



AN INTEGRATED TIME TABLE FOR RAILWAYS A BENEFICIAL SOLUTION FOR CENTRAL-EASTERN-EUROPEAN-COUNTRIES

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Abstract

There is a lot of discussion going on regarding the interoperability of the system railway, but preparations on internationally adjusted time tables or even networks are still missing. Especially the Central and Southeast European countries face comparable situations regarding limited distances between various cities and limited population in most of the cities with exception of the national capitals. Thus there is small place for high speed operation in these countries and far distance passenger traffic must be questioned under these conditions at all. However, in some countries facing similar conditions these constraints lead to a very successful implementation of integrated time schedules. The target of an integrated time table is optimizing travelling times mainly by reducing time for changing trains and thus allowing far distance passenger transport even in regions with low population density and a lack of mayor cities. To achieve reduced transfer time of trains, all trains need to be in the stations in the same time. This demand forms the main construction principle of integrated time tables. Within the presented paper an integrated time table for Eastern Austria, Western Hungary, Slovenia and Croatia is presented. It can be demonstrated that an integrated time table would be beneficial for the entire region, as travelling times can be reduced by a mix of optimisation of train schedules, upgrading of sections within the existing networks, and some network additions. Thus the integrated time table is the back bone for defining the demands for the future network.

The solution is finally discussed regarding its importance of the reduced travelling times and the demands for upgrading of some sections within the HŽ network, taken into account the existing and planned projects.

Keywords: railway, passenger transport, time schedule, international integrated time table

1 Introduction

Railway is a mass transportation system, as it can show its benefits in transporting masses of goods and/or passengers over long distances. In the following the focus will be on passenger transport.

Transportation of many people over long distances is economically as soon as it allows direct point to point transport on a high speed level. Thus there is a precondition for successful far distance passenger transport on rail: long distances between high populated agglomerations. Facing such conditions changing of trains becomes of less importance; the attractiveness and thus the success are based on high speed.

Consequently high speed operation started with Shinkansen in Japan, where 80 million of total 120 million inhabitants live in city areas on one single main corridor Tokyo - Osaka.

350,000 passengers are transported daily on one double track line, with train head times of down to 3 minutes on train speeds between 230km/h and 300km/h. Another well known example is the TGV in France, connecting major cities of the country over long distances with its dominating capital.

However, how to operate economically far distance passenger rail traffic in countries facing total different situations, as all of the smaller Central Eastern European countries do? Thus the French or Japan high speed solution must not be imported into these countries. Imagine a high speed railway system in Central Eastern Europe where trains do not stop in cities with less than a quarter of a million inhabitants and just in distances of 300km to 400km. Very few corridors would remain, in general connecting capitals of different countries. This cannot be a solution for these countries. By the way, these trains would need a network with radii of 5000m and more, another rather ambitious demand.

But there is a different system for an attractive passenger rail transport operated in several countries. And these countries are comparable with the Central Eastern European countries. Many relatively small cities spread all over the country, not just on one major line but in a pattern, with distances of 50km to maximum 100km in between. This system is called integrated time table, first implemented in the 1930ies in the Netherlands and forming the backbone of the famous Swiss rail transport system.

The attractiveness of an integrated time table is based on short travelling times, too. The reduction of the travelling times are achieved by optimising the changing of trains, as the structure of the countries and the number of inhabitants of the agglomerations do not allow offering direct trains between all cities. To achieve reduced transfer times, all trains need to be in the stations in the same time. This demand forms the main construction principle of integrated time tables.

2 Integrated Time Tables

Figure 1 shows the principle of an integrated time table based on a 1-hour service time. All trains meet at the full hour in the various stations. Some minutes after the full hour all trains leave the stations, after allowing the passengers to change trains. Some minutes before the next full hour all trains enter a station again. The time difference between the trains on one line, in the given example one hour, is called service time. One hour was chosen, as it covers the customer needs quite well and thus was selected in Austria, which is preparing its time tables towards an integrated one. Switzerland started with one hour service time as well, but switched in the last years to a half an hour service time due to its much higher population density north of the alps compared to the discussed area.

