Interaction of regional and high-speed transport in transport services: case study of Praha-Brno high-speed railway line in Vysočina region

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Abstract. The paper assesses the future interaction between the projected high-speed rail (HSR) and regional transport in the Czech Republic (CZ) with the aim of analysing potential interchanges.

The current decentralisation of transport service orders of regions and the liberalisation of the railway market create a complex system that poses many challenges for modern railway transport in CZ. Although these aspects improve rail transport due to competition within the existing network, at the same time they make it more complicated for passengers. Moreover, the effects of competition are not limited to certain lines, and its effects are only noticeable in selected parts of the network. There are already many conflicts between regional and conventional long-distance transport, such as transport concept, the carrier, the timetable and the capacity of the trains and the compatibility of travel documents. These conflicts will naturally be present even in the case between regional and high-speed long-distance transport.

The construction of high-speed networks should improve accessibility to major centres such as Prague and Brno and at the same time further connect Europe, as the current state of rail transport in CZ is not satisfactory in terms of speed. This construction could not only improve the transport within the country, but also improve the international transport through CZ as the centre of Europe. High-speed and regional transport are not mutually exclusive, but can create synergies that will offer people an alternative to travelling individually by car. Whether it is an alternative to commuting to an HSR terminal or an alternative to the journey itself.

This paper is a case study of the availability of the high-speed terminal in the Prague – Brno high-speed line (HSL), for the Vysočina region. The location and presence of a terminal can determine the disparity of regions, and consequently of cities that have/do not have access to HSL and thus influence the inclusion of these fast transport systems in the regions. In the paper is stated the optimal variant of the HSL line from the feasibility study, as well as the current traffic flows and the forecast of traffic demand in the selected region where the high-speed line Prague – Brno will lead. According to the best routing option according to the feasibility study of the infrastructure manager – Správa železnic, s. o. (SŽC), interchanges should take place at the future Jihlava-Pávov terminal near the regional town of Jihlava. The case study will address the surrounding railway network towards Okříšky, Slavonice, Horní Cerekev, Humpolec,

Hlinsko v Čechách, Třebíč and Znojmo with overlap to other neighbouring regions. For the time being, extensive reconstruction plans for the surrounding railway network are not anticipated, so an important part of the paper is also a proposal on how to improve the new connections without serious interventions in the railway infrastructure, as well as the use of alternative propulsion methods.

The paper is concluded by pointing out the various problems that the integration of the high-speed transport system into the current transport (regional) concept will face with the aim of increasing the inclusiveness of new high-speed rail transport and reducing the disparity for residents who are not in the relevant vicinity of high-speed line terminals.

Keywords: High speed Rail, Regional railway transport, Integrated Interval Timetable, Transport services

1 Introduction

The Czech Republic is trying to speed up its long-distance transport by high-speed rail (network), which is planned today. It is a big milestone, which needs many considerations, studies, and measures, because the whole project is high cost, and it is all about rentability that matters. One of the important aspects is the integration of this new long-distance transport mode into existing transport systems and concepts with proper integration of connectivity between each mode. Only that can be achieved more complex systems of public transport that can compete with private car transport, which is widely used, thus the congestions are happening. This is the aim of the article that focusses on creating a transport link between regional rail transport and high-speed transport in transport of the regions of the Czech Republic, Vysočina, where the first high-speed line will be built. For this case, a detailed analysis of existing connections is needed, as well as a comparative analysis of the prognostic transport concepts. The prognosis of transport flows of passengers is also important which could help to estimate transport capacities and transport routings.

The beginning of the construction of the high-speed system in the Czech Republic inherently includes research activities that can support the design of specific steps for the construction of lines of this system, as well as its operational concept and integration into the existing environment, whether economic, transport, ecological, urban, or architectural.

The essay by the Svoboda, Jiroušek, Plášek collective (2022) attaches great importance to the construction of a high-speed network in the Czech Republic (CZ), together with an increase in the capacity of the conventional network and the improvement of regional connecting transport. The research sees the optimal variant with a transfer node in Jihlava-Pávov, which will significantly improve accessibility in the Vysočina region. Furthermore, the Brno – Ostrava high-speed line (HSL) with a transfer terminal in Přerov will create a link with the conventional network and improve accessibility in the Olomouc region. These and other similar parameters of the future network will result in an increase in regional traffic (freeing up the necessary capacity),

which, according to research, will reliably allow 52% of the population to reach high-speed rail (HSR) stations comfortably [1].

The paper by Tomeš, Kvizda, Nigrin and Seidenglanz (2014) addresses the current state of accessibility of competition to the railway market, which is slowed down by the slow transformation of the domestic railway sector. The research was carried out in 2014, when there were already separate infrastructure managers and carriers. In this period, the increasing capacity pressure on the main line Prague-Ostrava started, where three carriers (České dráhy, RegioJet, and LeoExpress) are still fighting for passengers. This has resulted in a very poor state of the local infrastructure, which has required extensive closure works on several sections and a large increase in delays for all connections. Ordering of public transport services was then more in the form of direct tendering and now has started to make more use of competitive tendering [2].

A study by Wenner and Thierstein (2021) produced the expected results of accessibility using HSL. Changes in rail accessibility at four time milestones (1990, 2000, 2010 and 2020) were analysed. It should be mentioned that no evidence of increasing differences in accessibility across Germany was found; rather on the other hand there were extraordinary increases across the whole network not only using HSR. German geography is closer to the CZ than other countries with HSR. In Germany, HSRs do not fit into the city-periphery concept, but are spatially more extensive and also more discrete. This is due to the interconnection of HSR, conventional rail networks, a more dispersed settlement structure, and the time-phased implementation of high-speed transport. The research focused mainly on travel times between regions as a factor of accessibility. It is rightly pointed out that transport infrastructure is very costly, slow to change, and can have long-term consequences for the flow of people, goods, and services [3].

Pagliara, Henke, Russo and Guigon (2021) in their paper point to current HSR systems that are not inclusive (France, UK, Italy, and Spain). In other words, HSR systems create geographical inequalities or exacerbate existing ones. It is therefore important to ensure that people are not excluded from using HSR because of relatively high ticket prices or for territorial/geographical reasons, as most destinations on the network may not be directly served. The solution may be additional HSL, which is an expensive solution, or more HSR stations located outside the HSR network but still close enough, or more generally, investment in public transport and creating synergies between high-speed and regional transport (buses, rail). Spatial planning and mobility planning are often mentioned, but have rarely been included in specific policies [4].

Track statements from individual rail infrastructure managers in countries where there is HSR do not specifically address access to HSR versus conventional lines. In most cases, consideration is given to the time occupation of the HSL sections in question in relation to the elimination of over-allocation of time and closure works, and alternative routes are also given in the event of exceptional circumstances [5].

2 Rail transport system in the Czech Republic

Currently, transport services and the liberalisation of the rail market in general are regulated by European legislation, e.g.,

- Regulation (EC) No 1370/2007 of the European Parliament and of the Council of 23 October 2007 on public passenger transport services by rail and by road and repealing Council Regulations (EEC) Nos 1191/69 and 1107/70, in its latest consolidated version.
- Directive 2012/34/EU of the European Parliament and of the Council of 21 November 2012 establishing a single European railway area, in its latest consolidated version.

Based on these regulations, national legislation is being developed to regulate the conditions of transport services in the EU countries. However, not all countries are subject to this system regulation. In the Czech Republic, Regulation no. 1370 was used, which defines how state authorities can intervene in the field of public passenger transport in order to improve the quality of related services, rather than if market mechanisms alone were to attempt to provide these services. Another important regulation is Act no. 194/2010 on public services in passenger transport. An important aspect is the compensation that will be provided by the customers of the services:

- state – Ministry of Transport of the Czech Republic (MoT),
- regions,
- municipalities,

Under the public service obligation (PSO) to the operators of these services, i.e., the carriers. Compensation exists to cover the costs arising from the operation of these services. The contracts that address this further define the services to be provided, the territory, the process for calculating compensation, and the extent of exclusive rights that prevent overcompensation. The plan for the provision of services, that is, the transport service, shall be for a minimum period of 5 years and shall also be limited to and not exceed 15 years [6], [7].

2.1 Impacts of liberalized railway transport

Long-distance rail transport in the Czech Republic is ordered by a single authority, which is the MoT. Since 2020, private carriers have entered the long-distance lines, competing with the national carrier České dráhy (ČD). In general, the entry of private carriers into the market, whether on lines in PSO or on commercial risk, has led to an increase in the quality of transport, a reduction in ticket prices, and an increase in the frequency of services. However, it must be said that these positive aspects are not universal and occur only on part of the railway network (e.g. Prague – Ostrava). A significant transport complication is the different tariffs of carriers on long-distance lines, where until recently passengers used to pay their tickets on two or more carriers. This is solved by the unified tariff system for the public called OneTicket, which has been applied since 2020. This allows one to travel on one ticket between multiple carriers; on the other hand, it is more expensive than a single carrier ticket.

