

PERIODIC TIMETABLE-MAP FOR THE HUNGARIAN RAILWAY SYSTEM BY THE ADAPTATION OF THE EUROPEAN STRUCTURE

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Summary: A modern intermodal timetable structure relies on three basic factors: the periodicity, the symmetry and the everywhere-to-everywhere connection system at the network nodes. In the first part, the paper defines the role of these factors in an integrated timetable structure and presents the standard values for the parameters used in the united European timetable structure. The second part presents the basic requirements and some details of an adaptation of the united European structure for the Hungarian railway network.

1. Introduction

As early as in 1960s, most railway companies of Western Europe had to face with formidable decrease in the passenger transport, due to the dramatic shift towards private vehicle use. The development of transport infrastructure has concentrated on motorways while the rail network has remained more or less unchanged. As the number of cars increased and the motorways spread, public transport regressed or in some places – even ceased. Due to the lack of competitive innovations and investments, most state railway companies were inert, not being able to cope up with individual transport.

Some railway companies had various solutions for the problem. However, these solutions required such costly infrastructure and rolling stock investments, that not all countries could afford them, not even in Western Europe.

In 1972, three young Swiss engineers came with the idea of a revolutionary new public transport system, which was based on a symmetric, regular interval timetable structure, which is now called “ITF⁴”. The greatest advantage of the new system was that it was able to provide new, attractive passenger services, without requiring expensive investments.

Although periodic timetables were introduced in the suburban traffic of many European countries as early as 1960, the ITF system is much more than periodic easy-to-remember timetable with frequent services. The ITF means a complex network-wide periodic

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⁴ Integrierter Taktfahrplan: Symmetrical regular-interval timetable. Also known as „Intelligent Timetable”, or „Clockface schedule”.

timetable structure with systematic and symmetric connections, covering every layer of the public transportation system.

The first real ITF system was introduced in Switzerland, on the network of the SBB⁵ on 23rd May 1982, with a motto “One train in every hour”. The new system provided 21% increase in the number of train services, with only 4% increase of costs. The introduction was followed by great success, since railway passenger traffic has grown by more than 40% in long term, and still increasing [3].

Nowdays, ITF is spreading through Europe. United, international ITF system covers and interconnects many countries of Europe, like Switzerland, Germany, Austria, the Benelux states etc.

It is a positive fact, that the Hungarian and other new EU member state railways are lucky, since ITF has now proven its efficiency in practice. So, the chance is given to adapt it in order to interconnect the railway networks in an attractive way, at the earliest convenience.

In the following sections, we will go through some details of an integrated timetable system which can be the backbone of a Hungarian ITF. It is important to note that the demonstrated periodic-map can be realized on the spot, without significant infrastructural investments. A special adaptation of the ITF will be put into operation in the northern suburban area of Budapest by 13th June 2004, as a pilot project.

2. Principles and definitions

In this section, we will go through the most important rules and definitions needed to build up a modern ITF-system. The ITF relies on three main factors: the periodicity, the symmetry and the optimized connection-system at the network nodes [2] [3].

2.1 Periodicity

First of all, let’s see the explanation of the periodic timetable from the aspect of technology. In case a T term can be found wherein each adjacent $s_i(t)$ and $s_j(t)$ ⁶ path-pairs of the same path type mask each other by shifting the same τ_{ii} value, the paths are periodic.

$$\frac{ds_i(t)}{dt} = \frac{ds_j(t)}{dt}; t \in T; \exists \tau_{ii}, j, \forall i \Rightarrow \mathbf{s}_i(t) = \mathbf{s}_j(t \pm \tau_{ii}) \quad (1)$$

*where T means the validity-term of period-structure
 τ_r means the value of periodicity*

In case if there is a homogeneous line (with only one train path type), and the headway is identical between any arbitrary chosen adjacent path-pairs, the line has a periodic timetable, irrespectively of the value of periodicity. In this context, the value of τ_r could be as well 37 minutes, 24 hours or any other extremity.

The same principle can be applied to a line with heterogeneous train services, but there have to be equal τ_r for each train types.

⁵ Swiss Federal Railways

⁶ $i := 1$ to $n-1$ and $j := 2$ to n

2.2 Symmetry

Connections, travelling times and station stop times can be symmetrically built up for the outward and homeward journey of any connection. This means that if an optimal connection has been set up for the outward journey, the corresponding timetable slot can also be filled with a train path in the reverse direction, as a matter of principle.

