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High-Speed and Long-Distance Railway Periodic Timetable: Interpositions vs Interconnections

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Abstrakt: *Integrální taktový jízdní řád (ITJŘ) je často vylepšován prokladem dvou linek do poloviční intervalu. Nicméně, za účelem zajištění přímého spojení mezi různými aglomeracemi, je tento proklad někde přerušen, čili určité spojení je jednou přímé a podruhé s přestupem. Jelikož přestupní doba je obvykle delší než doba pobytu, jejich rozdíl vede buď k nepřesnému prokladu, anebo ke ztrátě času cestujících vlivem delšího pobytu. Pojmy prokladu a přestupu jsou v článku porovnány a diskutovány v kontextu aktuálního výzkumného projektu - návrhu budoucího ITJŘ pro Rychlá spojení - propojenou vysokorychlostní a konvenční železniční síť.*

Klíčová slova: *integrální taktový jízdní řád, proklad, přípojná vazba*

Abstract: *Integrated Periodic Timetable is often improved by interposition of two public transport lines into half period. However, for the sake of direct connections between various agglomerations, such interposition is interrupted somewhere, so once the connection is direct, and once the passenger has to change. Since the changing time is usually longer than the dwell time, the difference leads either to inaccurate interposition, or to loss of passengers' time by longer dwell time. These phenomena are compared and discussed in the context of the ongoing research - design of future IPT on interconnected high-speed and conventional railway networks.*

Keywords: *Integrated Periodic Timetable, interposition, interconnection*

1. Introduction

1.1. Integrated Periodic Timetable – Interpositions vs Interconnections

Integrated Periodic Timetable (IPT, in German-speaking countries Integraler/Integrierter Taktfahrplan), or clockface timetable, is based on unified (or twice, or half) service period, and on unified symmetry (the minute zero as a rule). So, any interconnection between two services works equally (symmetrically) in the opposite direction. For maximization of changing possibility, ITF-nodes (Taktknoten, rendezvous concept) are introduced. Ideally all services arrive to such node shortly before symmetry time (minute zero) and depart after this time. If a service arrives *x* minutes before zero, then it departs back *x* minutes after zero. If such ITF-nodes are achieved (which requires not to exceed *system travel time* between these nodes), then the ITF represents, to some degree, an alternative to individual transport (possibility of travelling in any time, to any destination).

Thus, interconnections represent an organic part of the ITF, be it within an IPT-node or not. The changing time must not be lower than certain minimum time, which depends on complexity of the station. It can vary from 3 to 8 minutes (8 min in Prague main station [1]) or more. Either

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the interconnection is tight, so the minimum changing time is chosen, or it can contain some buffer (reserve) time for coping with minor arrival delays. Nevertheless, such buffer time must not replace linear buffer time (surcharge) in every scheduled running time.

The specific case is *cross-platform interchange*, when the subsequent train stands just opposite, on the same platform. So, the changing time can be 3 minutes, or even 2 minutes (for very stable operation). The cross-platform interchange saves passengers' time and may help to achieve system travel time. On the other hand, if there is no dedicated infrastructure (flyovers), usually at least one of meeting trains in one direction has to cross one or more another directions. This lowers node capacity and deteriorates stability of the traffic.

1.2. State of the Art – Austria and Switzerland

Passenger railway service offer in Austria (realized mostly by state-owned operator ÖBB) is based on IPT, including the only operating high-speed line – Westbahn (Western Railway) westwards from Vienna [2].

The "Westbahn" part of long-distance and fast regional IPT is displayed in Figure 1 in the form of *netgraph* (for more detailed explanation, see Michl, Drábek and Vávra [3]).

There are two segments of *Railjet* long-distance services: *Railjet Xpress* (marked with a dark red line) stops between Vienna and Salzburg only in capitals of federated states. The slower one, *Railjet* (marked with a red line), stops approximately like Intercity services in other European countries. From Vienna to St. Pölten, both public transport lines make together an exact interposition into 30-min period (except an extra stop of *Railjet* in Tullnerfeld). But in Salzburg both segments make an interconnection, and Railjet *Xpress proceeds* westwards to Feldkirch and Bregenz or Zurich, with "fast train" (i.e. more often than Intercity) stopping pattern [2].