Regional transport is ordered by individual regions within their territory. Long-distance lines of the MoT or special cases of regional transport agreed by two or more regions can be considered as interregional transport. Private carriers are already present here. Here, as in the case of long-distance transport, passengers must have an overview of the routes where the various carriers are located. In contrast, each region has an integrated transport system (ITS), which is applied to all public transport lines in that region. Thus, the passenger has a choice between individual carrier tariffs, OneTicket, and ITS tariff.

In general, tenders for carriers do not have a uniform form, which allows different conditions of entry between regions. Furthermore, discrepancies may arise between regions in the aforementioned interregional transport (forced transfers due to the operation of transport on the border of regions, suboptimal allocation of even different vehicles to one line, etc.). Each new carrier in the whole system increases the tariff mismatch and the variation of vehicles. Furthermore, the terms of these tenders are also currently spilling over into the vehicle fleets of carriers. An example is the South Moravian Region, which owns electric units for its regional transport and the carrier is only supposed to operate them [8], [9].

2.2 Future high-speed network

Several high-speed lines have been planned in the Czech Republic, connecting the two largest cities (Prague, Brno) of the Czech Republic to other countries and at the same time connecting the West with the East. Rapid transit (RT) lines, RT3 and RT4, connect the Czech Republic with Germany, the RT5 and RT1 lines connect the Czech Republic with Poland, and the RT2 line with Austria. The entire concept of the high-speed network is estimated to be completed by 2050 at the earliest. For each proposed line, there are several speed and line variants, which then allows the line to be used by trains other than high-speed (freight) or not. The construction of the RT1 line between Prague and Brno will start first. This part of the network aims to connect most of the country from Prague to Ostrava via Brno. However, this bypasses other important cities such as Pardubice (where a future connection is planned), Česká Třebová, Zábřeh na Moravě and Olomouc, which are currently on the busiest long-distance corridor. Furthermore, České Budějovice, Karlovy Vary or Liberec will not be included in the network. The primary objective is to connect the Czech Republic with Europe and secondarily to create links within it [10]. The plan can be seen on the Fig. 1.

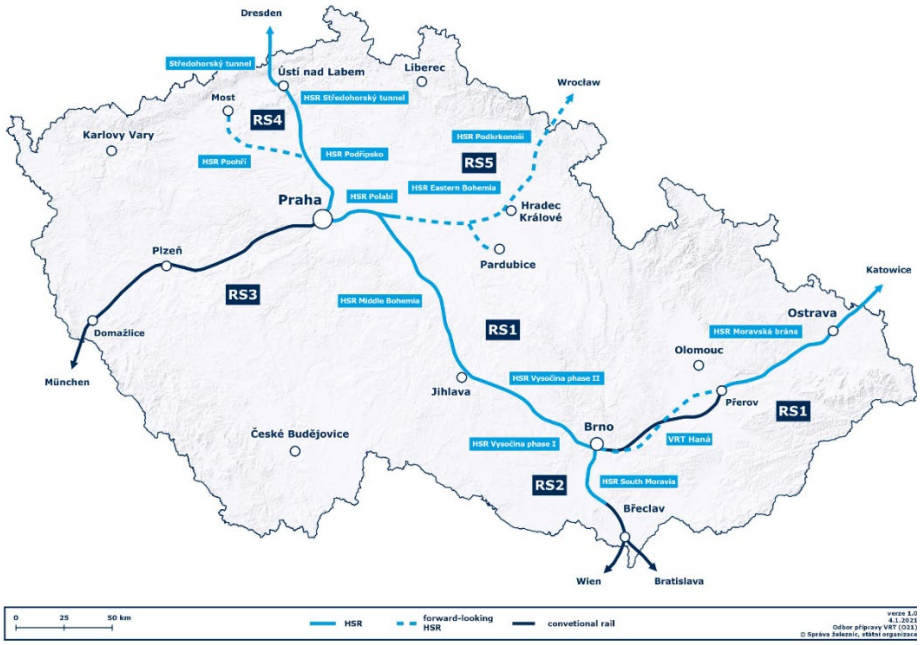

Fig. 1. Future high-speed network in the Czech Republic (source: author, based on [11])

Rapid connection 1: Prague – Brno

This paper focuses on the RT1 line in the section Prague – Brno with details on the Vysočina region with the regional town of Jihlava. The first stage of the feasibility study presents 4 variants of the HSR project marked as SK, JK, PK and BK.

- The SK variant is routed from Prague to Jihlava via the northern corridor (Poříčany) and considers the Jihlava-Pávov terminal.
- The JK variant runs from Prague to Jihlava via the southern corridor (Benešovsko) and, like the SK variant, assumes the Jihlava-Pávov terminal.
- The PK variant is identical to the SK variant, but places the Svatý Kříž terminal near Havlíčkův Brod, which will not be significantly connected to conventional lines.

The feasibility study best evaluates the SK option. Each variant, except BK, has 3 operational concepts, these are described in Table 1.

Table 1. Possible operating concepts on the high-speed line Prague-Brno (source: [10]).

	Variants SK, JK, PK
Operating concept no. 1	Maximum speed up to 350 km/h. Segregated operation (high-speed trains only).
Operating concept no. 2	Maximum speed up to 300 km/h. It is possible to operate trains at lower speeds (approx. 230 km/h) to partially use part of the HSR and to serve the area along conventional lines.
Operating concept no. 3	Similar concept to no. 2, but top speed up to 250 km/h.

The second stage further developed the SK and PK variants, which were based on operational concepts 2 and 3, which also allowed the use of conventional trains for area servicing. A 'no project' option was added to the whole process, which did not foresee the implementation of the RT1 HSR project, but presented the development of the surrounding network, including the other HSLs mentioned. In the final process, the project variants were developed into the MAX scenario, which considers additional projects beyond the approved network development (e.g. HSL Prague – Hradec Králové – Wroclaw or HSL Brno – Přerov. For each of the above-mentioned variants, the line routes were created and their intervals, stopping points, and train categories were defined.

At the end of the feasibility study, after the evaluation of the options in terms of social objectives, environmental impacts, and economic efficiency, the option SK4-320 is recommended. The second ranking according to the feasibility study was given to the option PK4-320. Advantages of the SK4-320 variant:

- Better service of Jihlava and its surroundings thanks to direct exits, thus reducing travel times to other directions such as České Budějovice or Třebíč.
- The location of the terminal in Pávov offers a closer position to Jihlava and a direct connection to line 225 opposite Svatý Kříž.
- Potential connection to public transport in Jihlava thanks to the terminal in Pávova and better integration of the HSL into the transport system of the Vysočina region.

Logically, the most significant benefit of the study will be the speeding up of travel times in long-distance passenger rail transport and the estimated transfer of passengers from private car transport (PCT) to public transport depending on the specific option (about 30% benefit). Furthermore, the release of road capacity on conventional long-distance routes for freight transport (approx. 17%). Last but not least, the development of the region due to faster population mobility (approx. 13%). The remaining percentage of the study is attributed to lifetime investment and social benefits (approx. 34%) [10].

Negative reviews

A certain opposition is represented by a part of the population of the Vysočina, which considers the construction of the HSR to be hasty without expert discussion with the general public. They also consider its management near the affected non-consenting villages (e.g., Okrouhlička, Lípa, Kounice) to be wrong in terms of environmental destruction (destruction of the landscape, endangerment of protected animal species), as their opinion is that they will not use the HSL, and the built infrastructure will create an obstacle to the currently accessible places. The affected municipalities also complain about practically no communication from the authorities (MoT, SŽC), which did not consult the construction with the affected municipalities. However, SŽC denies this and documents their field work including consultations with the municipalities. The regional town of Jihlava itself agrees with the construction of the HSL. Speeding up and improving long-distance and regional transport could lead to better acceptance by

this dissenting part of the population, although they argue the competitiveness of the HSR in the 400-1000 km range [12], [13], [14].

Transport flow prognosis

This subchapter offers information on the prognosis of transport flows in long-distance and regional transport for the mentioned HSL in the Vysočina region. The prognosis was created while processing every variant of HSL (SK, JK, PK) with a focus on optimising variant SK. The prognosis also considers partial use of HSL by specialised express train lines R11, R33, and R34. The emphasis is put on the transfer between high-speed long-distance and regional connections, also with using the entrance and exit places to / from conventional railway lines (current corridors) in Světlá and Sázavou, Velká Bíteš and in HSL Jihlava-Pávov terminal.

