exits was set at a slightly under-limited 125 km per hour (the maximum permitted speed on motorways in Czechia is 130 km per hour). The resulting travel time by car between Prague and Brno, i.e., the average time from anywhere in Prague to anywhere in Brno or vice versa, came out to 158.9 minutes at peak hours and 128.9 minutes in the off-peak time, i.e., 15 minutes longer (see Figure 2).

Figure 2. Model of an IAD journey between Prague and Brno



Source: author's calculations in GIS traffic model, CSO population records, Google route planner

1.2 Travel time by public transport

A trip using public transport can also be divided into 3 basic phases – travelling through Prague to the railway station, Brno from the railway station and then there is the actual journey by high-speed train (or in the opposite direction). In the model, we assume that the highest segment of trains on HSR will stop at Prague main station and Brno main station in its current location. We will comment later on the issue of Brno-Vídeňská station, which is currently planned for HSR trains.

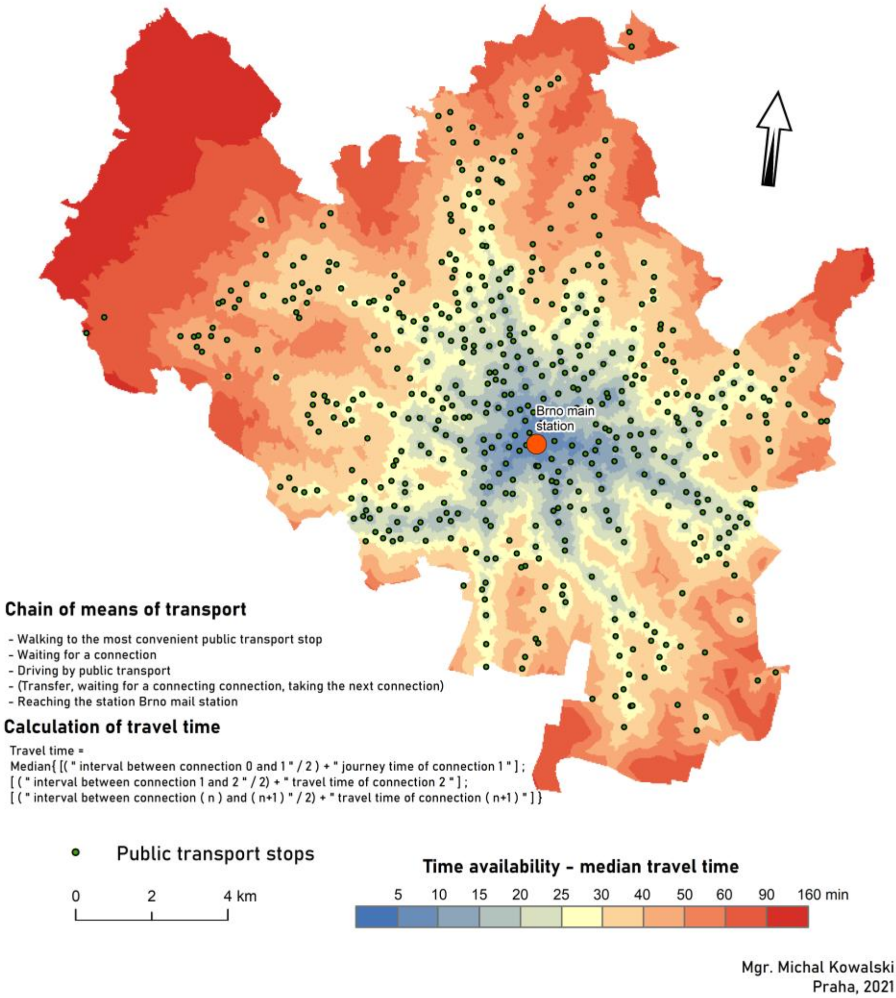
The transport chain to the main station unfolds as follows: the passenger leaves home, goes to the most convenient public transport stop, and from there travels (including any transfers) to the main station. It is important to deal with the fact that the public transport service is not continuous, and the connection is not immediately available as in the case of car use. Therefore, the mean travel time by public transport was determined as the sum of the travel time according to the timetable plus the mean waiting time from each stop. This was determined as the median of a set consisting of the halves of the intervals between connections at each public transport stop. The model assumes that the demand for public transport is a continuous variable between two consecutive connections, but that the actual departure of connections is a discrete variable. The most unfavourable option is for the passenger to arrive at the stop and miss the service, and the most favourable option is for the passenger to board the service directly upon arrival at the stop without waiting. We assessed the intervals for the morning peak between 6:30 a.m. and 7:30 a.m. and for the transport saddle between 10 a.m. and 11 a.m. Data was collected automatically for the period from January to June 2021 from the Google Maps route planner and combined with IDOS timetable data. The resulting times provided by the searches were inclusive of any transfers. The model assigned to each house with permanent residents the walking distance to the nearest public transport stops and journey times to the Brno and Prague main stations, respectively. The model then determined the most time-efficient combination. A map of accessibility to the Brno main station with public transport and peak hour commuting times is shown in Figure 3. The same models were produced for the peak period for Prague as well.

