

# INTEGRATED CYCLIC TIMETABLE ON THE RAILWAYS IN THE KARLOVY VARY REGION

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**ABSTRACT.** The concept of public transport with periodic timetables has been slowly spreading in the Czech Republic for many years. Together with the announcement of tenders for the operation of compulsory transport according to the European Parliament's Regulations 1370/2007 and 2338/2016, circular integrations occur in many regions, which usually represent the adjustment of public transport to a concept corresponding to current trends and needs.

**KEYWORDS:** Integrated cyclic timetable, optimization, railway transport, transfer links transport connections.

## 1. INTRODUCTION

When the need to prepare tenders for the operation of obligatory transport began to enter public consciousness around 2014, it became clear that the time of Integrated transport system (ITS) development, with all that comes with it, was also coming. The first region to fundamentally change the concept of public transport was the Ústí nad Labem Region, where from 1 January 2015, completely new green buses of the Transport of the Ústí nad Labem Region (TÚLR) system were introduced. Although most regions did not require completely new buses (for example, the Central Bohemian or Moravian-Silesian region manages to achieve a low average age even without this requirement), the Pilsen region was also expected to reduce the average age of the fleet to 0 years in 2020, and the new blue buses in the paint of the Integrated Transport of the Pilsen Region (ITPR) system were rolled out in the region. From the point of view of the Karlovy Vary Region, both neighbouring regions – Ústí and Pilsen region – have a well-developed ITS, elaborate regional tariffs, developed periodic transport, etc. The cross-border neighbours, the German states of Bavaria and Saxony, also have their own ITS, and thanks to this there is also an established timetable on cross-border lines.

This text shows one of the possibilities for the redevelopment of transport in the Karlovy Vary Region – the possibility of building on the foundations of clockwise transport to the skeleton provided by the fact that all neighbouring regions have periodic transport. This skeleton means an established timetable on lines Ex6, R15, R29, and several other regional lines that enter the Karlovy Vary Region from neighbouring areas. At the outset, it is necessary to mention the Central Bohemian Region, which is not directly adjacent to the Karlovy Vary Region, but the integration of Rakovnicko II (in August 2020) and Rakovnicko III (in December 2021) will allow passengers to switch

from Integrated Transport of the Karlovy Vary Region (ITKV) to Prague Integrated Transport (PIT) connections. Here, we will also see a unified ITS image, user-friendly tariffs, and other elements that result in an influx of passengers to public transport.

The aim of the text is to research the possibilities of transport in the Karlovy Vary Region. The methods used will be the implementation of periodic transport, and an attempt to take maximum account of the possibilities of demand-responsive transport.

### 1.1. A MODERN CONCEPT OF PUBLIC TRANSPORT

Why try to introduce cyclic timetable and improve public transport (PT) in general? Cyclic transport is a trend that has already proved its worth in many regions of many countries, the city of Lindau, the two neighbouring counties and hundreds of other examples of how to make public transport more attractive. At the same time, public transport is no longer just a necessity, it is a service for people, a way of travelling in an environmentally friendly way and, at its very core, a matter of course for people across Europe. **We live in an age where distance is no longer measured in kilometres, but in minutes.**

PT will make places more attractive to live that, with poor quality PT, means that residents depend on the use of cars in their lives. For example, commuting from Teplá in the absence of reliable and fast interchanges in Mariánské Lázně means that if a given person travels anywhere outside of Mariánské Lázně, they are likely to do so by car (which is disadvantageous both economically for people and environmentally for everyone else). This is the case not only in towns with a lack of employment opportunities, but also in towns from which it is necessary to commute to another town for highly specialised (e.g., higher education) jobs.

The Karlovy Vary Region plans to sign new contracts resulting from tenders that will take place during 2022 and 2023. Given the high number of low-capacity buses in the tender documents, it is possible that by the end of 2023 the Karlovy Vary Region will represent a plausible simulation of Eastern European public transport, which, although it has potential, gives the impression of an anthill of irregularly running small vehicles. However, it is also possible that the ITKV system will adopt the necessary changes and take its place among the leading ITS in the Czech Republic – there are many opportunities for inspiration and learning in 2022.

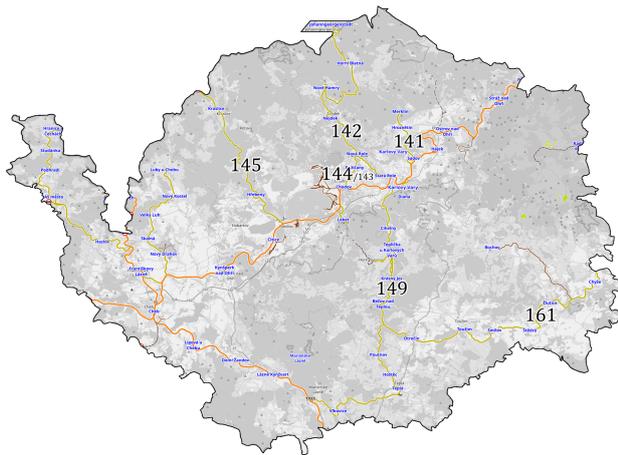


FIGURE 1. Map of Karlovy Vary Region with railway network [1].

Legend of the Figure 1:

- orange graphic elements – main railway lines,
- yellow graphic elements – branch railway lines,
- blue graphic elements – stations on railway lines,
- brown graphic elements – connecting tracks and sidings,
- dashed graphic elements – abandoned lines.