Express train line R11 and its current transport route is between Plzeň and Brno through České Budějovice and Jihlava. In the future, this express line should use HSL in part of the travel between Jihlava and Brno and use the Jihlava-Pávov terminal for entrance and exit. The same concept is planned for express train line R33 which currently does not exist. This train line should start in Jihlava and end in Praha immediately starting on HSL from the Jihlava-Pávov terminal. Also, non-existent R34 will be using the HSL in all parts of the journey except the Vysočina region – it will drive off from HSL in Velká Bíteš and service stations along the conventional line including Havlíčkův Brod and going back on to HSL in Světlá na Sázavou. This concept could produce approx. 51 000-65 000 passengers per day on HSL considering SK sub-variants 1, 2 and 3 [10].

3 Transport system analysis with HSR construction

This chapter deals with the design of the regional transport system in the vicinity of the planned HSL Jihlava-Pávov terminal. The reader will learn the concept of transport of the current transport system and the journey times when using the HSL. The aim of this chapter is to find the isochrone of terminal availability, which will be the limit telling when it is worthwhile for a passenger to use HSL from a time point of view. That is, the total travel time from Prague/Brno to one of the rail stations in the Vysočina region using HSL, including transfers, must be less than or equal to conventional rail and PCT. With the obtained isochrones, a regional transport system is designed that forms a synergy with high-speed transport.

Looking at figure no.1, one can notice two planned exits and entrance points to the HSR, namely in Světlá nad Sázavou and at Velká Bíteš, which is currently without railway infrastructure, i.e., the section Křižanov – Vlkov u Tišnova. A very important infrastructure that already exists is the connection between Jihlava and Havlíčkův Brod. The future Jihlava-Pávov terminal should be located on this link, specifically near or instead of the Jihlava-Bosch Diesel stop, where all connections, including high-speed ones, should stop. The terminal therefore appears to be the optimal interchange for serving the Vysočina region. According to the feasibility study, the total travel time on

high-speed trains between Prague and Brno should be between 58 and 68 minutes (with stops), depending on the category of the train. For design purposes, the paper uses stop values (half minutes have been neglected), which are estimated to be:

- *Prague – Jihlava and vice versa: 41-52 minutes,*
- *Brno – Jihlava and vice versa: 28-36 minutes.*

On Fig. 2 is shown the current regional rail network in Vysočina with overlap to other regions (grey borders of Vysočina) with current long-distance corridors (purple lines) and with the future high-speed line RT1 (blue line). There are also shown important stations (transfers – red stations, terminals, future places of entrance and exit, and future HSL terminal). Grey railway lines have low demand and thus there is only partial operation (for example, only in summer months) and these lines are not in the scope of this paper [10], [15].

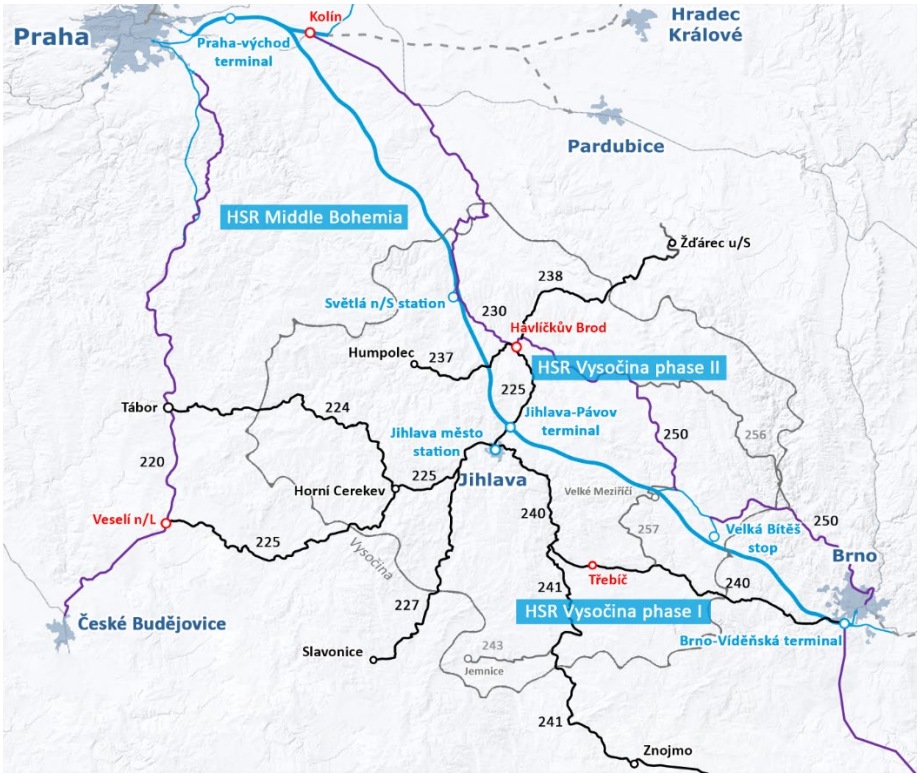

Fig. 2. Current rail network of Vysočina with current corridors and future high-speed line RT1 (source: author, based on [10]).

3.1 Current statistics of commuting

The statistic **Tables 3** and **4** below includes selected districts and municipalities, which are relevant according to Vysočina's railway network. Commuting statistics is aimed at Prague city and South Moravia region (Brno does not exist as the statistical

unit itself), then at Jihlava and Havlíčkův Brod cities, if it is possible according to statistical data set from survey census, which was made in year of 2021. To understand regionalization in the Czech Republic, the paper offers very simplified tree explanation with example:

- Region – it has several districts, which represents big cities.
    - District – one city has its district that includes a larger number of municipalities.
    - Communities = Municipalities with extended powers and its administrative district – one community has its administrative district that includes a smaller number of municipalities.

Communities do not have the same level of powers as districts, but administratively have their own territory and are responsible to the district in charge. Although, Prague is city itself, it is considered as its own region in the Czech Republic.

Notes for tables:

- PK – Pardubický kraj (region), V – Vysočina region, JK – Jihočeský kraj = South Bohemia region, JMK – Jihomoravský kraj = South Moravia region
- 5x+ = 5x and more per week
- Brno district consists of Brno-město and Brno-venkov districts, Prague district consists of Prague-West and Prague-East parts.

Table 2**.** Commuting citizens of districts and communities with their district inside Vysočina region (source: [16])

Districts and Communities with their district	Region	Population	Commuting citizens	to Havlíčkův Brod district	to Jihlava district	to Pelhřimov district	to Třebíč district	to Brno district	to Prague district
Humpolec	V	17 740	8 298	462	481	6 579	3	81	15
Chotěboř	V	20 949	9 694	7 550	165	51	2	119	15
Jihlava	V	98 782	48 941	693	43 397	907	678	771	56
Náměšť n/O	V	13 791	6 415	4	44	4	3 905	961	2
Telč	V	12 542	5 884	8	4 473	74	224	134	4
Třebíč	V	71 915	34 473	37	1 816	37	28 121	1 601	26
Moravské Budějovice	V	22 291	10 122	8	563	17	7 506	327	8
Pelhřimov	V	43 962	20 148	113	1 117	16 346	21	175	49
Havlíčkův Brod	V	52 056	25 253	18 659	2 541	878	32	333	48
Hlinsko	PK	20 406	9 102	540	33	4	3	97	20
Chrudim	PK	82 337	39 111	205	35	6	5	224	44
Znojmo	JMK	90 118	41 397	9	150	15	939	3 131	31
Jindřichův Hradec	JK	45 377	20 160	12	160	1 138	32	137	43

Table 3. Number of commuting citizens of districts and communities with their district from Vysočina region (source: [16])

Municipality	Population	Commuting citizens	to Prague	to South Moravia	to Vysočina	5x+ per week	1-4x per week	Transport Mean		
								car	bus	train
Třebíč	34 368	15 761	258	754	14 280	10 926	1 874	6 759	1 074	400
Okříšky	1 960	947	11	42	877	646	139	405	102	104
Náměšť n/O	4 705	2 272	22	474	1 718	1 544	323	1 083	100	353
Jaroměřice n/R	3 909	1 820	27	137	1 599	1 212	206	963	275	37
Slavonice	2 241	920	16	17	42	583	112	427	92	38
Dačice	7 022	3 064	54	57	362	2 104	296	1 370	291	45
Sedlejov	294	141	2	4	130	114	10	79	2	32
Telč	5 151	2 281	50	60	1 872	1 548	221	1 023	192	44
Humpolec	10 835	4 766	196	59	4 340	3 193	554	2 227	480	62
Pelhřimov	15 577	6 907	295	80	6 258	4 673	744	2 955	452	50
Horní Cerekev	1 152	817	19	10	754	556	68	425	95	53
Počátky	2 505	1 097	29	13	922	693	135	471	188	34
Žirovnice	2 761	1 130	21	4	915	741	97	400	143	37
Jindřichův Hradec	20 437	8 584	242	360	89	5 477	1 050	3 398	412	339
Jihlava	50 523	23 604	387	390	22 229	16 354	2 534	8 917	710	219
Dobronín	1 800	993	12	15	946	699	97	535	55	110
Batelov	2 276	1 144	16	21	1 080	834	97	1 385	130	70
Kostelec	900	463	2	7	440	367	35	213	94	9
Havlíčkův Brod	22 920	10 432	352	148	9 474	6 746	1 455	4 376	446	542
Chotěboř	8 787	3 887	141	54	3 407	2 555	438	1 589	254	213
Ždírec n/D	2 994	1 469	20	21	1 193	1 061	137	644	166	95
Hlinsko	9 271	3 818	88	48	444	2 405	415	1 558	174	279
Skuteč	5 036	2 147	49	25	23	1 433	223	1 072	237	99
Znojmo	33 736	14 452	139	12 610	188	8 932	2 258	6 266	753	160
Moravské Budějovice	7 093	3 104	54	2 554	238	2 061	380	1 416	292	60

3.2 Long-distance transport on conventional lines

Currently, transport in the relation Jihlava – Prague/Brno or Prague/Brno – Jihlava is mostly along the corridor of line no. 250 with a change in Havlíčkův Brod.