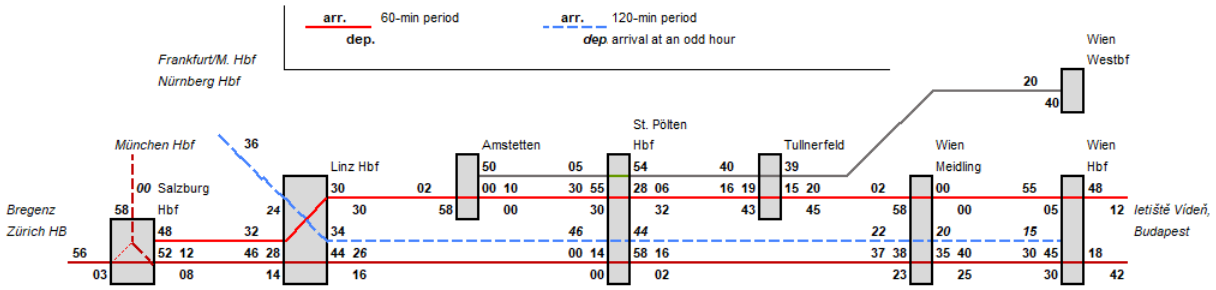

Fig. 1 *Netgraph of ÖBB fast and long-distance services on Westbahn. Data from [2].*

Swiss long-distance IPT system is based on public transport lines with 60-min period (with few exceptions of 120-min period or interposition of such lines into hourly service). However, all significant interurban connections are ensured in 30-min period, which requires exact interposition of two public transport lines on the common section.

In some cases, when stopping patterns of two lines (even slightly) differs, the interposition is not exact, like, for instance, between Zurich and Luzern.

The largest IPT-node (in the minutes 00 and 30) in Switzerland is in the station Zürich HB (Zurich Main Station). Because interposition of different long-distance public transport lines, passengers which transit Zürich HB, often have direct connection only hourly. After 30 min the passengers have to change. The typical changing (or dwell) time is between 10 and 15 min [4].

Swiss Federal Railways (SBB) are aware of limits of interposition in terms of clarity of public transport offer. So they plan in middle-term horizon (2030-35) to switch to public transport lines with mostly 30-min period (and with possible interpositions into 15-min period) [5].

2. Rapid Services in the Czech Republic

2.1. Purpose of Rapid Services

Rapid Services System (RS) is defined by Czech Ministry of Transport as follows: "The operational infrastructure system of high-speed railways in the Czech Republic includes new high-speed lines (HSL), conventional lines modernized with high-speed parameters as well as modernized conventional lines of higher parameters including a rolling stock, and an operational concept." [6]

From a practical point of view, RS is a merger of HSLs and conventional railway network (with some additional improvements or new constructions).

There are two main reasons for RS. One is low competitiveness of railway compared to car in terms of time (see, for instance, Vávra and Janoš [7]). Other, not so visible, reason is urgent need of new railway capacity in agglomerations like Prague and Brno. Benefits of application of IPT and achieving of system travel times in high-speed line network, on the example of prospective Czech network, were outlined by Drábek [8].

The authors take part in research team that has in May 2020 begun to work on the project CK01000004 Efficient Operational Concept for Rapid Services, officially guided by Public Transportation Section of Czech Ministry of Transport (see the Acknowledgement).

2.2. Basic requirements for RS Operation Concept

The project team is aware that substantial shortening of running time, which will become even lower than by car, will lead to substantial increase in passenger demand. Since present long-distance railway offer is based on 60 to 120 min periods [1], the offer on RS in core area (between regional centres) is planned to be based on *Integrated Periodic Timetable with 30 min period*.

The long-distance public transport line layout, as agreed by Ministry of Transport and Správa železnic (Czech Railway Infrastructure Administration) [9] supposes variety of direct interurban connections, so basic period of a public transport line is 60 min.