This main principle defines the travelling time between transfer stations and not the travelling speed. There is another specific point in time. After half of the service time, in the example after 30 minutes, trains pass one another. This again is a splendid situation for a transfer station, where again the trains from all directions enter the same station. Thus there are transfer stations possible after travelling times of a multiple of 30 minutes.

However, in practice it depends on the rail routes in a station, how many trains can enter the station in the same time. Normally quite a lot of trains meet in a transfer station. Thus the most important ones go into the station as the last ones and leave as the first, having the shortest time loss in the station, which is just defined by the time required for changing the train. Trains with a lower priority enter the station before the inter city trains and leave afterwards, giving the passengers enough time to walk to the transfer trains. To sum up: the more parallel travelling possibilities trains have to enter and to leave a station, the shorter the time loss of trains in the station will be. As all trains enter and leave stations in the same time, there are no trains close to a station using the opposite direction. Thus on double track line parallel train runs are an option for reducing station time of trains, towards the station before the full hour and from the station after the full hour.

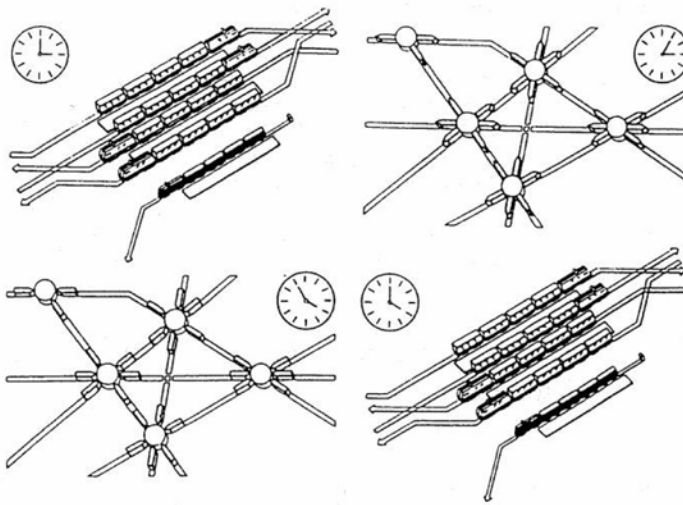


Figure 1 Principle of Integrated Time Tables

In practice integrated time tables are constructed not by an algorithm but by try and error. However, already in the 1990ies at the Institute for Railway Engineering and Transport Economy a mathematical model for calculating integrated time tables was developed based on the theory of vectored graphs [1]. Figure 2 depicts on a simple example this theory. To ensure all trains possible to meet every 30 minutes in stations, all possible train runs within a pattern of cities and railway lines must fulfil this demand. Within the theory of vectored graphs there are several train runs defined in circles, the basic ones (green), linear non dependent cycles (pink) and linear dependent ones (red).

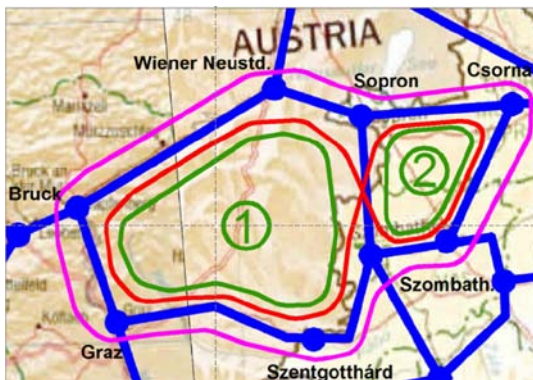


Figure 2 Theory of Vectored Graphs forming Cyclic Train Runs

This calculation model delivers numerous integrated time tables. Thus optimisation tools can be added for choosing specific ones. Within the discussed study the upgrading demand for the network was kept to a minimum to reduce infrastructure costs of implementation.

In the 1980ies the calculation was limited by the capacity of the computers, not allowing calculating integrated time tables for bigger networks. As these restrictions are overcome the presented solution could already be calculated automatically.