Of the two routes, the lowest total transport time is shown by the Brno – Jihlava route and vice versa, which is due to the smaller distances between these cities, but is also due to the transport concept, which thus offers the most transport variants (6 variants). The shortest journey time of 1 hour 53 minutes is the non-stop variant of the fast train line R11. This is followed by two variants with a change in Havlíčkův Brod,

which take just over 2 hours. The last three variants take about 2 and a half hours by passenger trains, where in two variants there is a change in Trebíč.

On the other hand, Prague – Jihlava contains the connection with the longest total transport time mainly due to the number of changes and the time spent on them, a total of 5 variants towards Jihlava and 4 towards Prague. All transport variants to Jihlava are with a change in Havlíčkův Brod. The shortest variant takes 2 hours and 22 minutes, the longest 4 hours, and 15 minutes, also with a change in Kolín. In the direction of Prague, the situation is similar, the shortest variant is 2 hours and 19 minutes. An interesting variant is heading west with a change in Veselí nad Lužnicí, but it takes 3 hours and 32 minutes.

For comparison with high-speed transport, the paper considers the shortest journey times between Jihlava and Prague/Brno, even though these connections are not the only ones during the day, and also uses one value for both directions between origin and terminus:

- *Prague - Jihlava and vice versa: 2 hours, 29 minutes,*
- *Brno - Jihlava and vice versa: 1 hour 53 minutes.*

The interchanges on conventional lines are shown in red on Figure 2.

3.3 Regional transport in the Vysočina Region

At present, the railway network in the Jihlava Region reaches 536 km of lines and 140 stations and stops are served by public transport. The regional town of Jihlava does not lie on an important main line connecting two important cities of the Czech Republic (Prague, Brno) and this role is represented by the not much smaller town of Havlíčkův Brod. It can be said that the most important transfer nodes in the region are Jihlava and Havlíčkův Brod, which have a bicentric relationship with each other. Jihlava serves the southern part and Havlíčkův Brod the northern part. There is ITS named Veřejná doprava Vysočina (VDV) in the region. Looking at Figure 2, it can be seen that the routing of some lines may not correspond to the division of the Czech Republic into regions, e.g., Slavonice. This final form of the Czech Republic was acquired in 2000 with the help of the Constitutional Act no. 1/1993 [17], [18].

Description and transport frequency

Lines no. 240 (Jihlava – Okříšky – Třebíč – Brno), 241 (Jihlava – Okříšky – Znojmo) and 225 (Jihlava – Kostelec u Jihlavy – Jindřichův Hradec – Veselí nad Lužnicí), which are further divided into lines no. 224 (Horní Cerekev – Obrataň – Tábor) and 227 (Kostelec u Jihlavy – Slavonice), lead to Jihlava. The largest number of trains can be found here on railway line no. 240, where around 50 trains a day move. However, the highest number of trains is between Jihlava and Havlíčkův Brod, where there are 75 trains per day, which confirming the bicentric relationship between these two towns.

However, the number of trains on regional lines near Havlíčkův Brod is considerably weaker. There are lines no. 237 (Havlíčkův Brod – Humpolec), 238 (Havlíčkův Brod – Chotěboř – Hlinsko v Čechách – Pardubice). Furthermore, line 212 (Světlá nad Sázavou – Zruč nad Sázavou – Čerčany) branching off the main line 230 (Kolín - Havlíčkův

Brod) and line 257 (Žďár nad Sázavou – Věžná – Tišnov) branch off the main line 250 (Havlíčkův Brod – Brno). Lines 230 and 250 in their final form connect the cities of Prague and Brno.

The number of trains per day takes on minimum and maximum values not only in terms of the time of day of operation, but also this number is influenced by what part of the line section we are looking at. For example, on the line no. 250 from Havlíčkův Brod to Žďár nad Sázavou, the number of trains per day is 155, while from Tišnov to Brno it is a minimum of 235 trains per day [19]. Full list of railway lines with connections per day in the Vysočina region can be found in the table Table 4.

Table 4. Number of trains per day on the railway network of the Vysočina region (source: [19]).

Railway line	Connections per day	Node
240 (Havlíčkův Brod) – Jihlava – Okříšky – Třebíč – Brno	50	Jihlava
241 Jihlava – Okříšky – Znojmo	25	Jihlava
225 Havlíčkův Brod – Jihlava – Kostelec u Jihlavy – Jindřichův Hradec – Veselí nad Lužnicí	45	Jihlava
224 Horní Cerekev – Obrataň – Tábor	24	Jihlava
227 Kostelec u Jihlavy – Slavonice	30	Jihlava
240 Havlíčkův Brod – Jihlava (– Okříšky – Třebíč – Brno)	75	Jihlava/Havlíčkův Brod
237 Havlíčkův Brod – Humpolec	22	Havlíčkův Brod
238 Havlíčkův Brod – Chotěboř – Hlinsko v Čechách – Pardubice	35-55	Havlíčkův Brod
212 Světlá nad Sázavou – Zruč nad Sázavou – Čerčany	22-35	-
230 Kolín – Havlíčkův Brod	155-175	Havlíčkův Brod
256 Žďár nad Sázavou – Věžná – Tišnov	18-40	-
257 Křižanov – Studenec	12-35	-
250 Havlíčkův Brod – Brno	150-240	Havlíčkův Brod

Transport concept of individual lines and its evaluation

An analysis of individual train lines on these lines was carried out in the following parameters:

- number of connections,
- interval,
- inconsistency of routing,
- complementarity,
- travel times:
  - given for a given train set for the entire length of the line, where connections stop, unless otherwise specified,
  - valid for both directions of travel,
- continuity for transport to Jihlava.

A total of 16 train lines (1 fast train, 4 express, 11 passenger) were examined. All railway lines are managed by the national infrastructure manager SŽC. Lines no. 225 and 224 lead to one of the transit corridors (no. 4 Austria – České Budějovice – Prague – Ústí nad Labem – Děčín – Germany) included in the TEN-T system. For each railway line, the conclusion indicates what the isochrones of HSL terminal accessibility depend on for Chapter 5.3, where commuting times from selected municipalities in the Vysočina region to Prague or Brno are given. Accessibility isochrone can be described as the time it takes to get from a given point to a depicted distance, most often on maps. In this case, it is the time it takes to get from the future Jihlava-Pávov terminal, but also in the direction of the terminal [19].

Railway line no. 224 (Horní Cerekev – Obrataň – Tábor)

The regional nonelectrified line is 69 km long with a maximum speed of 70 km/h, which enters line no. 225 in Horní Cerekev. There is 1 train line with operation of various length routes:

- RL 18402-18443: Tábor – Jihlava hl. n. (– Dobronín), it switches to line 225.
  - interval: 1-2 h
  - number of connections: 22 (9 connections are routed inconsistently)
  - time of travel (Tábor – Jihlava): 2:15-2:18

There is a single-line all-day service on this railway line with 1- or 2-hour intervals depending on the time of day. The disadvantage is the inconsistency of 9 connections out of 22, when trains exceed or do not reach the basic route of connections (Tábor – Jihlava), e.g., at the stations Pelhřimov, Dobronín. In these cases, the passenger is forced to change trains on railway line no. 225, which lengthens the already long journey time. Here, the size of the isochrones to the terminal is limited by the competitive journey time of a PCT to Brno from a particular station on this line [20], [21].