This means that in case the system is symmetric, we can find a t_s symmetry-axis for each path-pair, which can be calculated as the average of the departure time pairs at any station:

$$\forall i \exists j; \frac{ds_i(t)}{dt} + \frac{ds_j(t)}{dt} \equiv 0 \Leftrightarrow s_i(t + \tau) = s_j(t - \tau) = t_s \quad (2)$$

where t_s means the symmetry-axis

τ means the duration from/to the symmetry-axis, along the time axis

When the complete daily timetable chart is symmetric to a common axis, there is the global symmetry-axis (typically at about early afternoon). Moreover, there can be several local symmetry-axes within every basic period.

2.3 Spiders

The optimal connections at interchange-stations are crucial for an ITF, since keeping the connection times low is the cheapest way to reduce journey times. This requires that in a connecting terminal all trains meet always at the same time to enable the passengers to change between all lines. The name “spider” of such a sophisticated connection system comes from its typical graphical representation: if we plot the traffic diagram at an interchange-station, the diagram will resemble the contours of a spider (Figure 1).

In a station with interchange-spiders at every period, trains arrive and depart in the sequence of their gradient from/to each direction.

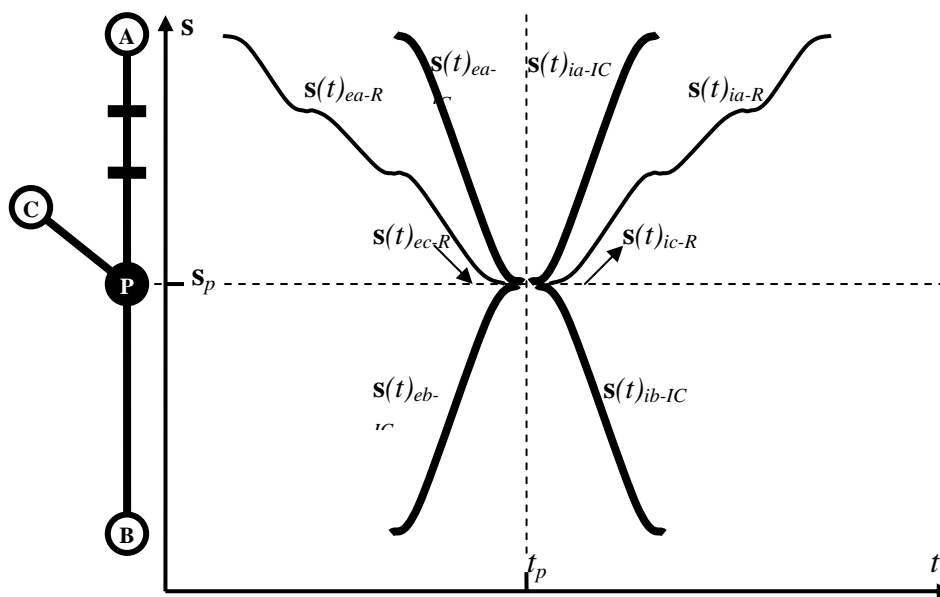


Fig. 1. Classic interchange-spider with arriving (index: e) and departing (index: i) trains from/to station A (index: a), station B (index: b) or station C (index: c) as type InterCity (index: IC) or regional (index: R)

e.g. Direction A:

$$\frac{ds(t)_{ea-R}}{dt} \leq \frac{ds(t)_{ea-IC}}{dt}; \max\{Ran[s(t)_{ea-R}]\} \leq \max\{Ran[s(t)_{ea-IC}]\} \quad (3)$$

furthermore

$$\frac{ds(t)_{ea-IC}}{dt} + \frac{ds(t)_{ia-IC}}{dt} \equiv 0; \quad \mathbf{s}(t - \tau)_{ea-IC} = \mathbf{s}(t + \tau)_{ia-IC} = t_p \quad (4)$$

where t_p means the spider-time axis

For example, before the “spider-time” the slowest (*Regional*) train-types arrive first, which are followed by *InterRegio* and *InterCity* trains (3).