As part of the accessibility analyses in GIS, a variant of the currently promoted relocation of the Brno railway station was also produced. By analysing the population distribution, it was found that the geographical centre (gravity centre) of Brno's population is located 200 metres west of the Antonínská tram stop. It can therefore be concluded that if we want to bring the Main Station closer to the population, we need to move it 1.5 km to the north. In terms of accessibility of the current public transport, the current location of the station is more advantageous for 207,851 inhabitants (65%) and the relocated location is more advantageous for 113,220 (35%) inhabitants. In the case of an adequate public transport network, the relocation of the station represents a significant improvement in accessibility only for Komárov, Černovice and the inhabitants of Líšeň, Židenice and Starý Lískovec/Bohunice. In reality, however, it is only a one- to three-minute speed-up at most. For the entire area of the city centre and the districts north of the centre of Brno, the removal of the station represents an increase in travel times from 5 to 12 minutes. Based on the accessibility analysis, it was found that the removal of the station would increase the average Brno resident's travel time by 5.7 minutes (see also Figure 4). Due to the uncertainties regarding the future operational concept of public transport (line routing, investment in new infrastructure, capacity constraints of trams between the new station and Brno city centre), an increase of 5 minutes for the relocated station was determined in the model.

Adding the travel times for commuting, public transport trips and the 20-minute margin for transfers between public transport and HSR trains in Prague main and Brno main, we obtain cumulative model travel times of 73.3 minutes to 82.5 minutes (summarised in *Table 1*). The only unknown for comparing the time competitiveness of the IAD and HSR chains at this point is the travel time of the high-speed train. This evaluation is the subject of the following subsection.

