TIMETABLE BASED RAILWAY INFRASTRUCTURE DEVELOPMENT ON THE HUNGARIAN RAILWAY NETWORK

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Abstract: *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 presents the principles; afterwards it defines the role of these factors in an integrated timetable structure and presents the standard values for the parameters used in united European timetable structure.*

Public transport in the Central Eastern region of Europe currently faces a situation very similar to Western European experiences from the 1970ies onwards. Yet this current "curse" can be viewed as a "blessing" as we are now in a position to select, as a point of depart towards progress, the most suitable, tried and tested method from amongst a number of approaches.

Keywords: *economic public service, regular interval timetable*

1. INTRODUCTION

Some decades ago most railway companies in Western Europe - due to the dramatic shift towards car use - had to face with formidable decrease in the passenger transport. The development of transport infrastructures 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 developed several solutions for this problem. However, these solutions required such expensive infrastructure and rolling stock investments, that not every country could afford them, even in Western Europe. Some others came up with the idea of a revolutionary new public transport system, which is based on a symmetric, regular interval timetable structure. The greatest advantage of the new system was that it was able to provide new, attractive passenger services, without requiring expensive investments.

In the first part of the article I introduce the main attributions and the Hungarian experiences concerning the regular interval timetable. In the following part of the article I describe the principles and the mathematical background of the timetable based infrastructure development, and I will present some examples as well as from Hungary and from other countries.

2. POSSIBLE APPROACHES

The French Model

Main characteristics:

- Operating only "fully" trains
- Keeping passengers by expensive rolling stock and infrastructure developments
- Preferential approach – market segmentation
- Using high speed networks (TGV)
- Procreating hyper-modern suburban system (RER)

The Swiss Model

Main characteristics:

- Since 1982 a regular timetable designed to meet peak period demand is maintained all day and all week long.
- In 1982 to begin with, the Swiss had some of the oldest (but well maintained) rolling stock in Western Europe.
- Relatively low speed on main lines (80-140 km/h).
- Between 1982 and 1992 only isolated infrastructure developments took place with minimal costs, geared to service needs in harmony with the timetable.
- A national transport scheme with broad inter-modal cooperation based on the integral timetable which includes bus and city transports.

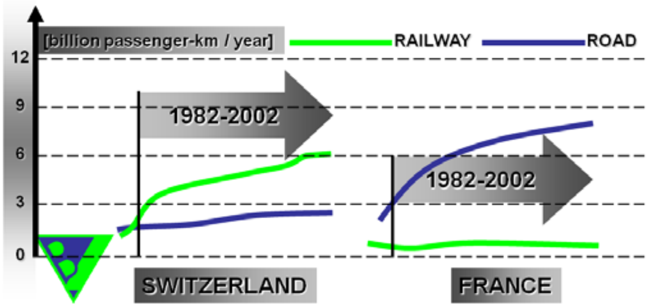

Figure1. Transalpine traffic

3. THE SUGGESTED APPROACH

Being efficient is essential in all fields of life. The infrastructure investments are one of the most expensive issues of the national budget. Naturally it is an essential requirement to spend the limited sources in the most effected way. From my point of view the best way to plan and prioritize the infrastructure investments is taking into consideration the bottlenecks in the line capacity and the timetable.

The suggested procedure is called timetable based infrastructure development thus the Swiss model. It means that we should focus on those parts of infrastructure where it is essential to reduce some minutes in the running time of the trains. Anyway we should continue the “big projects”, when a relative long line section going to be fully upgraded, but in this case we also have to take into consideration the needs of the timetable, and increase the allowed speed, or plan second or third track where it is required form the timetable point of view.

3.1. Short description of the regular interval timetable system

There are three basic requirements which have to meet the regular interval timetable:

- It has to be symmetric;
- It has to be periodic;
- It is based on connections;

The fourth main rule is that the running time between the junctions has to be less than 30 or multiple of 30 minutes. This rule is obtainable from the symmetrisation as the arrival to the junction has to be just before xx:00 or xx:30. When a train can not fulfil this essential requirement than it will impossible to ensure the quick connections for the passengers.

From my point of view the regular interval timetable and the timetable based infrastructure development are the only one chance to reverse the unfavourable trend of the modal split. Unfortunately today the tariff of the passenger transport is constantly increasing and the quality of the service is stagnant or decreasing. Foe this reason more and more people use the car instead of the public transport. The main objective of this article is to describe one approach solving this problem, and ensure a quality service by using the available sources.

The introduction of the regular interval timetable does not need a significant extra cost as the percentage of the fix cost at the railway industry is almost 90%, so 10% increasing of the traffic volume costs only 1% more.