## 2. MATERIALS AND METHODS

The methodology is based on the nature of the integrated cyclic timetable (ICT). For such a timetable, a so-called periodic (cyclic) node is necessary – a place where the connections of the lines to the node meet and thus form system links between them. The so-called axis of symmetry, which marks the beginning of the period, is used for this purpose. The period can be of different sizes, e.g. most often 1 or 2 hours. The axis is symmetric precisely when, before the end of the period, all the links concerned meet at the periodic node and all leave it again at the beginning of the period. The time during which the line links are in the node is used for transfers, delay compensation time or other technological operations.

If there are periodic nodes in the transport network, an integrated timetable can be constructed, which is

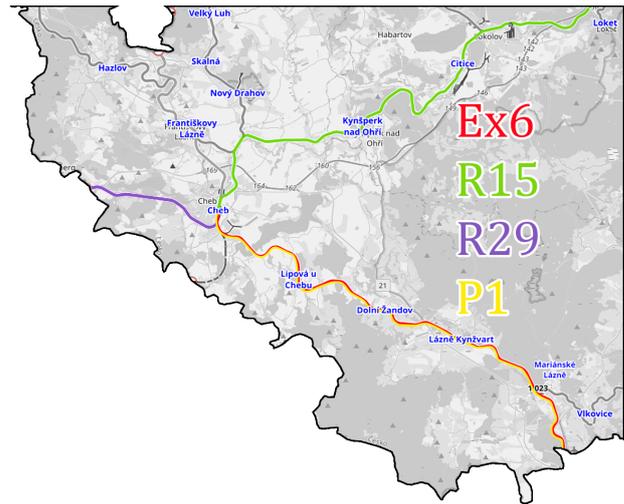


FIGURE 2. Part of railway map with long-distance train lines [1].

an extension of the periodic timetable described above. In order to establish and maintain interchanges at the node, it is necessary to observe the travel times at the individual edges of the transport network carried out by the lines concerned – this is the main focus of the integrated timetable.

### 2.1. DEFINITION OF THE STUDY AREA, BASIC TRANSPORT LINKS, AND INTRODUCTION OF BASIC CYCLIC POSITIONS

It has already been mentioned that the initial idea of the research is to link the cyclic positions in the Karlovy Vary region to the cyclic positions in neighbouring regions. Within the region, the railway backbone network will then be addressed first. This research includes regional railway connections in the Karlovy Vary region, in addition to connections that go to the Cheb junction. The railway network is represented by three long-distance lines of trains of category R (fast train with higher amount of stops than express) and higher (express etc.). Train lines Ex6 (Prague – Plzeň – Cheb), R15 (Prague – Ústí n. L. – Cheb), and R29 (Cheb – Germany). The routes of these lines show an important railway junction in Cheb. In the Karlovy Vary Region there is another important train line – P1 (Plzeň – Cheb – Karlovy Vary) in the section Plzeň – Cheb forms an hourly interchange to train line Ex6, and in the section Cheb – Karlovy Vary it complements passenger trains in the time position of the departure 10 minutes after train line R15 on departure from Cheb (or 10 minutes before on arrival from Karlovy Vary to Cheb).

On the basis of the above-mentioned transport information, an effort will be made to create integrated interchanges mainly in the vicinity of the Sokolov region (north-eastern part of the Karlovy Vary region) between the main railway lines, where the 4 train lines mentioned in Figure 2 are located, and the regional lines, the location of which is shown in Figure 1.

In the design part of the text, the current valid timetables are used, i.e. timetables from the Theoretical railway graph (TRG) 2021/2022. In addition, the timetables from this TRG are used, which have developed into stable time positions in the region (albeit without the implementation of an integrated timetable). The authors assume a state that is stable but not periodic. The integrated timetable is determined here by the time positions in the surrounding regions, which also determine some time positions in the Karlovy Vary Region. The rest of the time positions are determined in such a way that the one which can be considered as the system optimum is always selected from the available variants.

Authors are using odd and even specification for time position of trains in further text of article (E – even, O – odd, X – every hour). There are existing restrictions in daily hours of operation for trains which are shown in tables. Authors are using these symbols:

- X – train is operated on workdays,
- 1 – train is operated on 1st day of week (Monday),
- . . . ,
- 6 – train is operated on 6th day of week (Saturday),
- 7 – train is operated on 7th day of week (Sunday) and on Public Holidays.

**2.2. RAILWAY LINE 149**

The connection of the R15 and Ex6 train lines in the east of the region is important for further modifications. This link is railway line 149 Karlovy Vary – Bečov nad Teplou – Mariánské Lázně. The timing of the Ex6 and R15 train lines has been stable for years and apart from the Cheb junction, they form several junctions along their routes. The timing of train line P1 can also be considered stable, although in the future it may be recommended to try to shorten the journey time between Plzeň and Cheb to reach the XX:30 node in Cheb.

For railway line 149, two connection options can be considered in Mariánské Lázně:

- (1.) Connecting trains to the Ex6 train line, or
- (2.) Connecting trains to the P1 train line.