As depicted, an integrated time table defines travelling times between transfer stations to a multiple of the half service time, for the discussed network to a multiple of 30 minutes. This

travelling time includes waiting times in stations as well as time margins for time tabling. In the following chapter the characteristics are discussed for the study on an integrated time table for Austria, Hungary, Slovenia, and Croatia, based on a system time of one hour.

2.1 Pattern of Agglomerations

The main question is, if this pattern of possible transfer stations fits to the pattern of cities, taking into account trains on an attractive and realisable speed level.

In fact in mid of Europe the distances between most of the neighbouring cities is 50km or 100km. This distance obviously has historical reasons, as e.g. travelling times by horses, resulting in such a pattern of cities in the entire discussed region. There is just one main reason identified for different distances: the topography. In Austria there are just three cities, which do not fit into this pattern, showing shorter distances to the neighbouring ones. These cities were founded at meeting points of main trading routes following main valleys.

2.2 Train Speed - Costs

There is one main advantage caused by the 50km pattern. A distance of 50km fits to a travelling time of 30 minutes by an operating maximum speed of 160km/h. Analysing the relations between costs of operating trains on shared corridors it can be demonstrated, that these costs are not linear at all [2]. There are some speed ranges, with linear cost functions, e.g. from 120km/h to 160km/h. However, these linear sections are interrupted by dramatic cost discontinuities. In this regard 160km/h is such a unsteadiness, as train costs increase by overriding 160km/h for about 20% (!). Thus offering an integrated time table based on a maximum speed of 160km/h is very cost efficient.

Due to the characteristics of integrated time tables high efficiency regarding the train use and thus the train staff productivity is given.

2.3 Train Speeds-Market

A maximum train speed of 160km/h results in an average travelling speed of about 130km/h taking into account stopping time in stations and time margins necessary. 130km/h as average travelling time is significant higher than possible average travelling times on the road. Even on motorways an average travelling speed of 100km/h cannot be overridden.

Another positive effect is the easy way to remember such time tables from the customer's point of view, as all trains start either few minutes after the full hour or few minutes after the half hour.

2.4 Regional and Local Public Transport

Integrated time tables for far distance passenger trains (inter-city-trains) define the demand of the railway network in case of travelling times between stations. However, an integrated time table as back bone shows tremendous advantages for regional and local public transport systems independently from their transport mode. As all trains are in the station in the same time the additional regional and local transport can be organised efficiently. For example a bus service carrying passengers to the trains need to arrive at the station only once an hour, offering the passenger transfer to trains in all directions without waiting times. Thus the principle of an integrated time table is a precondition for an efficient regional and local public transport system, which then will be an integrated as well.

However, this needs cooperation of all stakeholders in the public transport market, but for their own benefits and the benefits of the customers.

2.5 Stations

This nice world of a totally integrated public transport system is based on transfer stations, overcrowded one time an hour. The rest of the time the stations will be rather empty. Therefore the requirements for stations are high, as all trains are there at the same point of time. Normally one platform is used by different trains over the time. Of course, double use of long platforms by short local trains is possible, depending on the turnouts and the signalling system. Within this peak minutes in the stations no freight trains must pass the stations. However, the rest of the hour the stations are empty, allowing freight trains to pass and even to stop in the station for being overtaken.

2.6 Strictness of the System

An integrated time table is a strict time schedule system. Thus it can form a “target railway network” for an entire region. Such a target network is the precondition for optimising the whole system railway but requires stability over time. The pro, allowing a target network has a con in common: it does not just allow a target network it requires a stable strategy. Thus changes of the time tables are limited. It is possible to change the service time from one hour to two hours or to 30 minutes depending on the demand during the day. But the main principle must not be touched.

Of course there is the possibility to run trains additionally to the integrated time table, some special trains on higher speed levels connecting big cities for example in the morning and in the evening, if the demand is given. These trains are point to point connections, and therefore do not need to be within the transfer stations during the transfer times. Thus travelling slots are available. However, this can be understood as an addition to an integrated time table, if the market allows operating such trains. In Austria on the Danube corridor such additional trains are operated.