From operational point of view there are also many advantages. As the timetable is symmetric, we do not need to run empty “ghost” trains on the network. The “spiders”[1] can be only at xx:00 or xx:30, so the staff in the intermediate time are not very busy.

From user point of view it is also very comfortable that the trains depart in every hours in the same time and the changes average changing time is less than 10 minutes, so the whole journey time can be reduced significantly.

4. THE MAIN OBJECTIVES OF THE REGULAR INTERVAL TIMETABLE

The most important aim is to ensure the shortest journey time for the passengers in the public transport. That means not only the railway traffic but all of the public transport modes. It is needed to construct several intermodal junctions throughout the country and it is also essential to harmonize the timetables of all transport modes. By these arrangements there will be surely a competitive public transport.

In a current Hungarian setting even the most carefully prepared and executed reduction of train services will typically result in a loss of passengers, though one might suspect an improved efficiency resulting in a cut in costs to a greater extent than causing increased costs elsewhere. A further loss in passengers is detrimental to EU transport policy and principles of sustainability. In the French Model, in order to gain passengers the attraction of those services which are maintained must be significantly increased by means of extremely costly development of infrastructure and rolling stock. The results:

- Rising passenger numbers in the preferred segments – partly to the detriment of traditional segments (cannibalization)
- Further decrease of the share of the entire rail transport within the sector
- Ever more costly railway systems next to an increasing measure of state budget commitments.

It is interesting to compare transalpine traffic in Switzerland and France (Fig.2) despites, the model called French here is no longer consistently applied on the French railway market, and naturally we meet such demand driven service models elsewhere. SNCF have adopted a regular interval timetable structure on some of their partial networks.

4.1. The principles

Let we see what is this Regular Interval Timetable (ITF) anyway? Not more but not even less than a standard, for organizing effectiveness transportation system. In this section, we will go through the most important rules and definitions needed to build up a modern ITF-system. The regular interval timetable relies on three main factors: the periodicity, the symmetry and the optimized connection-system at the network nodes.

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 $s_j(t)$[2] path-pairs of the same path type mask each other by shifting the same τ_{ii} value, the paths are periodic.

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

where:

$T -$ *the validity-term of period-structure*

τ_{ii} *– the value of periodicity*

In case 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_{ii} could be as well 37 minutes, 24 hours or any other extremity.

[1] The spider means the encounter of the trains at a station. This name comes from the graphic timetable as the train paths stand out a picture like a spider in the junctions. The detailed description is given chapter 4.1.

[2] $i := 1$ to $n\text{-}1$ and $j := 2$ to n

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

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:

$$\forall i \exists j; \frac{d\mathbf{s}_i(t)}{dt} + \frac{d\mathbf{s}_j(t)}{dt} \equiv 0 \Leftrightarrow \mathbf{s}_i(t+\tau) = \mathbf{s}_j(t-\tau) = t_s \quad (2)$$

where:

t_s *– the symmetry-axis*

τ *– 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.

Spiders

The optimal connections at interchange-stations are crucial for an ITF, since keeping the connection times low is the cheapest way to significantly 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 sophisticated connection system comes from its typical graphical representation: if we plot the traffic diagram at an interchange-station, the diagram resembles the contours of a spider. (Fig.2)

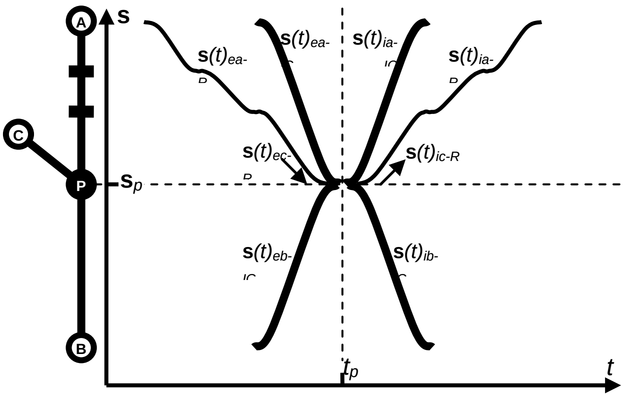

Figure 2: Classic interchange-spider with arriving (index: e) and departing (index: i) trains from/to station A (index: a), station B (index: b) or station C (index: c) as type InterCity (index: IC) or regional (index: R)

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

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

<u>*Direction A:*</u>

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

furthermore

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

where:

t_p *– the spider-time axis*

Similarly to B and C

It's 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 just 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.