Connecting to the Ex6 train line is clearly more advantageous, why:

- a faster turnaround in Mariánské Lázně will allow the creation of transfer at E:00 in Bečov nad Teplou junction with a larger margin,
- extending railway line of passenger trains to Horní nádraží in Karlovy Vary, will allow a transfer to the R15 train line,
- the crossing on the single-track 149 will take place in Bečov nad Teplou, in the case of the inserted more connections Karlovy Vary – Bečov nad Teplou in peak hours for better frequency, the crossing will also take place in Karlovy Vary dolní nádraží.

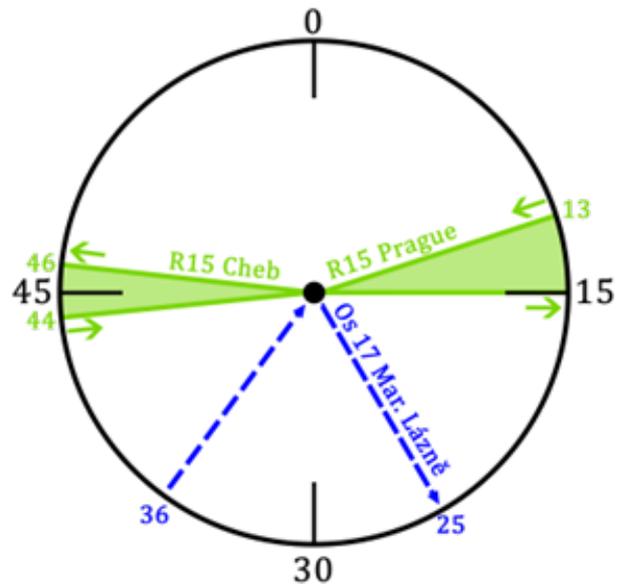


FIGURE 3. Integrated transfer in Karlovy Vary.

Proposed measures for the railway line 149:

- extension of all trains to Karlovy Vary station,
- binding to trains of train lines Ex6 and R15,
- two-hourly running throughout the day.

Resulting situation on the railway line 149:

- connection of Mariánské Lázně (Ex6) and Karlovy Vary (R15),
- creation of a junction at E:00 in Bečov nad Teplou,
- together with the optimised bus line, forming an hourly Mariánské Lázně – Teplá route,
- improving the connection of railway line 161 to PT in the Karlovy Vary Region.

Travel times (see the Table 1):

- Mariánské Lázně – Bečov n. T.: 50 minutes,
- Bečov n. T. – Karlovy Vary: 35 minutes.

For Figure 3 – dashed lines for passenger trains (in Czech: Os) means that they are not the same train unit. In that case, arrival is in 36th minute of even hour and departure is in 25th minute of odd hour. The proposed draft of the train timetable for railway line no. 149 is in the Table 1.

**2.3. RAILWAY LINE 161**

The transport solutions of railway lines 149 and 161 are directly related. Line 161 is a regional line that runs from the Central Bohemia Region to Bečov nad Teplou in the Karlovy Vary Region. In 2022 the line has very low passenger frequency. Line 161 is connected to line 163 in Protivec in Central Bohemia Region, i.e., without regular operation of passenger trains.

The area around railway line 161 is characterised by the absence of large towns (the largest town is

Train	Restriction	Mariánské Lázně	Bečov n. T.	Karlovy Vary
7120	X	–	4:41	5:16
7122	X	–	6:01	6:36
7100	X, 6, 7	6:11	7:01	7:36
7102	X, 6, 7	7:11	8:01	8:36
7104	X, 6, 7	9:11	10:01	9:36
7106	X, 6, 7	11:11	12:01	12:36
7108	X, 6, 7	13:11	14:01	14:36
7124	X	–	15:01	15:36
7110	X, 6, 7	15:11	16:01	16:36
7126	X	–	17:01	17:36
7112	X, 6, 7	17:11	18:01	18:36
7114	X, 6, 7	19:11	20:01	20:36
7116	X, 6, 7	21:11	22:01	22:36
7140	X, 6, 7	23:11	0:01	–

Train	Restriction	Karlovy Vary	Bečov n. T.	Mariánské Lázně
7141	X, 6, 7	–	4:00	4:48
7101	X, 6, 7	5:25	6:00	6:48
7103	X, 6, 7	7:25	8:00	8:48
7105	X, 6, 7	9:25	10:00	10:48
7107	X, 6, 7	11:25	12:00	12:48
7109	X, 6, 7	13:25	14:00	14:48
7121	X	14:25	15:00	–
7111	X, 6, 7	15:25	16:00	16:48
7123	X	16:25	17:00	–
7113	X, 6, 7	17:25	18:00	18:48
7125	X	18:25	19:00	–
7115	X, 6, 7	19:25	20:00	20:48
7117	X, 6, 7	21:25	22:00	22:48
7127	X, 6, 7	22:25	23:00	–

TABLE 1. Simplified draft timetable for railway line 149 [2].

Toužim, which has over 3000 inhabitants), there is no district town in the area and no Municipality with extended area of competence (MEC). Primary schools on line 161 in the Karlovy Vary Region can be found in Toužim, Štědrá, and Žlutice. Another one is in Lubenec. The area has strong tourist potential, but the nature of the area and lack of job opportunities forces residents to commute for work to another towns.

In the 2022 timetable, there are interchanges between trains on railway lines 149 and 161, although these are usually interchanges that include a 20-minute wait (for example, the afternoon connection between Os 7109 and Os 16747).