However, there is one main problem regarding integrated time tables. Due to their constructive principle (all trains in the stations at the same point of time) allowing high efficiency of the use of rolling stock, train delays have very negative consequences. If a train enters a transfer station delayed, there are just two possibilities: either to delay all other trains, resulting into delays all over the network in a short time, or to force the passengers who wanted to change the train in the station to wait a whole service time, in order to limit the delay to the one train. Both solutions are not satisfactory at all. Therefore the margins for calculating the time table must be much higher than due to a standard time table. As normally 5% to 7% time margins are used, in case of integrated time tables a minimum of 10%, better 15% should be taken into account.

3 Integrated Time Table for Eastern Austria, West Hungary, Slovenia, and Croatia (ITT–CEE)

In figure 3 the main railway lines taken into account for calculating an integrated time table is presented, including the net additions of the Koralm-link in Austria and the Krapina-corridor [3].

This network was chosen due to its topography and characteristics in regard of population density. West of Austria was not taken into account, as no more relevant “cycles” occur; the Danube was taken as border line in Hungary, as only a few railway lines cross the river. Just now the possibility to enlarge the region towards south is studied.

As integrated time tables follow a strict mathematical calculation it is worth to enable the calculation delivering various time tables. In this case optimisation is possible, by choosing the result fitting best to the traffic demands. In order to enable the construction of various integrated time tables some definitions were set:

- 1  If transfer relations in stations are not required by the passengers they can be neglected. Therefore transfer possibilities in stations were classified (1: very important, 2: relevant, 3: less important). Less important transfer possibilities could be skipped, if the then resulting time table shows other relevant benefits.
- 2  If some stations do not fit into the pattern of the time table, these stations can nevertheless be transfer stations. Normally this situation leads to necessary increasing of travelling times or an enormous demand in upgrading. On the other hand a time table can be calculated without this transfer station (keeping it a station like in a standard time table) and both solutions can be compared.
- 3  If unrealistic upgrading demand on a line occurs a slight increase of travelling time can be accepted (first value: target travelling time, second value: difference to present travelling time).

Based on these definitions different integrated time tables have been calculated, allowing a step by step implementation [3]. However, within this paper the final one, originally step 3, will be presented.



Figure 3 Railway Network Taken into Account

3.1 Target Network based on an Integrated Time Table

Figure 4 and table 1 present as main result the travelling times within the proposed integrated time table. The travelling times are given from the starting point Zagreb.