Railway line no. 225 (Havlíčkův Brod – Jihlava – Veselí nad Lužnicí)

A national line fully electrified with AC traction system 25 kV/50 Hz, 117 km long with a maximum speed of 120 km/h (this speed is only in a small part of the railway line). In Jihlava this line converges with line no. 240. There are 7 train line with operation of various length routes:

- RL 8300-8329: Veselí nad Lužnicí – Jindřichův Hradec
  - interval: 2 h
  - number of connections: 23
  - time of travel: 0:32-0:37
  - transport continuity: transfer to EX 650-669 in Jindřichův Hradec
- FL 1730-1740: České Budějovice – Jindřichův Hradec
  - interval: 2 h, operation only during peak hours
  - number of connections: 10
  - time of travel (Veselí nad Lužnicí – Jindřichův Hradec): 0:30-0:37
  - transport continuity: transfer to EX 650-669 in Jindřichův Hradec
- EX 650-669: Plzeň – Veselí n/L – Jihlava – Třebíč – Brno, switches to railway line No .240

  - interval: 1-2 h
  - number of connections: 16
  - time of travel (Veselí nad Lužnicí – Jihlava): 1:48
- FL 1900-1923: Havlíčkův Brod – Jihlava hl. n. – Slavonice, switches to railway line no. 227
  - interval: 1-2 h
  - number of connections: 22 (5 connections are routed inconsistently)
  - time of travel (Havlíčkův Brod – Jihlava): 0:19
- RL 8340-8379 + RL 58931: Havlíčkův Brod – Jihlava hl. n.
  - interval: 0,5-1 h
  - number of connections: 32 + 1
  - time of travel: 0:28-0:33
- RL 18402-18443: Tábor – Jihlava hl. n. – Dobronín, is switching to railway line no. 224.
  - interval: 1-2 h
  - number of connections: 22 (9)
  - time of travel (Dobronín – Jihlava): 0:11

This railway line connecting Jihlava with the west is full of train lines, but only the long-distance train line EX 650-669 traverses the entire railway line, i.e., the emptiest section is Jindřichův Hradec – Horní Cerekev, where line no. 224 connects. The passenger line RL 8300-8329 and the fast line FL 1730-1740 create traffic service only for Veselí nad Lužnicí, therefore the border station for isochronous availability for the journey to Brno/Prague is Veselí nad Lužnicí station, otherwise Horní Cerekev, which is also served by passenger trains [20], [21].

Railway line no. 227 (Kostelec u Jihlavy – Slavonice)

The regional nonelectrified line is 53 km long with a maximum speed of 60 km/h, starting from line no. 225 in Kostelec u Jihlavy. Two train lines of different lengths are operated on the line, which are complementary to each other:

- RL 28300-28324: Slavonice – Jihlava hl. n. (– Třebíč)
  - interval: x
  - number of connections: 17, routed inconsistently
  - time of travel (Slavonice – Jihlava): 2:11-2:26
- FL 1900-1923: Havlíčkův Brod – Jihlava hl. n. – Slavonice
  - interval: 1-2 h
  - number of connections: 22 (5 connections are inconsistently routed)
  - time of travel (Slavonice – Jihlava): 2:00-2:11

It is a slow regional line, the operation of which, in the case of passenger trains, is rather shuttle – many connections of passenger trains RL 28300-28324 are not routed to Jihlava or Slavonice and move between the stations Dačice and Telč. On the other hand, the express trains FL 1900-1923 that start from Havlíčkův Boda are usually routed to Slavonice. In the direction from Slavonice to Jihlava, these two train lines are complementary until Telč station. Here, the size of the isochrone to the terminal is limited by the competing journey time of a passenger car to Prague/Brno from a particular station on this line [20], [21].

Railway line no. 237 (Havlíčkův Brod – Humpolec)

Regional non-electrified track 25 km long with a maximum speed of 50 km/h. 1 train line is operated on the line in its entire length:

- RL 15950-15969: Havlíčkův Brod – Humpolec
  - interval: 2 h
  - number of connections: 20
  - time of travel: 0:41
  - transport continuity: transfer to FL 1900-1923 or RL 8340-8379 in Havlíčkův Brod

Another slow but short regional line with fully consistent service. Here, the size of the isochrone to the terminal is limited by the competitive journey time of a passenger car to Prague/Brno directly from Humpolec. As a result of the shorter distance, this line is also suitable for alternative battery hybrid vehicle propulsions [20], [21].

Railway line no. 238 (Havlíčkův Brod – Žďárec u Skutče – Pardubice-Rosice nad Labem)

Regional non-electrified line – only a part of the line (to Žďárec u Skutče) was analysed for the article, this part is 55 km long with a maximum speed of 90 km/h. On the mentioned part of the railway line, there are 3 train lines with operation of various length routes:

- RL 5300-5305: Havlíčkův Brod – Žďárec u Skutče – Pardubice-Rosice nad Labem
  - interval: x
  - number of connections: 5
  - time of travel (Žďárec u Skutče – Havlíčkův Brod): 1:06
  - transport continuity: transfer to FL 1900-1923 or RL 8340-8379 in Havlíčkův Brod
- RL 5370-5392: Havlíčkův Brod – Hlinsko v Čechách
  - interval: 1-2 h
  - number of connections: 22
  - time of travel: 0:45
  - transport continuity: transfer to FL 1900-1923 or RL 8340-8379 in Havlíčkův Brod
- FL 1450-1465: Havlíčkův Brod – Pardubice hl. n.
  - interval: x
  - number of connections: 5
  - time of travel (Žďárec u Skutče – Havlíčkův Brod): 1:05-1:09
  - transport continuity: transfer to FL 1900-1923 or RL 8340-8379 8379 in Havlíčkův Brod

This regional railway line is an important straight connection between Vysočina and Pardubice region. When passengers want to travel to Prague or Brno, they have to travel to Havlíčkův Brod or Pardubice to transfer, according to their origin of travel, which they start considering the distance. The part of the railway line, which is in the scope of this paper, has 3 train lines, but only the RL 5370-5392 is consistent and operational

throughout the day. The other two act as supplementary and traverse the entire railway line, where the concept of transport aims to suburban transport concept, and thus these lines act differently after the station Žďárec u Skutče [20], [21].

Railway line no. 240 (Brno hl. n. – Jihlava)

The national line is largely non-electrified, 104 km long (13 km electrified by AC traction system 25 kV/50 Hz). In the future it is planned to extend the electrification of the same traction system to the stop Zastávka u Brna (10 km more). Five train lines are operated on the line, including the long-distance line R11 (Brno – Jihlava – České Budějovice – Plzeň), which runs longitudinally across the entire region, then along line no. 225. Three train lines of different lengths are operated on this part of the line:

- RL 28300-28324: Slavonice – Jihlava hl. n. (– Třebíč)
  - interval: x
  - number of connections: 17, routed inconsistently
  - time of travel (Třebíč – Jihlava): 1:04
- EX 650-669: Plzeň – Veselí n/L – Jihlava – Třebíč – Brno
  - interval: 1-2 h
  - number of connections: 16
  - time of travel (Třebíč – Jihlava): 0:43
- RL 14801-14859: Jihlava hl. n. – Třebíč – Rapotice – Zastávka u Brna
  - interval: 1-2 h
  - number of connections: 32 (11 connections are inconsistently routed)
  - time of travel:
    - Třebíč – Jihlava: 0:53-1:10
    - Rapotice – Jihlava: 1:44
    - Zastávka u Brna – Třebíč: 0:52 (for mandatory transfer)
- RL 4800-4863: Brno hl. n. – Zastávka u Brna (– Třebíč):
  - interval: 1 h
  - number of connections: 48 (28 connections are inconsistently routed)
  - time of travel (Zastávka u Brna – Třebíč): 1:02-1:05
  - transport continuity: transfer to RL 14801-14859, EX 650-669 in Třebíč
- FL 1903-1935: Znojmo – Okříšky – Jihlava hl. n.
  - interval: x
  - number of connections: 6
  - time of travel (Okříšky – Jihlava): 0:25

The second national railway connecting Jihlava to the east with a large number of train lines. Worth mentioning is the RL 28300-28324 passenger line, one connection of which goes to this line. There is also the FL 1903-1935 express line, which reinforces the rush hour service. The passenger service is divided into two parts, with Trebíč station forming the boundary, but not in all cases. This border is shifted from Třebíč by passenger line RL 14801-14859 to Rapotice or Zastávka u Brna (closer to Brno). On the other side, there are connections of line RL 4800-4863, which can go as far as Třebíč (closer to Jihlava), thus moving the border backward. However, in some parts of the day, these two parts are not connected at all. All this is a consequence of the inconsistency of the connection between the two lines. Passengers therefore have no

choice but to wait for the connection of the EX 650-669 express line. Logically, the limit of the isochrony of accessibility for the journey to Prague is the Třebíč station, which is supposed to be the imaginary transport border of the region [20], [21].