The proposed transfer at E:00 on railway line 149 in Bečov nad Teplou encourages the introduction of clockwise services on line 161. The almost hourly journey time in the section Bečov nad Teplou – Žlutice determines the O:00 crossing to Žlutice. In the event of the termination of the order of passenger trains on line 161 by the Central Bohemia and Ústí nad Labem Region, the situation can be resolved:

- termination of connections in Žlutice, with sharp turnarounds (potential for delays),

- extension of connections on the territory of the Karlovy Vary Region to Chyše town, with approximately half-hour turnarounds.

The current frequency through Žlutice is minimal on line 161, but given the trains' stays of up to one hour in Žlutice, no other result can be expected. Running the trains Bečov nad Teplou – Chyše means the need for a second train unit, while terminating in Žlutice, thanks to the stable running times, one train unit would be sufficient.

Proposed measures for the railway line 161:

- modification of the time positions of the connections using the E:00 transfer in Bečov nad Teplou.

Resulting situation on the railway line 161:

- two-hourly clock in peak hours within the Karlovy Vary Region.

For Figure 4 – the blue lines show the passenger trains in question. Brown lines are trains outside the competence of the Karlovy Vary Region. Pink lines are trains of railway line 142.

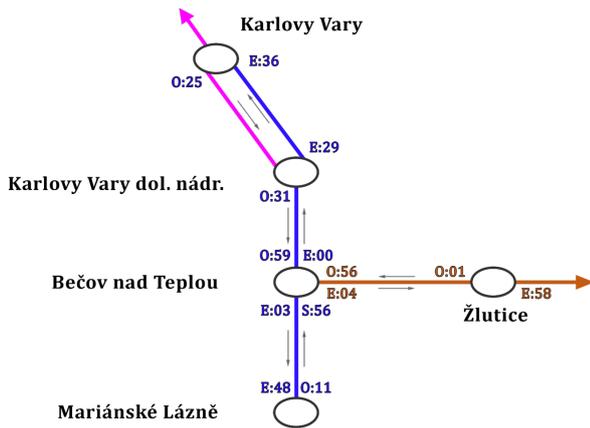


FIGURE 4. Schematic timetable for railway lines 149 and 161.

### 2.4. RAILWAY LINE 145

Modification of the timetable and the introduction of cyclic positions according to the existing cyclic positions of another railway line can also be introduced on line 145. Train lines P1 and R15 always meet in Sokolov around X:00. On railway line 145, it is possible to design a connection position that considers the X:00 junction in Sokolov as well as the existing clock positions of cross-border trains to Kraslice from Germany. Line 145 is an important link in the district of Sokolov, connecting the district town with the northern part of the district, where the towns of Rotava and Kraslice are located, which have a combined population of around 10000. The line provides transport services to Oloví, which does not have a bus connection (the bus goes to the local part of Studenec, 1.5–2 km west of Oloví).

Sokolov, Rotava, and Kraslice are also connected by bus line 481660, but its route is very different. It does not serve Oloví, but in Rotava it goes to the city centre, thus providing a better transport service than the train at the 3 km away station. Line 145 is a frequently used suburban line, and the current situation in the 2022 TRG resembles an hourly cycle in terms of frequency of services. With the introduction of fixed positions from Sokolov X:10 to Kraslice X:45, and back from Kraslice X:11 to Sokolov X:46, it is based on a crossing at X:28 in Oloví in addition to the connections at Sokolov. In the case of Rotava, it is desirable, in addition to optimising bus routes in the region, to link the city with the rail network. For the connection with the railway station, the authors propose a bus line on the route Rotava railway station – Rotava bus station – Rotava, Zátíší, using elements of demand-response transport, especially at the outskirts of the day.

Proposed measures for the railway line 145:

- introduction of an hourly interval between Sokolov and Kraslice,
- operation in the section Kraslice – state border unchanged,

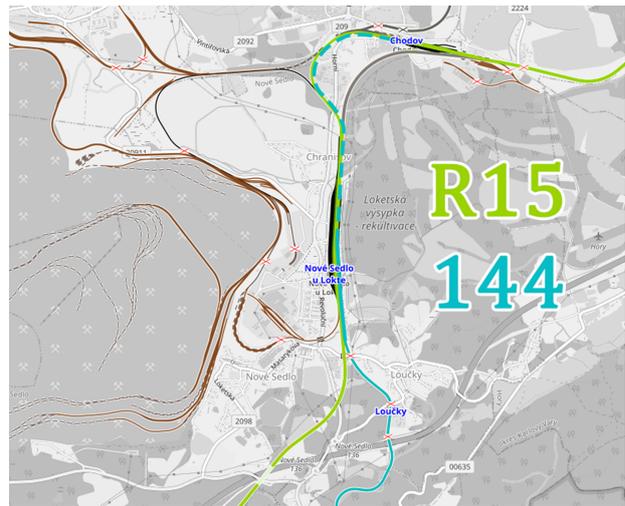


FIGURE 5. Extension of passenger trains of railway line 144 to Chodov [1].

- introduction of a bus line connecting the city of Rotava with the Rotava railway station.

Resulting situation on the railway line 145:

- maximising the accessibility of Sokolov for passengers from Kraslice, Rotava, and Oloví,
- providing connections to long-distance transport in Sokolov,
- establishment of junction at E:00 (peak X:00) in Kraslice.