Thus, integral 30-min period in this case inevitably means interposition (in the common section) of two parallel long-distance public transport lines, and interconnection (changing) in end nodes of such section.

Maintaining of an integrated 30-min period is important not only for the attractiveness of fast public transport offer, but for efficient utilization of railway capacity as well – especially in mixed-traffic sections with regional passenger and freight services.

3. Methodical Approach

3.1. Integral 30-min timetable and zero symmetry

All interpositions make exact 30-min period, so both direct line proceedings and interconnections are planned in 30-min period, and with unified symmetry time in the minute 00.

3.2. Regional Centres – IPT-nodes

Due to high timetabling complexity in (and around) Prague and Brno railway nodes, the authors have made a decision to give priority to regional IPT-nodes, that will almost surely be preserved for practical reason – for instance, Plzeň and Hradec Králové (main stations, both in the minute 00).

3.3. Regular Running Times

Regular running times were mostly taken from the unpublished official material from Správa železnic, s.o. [10], which the authors have received for the sake of work on the research project. The only exceptions are running times to Plzeň and Liberec, which are expert estimations by Jiří Pospíšil, member of project team, based on his work on various project studies.

3.4. Time Horizon

The time horizon was considered as *2050+*, i.e. "after 2050", including complete HSLs from Beroun to Plzeň and from Prague to Mladá Boleslav, which would, according to best possible construction variants, enable scheduled runtimes from Prague to Plzeň and Liberec circa 40 min (36 min to Plzeň and 43 min to Liberec – expert estimations by Jiří Pospíšil).

3.5. Endeavour for IPT-node in Prague

Fixed time slots for "Eurotakt" services to Dresden and Vienna (depending on prospective IPT-nodes in these main stations) and around 40 min running time to Plzeň, Liberec and Hradec Králové (all after a completed HSL, with IPT-nodes in the minutes 00 and 30) have led to endeavour for *IPT-node in the minutes 15 and 45 in Prague main station*.

4. Results

4.1. Prague IPT-node in the Minutes 15 and 45

The result is displayed in Figure 2 in the form of *netgraph* (for more detailed explanation, see Michl, Drábek and Vávra [3]).

For the sake of comprehensibility, there is displayed only the fastest segment of non-stop services between Prague and regional centres. The only exception (marked with blue colour) are fast train lines to Žatec and Most, because they proceed eastwards as express trains.