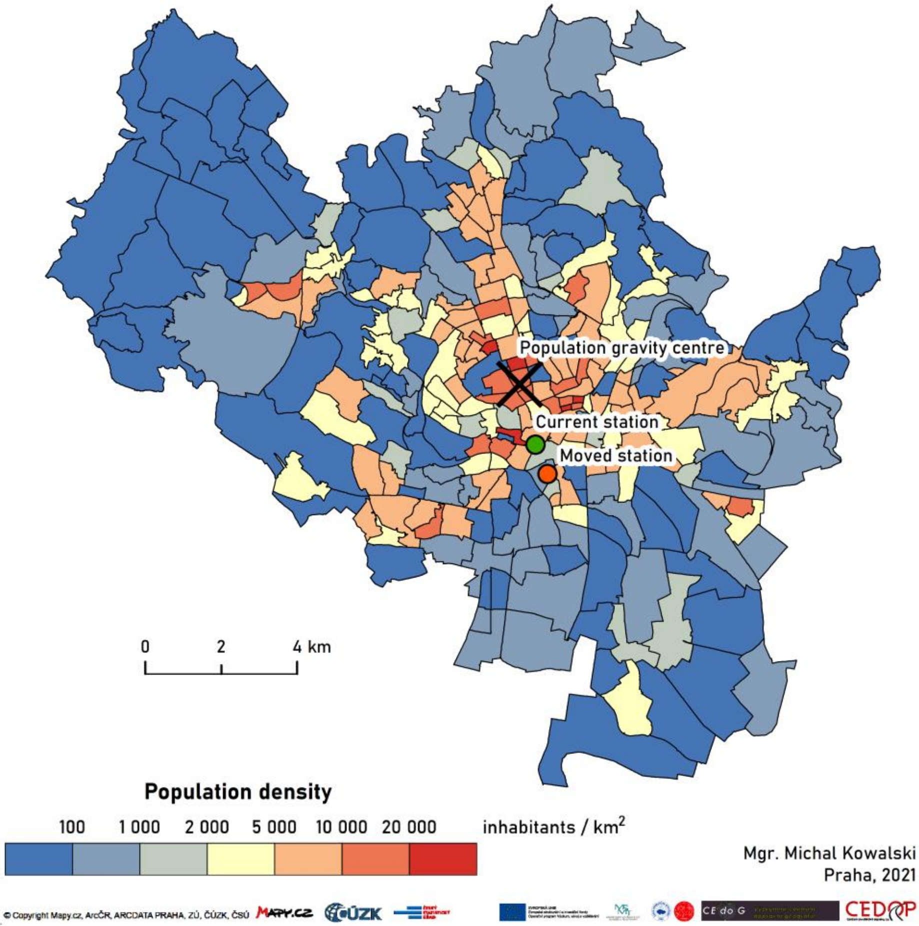
For the purpose of a detailed comparison, variants of a passenger travelling to the wider centre of Prague or Brno were also made. This is the destination for the majority of passengers with the following objectives: business trip, commuting to school or for culture or entertainment. Public transport commuting time was set at 20 minutes for Prague and 15 minutes for Brno. The average travel times by car for commuting to the wider centres are the same in the model as for the whole city.

Figure 3. Time accessibility of the Brno main station (Hlavní nádraží) by public transport from the territory of the city of Brno (peak hour)



Source: author's calculations in GIS traffic model, CSO population records, Google route planner

Figure 4. Population weight and density in Brno in the context of the station location



Source: author's calculations in the GIS traffic model, CSO population records

Table 1. Summary of model travel times – car and public transport in Prague and Brno

Car travelling [min]							
Relation	**Getting to the car**	**Travelling to the D1 motorway**	**Travelling on the D1 motorway**	**Travelling to the destination from the D1 motorway**	**Parking and reaching the destination**	**Total travel time - saddle**	**Total travel time - rush hour (+15 min)**
Prague - Brno / (Brno - Prague)	5.0	18.1	80.0	20.8	5.0	**128.9**	**143.9**

Public transport travelling without travelling by high-speed railway [min]						
Relation		**Getting to public transport + public transport ride**	**Transfers and time reserve for the high-speed train**	**Public transport ride + reaching the destination**	**Total travel time - saddle**	**Total travel time - rush hour**
Prague - Brno / (Brno - Prague)	Saddle	26.3	20.0	31.2	**77.5**	
	Rush hour	24.9	20.0	28.4		**73.4**
Prague (from anywhere) to the wider centre of Brno	Saddle	31.2	20.0	15.0	**66.2**	
	Rush hour	28.4	20.0	15.0		**63.4**
Brno (from anywhere) to the wider centre of Prague	Saddle	26.3	20.0	20.0	**66.3**	
	Rush hour	24.9	20.0	20.0		**64.9**