It is obvious that at the interchange-station, periodicity of the t_p spider-time axis is τ_r or $n\tau_r$, depending on the interconnected periodic schedules’ basic periodicity.

In case the timetable is not only periodic but symmetric as well, the t_p spider-time axis has a definitive position (5), which makes the planning of an ITF system easier.

$$t_p = \begin{cases} t_s + n\tau_r \\ t_s \pm \frac{\tau_r}{2} + n\tau_r \end{cases} \quad (5)$$

2.4 Parameters of ITF

ITF is just an application of the principles presented above, with properly selected values of the parameters. Different types of traffic (regional trains, long-distance passenger and goods trains) can be operated in the same system, respectively harmonise with each other, because built-up according to the same systematics. This means that it is possible to create CAD software tools which can be used to efficiently build up an ITF structure on a network [5].

The basic parameter values of the international ITF system are:

- i. $T := 5:30..22:30 \pm 2$ hours,
- ii. τ_r [minutes] := 120, **60**, 30,
- iii. *global symmetry-axis* := theoretically 13:59 \pm 5 minutes,
- iv. *transfer time* := 1.**4**..29 minutes.

ad i. These values are used for the long-distance traffic, which forms the basic structure of the ITF. Especially for suburban traffic, the situation gets somewhat more complicated when we take the daily and weekly distribution of passengers into consideration (Figure 2).

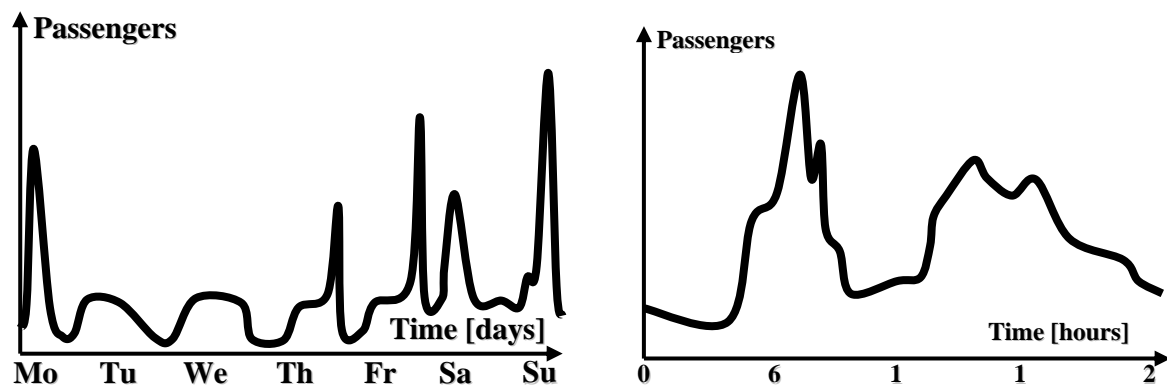


Fig. 2. Typical daily and weekly distribution of passengers. (Source: Hungarian State Railways)

To eliminate congestions, auxiliary structures must be superponed to the basic structure in the peak hours, but these supplementary structures must not cause any distortion to the basic structure.

ad ii.,iv. The period of the base-structure is usually 60 minutes, which can be increased to the absolute maximum value of 120 minutes on lines with low passenger traffic. Period values above 120 minutes are not allowed.

The service frequency can be increased to 30 minutes or any other submultiples of 60 minutes. However, a structure with periodicity less than 20 minutes is not a real ITF, as there is no need to harmonise the connections.

ad iii. The global symmetry-axis is not as important as the local axes (which can also be derived from the global axis). Local axes can be positioned at $-:59$ by hourly period or 59 minutes past every odd hour (betoken: $o:59$). Depending on special local features, this value could fluctuate from line to line, but with only with a maximum of some minutes.

3. The adaptation

The nearest spiders where the Hungarian system can be connected to the European one are in Vienna and Wiener Neustadt. These were the starting points where the timetable-map for Hungarian Railway System was built up from.

3.1. Requirements

Basic requirements of the Hungarian ITF system are as follows:

- periodicity of 120 minutes on 90% of the network in daytime,
- persistent and optimal (3 to 20 min.) connections at all network nodes,
- optimal technology to minimize waste-time (especially the crossing times) and
- minimal infrastructure investments.