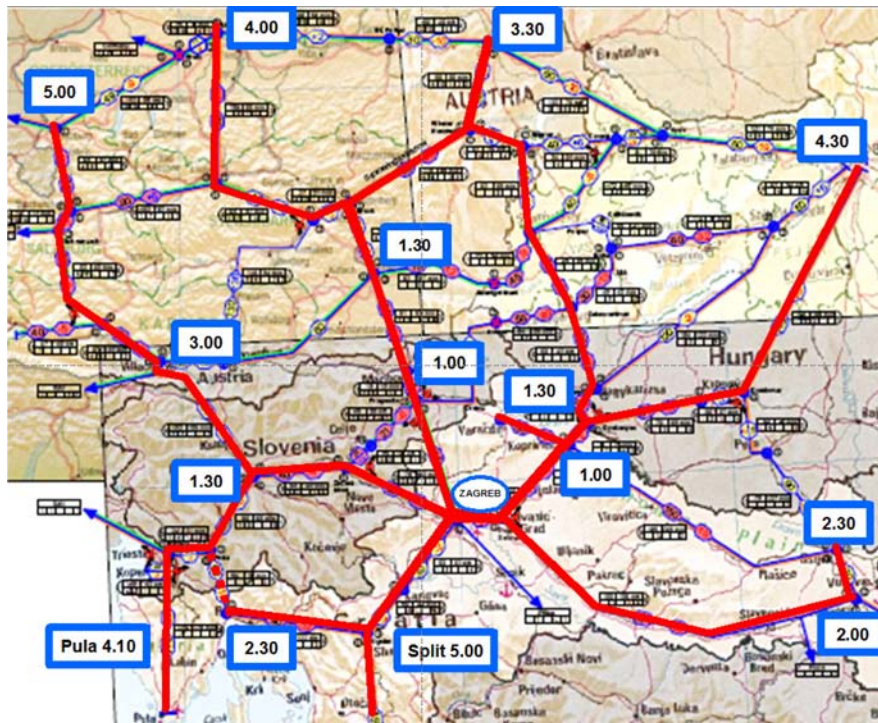


Figure 4 Main Travelling Times within an Integrated Time Table

Table 1 Travelling Times

from Zagreb to	travelling time [hours.minutes]
Vukovar / Osijek	2.00 / 2.30
Koprivnica / Varaždin	1.00 / 1.30
Budapest	4.30
Maribor / Graz / Vienna	1.00 / 1.30 / 3.30
Linz	4.00
Ljubljana / Villach / Salzburg	1.30 / 3.00 / 5.00

Within this final solution all major stations in Croatia due to figure 4 are transfer stations. Just one transfer relation cannot be offered, the changing of trains coming from Slavonia (Vukovar, Slavonski Brod) going to Koprivnica at the station of Dugo Selo.

3.2 Key Infrastructure Projects

There are some major upgrading and/or network additions which are relevant for the whole discussed region. Thus they have been identified as key projects for this target network:

- Austria: Semmering Base Tunnel and upgrading of the section Linz–Selzthal (Pyhrn-route)
- Slovenia: upgrading of the section Ljubljana–Maribor
- Croatia: new line Ogulin–Rijeka
- Slovenia–Croatia: Krapina corridor

The Krapina corridor (figure 5) has a specific importance within this network. On the Slovenian main line Zidani Most is a relevant transfer station, as well as Pragersko. Pragersko is too close to Maribor, thus it cannot be a fully transfer station. As long as Zidani Most needs to be a transfer station Celje cannot become a fully working transfer station, as the distance Zidani Most–Celje again is too short and an increase of travelling time on this Slovenian main line is not acceptable.

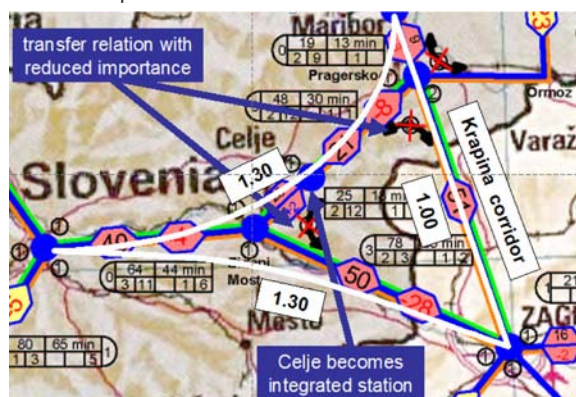


Figure 5 Krapina Corridor

Implementing the Krapina corridor these problems can be solved. The transfer relations in Zidani Most from Zagreb to Maribor as well as the transfer relation in Pragersko from Zagreb to Ljubljana are not relevant any more. This allows running two different trains each from each corner of the triangle Ljubljana–Maribor–Zagreb; from Ljubljana towards Maribor and Zagreb, from Maribor towards Ljubljana and Zagreb, and from Zagreb towards Maribor and Ljubljana. Thus the travelling time from Ljubljana to Maribor can be reduced to one and a half hour and Celje becomes a transfer station. On the other hand Zidani Most and Pragersko need not to be transfer stations for inter-city-traffic any more. However, a high demand of travelling time reduction occurs for the section Zagreb–Zidani Most.

4 Relevance of the Described Target Network for Croatia - Infrastructure plans on HŽ network

The operating condition of the permanent way and track maintenance activities have great influence on the regularity of railway traffic and on the realisation of the planned transport effect. Knowing the technical operating condition of the capacities and purposeful planning of activities aimed at maintaining balanced transport capabilities of the whole railway network and the required safety level have great importance for normal functioning of the railway traffic and its competitiveness in relation to other traffic systems.