Source: author's calculations in the GIS accessibility model

2. Evaluation of time competitiveness of HSR and car

The following table identifies the minimum travel time for a rapid transit train between Prague and Brno that needs to be achieved for travel using HSR at the station to be as fast as by car. The analysis has been made for peak and off-peak travel and also as a variation for the Brno main station in an offset position. In addition, the competitive journey times of the high-speed train are also calculated to be 10% or 20% shorter than travelling by car (*Table 2*). It can be seen that if a HSR journey in combination with public transport were to be at least equal in time to a car journey, it would have to take 70 minutes in peak hours (and with the current location of Brno main station), and even 51 minutes in off-peak hours, which is less than the current operating models assume. If public transport travel is to be competitive, travel times must be noticeably shorter than by car for the improved time to compensate for the perceived inconvenience of travelling to and from the station by public transport. In this case, however, the HSR trip should be significantly less than one hour, which requires an operating speed on HSR well above 250 km per hour. With such journey times, not only an increase in day trips between Prague and Brno can be expected, but also a significant redistribution of the division of transport work in favour of rail and public transport (see Table 3 for a more detailed overview).

Conclusion

The analysis has shown that the journey time of the fast train between Prague and Brno should be shorter than 60 minutes to make travelling by public transport faster and more attractive than by car. It can be argued that many passengers will arrive at the station by car, but the current conditions in the two cities under consideration do not provide suitable conditions for this intermodality. There is a lack of parking spaces and congestion, especially at peak times. This makes the station less accessible timewise than by public transport. However, with regard to the environment, it is essential to focus transport policy on maximising the quality of public transport so that it becomes the main choice for short journeys in cities. A comparison with average public transport travel times, albeit modelled, is therefore considered relevant.

A specific issue that can significantly affect the time availability within cities is the location of HSR stations. The analyses presented here have been carried out for the current location of the main railway stations, which allows for optimal connections to the public transport system that has been designed in relation to them for a long time. In the case of Brno, the location of the displaced station was also considered, which is disadvantageously located due to the population distribution and the existing public transport. It has been shown that this option places even higher demands on the speed of the HSR connection. The planned Brno Vídeňská station has not been considered in the presented analysis; with a suitable operational concept, it will benefit only the southern and relatively sparsely populated part of Brno. From the point of view of intercity short-term commuting, which was the main focus of our analysis, the station at Vídeňská is completely irrelevant and will only be relevant for international traffic. For daily commuting and possible public transport to/from the centre of Brno, its location is completely inappropriate and will probably be the reason why travelling by car will be preferable. If the aim of building HSR between Brno and Prague is also to change the "modal split" in favour of more environmentally-friendly transport modes, the use of HSR will depend fundamentally on the speed of the connection to the centre of Brno by public transport or on the chosen traffic model. In the feasibility study for the HSR Prague–Brno–Břeclav, one line between Prague and Vienna is currently routed via Brno–Vienna station and the other line via Brno main station, without stopping at Brno–Vienna station. This would substantially reduce passenger comfort when commuting to Vienna or Bratislava and would unnecessarily limit the use of HSR. When planning a high-speed rail link between Prague and Brno - it is therefore necessary to assess the situation comprehensively and not primarily according to the availability of land for new terminals and lines.

Table 2. Competitive journey times for fast trains (in minutes)

Necessary travel time of the high-speed train [min]		**Saddle**		**Rush hour**	
		Brno - current station	**Brno - moved station**	**Brno - current station**	**Brno - moved station**
Prague - Brno / (Brno - Prague)	Travel time car = public transport	51.46	46.46	70.58	65.58
	Public transport 10% faster than car	38.57	33.57	56.19	51.19
	Public transport 20% faster than car	25.68	20.68	41.80	36.80
Prague (from anywhere) to the wider centre of Brno	Travel time car = public transport	62.77	57.77	80.52	65.58
	Public transport 10% faster than car	49.88	44.88	66.12	61.12
	Public transport 20% faster than car	36.98	31.98	51.73	46.73
Brno (from anywhere) to the wider centre of Prague	Travel time car = public transport	62.63	57.63	79.00	65.58
	Public transport 10% faster than car	49.73	44.73	64.60	59.60
	Public transport 20% faster than car	36.84	31.84	50.21	45.21