3.2. Types of train paths

The system consists of 9 types of trains in three groups:

- I. Long-distance (interregional) trains
 - **InterCity/EuroCity (EC/IC)** – the prime basic type in every 1 or 2 hours
 - stops only in larger cities with spiders
 - minimum 90 km/h average-speed (except for the Balaton-lines)
 - **InterRegio (IR)** – secondary basic type in every 1 or 2 hours
 - stops only in larger towns or network nodes with spiders
 - **InterPici (IP)** – special complementary service for **IC/IR** trains on branch lines
 - stops only in cities and towns or network nodes with spiders
 - **RegioSprinter (SPR)** – special complementary service for **IC/IR** trains
 - stops only in stations with significant passenger traffic or network nodes with spiders
- II. Direct trains (D)
 - traditional long distance trains with direct coaches,
 - four times a day, at about every 6 hours (even late night).
- III. Regional trains
 - **Regional trains** in every 1 or 2 hours (connections to/from long distance trains),
 - **Suburban trains** every hour or more frequently.

3.3. The system

As seen on Figure 3., Starting from Wiener Neustadt and Wien, according to the principles of the ITF, the basic structure of the national symmetrical, regular timetable was built up by “spreading” the system from West to East.

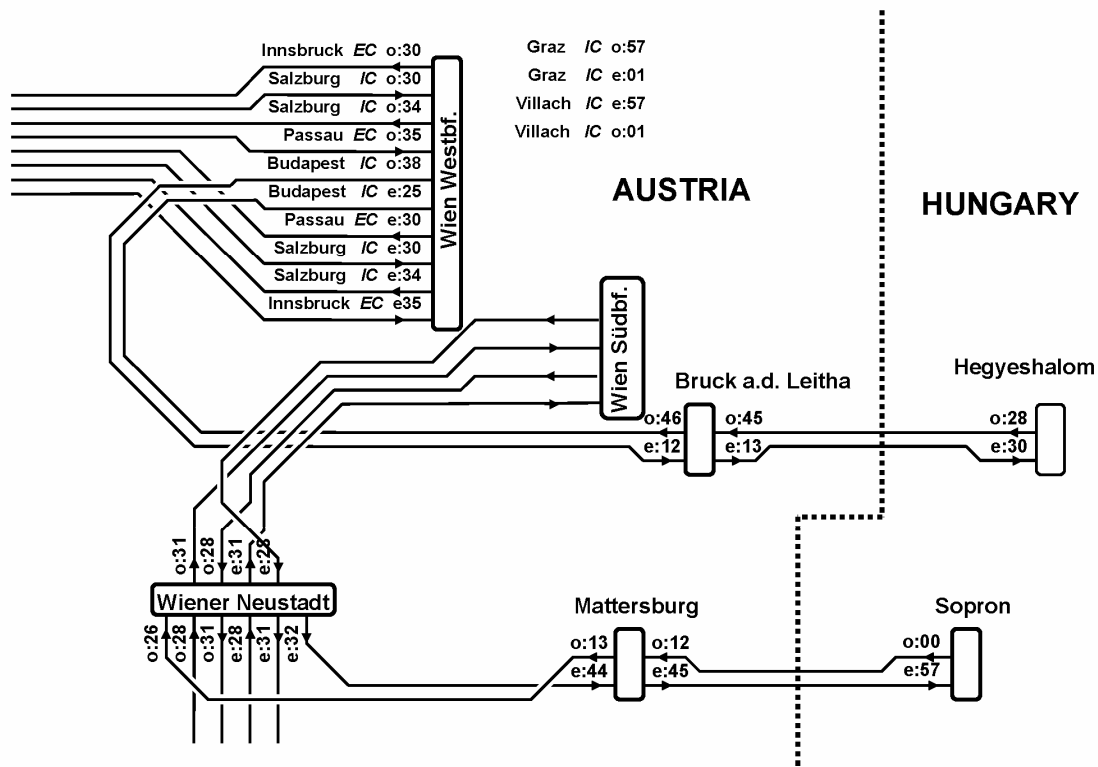


Fig. 3. Connecting the Hungarian timetable structure to the European ITF

As we moved towards East, paid even more attention to take the current infrastructural conditions as basis everywhere. A section of the final map is shown on Figure 4.