Travel times:

- Sokolov – Kraslice: 35 minutes,
- Sokolov – Oloví: 18 minutes.

The proposed draft of train timetable for railway line no. 145 is in the Table 2.

### 2.5. RAILWAY LINE 144

It is a short branch line from railway line 140 in Nové Sedlo to Loket. The line runs in the direction of the Loket – Karlovy Vary commute, and it is also possible to consider the Loket – Sokolov commute. The bus journey times are approximately 30 minutes for the Loket – Karlovy Vary route and approximately 20 minutes for the Loket – Sokolov route. The train has the potential to achieve the same (or even slightly better) times as buses. As an optimal solution, a revision of the train and bus timetables can be considered so that they complement each other in these directions.

The positions of passenger trains on the railway line 144 are determined by the fixed positions of long-distance services – same as on railway line 140. The continuity with the connections of the R15 train line that do not stop at Nové Sedlo u Lokte must be solved by the arrival of trains from the line 144 to Chodov. This solution can already be observed to some extent and is shown on Figure 5 by dashed blue line.

Train	Restriction	Sokolov	Oloví	Kraslice	Operational information
17000	X, 6, 7	5:10	5:28	5:45	
17002	X	6:10	6:28	6:45	crossing with 17007 in Rotava at 6:36
17004	X, 6, 7	7:10	7:28	7:45	
17006	X, 6, 7	8:10	8:28	8:45	
17008	X, 6, 7	9:10	9:28	9:45	
17010	X, 6, 7	11:10	11:28	11:45	
17012	X	12:10	12:28	12:45	
17014	X, 6, 7	13:10	13:28	13:45	
17016	X, 6, 7	14:10	14:28	14:45	
17018	X	14:54	15:12	15:29	crossing with 17023 in Rotava at 15:20
17020	X, 6, 7	15:10	15:28	15:45	
17022	X, 6, 7	16:10	16:28	16:45	
17024	X	16:54	17:12	17:29	crossing with 17027 in Rotava at 17:20
17026	X, 6, 7	17:10	17:28	17:45	
17028	X, 6, 7	18:10	18:28	18:45	
17030	X, 6, 7	19:10	19:28	19:45	
17032	X, 6, 7	21:10	21:28	21:45	two connected train units
17034	X, 6, 7	23:03	23:20	23:34	
Train	Restriction	Kraslice	Oloví	Sokolov	Operational information
17001	X, 6, 7	4:11	4:28	4:46	
17003	–	5:11	5:28	5:46	
17005	X, 6, 7	6:11	6:28	6:46	
17007	–	6:27	6:44	7:02	crossing with 17002 in Rotava at 6:36
17009	X, 6, 7	7:11	7:28	7:46	
17011	X, 6, 7	8:11	8:28	8:46	
17013	X	9:11	9:28	9:46	
17015	X, 6, 7	10:11	10:28	10:46	
17017	X, 6, 7	12:11	12:28	12:46	
17019	X, 6, 7	13:11	13:28	13:46	
17021	X, 6, 7	14:11	14:28	14:46	
17023	X, 6, 7	15:11	15:28	15:46	crossing with 17018 in Rotava at 15:20
17025	X, 6, 7	16:11	16:28	16:46	two connected train units
17027	X, 6, 7	17:11	17:28	17:46	crossing with 17024 in Rotava at 17:20
17029	X, 6, 7	18:11	18:28	18:46	
17031	X, 6, 7	19:11	19:28	19:46	
17033	X, 6, 7	20:11	20:28	20:46	
17035	X, 6, 7	22:11	22:28	22:46	

TABLE 2. Simplified draft timetable for railway line 145 [2].

The frequency of passenger trains on railway line 144, considering the current situation and the requirement for approximately the same volume of kilometres, corresponds to an hourly interval between connections.

Two options are evident when proposing a link to the long-distance services of the P1 and R15 train lines. The first option is to connect to the P1 train line at Nové Sedlo u Lokte in the time position E:40/O:16, which, however, implies:

- a rather sharp turnover at X:30 in Loket to return in time,
- the necessity to deviate from the timetable in cases where the Loket suburb stop is to be served,
- impossibility of connecting to the R15 train line, coupled with the requirement to locate passenger

trains on railway line 140.

The second possibility is to bind at position E:55/O:05 to the connections of train line R15 in Chodov, and around E:00 to bind to passenger trains of railway line 140 in Nové Sedlo. The requirement for the position of passenger trains on line 140 remains, but the junction at X:30 in Loket and other disadvantages are not present. Because there is no difference between passenger trains and P1 trains on the railway line 140 in terms of the number of stops, the latter option appears to be preferable.