Railway line no. 241 (Okříšky – Znojmo)

Regional non-electrified track 70 km long with a maximum speed of 80 km/h. On the mentioned part of the line 3 train lines of different length are operated:

- FL 1903-1935: Znojmo – Okříšky – Jihlava hl. n.
  - interval: x
  - number of connections: 6
  - time of travel: 1:31
- RL 24831-24840: Znojmo – Moravské Budějovice
  - interval: 2, operation only during peak hours
  - number of connections: 10
  - time of travel: 0:44
  - transport continuity: transfer to RL 24802-24825 in Moravské Budějovice.
- RL 24802-24825: Znojmo – Okříšky
  - interval: 1-2 h
  - number of connections: 14
  - time of travel: 1:20-1:40
  - transport continuity: transfer to EX 650-669, RL 14801-14859 in Okříšky

The furthest regional line from Jihlava, connecting the relatively large southernmost town of Moravia – Znojmo. Passengers from Znojmo have only 2 directions to choose from, namely Jihlava and Břeclav (then Brno or Vienna). Currently, and in both cases, passengers choose the direction of Břeclav and then use long-distance (international) lines that continue to Brno and then to Prague. A new high-speed line and better regional transport to Jihlava could change this situation and speed up the connection to Prague (west). Here, the size of the isochrones to the terminal is limited by the competitive journey time of a PCT to Prague from a particular station on this line [20], [21].

Full list of train lines is in the Table 5 which is related to the figure Fig. 3.

Table 5. List of train lines in Vysočina region (source: [20], [21])

Train lines	Relation	Interval [h]	Connections
EX 650-669	Plzeň – Veselí n/L – Jihlava – Třebíč – Brno	1-2	16
FL 1450-1465	Havlíčkův Brod – Pardubice	x	5
FL 1730-1740	České Budějovice – Jindřichův Hradec	2*	10
FL 1900-1923	Havlíčkův Brod – Jihlava hl. n. – Slavonice	1-2	22 (5)
FL 1903-1935	Znojmo – Okříšky – Jihlava hl. n.	x	6
RL 14801-14859	Jihlava hl. n. – Třebíč – Rap. – Zastávka u/B	1-2	32 (11)
RL 15950-15969	Havlíčkův Brod – Humpolec	2	20
RL 18402-18443	Tábor – Jihlava hl. n. – Dobronín	1-2	22 (9)
RL 24802-24825	Znojmo – Okříšky	1-2	14
RL 24831-24840	Znojmo – Moravské Budějovice	2*	10
RL 28300-28324	Slavonice – Jihlava hl. n. – Třebíč	x	(17)
RL 4800-4863	Brno hl. n. – Zastávka u Brna – Třebíč	1	48 (28)
RL 5300-5305	Havlíčkův Brod – Žďárec u Skutče – …	x	5
RL 5370-5392	Havlíčkův Brod – Hlinsko v Čechách	1-2	22
RL 8300-8329	Veselí nad Lužnicí – Jindřichův Hradec	2	23
RL 8340-8379 + RL 58931	Havlíčkův Brod – Jihlava hl. n.	0,5-1	32+1

* Operation only during peak hours.

x-y Interval during peak and off-peak in x-y format, otherwise the same interval throughout the day.

… The terminus of a relation that is outside the range of the image may vary by connection.

(x) Number of connections which are inconsistent with default route.

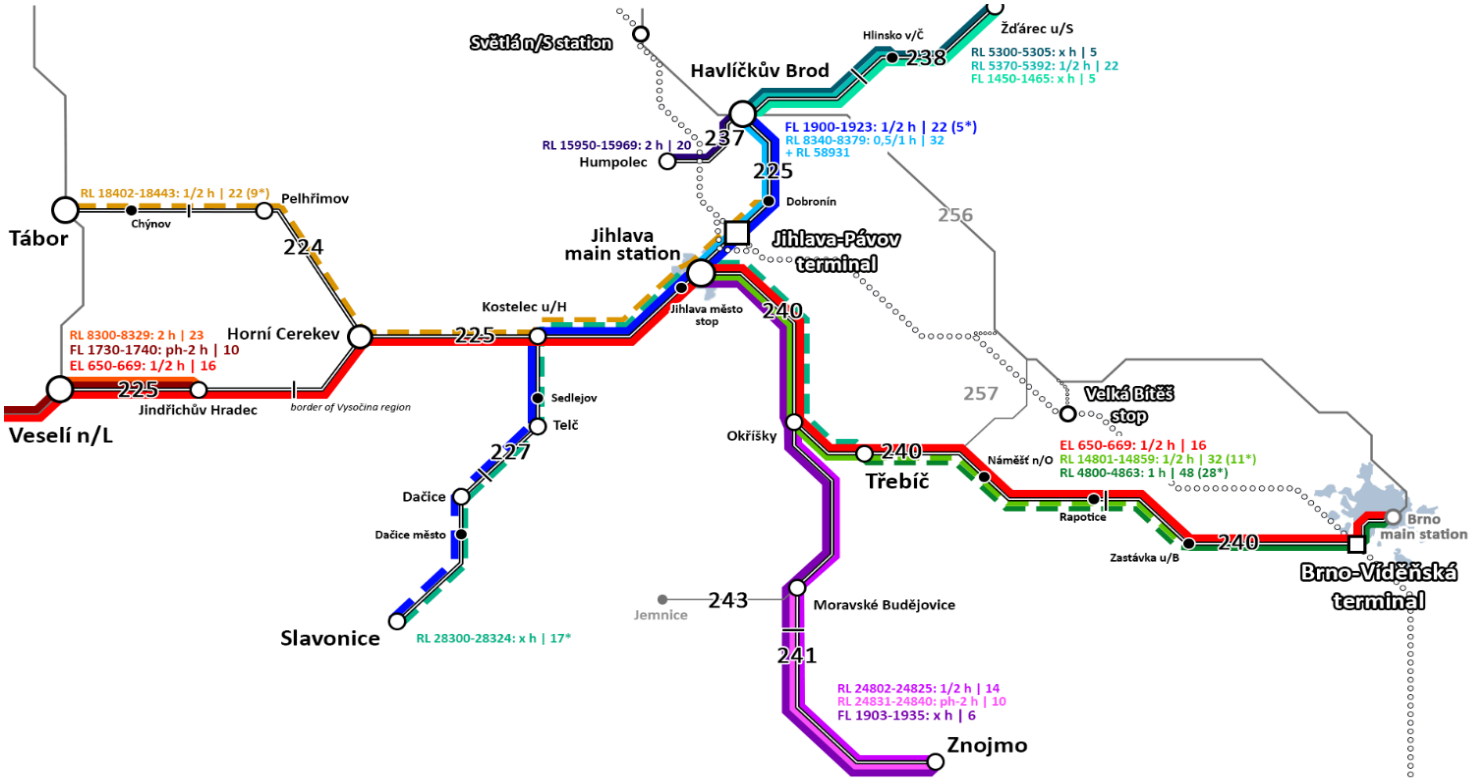

Fig. 3. Routing of train lines in Vysočina region (source: author).

4 Terminal availability in the regional context

This chapter analyses and verifies the existing HSL terminal availability estimate made by the infrastructure manager SŽC and compares the availability with its own time availability calculation for regional rail transport use, both currently and with a future state.

SŽC's commuter availability was calculated by QGIS using network analysis (Fig. 4). It can be observed that availability is considered not only for the terminal but also for selected rail stations on selected regional legs. The underlying data was Open Street Map, and the program calculated the commuting distance for a given time interval, where the speed used was the average for car and bicycle in all routes:

- dark blue: 15 minutes by bicycle,
- blue: 15 minutes by car,
- light blue: 20 minutes by car.

However, there is no assessment of accessibility from regional railway stations to the HSL terminal and also 4 transport branches (lines red outlined), namely Jihlava – Slavonice, Jihlava – Znojmo, Jihlava – Tábor and Havlíčkův Brod – Žďárec u Skutče, which have been added to the figure. The lack of accessibility between railway stations to/from the terminal is added to this article.