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

5. REGULAR INTERVAL TIMETABLE IN HUNGARY: EXPERIENCES AND POTENTIAL

The Hungarian regular interval timetable pilot project was established in 2004 in the Danube Bend region north of Budapest, a system of regional and so-called zonal trains running to a regular schedule. A 30% performance increase of the existing rolling stock was realized next to a cost increase of a mere 0,4%.

Due to the great success of the pilot project, in 2006 ITF system was (slightly diluted by the Ministry of Transportation but at least) adopted (only) for the north-eastern part of the country as a first step for extends a regular timetable to the entire country.

Table I.: First year results. There was a price rising (in 3 steps, together on average 30% rise) during the year

RESULTS	OTHER (NOT ITF) LINES	ITF LINES
NUMBER OF PASSENGERS	**-11%**	**-2%**
INCOME	**+15%**	**+31%**

It was planned the extension for the whole network the next year, but unfortunately this step was adjourned sine die due to political exigencies restricting performance. In 2008 and 2009 on some additional lines have been introduced the new timetable system (as a part of the yearly timetable-change procedure), but the needed exhaustive reorganization (like in the north-eastern part of the network) is still waited for. The network's partly developed statement and other external and internal factors dimmed the positive effects of the Hungarian regular interval railway timetable, such as a severe rise in ticket prices, a lack of regional transport schemes and truly integral inter-modal timetables etc. Even so, summarized we found the prosperous way for future by integrating our public transportation system by the rules of regular interval timetable in Hungary like in Switzerland or the Czech Republic.

Presently on a national network level contradictory tendencies prevail. While in the Danube Bend and in other areas a timetable with regular intervals is in force this has not been extended to the entire network and some hourly services e.g. in late morning were suspended because of the constraints of cost limitations which is still believed by some to be basically achieved by performance restraints. Meanwhile even the available poor statistical data clearly shows the results of several attempts at a performance cutback.

Summing up the aggregated performance function of costs and revenues in a manner true to measure we will get the business result (profit/loss) of the activity of passenger transport. Except for a few operators working with a regular integrated timetable passenger railway companies operate with losses throughout Europe, it is therefore reasonable to first and above all look at the performance function of business losses (Fig.3).

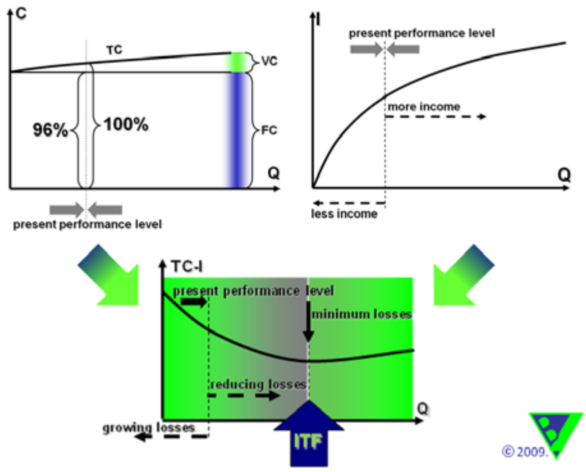

Figure 3.

Total costs (TC) in railway transportation include mainly fix costs (FC) and a marginal part of various costs (VC). On the other side it is always much more difficult to find new passengers (by increasing performance level) than lost them (by decreasing performance level). Aggregating costs and incomes (I) we could find the minimum point of deficit by developing regular interval timetable system.

At their present level of service a further performance reduction appears to threaten the very raison d'être of basic MÁV activities. It is a candid task to gain back passengers that railways have lost or are about to loose, let alone to become attractive to new potential passengers. The goal of a railway company operating in a rational manner should be to establish the point of minimal losses and attain it by reaching an optimal level of services. Regular interval timetable if consequently applied as "software" for operations appears to warrant such a level of service, it allows operators to maintain a level where the value of marginal revenues is in excess of marginal costs.

If looking at the local potential of regular interval timetable, companies must take care to operate the regular interval timetable system in a reasonable way given the local infrastructure situation, as well as mentalities, traditions and organizational structures which it is not always possible or appropriate to change. Nevertheless we put up the questions which transport policy and corporate measures (legal and institutional background, integral tariff system) would be suitable and necessary in order for regular interval timetable to exert all its benefits in view of an optimal cost and size proportionality.

6. PRINCIPLES OF THE TIMETABLE BASED INFRASTRUCUTRE DEVELOPMENT

Take into consideration the spiders, it is essential to ensure the required journey time between the hubs. When the running time is more than it would be necessary, than the trains have to wait in the station until the next spider, which is 30 or 60 minutes later. In this case the regular interval timetable would cause disapproval from the travelers as the whole journey time would be not less moreover sometimes longer than earlier. To avoid this social tension we have to create an absolutely clear and transparent system and generally quicker service than before.