Such an approach is the technical and technological base for producing a cycling time table for the CEE region. The whole system can be used as base for planning technical parameters to produce a timetable, but also for defining and planning of infrastructure demands, as

capacity, within the international railway corridors where transport is planned from a single railway infrastructure management centre.

Regarding the study on an integrated timetable for the CEE countries that means coordinated activities in the infrastructure sector, in order to achieve main technological targets for providing efficient passenger traffic on analysed parts of the Croatian railway network.

In order to make quality recommendations, analysis of current plans in modernisation and restructuring of monitored part of Croatian railway infrastructure have to be done in order to find out how they are corresponding with the proposed timetable for passenger traffic services.

The first key issue is the station Zagreb Gk where upgrade and reconstruction on station section and upgrade for passenger suburban traffic is needed. According to plans of Croatian railways it should be done between 2011 and 2012.

Parallel with this project in station Zagreb Gk upgrades for international traffic and safety of railway traffic are necessary regarding upgrade of signalling and safety devices, caused by the actual deterioration level. Croatian railways planed to accomplish this for the time period 2008–2010.

The third project which is also very important for the analysis, is the construction and upgrading of passenger train stops for urban/suburban traffic in Zagreb railway junction.

This should be done on the following lines:

- 1 Savski Marof (NB) – Zagreb Gk) – Dugo Selo) – Novska,
- 2 Zagreb Gk) – Novska,
- 3 Botovo (NB)) – Dugo Selo and
- 4 Zagreb Gk) – Rijeka in the area of railway junction Zagreb.

Croatian railways planed to accomplish this between 2008 and 2020.

Because of the need to upgrade conditions for international traffic, demands for town development and increased capacity in Zagreb railway junction are necessary. This includes the construction of additional tracks and lifting of railway lines in the downtown area (4 x 6.3km) including the upgrade and renewal of the signalling and safety system. This should be realized on several lines:

- 1 Savski Marof (NB)) – Zagreb Gk) – Dugo Selo,
- 2 Zagreb Gk) – Novska,
- 3 Zagreb Gk) – Rijeka in the area of station Zagreb Gk.,

Realisation time should be 2018 to 2023.

In addition there are another two very important projects. The first one concerns town development and capacity is construction of new double track line bypass around Zagreb for freight traffic (2 x 64km) and connection tracks with other lines (8 x 0.63xkm). This new freight line bypass Zaprešić - Dugo Selo should be realized between 2013 and 2016.

The second project concerns the construction of new technical stations and facilities for passenger rolling stock in Zagreb railway junction. These stations and facilities for passenger rolling stock and a new cargo terminal should be realized in the years 2013 to 2015.

Beside all those necessary activities and projects in Zagreb Gk. and in Zagreb railway junction there are projects that should be realised in order to the strategic goals for an integrated time table. These projects concern the Xa corridor connecting Zagreb and Graz via Maribor.

In technical and technological terms this line can be divided in three parts in Croatia:

- 1 Zagreb) – Zaprešić,
- 2 Zaprešić) – Zabok and
- 3 Zabok) – Đurmanec.

For the first part of the considered line the planed projects have been already mentioned. The second part between Zaprešić - where the Xa corridor actually begins - to Zabok, shows a single track line, non-electrified with a poor traffic control system, the train speed is around 60km/h only. On the third part from the station Zabok to the station Đurmanec there is a

single track line as well, also non-electrified with an old traffic control system. Train speeds vary between 60km/h (Zabok) – Krapina) and 20km/h (Krapina) – Đurmanec). For the existing line between Zagreb and Krapina the construction of a second track is taken into consideration, as well as an electrification of the line with 25 kV/50 Hz. With the realisation of those measures on the Zagreb) – Krapina line, the new connection to the Slovenian border can also be realised.

5 Conclusion

The discussed integrated time table shows the benefits by accorded investment in the railway networks of the entire discussed countries. Thus an integrated time table allows formulating a “target network”, especially for the CEE region. This idea insures far distance passenger traffic in this region, not only for connecting some few bigger cities, within acceptable train speeds. Further benefits occur of course for regional and local traffic.

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