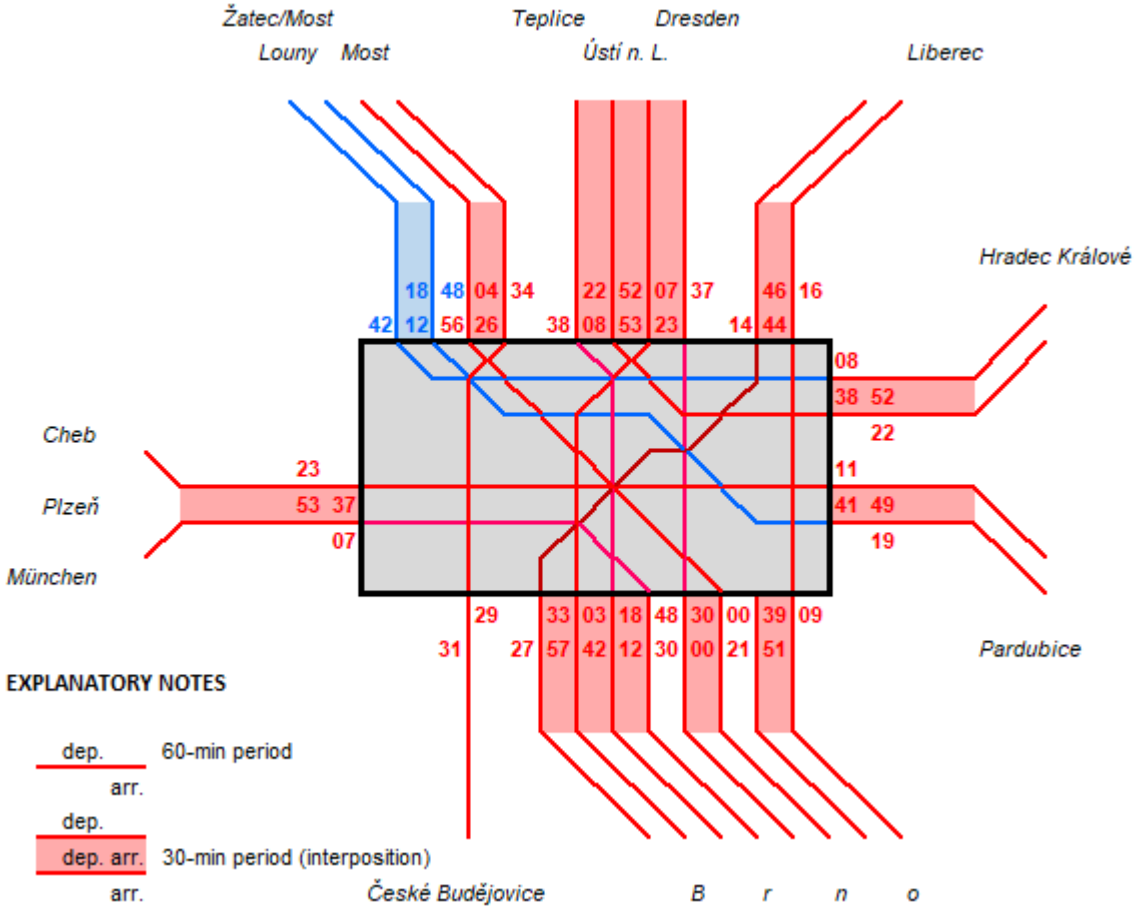

Fig. 2 *Netgraph of proposed high-speed services in Prague – ITF-node in the minutes 15/45 – horizon 2050+*

4.2. Achieved Changing and Dwell Times

Due to various regular running times and capacity restraints around Prague node (joint HSL sections for more directions), there were not always achieved ideal times – neither dwell nor changing ones. The achieved changing and dwell times are displayed in Table 1. Dwell times (once per hour only) are marked with **bold** script. Numbers with star (*) correspond to changing times that occur once per hour only. Alternative times are divided by semicolon. (X) stands for practically useless interchange (due to detour). For the same reason, interchanges between Louny, Most and Ústí nad Labem are not displayed at all.

Tab. 1 *Changing and* ***dwell*** *times in Prague main station (horizon 2050+)*

	Plzeň	**Č. Budějovice**	**Brno**	**Pardubice**	**Hr. Králové**	**Liberec**
Louny	11	19*	9	**7**	**10**	4; 34
Most	11*; 27	**5***	**4**; 16	**7***; 23	**10***; 26	20
Ústí n. L.	15	8*	**4**; **7**; 13	11	**14**	8
Liberec	9	17*	**7**; 13	5; 35	8	
Hr. Králové	15	23*	13	(X)		
Pardubice	**12**	20*	(X)			
Brno	**5**; 14	13*				
Č. Budějovice	(X)					

Some dwell times are as low (for Prague main station) as 4 min, other ones are as large as 14 min (between Ústí nad Labem and Hradec Králové).

Changing times vary between 8 min and 35 min. For interchange between Pardubice and Liberec, 5 min will be very probably too low for not perfectly mobile passengers, unless cross-platform interchange will be achieved. So, there should be considered changing time of 35 min as well.

One of "blue" fast train lines (departing in the minute 48 from Prague) proceeds from Louny to Most, with only 15 min longer running time than the direct express line. Provided considerably shorter changing times in Prague, this public transport line can be a viable alternative for connection of Most with some regional centres.

5. Discussion

Two directions were not able to fit in 15/45 IPT-node in Prague main station. The first one, from České Budějovice, is determined by 90 min running time after completion of "corridor" upgraded railway line. Because České Budějovice, as regional centre and central railway node as well, is supposed to remain to be an IPT-node in the minute 00, it would not be effective to arrive to Prague considerably later.