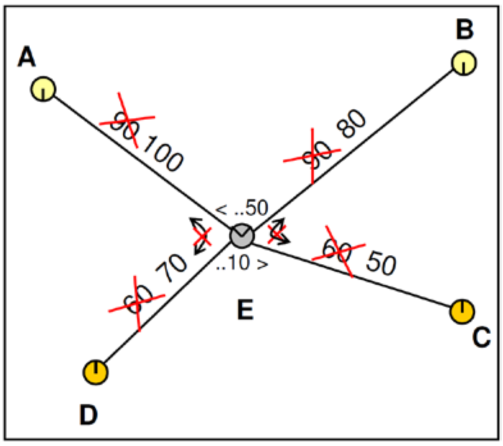

Figure 4. Adequate and ineligible running time between the hubs

Not only the quality of the service can be improved by the described method, but the following issues can be also enhanced:

- capacity allocation;
- traffic management;
- track and vehicle maintenance;
- rolling stock and staff circulation;

As the first step we should work out a long-term development strategy using the experiences of the regular interval timetable. After that the network should only gradually improved, only where it is crucial, in a very cost-effective way. In Switzerland for example an extremely rational infrastructural investment was conducted at low cost between 1982 and 1992. More than a decade later, in 2004, using the synergy of mainly local improvements, a radical change was implemented in the basic structure of the timetable. Keeping the rules of regular interval timetable, service quality has been significantly improved. Connection times have been reduced, more stations could be accessible without significant increase of the journey time.

In Switzerland the second included capacity increase of high-speed railway traffic, and railway infrastructure. The goal is to provide an infrastructural network that will be uniquely able to enhance the competitiveness of railway transportation. The long term planning stage, lasting until 2030, allows the government to implement the necessary funds into the budget.

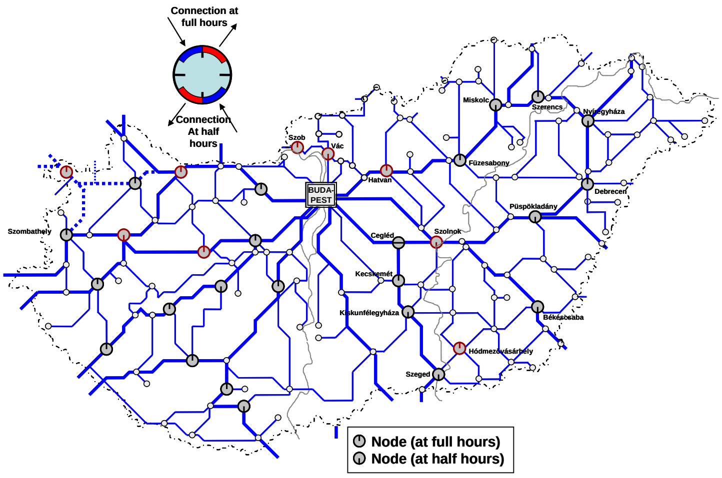

Figure 5. Map of the main nodes in Hungary

In Hungary there are several nice examples. The first "pilot project" was established in 2004 the in the northern suburb of Budapest (described in chapter 5). There are two lines, one of them is Budapest – Vác – Szob, and the other van is Budapest – Veresegyház – Vác.

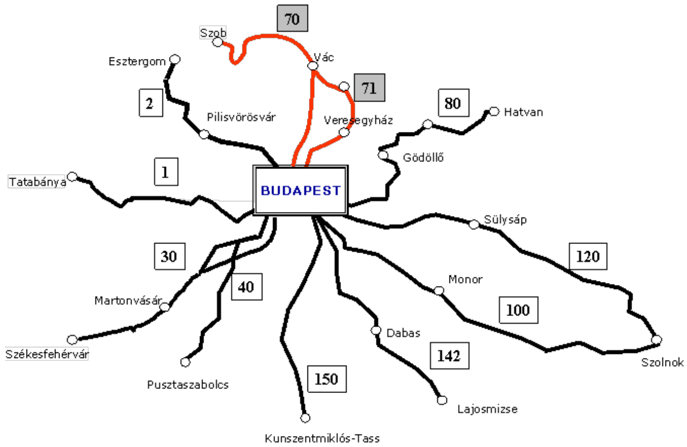

Figure 6. Suburban network, pilot project-lines no. 70 and 71

With reference to the success of the project above, value analysis should also be necessary for the further developments in order to achieve quick and resourceful improvement. As the first step the new system was peaceable using the existing rolling stock and staff.