Source: author's calculations in the GIS accessibility model

Table 3. Overview of the evaluation of model times and their impacts on travel

High-speed train riding time Prague – Brno	Evaluation of competitiveness	Impact on travelling
80 min and more	Similar travel time to car only for journeys to the wider centre at peak times or if the D1 motorway collapses	Near uncompetitive for travel between Prague and Brno using public transport; only relevant for transit
70 min	Alignment of car travel times at peak times	Weakly competitive only for journeys to the wider centre at peak times. or when the D1 motorway collapses.
60 min	Rush-hour journeys start to be convenient for travellers between city centres	Attractive connections only when travelling to/from the wider city centre.
55 min	For the current location of Brno main station, public transport is 20% faster when travelling to the wider centre at peak times, in the saddle time the travel times between Prague and Brno are equal	Regularly scheduled trains, convenient for converting Prague and Brno into hubs with connecting transfers. A journey time of up to 60 minutes is reasonably technically achievable and will have a significant impact on the passenger's psychology.
50 min	The relocated station compensates for its locational handicap and provides a similar transport speed as the station in its current location, where the train goes from Prague to Brno in 60 min.	Achievable for the sector of non-stop trains without stopping at Nehvizdy and at Brno-Vídeňská. it will ensure attractive transport even in saddles.
45 min and less	Connections starting to be attractive for almost all links, excellent city centre connections, comprehensive change in transport behaviour of residents	At or beyond the limits of conventional rail, route at 350–400 km per hour, tunnel feeder to Brno city centre required. Benefit is extremely attractive connection, possibility of daily commuting.

Source: author's calculations in the GIS accessibility model

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References

AHLFELDT, G. M., FEDDERSEN, A., (2018). From periphery to core: measuring agglomeration effects using high-speed rail. *Journal of Economic Geography*, 18, 2, pp. 355–390.

BERGANTINO, A. S., MADIO, L., (2020). Intermodal competition and substitution. HSR versus air transport: Understanding the socio-economic determinants of modal choice. *Research in Transportation Economics*, 79, Elsevier,

GUIRAO, B., CAMPA, J. L., CASADO-SANZ, N., (2018). Labour mobility between cities and metropolitan integration: The role of high-speed rail commuting in Spain. Cities, 78, Elsevier, pp. 140–154.

HUDEČEK, T., (2011). Accessibility in the Czech Republic in the period 1991–2001: Relationship to commuting to work and school. Geographica, Prague: Czech Geographical Society, 141 p.

JUNMEI CHENG & ZHENHUA CHEN (2022). Socioeconomic impact assessments of high-speed rail: A meta-analysis, *Transport Reviews*, 42, 4, pp. 467–502.

MOYANO, A., CORONADO, J. M., GARMENDIA, M., (2015). How to Choose the Most Efficient Transport Mode for Weekend Tourism Journeys: An HSR and Private Vehicle Comparison. *The Open Transportation Journal*, 10 (Suppl-1, M8), Bentham Open, pp. 84–96.

GOOGLE MAPS APPS – route planner, a source of travel time by car and by city public transport.

IDOS – official web timetable of public transport in Czechia.

CZECH STATISTICAL OFFICE (CSO) (2019). Population records.

CZECH GEODETIC AND CADASTRAL OFFICE (2021). Map sources: register of territorial identification, addresses and real estate.

ARCDATA PRAHA, s.r.o. (2021). Gaodatabase ArcČR.

GEOFABRIK, GmbH (2021). Open Street Map: Public transport stops.

A EUROPEAN HIGH-SPEED RAIL NETWORK. (2018). Not a reality but an ineffective patchwork. Special report of the European Court of Auditors, No. 19/2018. Available at https://op.europa.eu/webpub/eca/special-reports/high-speed-rail-19-2018/en/