Proposed measures for the railway line 144:

- hourly interval between Nové Sedlo u Lokte and Loket, with a zonal operation Nové Sedlo u Lokte – Chodov once every two hours,

Train	Restriction	Nová Role	Chodov	Nové Sedlo u L.	Loket předm.
27100	X	–	5:11	5:14	5:24
27130	X, 6, 7	–	–	6:14	6:24
27150	X, 6, 7	6:29	6:41	–	–
27102	X, 6, 7	–	7:11	7:14	7:24
27132	X, 6, 7	–	–	8:14	8:24
27104	X, 6, 7	–	9:11	9:14	9:24
27106	X, 6, 7	–	11:11	11:14	11:24
27108	X, 6, 7	–	13:11	12:14	–
27134	X, 6, 7	–	–	13:14	13:24
27152	X, 6, 7	14:29	14:41	14:14	14:24
27110	X, 6, 7	–	15:11	–	–
27136	X, 6, 7	–	–	15:14	15:24
27112	X, 6, 7	–	17:11	16:14	16:24
27138	X, 6, 7	–	–	17:14	17:24
27114	X, 6, 7	–	19:11	18:14	18:24
27140	X, 6, 7	–	–	19:14	19:24
27116	X, 6, 7	–	21:11	20:14	20:24
27118	1, 2, 3, 4, 7	–	–	21:14	21:24
Train	Restriction	Loket předm.	Nové Sedlo u L.	Chodov	Nová Role
27101	X	4:45	4:57	5:00	–
27151	X, 6, 7	–	–	5:10	5:23
27131	X	5:34	5:46	–	–
27103	X, 6, 7	6:34	6:46	6:49	–
27133	X, 6, 7	7:34	7:46	–	–
27105	X, 6, 7	8:34	8:46	8:49	–
27107	X, 6, 7	10:34	10:46	10:49	–
27109	X, 6, 7	12:34	12:46	12:49	–
27153	X, 6, 7	–	–	13:10	13:23
27135	X, 6, 7	13:34	13:46	–	–
27111	X, 6, 7	14:34	14:46	14:49	–
27137	X, 6, 7	15:34	15:46	–	–
27113	X, 6, 7	16:34	16:46	16:49	–
27139	X, 6, 7	17:34	17:46	–	–
27115	X, 6, 7	18:34	18:46	18:49	–
27141	X, 6, 7	19:34	19:46	–	–
27117	X, 6, 7	20:34	20:46	20:49	–
27119	X, 6, 7	21:34	21:46	–	–

TABLE 3. Simplified draft timetable for railway line 144 [2].

- competitive connection for commuting Loket – Karlovy Vary, Loket – Sokolov, and further destinations.

The proposed draft of train timetable for railway line no. 144 is in Table 3.

Resulting condition on the railway line 144:

- the ITS will complement bus and train connections between Karlovy Vary, Loket, and Sokolov,
- establishment of a junction at X:30 in Loket,
- use of the node at O:00 in Chodov.

Travel times:

- Nové Sedlo u Lokte – Loket: 10 minutes,
- Chodov – Loket: 13 minutes,
- Karlovy Vary – Chodov: 10 minutes.

## 2.6. RAILWAY LINE 142

The suburban line connecting the north of the Karlovy Vary district with the regional town of Karlovy Vary crosses Nova Rola, Nejdek, Pernink, Horní Blatná, Potůčky and other villages along its route. The journey time along the entire route is approximately 75 minutes, with a slight deviation between trains heading to the Krušné hory and trains coming from the Krušné hory to the regional town of Karlovy Vary. The Karlovy Vary – Nejdek line is also served by bus line 421190 (outside Nová Rola), the Karlovy Vary – Pernink – Potůčky line is also served by bus lines 421103 and 421104 (outside Nejdek).

The (non-)existence of a periodical node at Karlovy Vary railway station is essential when researching the cyclic positions for railway line 142. The fixed

positions of the R15 train line at E:45 and O:15 offer two possibilities:

The first option means arrival from Nejdek shortly before the departure of the train line R15 to Cheb at E:45. Departure shortly after O:15 – after the arrival of the R15 from Cheb. The advantage of this solution is the possibility of running 142 passenger trains on the railway line to the Karlovy Vary dolní nádraží (hereinafter lower station), arriving at approximately E:51 and departing at approximately O:06. This would link the O:00 junction at the bus terminal adjacent to the lower station, and the transfer links to Karlovy Vary station. The bus station at Karlovy Vary dolní nádraží station can be seen in Figure 6.

The second option means arrival from Nejdek before O:15 to Karlovy Vary, and departure after E:45. The R15 train line would thus be connected to Ostrov, Kadaň, Chomutov, and further to the Ústí nad Labem region. In this variant, the extension of connections to the lower station would mean departure immediately before the railway line 149 connection, and on return from the lower station as well. In addition, the position of passenger trains on the railway line 149 takes advantage of the possibility of crossing at the lower station at X:30 between the Karlovy Vary – Mariánské Lázně and the inserted connections of Karlovy Vary – Bečov nad Teplou, which must be taken into account.

From the point of view of the junctions in Karlovy Vary, the first option seems to be more beneficial. From the point of view of other settlements on the route, only Nejdek, where there is also a half-kilometre distance between the train and bus stations, has enough lines to form a node. Thus, the first option can be recommended, and taking into account the positions of the passenger trains of line 142 when constructing the timetable (not only) of the backbone bus line Karlovy Vary – Nejdek.

For railway line 142, considering the existing timetable, a two-hour interval between connections can be recommended, using zonal operation and hourly interval in peak hours in the Karlovy Vary – Nejdek – Nové Hamry section. The crossing on the single-track railway line 142 takes place in Stará Rola (X:30) and in Nové Hamry (E:00). The shortened zonal connections in Nové Hamry have a sharp turnover at O:00.