During the described suburban pilot project many experiences were gained which supported the forthcoming timetable and infrastructure development plans. We used this knowledge not only in the suburb of Budapest but the new approach has covered the whole country.

Connected to the railway line development we have also worked out a strategy for the modernization of the hubs, which is called intermodal stations.

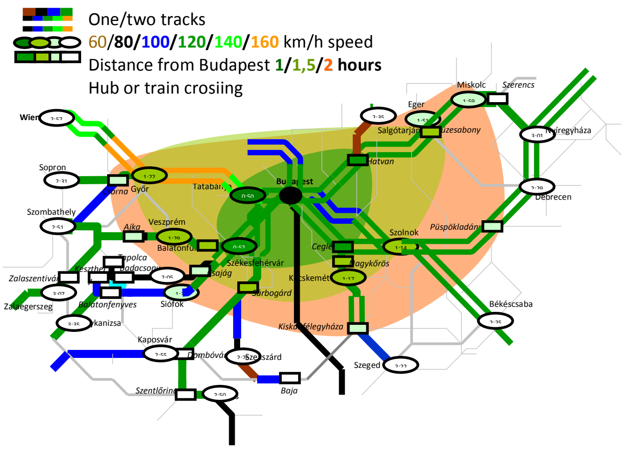

Figure 7. Main infrastructure parameters

The figure No. 7 contains only the long distance lines including Budapest and the capitals of counties as well as the main centres of regions. (Sopron, Nagykanizsa and the area of Lake Balaton), such as the Trans-European network.

The basic parameters for the timetable based infrastructure development plans are the following:

- hourly cadenced service;
- symmetric regular interval timetable;
- based on the running times between the predetermined connection terminals;
- it is optimised not only on the travelling time between two particular hubs but between any terminals on the whole network due to the short connection time.
- the travel time is real, not calculated.

7. CONCLUSION

The crisis situation typical for this region today was faced in Western Europe some 30 years ago. From amongst the numerous approaches to cure the problems the Swiss Model appears the most effective given that regular interval timetable based operations proved to be the only system for passenger railway companies to operate without losses.

Looking at the present macroeconomic performance levels of the regional states an important aspect of the Swiss Model is that with its help an almost immediate rise in the level of service can be attained without the need for costly investments. Based on Swiss (and partly, Hungarian) experience, within 1 to 7 years and next to a 4% cost increase, a 10% to 40% rise in revenues can be attained, improving the situation of companies afflicted by losses amounting to billions and that have to be compensated from time to time by the state budget. Therefore regular interval timetable, next to attaining a positive shift in the modal split, helps to decrease the external costs borne by society at large.

An regular interval timetable-based system of operations greatly contributes to creating a viable conception for efficient infrastructure development priorities. It also shows which possible developments is *not* a priority. It clearly favours efficient human resources management (this area still makes up for 45% of MÁV's cost structure) and due to its transparent, periodic nature the amount of planning work can be reduced to a fraction of the previous level, the remaining tasks not necessarily requiring in-depth railway related knowledge.

As the process of railway liberalization advances in line with EU transport policy, track access for all operators without discrimination is a critical expectation, in view of which a general requirement is an objective set of rules based on related standards. A regular interval timetable is a viable setting for that.

In case the system can be extended to the entire network and the other branches of public transport would be integrated, based on experience it does not appear an audacious claim that within a decade rail passenger transport can be made a profitable business in Central Eastern Europe.

Opening the argument I ask a question: Why should we maintain any more expensive and less efficient system of railway transportation, instead of adopting a regular interval timetable?

LITERATURE

[1] *Borza, Viktor – Kormányos, László – Vincze, Béla*,
Periodic timetable-map for Hungarian railway system by an adaptation of the European structure (ŽEL 2004, Žilina 2004, pp. 182-189.)

[2] *Borza, Viktor – Kormányos, László – Vincze, Béla*,
New regular interval timetables in operation on the suburban line of the Hungarian State Railways (ŽEL 2005, Žilina 2005, pp. 57-64.)

[3] Borza, Viktor – Horváth, Zoltán,
Regular interval timetable in Hungary
Periodica Politechnica Transportation Engineering 38/2 (2010) 1-7

[4] *Leu, Hans-Peter,*
Bahn2000 Project, (conference presentation – Strategy of ŽSS,A.S. int he context of European Transport Policy. Bratislava, 18 October 2005

[5] Uttenthaler, Helmut,
Principles of railway infrastructure upgrading based on an integrated periodic timetable using the example of central Europe
Thesis in University of Graz
October 2010., Graz, Austria

[6] www.alptransit.ch