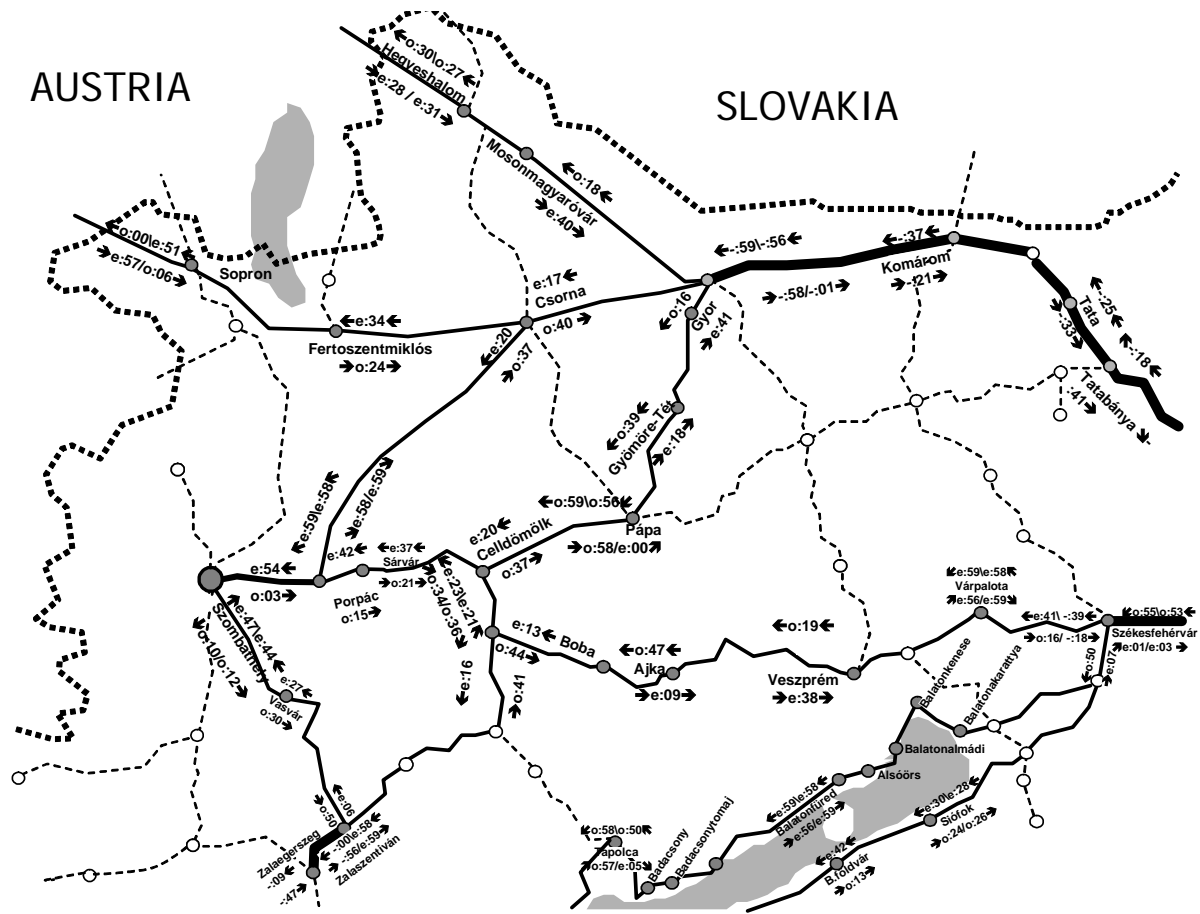


Fig. 4. The final map, showing North-Western Hungary

4. Conclusion

However the ITF system has proved its efficiency in many Western European countries, we still had to manifest that the introduction of the system would not require expensive infrastructure investments and would not cause significant increase of operation costs.

To give evidence of this, an adaptation of value analysis was used [6] for the suburban ITF pilot project mentioned earlier. We pointed out the fact that an ITF system can be implemented on any network, regardless the infrastructural conditions and limited resources. This means that there is room for service improvements everywhere, even with poor financial background.

Since the application of ITF shows both the bottlenecks and spare capacities (e.g. unnecessary crossing stations) of the network, it must be the basis of long-term infrastructure developments in the future.

5. References

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