Proposed measures for the railway line 142:

- adjustment of the timing of connections and creation of a two-hour interval on the whole railway line with connection to the R15 train line to/from Cheb,
- extension of trains to the lower station to ensure connection between buses at the O:00 junction at the bus terminal and the connection at the time of



FIGURE 6. Iveco Crossway bus at terminal station at Karlovy Vary dolní nádraží.

the passage of the R15 train line to Karlovy Vary station,

- introduction of zone operation and hourly interval Karlovy Vary – Nové Hamry.

Resulting situation on the railway line 142:

- strengthening the role of the railway line 142 in the suburban transport of Karlovy Vary,
- basis for optimisation of the Karlovy Vary – Nejdek and Karlovy Vary – Pernink – Potůčky connections.

Travel times:

- Nejdek – Johanngeorgenstadt: 47 minutes,
- Karlovy Vary – Nejdek: 20 minutes.

The proposed draft of train timetable for railway line no. 142 is in the Table 4.

## 2.7. RAILWAY LINES 143 AND 141

The former railway line 143 Nová Role – Chodov (today incorporated into railway line 144) and railway line 141 are not backbone lines. They have only single pairs of connections and can only be counted in the ITS as a supplementary connection – the exact timing should be determined only regarding the overall optimisation of bus lines in the area. The railway line 141 has number of passengers that are not adequate for the cancellation of the line, the analysis of the use of the connections does not show that the lines should remain without service, and the tourist potential of line 141 should be considered.

In the case of the railway line 143, the proposed basic positions of the passenger trains of line 142 in Nová Role at E:20 (to Karlovy Vary) and O:38 (to Potůčky) can be considered. If the number of available vehicles is favourable, the O:00 junction in Chodov can be used.

In the case of the railway line 141, the location of the arrival and departure of the train line R15 in Karlovy Vary can be considered, or the timing of the connections can be worked with to improve the offer of connections between the upper and lower Karlovy Vary railway stations. However, the results

Train	Restriction	KV dolní nádraží	Karlovy Vary	Stará Role	Nové Hamry	Johanngeorgenstat
17100	X	5:06	5:23	5:30	6:00	6:35
17130	X, 6, 7	6:06	6:23	6:30	7:00	–
17102	X, 6, 7	8:06	7:23	7:30	8:00	8:35
17104	X, 6, 7	9:06	9:23	9:30	10:00	10:35
17106	X, 6, 7	11:06	11:23	11:30	12:00	12:35
17132	X, 6, 7	12:06	12:23	12:30	13:00	–
17108	X, 6, 7	13:06	13:23	13:30	14:00	14:35
17134	X, 6, 7	14:06	14:23	14:30	15:00	–
17110	X, 6, 7	15:06	15:23	15:30	16:00	16:35
17136	X, 6, 7	16:06	16:23	16:30	17:00	–
17112	X, 6, 7	17:06	17:23	17:30	18:00	18:35
17138	X, 6, 7	18:06	18:23	18:30	19:00	–
17114	X, 6, 7	19:06	19:23	19:30	20:00	20:35
17140	X, 6, 7	20:06	20:23	20:30	21:00	–
17116	X, 6, 7	21:06	21:23	21:30	22:00	22:35
17142	X, 6, 7	22:06	22:23	22:30	23:00	–

Train	Restriction	Johanngeorgenstat	Nové Hamry	Stará Role	Karlovy Vary	KV dolní nádraží
17131	X, 6, 7	–	5:00	5:30	5:47	5:51
17101	X, 6, 7	5:26	6:00	6:30	6:47	6:51
17133	X	–	7:00	7:30	7:47	7:51
17103	X, 6, 7	7:26	8:00	8:30	8:47	8:51
17105	X, 6, 7	9:26	10:00	10:30	10:47	10:51
17107	X, 6, 7	11:26	12:00	12:30	12:47	12:51
17135	X	–	13:00	13:30	13:47	13:51
17109	X, 6, 7	13:26	14:00	14:30	14:47	14:51
17137	X, 6, 7	–	15:00	15:30	15:47	15:51
17111	X, 6, 7	15:26	16:00	16:30	16:47	16:51
17141	X, 6, 7	–	17:00	17:30	17:47	17:51
17113	X, 6, 7	17:26	18:00	18:30	18:47	18:51
17143	X	–	19:00	19:30	19:47	19:51
17115	X, 6, 7	19:26	20:00	20:30	20:47	20:51
17145	X	–	21:00	21:30	21:47	21:51
17117	X, 6, 7	21:26	22:00	22:30	22:47	22:51

TABLE 4. Simplified draft timetable for railway line 142 [2].

of the optimization of bus lines terminating at the bus terminal (adjacent to the lower station) must be considered when adjusting the operation between the Karlovy Vary stations.

Travel times:

- Bečov n. T. – Štědrá: 44 minutes,
- Štědrá – Žlutice: 11 minutes.

### 3. RESULTS (GRAPHICS OF INTEGRATED CYCLIC TIMETABLE)

The research presented in Chapter 3 can be succinctly summarised in a graphic showing the nodes and the temporal positions of the links between them.

The proposed solution allows, among others, the following commute times (hh:mm) in Table 5.

All the above journey times can be reached periodically every one or two hours. Compared to the

current situation, we can speak of a considerable simplification of timetables, and at the same time of an increase in ordered kilometres of no more than a few percent.