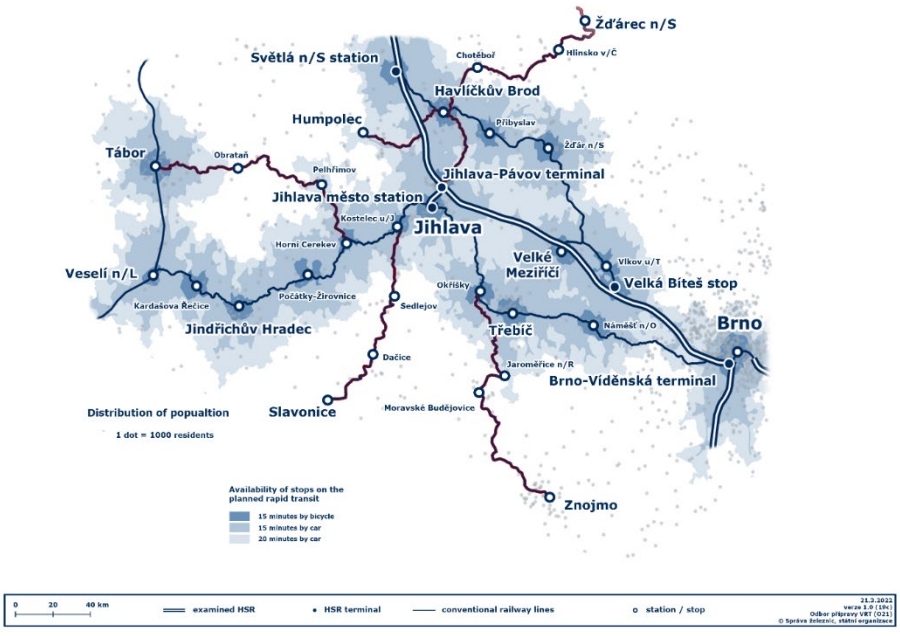

Fig. 4. Commuting availability for selected lines on Vysočina by SŽC (source: [22])

4.1 Transfers and linking the long-distance and regional segments

Transfers should take places especially in Jihlava-Pávov terminal but as was stated before, this linking should be executed also by specialized express train lines of lower segment (R11, R33, R34, and R37) – figure no. 4. Another example is proposed introduction of the fast train line Brno – Velká Bíteš – Velké Meziříčí, which will enable the connection of the HSL near Velká Bíteš and the electrification of the line to Velké Meziříčí, but this is not scope of this paper.

Complex transfer system

In the current state, transfer is happening in Havlíčkův Brod when travelling to/from Praha or Brno to/from Jihlava. Transfer in the future can be only an estimate. As was stated before, the terminal should be located somewhere near the Jihlava-Bosch Diesel stop or it should replace the stop. The current transfer time in Jihlava and Havlíčkův Brod to/from Jihlava-Bosch Diesel stop depends on the railway line from which the passenger is travelling and the train line on which the passenger is travelling. *The service Jihlava město stop / Jihlava main station and Jihlava-Bosch Diesel stop is served by RL 8340-8379 train line and travel time is only 4 minutes. The same applies to service from Havlíčkův Brod: 27 minutes.*

But the future situation must also be taken into account. The transfer times between particular train line and RL 8340-8379 train line can be found in table no. x. RL 8340-8379 was chosen because it acts like a suburban frequent train line. Of course, there are also other possible combinations of transfers, but they are not as common.

Table 6**.** Transfer times in Jihlava and Havlíčkův Brod (source: [21])

Transfer times from particular train line to RL 8340-8379 (in Jihlava/Havlíčkův Brod)		
Train line	Railway line	Transfer time dispersion (median)
EX 650-669	225 (Horní Cerekev)	0:04-0:34 (19 minutes)
EX 650-669	240 (Třebíč)	0:04-0:49 (27 minutes)
FL 1450-1465	238 (Žďárec u Skutče)	1:12
FL 1730-1740	not routed to Jihlava/Havlíčkův Brod	x
FL 1900-1923	227 (Slavonice)	0:16-0:48 (32 minutes)
FL 1903-1935	not routed to Jihlava/Havlíčkův Brod	x
RL 14801-14859	240 (Třebíč)	0:14-0:30 (22 minutes)
RL 15950-15969	237 (Humpolec)	0:43-1:10 (57 minutes)
RL 18402-18443	224/225 (Pelhřimov / Horní Cerekev)	0:59-1:40 (80 minutes)
RL 24802-24825	not routed to Jihlava/Havlíčkův Brod	x
RL 24831-24840	not routed to Jihlava/Havlíčkův Brod	x
RL 28300-28324	227 (Slavonice)	0:48
RL 4800-4863	not routed to Jihlava/Havlíčkův Brod	x
RL 5300-5305	238 (Žďárec u Skutče)	0:15-0:55 (35 minutes)
RL 5370-5392	238 (Hlinsko v Čechách)	0:22-1:12 (47 minutes)
RL 8300-8329	not routed to Jihlava/Havlíčkův Brod	x
Average waiting time (median)		44 minutes (41 minutes)

As you can see, transfer time is an important (in negative way) part of the travel time from Jihlava to Jihlava-Bosch Diesel in its current state. The dispersion of waiting times in transfers is wide and that confirms that transport combinations of trains are not united, even it consists of connections of the same train line. Moreover, the waiting times are big which affect the whole travel to Prague or Brno. There should be effort to make as many as train lines consistent and cyclic schedule could be integrated. This could help passengers to remember their transport options as well as making the rail transport more efficient. On the other hand, this will increase vehicle, personal and infrastructure costs, which may not be covered by demand**.** *Considering optimal variant, the waiting time should be maximally 10 minutes in one station and transfer time between connections needed to get from one platform to another should be around 5 minutes:*

- *Havlíčkův Brod – Jihlava-Pávov: 35 minutes,*
- *Jihlava – Jihlava-Pávov: 15 minutes***.**

It is also appropriate to mention the future situation in the vicinity of Jihlava. HSL Prague – Brno envisages the creation of a central interchange terminal for urban and regional transport in the present Jihlava město stop. The SŽC wants to modernise this stop to station, including barrier-free access. It is also envisaged to extend the stop with additional platforms and to introduce new connecting lines so that it is not necessary to change the direction of travel for train sets. It needs to be said, that these suggestions are not final. The track layout of the stations can be seen in figure no. 5.

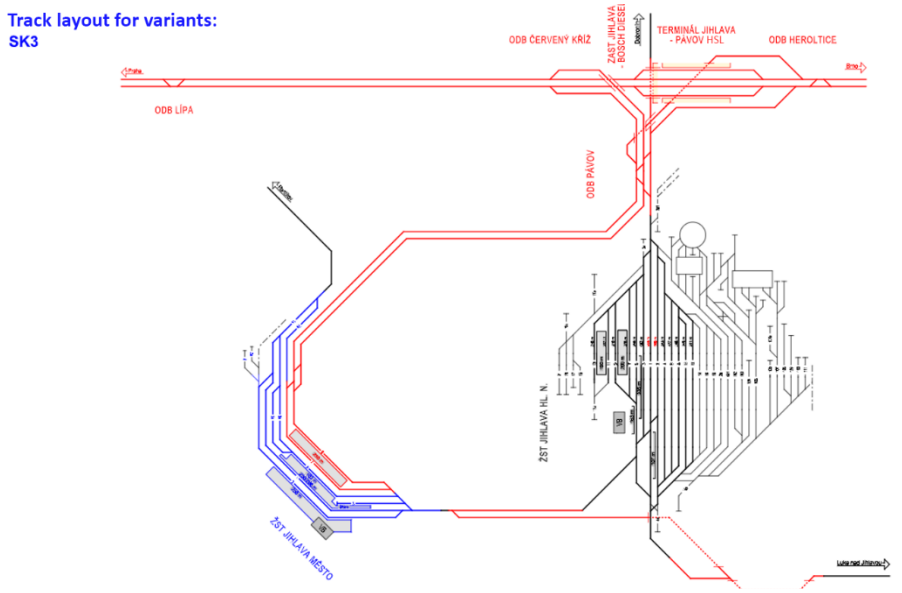

Fig. 5. The track layout of the Jihlava main station and the Jihlava město stop (author, based on source: [22]).

Partial high-line usage

The service between Jihlava město stop / Jihlava main station or Havlíčkův Brod and Jihlava-Pávov terminal will be served not only by passenger trains but also by specialized express trains, and this influences the transfer times. This is shown on the figure no. 6.

In the conclusion, passengers have options to use these lines without the transfer:

- for Jihlava case:
  - R33 to travel to/from Prague from/in direction on railway line no. 240 with stops in Okříšky and Třebíč.
  - R11 to travel to/from Brno from/in direction on railway line no. 255 with stops in Horní Cerekev, Kostelec u Jihlavy and some small stops along the line.
- for Havlíčkův Brod case:
  - R34 to travel to/from Prague/Brno from/in direction on corridor lines no. 230/250 with stops in Světlá n/S, Přibyslav and Žďár n/S.

Shall we not forget that these R train lines are not high-speed one and thus this is only partial usage of high-speed line that requires specific train vehicles, which will be likely speed compromised up to 250 km/h in order to save operational cost. This is a case of a high-speed train on a slow regional railway line. That influences the final travel time which will be longer. In the end, whole travel time for R11, R33, and R34 is not known [23].