The second direction is to/from Most. There is a timetabling constraint not any IPT-node, but capacity of joint HSL-tunnel (running to the north from Prague node) for HSLs to Ústí nad Labem and to Most, which further divide. Since express trains from Ústí nad Labem are determined by IPT-node in Dresden and regular service interval of 15 min, and fast trains on both HSLs are determined by local IPT-nodes (e.g. Lovosice) or another interconnections, there is not much space left for alternative time slots for express trains to Most.

6. Conclusion

The presented first attempt of conceptual design of interpositions and interconnections in Prague main station (although not yet examined on the level of track and platform occupation) can be considered as "least bad" solution so far. However, it illustrates some

timetabling interdependencies that have to be considered anyway – joint tunnel (or HSL) sections, regional IPT-nodes and anticipated regular running times to/from them.

In the case that some running times are too long, it is an important feedback to project process that sends a message about necessity of shortening this running time by targeted improvement in terms of speed or node capacity [11].

The results have shown that precise interpositions into 30 min period and alternative direct proceeding or interconnections can successfully coexist together.

7. Acknowledgement

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References

[1] SŽDC, s. o. Railway timetable 2019/2020 for employees. Unpublished. Prague, 2019.

[2] ÖBB-Personenverkehr AG. Schnell und komfortabel Richtung Westen. [online]. 2019 [cit. 2020-11-13]. Available from: https://www.oebb.at/dam/jcr:21c69cd4-78f6-472e-a907-637f9ee11a08/folder-go-west.pdf

[3] Z. Michl, M. Drábek, R. Vávra. Netgraph - an Efficient Tool for Periodic Timetabling and Capacity Planning. *Acta Polytechnica CTU Proceedings* [online]. 2017. https://doi.org/10.14311/APP.2017.11.0043, DOI:10.14311/APP.2017.11.0043.

[4] SMA und Partner AG. Netgraph Switzerland [online]. 2020. [cit. 2020-11-13]. Available from: https://www.sma-partner.com/images/Downloads/2019-12-20_Netzgrafik_Schweiz_2020.pdf

[5] SBB AG. STEP Ausbauschritt 2030/35: Halbstundentakt für alle. SBB News [online]. 2018 [cit. 2020-11-13]. Available from: https://news.sbb.ch/medien/artikel/73165/step-ausbauschritt-2030-35-halbstundentakt-fuer-alle

[6] Rapid services development programme in Czech Republic. *Ministerstvo dopravy ČR - Homepage* [online]. Prague: Ministry of Transport of Czech Republic, 2018 [cit. 2020-10-23]. Available from: https://www.mdcr.cz/getattachment/Dokumenty/Strategie/Vysokorychlostni-trate/Rapid-services-development-programme-in-Czech-republic.pdf.aspx

[7] R. Vávra, V. Janoš. Analysis of competitiveness of railway passenger transport between Rakovník and Prague. *Acta Polytechnica CTU Proceedings* [online]. 2017. https://ojs.cvut.cz/ojs/index.php/APP/article/view/4462, DOI:10.14311/APP.2017.11.0086.

[8] M. Drábek. On efficient operational concept of future high-speed railway in the Czech Republic. *Acta Polytechnica CTU Proceedings* [online]. 2016. https://ojs.cvut.cz/ojs/index.php/APP/article/view/3832/3706, DOI:10.14311/APP.2016.5.0004.

[9] Ministry of Transport of Czech Republic and SŽ, s. o. (2020, Jun). Layout of long-distance public transport lines (trains) for Rapid Services, horizon 2050. Unpublished. Prague, 2020.
[10] SŽ, s.o. Table of regular running times for Rapid Services. Unpublished. Prague, 2020.
[11] J. Gašparík, B. Abramović, V. Zitrický. Research on Dependences of Railway Infrastructure Capacity. *Tehnički vjesnik - Technical Gazette* [online]. 2018. https://doi.org/10.17559/TV-20160917192247, DOI:10.17559/TV-20160917192247.