The graphic in Figure 7 shows a solution that can be considered optimal based on the options based on the locations of long-distance trains, the volume of traffic ordered in the current timetable (2021/2022) and, in particular, the demand on individual transport routes. The possibility of changing trains from Mariánské Lázně towards Žlutice in Bečov nad Teplou has been maintained, and the proposed solution also includes much shorter travel times both outside the study area and within the study area. It must be said that the colours of Figure 5 of passenger train lines do not correspond with the colour layout of the other images. Black line is main line where long-distance R15 train line is operated from Cheb to Ústí and Labem and

Connections	Part of the railway line	Commute times [hh:mm]
Plzeň – Bečov nad Teplou	149	1:51
Karlovy Vary – Kraslice	145	0:59
Kraslice – Cheb	145	1:19
Loket – Karlovy Vary	144/143	0:37
Karlovy Vary – Toužim	161	0:58
Sokolov – Nové Hamry	142	1:02

TABLE 5. Commuting times on selected routes.

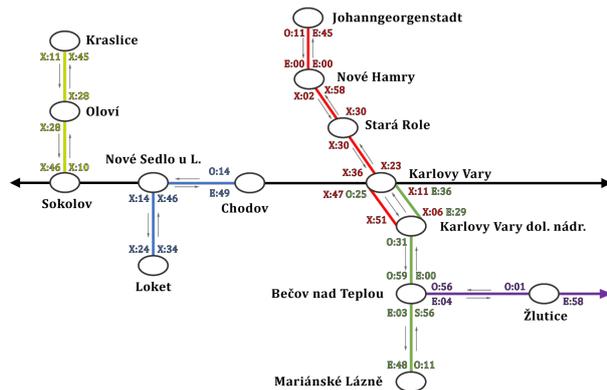


FIGURE 7. Output time positions for regional lines in the Karlovy Vary and Sokolov region.

further to Prague. Purple line is passenger trains outside the competence of the Karlovy Vary Region.

#### 4. DISCUSSION

The main impulse for the authors to write the article is the vision of the possibility of future use in solving the current dismal state of Karlovy Vary regional public transport. As the locations determined by the surroundings offered more possibilities for the intra-county routes, the authors explored all the possibilities that opened up and selected the system optimum, it can be said that the locations should serve as a basis for determining the number of vehicles needed and the creation of circulations.

The Karlovy Vary region currently operates modern rail vehicles, and at the same time, the change is so radical that the increase in passengers may be in the tens of percent on some routes (which are the values that both neighbouring regions achieve). Only after the implementation of periodic transport will it be possible to determine suitable vehicles for individual lines in the Karlovy Vary Region. However, the current frequencies are a sufficient guide to make an informed estimate of which routes have higher and which have lower potential.

At present, both neighbouring regions are dealing with traffic that directly affects their territory, but even passenger demand could increase on these lines due to appropriate measures. For example, if the connections from Teplá were linked to the connections to Plzeň, it is certain that the number of passengers

would increase here as well. Neighbouring regions cannot be interested and change the transport on the territory of a foreign region, but it is certain that the proposed measures would bring the Karlovy Vary Region closer to the position of an equal partner in public transport planning for regions that are currently among the best.

On the basis of the aforementioned – the article offers ways to improve the quality of rail transport in the Karlovy Vary Region. For even greater materialization of the proposed modifications it seems to be most appropriate to create related vehicle circuits and to determine the type of vehicles and to submit the whole proposal to the authorities responsible for transport in the Karlovy Vary Region, as there is no publicly available information on the performance prices on individual railway lines/train lines. These could show whether the set solution also brings any economic advantage. This article is followed by another article dealing with the integrated timetable in the north-western part of the Karlovy Vary Region: the transport connections Cheb – Luby u Chebu and Cheb – Hranice v Čechách (railway lines without numbers in Figure 1), which thus completes the regulation of railway transport in the Karlovy Vary Region.

#### 5. CONCLUSION

Most of the temporal locations that are presented in the text as research results are largely determined by the locations of the connections to which the investigated connections connect and which are anchored at nodes in the ITS in neighbouring regions and in Germany. It could be argued whether the proposed locations sufficiently respect the local conditions and whether the existing connections will not be disrupted? The answer here is two-fold. Firstly, the research and the very essence of periodic transport is to design transport in such a way that (among other things) the number of interchanges is optimized. This criteria is somewhat abstract in terms of measuring if the all possible transfer links are used. And in the end some transfer link isn't used as transfer because of null transport flows which are not publicly available. Second, except for railway lines 143 and 141, these are the backbone lines of the system (or lines that have the potential to become backbone lines), and for such lines, deviations in interval generally occur only at the extremes when travel times and transfer times are

shorter, or in the morning peak when surge demand must be accounted for. For railway lines 143 and 141 their nature is reflected and indicated.

#### LIST OF SYMBOLS

ICT Integrated Cyclic Timetable  
ITKV Integrated Transport of the Karlovy Vary Region  
ITPR Integrated Transport of the Pilsen Region  
ITS Integrated transport system  
MEC Municipality with extended area of competence

PT Public transport  
TRG Theoretical railway graph  
TÚLR Transport of the Ústí nad Labem Region  
PIT Prague Integrated Transport

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- [1] M. R. Bäumerstrasse. OpenRailwayMap. Germany, [2022-07-24], <https://www.openrailwaymap.org/>.
- [2] Správa železnic. Timetable for official use. Prague, ČR, 2000-2022.