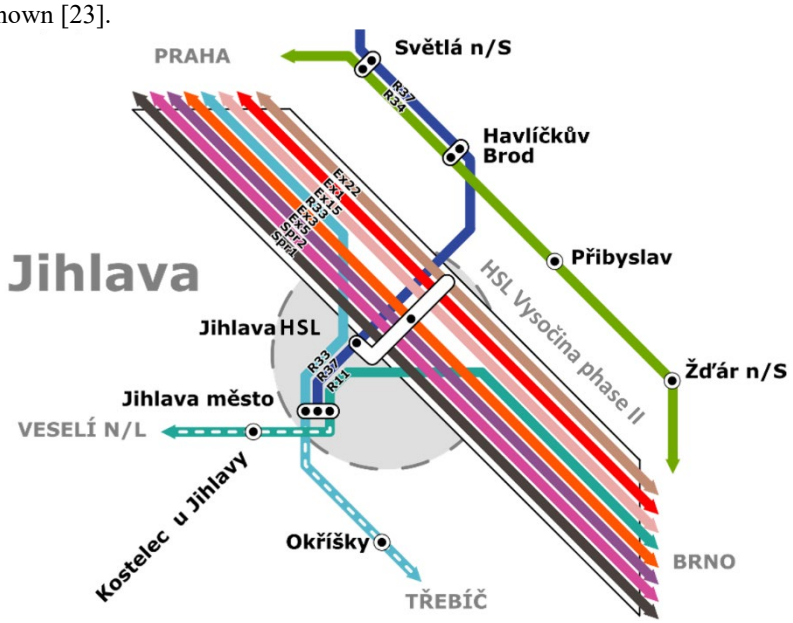

Fig. 6. Future long-distance train lines in Jihlava (source: author, based on [24])

4.2 Comparison of travel times and isochrone

The values are based on real-time schedules and calculations from map in columns “Car” and “Conventional Rail” the tables no. 7 and 8. rather than summing available travel times. Summing travel times was used for column "High-speed rail", which were based on available data and estimations:

- regional transport from particular station to Jihlava for transfer:
  - choosing the highest travel time from all the alternatives but with the lowest number of transfers, depending on the most common option,
- transport between Jihlava and Jihlava-Pávov with waiting times - optimised case: 15 minutes from Jihlava, 35 minutes from Havlíčkův Brod,
- long-distance transport to Prague or Brno:
  - choosing the highest one from the interval

For example, from Pelhřimov to Prague:

- regional transport: 1:07,
- transfer transport: 0:15,
- long-distance transport: 0:52

Summary: 2:14

Symbol *: this transport option contains driving in opposite directions (to get closer to the destination, the passenger has to first go away from the destination)

Table 7. Comparison of travel times to/from Prague before and after construction of HSL (source: [21]).

Travel times to/from Prague					
Railway line / Station	Car	Conventional rail	High-speed rail	High-speed vs. Conventional	High-speed vs. Car
224 / Pelhřimov	1:21	3:41*	2:14*	**-1:27***	**+0:53**
225 / Horní Cerekev	1:35	3:14*	1:47*	**-1:27***	**+0:12**
227 / Slavonice	2:23	4:22-4:44	3:18	**-1:04**	**+0:55**
237 / Humpolec	1:10	2:40	2:08	**-0:32**	**+0:58**
238 / Žďárec u Skutče	1:55	3:19	2:42	**-0:37**	**+0:47**
240 / Třebíč	1:55	3:04-4:32	2:02	**-1:02**	**+0:07**
241 / Znojmo	2:42	4:16-4:56	3:02	**-1:14**	**+0:20**

Table 8. Comparison of travel times to/from Brno before and after construction of HSL (source: [21]).

Travel times to/from Brno					
Railway line / Station	Car	Conventional rail	High-speed rail	High-speed vs. Conventional	High-speed vs. Car
224 / Pelhřimov	1:34	3:27-4:01	1:58	-1:29	+0:24
225 / Horní Cerekev	1:34	2:35	1:31	-1:04	-0:03
227 / Slavonice	1:56	4:15-4:30	3:02	-1:13	+1:06
237 / Humpolec	1:22	2:26	1:52	-0:34	+0:30
238 / Žďárec u Skutče	1:49	2:56*	2:26	-0:30	+0:37
240 / Třebíč	1:15	1:02-1:38	1:46	+0:44*	+0:31
241 / Znojmo	0:53	4:02*	2:46	-1:16*	+1:53

Isochrone

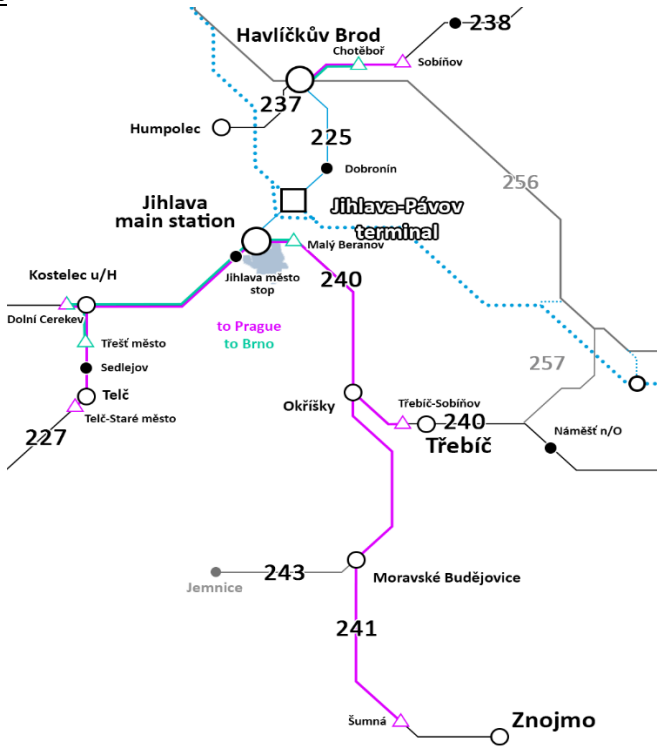

Fig. 7. Reachable stations according to the isochrone of the remaining car travel time (source: author).

Isochrone for every regional railway line is based on comparison of travel time and it is calculated as the difference between the travel time of a car and transfer transport + long-distance high-speed transport: $Iso_{rl} = CT_{rl} - (TT_{node} + HST_{city})$, where:

- Iso_{rl} = isochrone for particular railway line [min],
- CT_{rl} = car transport time from tables 7 and 8 [min],
- TT_{node} = transfer transport to/from node Jihlava or Havlíčkův Brod [min],
- HST_{city} = high-speed long distance transport to/from Prague or Brno [min].

The value in parentheses is the same for all combinations of node and city:

- Jihlava – Prague: 15 + 53 = 68 minutes, Jihlava – Brno: 15 + 36 = 51 minutes
- Havlíčkův Brod – Prague = 35 + 53 = 88 minutes, Havlíčkův Brod – Brno = 35 + 36 = 71 minutes

Table 9. Calculation of isochrone of the remaining car travel time (source: author).

Isochrone of the remaining car travel time						
Railway line	Prague			Brno		
	Calculation $CT_{rl} - (TT_{node} + HST_{city})$	Iso_{rl} [min]	Reachable station	C Calculation $CT_{rl} - (TT_{node} + HST_{city})$	Iso_{rl} [min]	Reachable station
224	81-68	13	x[1]	94-68	26	Dolní Cerekev
225	95-68	27	Dolní Cerekev	94-68	26	Dolní Cerekev
227	143-68	75	Telč-Staré město	116-68	48	Třešť město
237	70-88	0	-	82-88	0	-
238	115-88	27	Sobíňov	109-88	21	Chotěboř
240	115-68	47	Třebíč-Borovina	75-68	7	Malý Beranov
241	162-68	94	Šumná	53-68	0	-

5 Conclusion

The paper analysed the current situation of the liberalised railway market in the Czech Republic with its advantages and drawbacks. Then we introduced data about the future high-speed network from the feasibility study with a focus on the high-speed line RT1 between Prague – Brno with its opportunities, but the most important part was the future situation in Vysočina region when the line will be built. The goal of the paper was to evaluate the integration of the high-speed line into the region with its terminal to create synergy between the existing regional transport system and the new variant of long-distance transport, which is the high-speed one. It must be said that the state of current regional transport is not satisfactory; it is slow and travel time is abysmal in many cases. The benefit of high-speed traveling will earn only metropolitan cities (Prague and Brno) and Jihlava, which is capital city of Vysočina region. Other regional

[1] Although railway line 224 starts from railway line 225 in Horní Cerekev and thus it is further from Jihlava, the car transport is routed to highway D1, which is closer to 224 than 225.

cities and municipalities will be forced to use private car transport to get to the terminal or make the whole travel by car, which will show signs of non-integration. This is proven by comparing travel times and reachability of stations using an isochrone. The combination of using regional rail transport and high-speed transport as a public transport cooperation can decrease the portion of using private car transport for traveling (commuting, holidays) and thus decrease the saturation of the road network. The related income of the synergic transport system with a speed of the same level as other alternatives can expand the options to commute in a longer distance for the job, but in the same or shorter time than before.

Further research could be dedicated on the partial use of the HSR by conventional transport, the tariff advantage of combining regional and high-speed public transport to increase the attractiveness of the system and reduce the use of car transport to the terminal, commuting to the surrounding regions from Vysočina in connection with the use of the HSR, the use of alternative drives in connections with HSR and the introduction of HSR into the open market of railway transport.

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