A Possible Timetable to Support More Effective Vehicle Utilization based on a Transdanubian Example

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Abstract: This paper contains the possibilities to make more efficient vehicle utilization.

1. Introduction

Public transport is not suitable for economical operation, therefore it requires government subsidy, and in the present economic situation it is essential that it be as efficient as possible. This is supported by the clock-face schedule (a kind of schedule that is becoming more and more popular across all Europe), recently introduced in Hungary, and MÁV's preference of vehicles that guarantee more effective usage in its recent purchases.

It is also important to utilize the capacity of the extant fleet for multiple reasons:

- First of all, many of the vehicles are affected by aging and the majority of those vehicles can only provide a low level of comfort. Therefore, the newer and more comfortable vehicles should be used predominantly instead (they should be assigned to busier lines).
- Second, the maintenance costs of vehicles are high, therefore operating a fleet used to its full potential is more economical than operating a larger fleet with idle vehicles because of the testing and maintenance costs.
- Third, less new vehicles should be purchased, or the new vehicles should be used in multiple lines. [1]

The utilization the capacity of the fleet can happen in many ways. First, by good maintenance (e.g. appropriate timing of the acquisition of spare parts; quality maintenance for less frequent failures, etc.) Second, by compiling appropriate vehicle schedules and timetables. In this article, I will deal with the second one.

The load factor of a vehicle is usually measured in hours, that is, the number of the hours a certain vehicle spent running one day is given. This number can vary greatly, however, typically it is between 8 and 12. Railway companies undoubtedly aim at operating most vehicles as many hours long as possible, because this improves the their load factor and, as a result, the whole system will require less vehicles. Of course, the load factor can be varied for each vehicle because in the case of some vehicles (for example newly-acquired multiple units) effective functioning is more important (that the least possible new vehicles can serve the most possible lines for a higher level of service; these vehicles could be characterized by lower running costs and higher maintenance costs) while to a highly energy-consuming, obsolete vehicle the company may prefer to assign fewer working hours (because of the high running cost and the low maintenance cost). In this paper, I do not intend to discuss the weighting of the load factor, I will only summarize the possible positive influences of schedule and infrastructure maintenance and improvement in terms of load factor.

It is important to take the reversal procedure time standards into consideration and occasionally schedule a longer period of time for cleaning.

The working time of vehicles during service is influenced by the length of the lines they run on, and the time they spend on the terminals. So the load factor of a vehicle can be increased by decreasing the time spent on terminals (this method can be applied in more cases) thereby improving the ratio of idle time and operating time.

The aim is to make sure that, in a certain line (e.g. Szombathely – Zalaegerszeg), in the terminal (e.g. Zalaegerszeg), the time difference between the arriving train (e.g. train #9830, arrives at 7:51 a.m.), and the departing train (e.g. train #9837, departs at 8:51 a.m.) is the shortest possible, but it is still more than how much the reversal procedure requires. If the time gap is too big, then the utilization of the vehicles is decreased and if it is too little, then the arriving train cannot supply the departing train, that is "it cannot be rotated into itself."

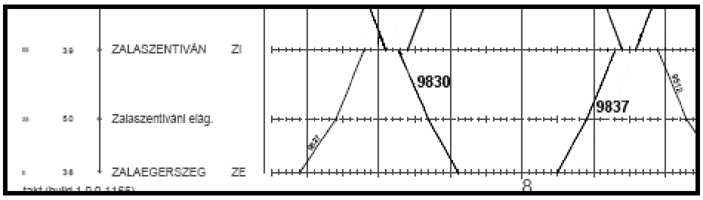


Figure 1. The time a pair of trains can afford for reversal procedure in a visual schedule.

This is 15 minutes in our case, which is a rather fortunate value (the train serving these lines (Bzmot) requires 4 minutes for reversal procedure). Unfortunately, in most of other cases, it is less favourable.

In a certain line, the most favourable case is when there is an appropriate amount of time available in both terminals (Szombathely and Zalaegerszeg in our case) for the reversal procedure. However this cannot always be attained because the railway schedule (one-way sections and speed limits etc.) restricts it.

2. Possibilities in the clock-face schedule

Introducing clock-face schedule (the typical one in Hungary) to a certain line may improve or worsen the situation a lot. By phasing the trains, it fixes their arrival and departure times and reversing times as well. This will make it either always favourable or always unfortunate.

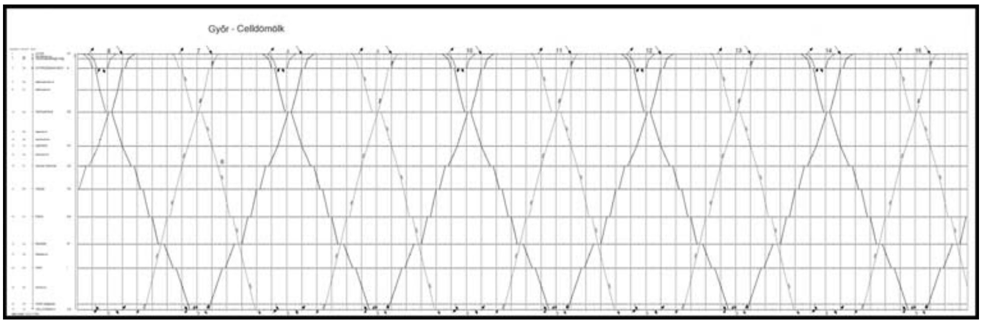


Figure 2. The visual schedule of the Győr-Celldömölk line, constructed under the rules of the clock-face schedule.

Figure 2 shows a fictional clock-face schedule. In this schedule, the trains represented by black lines have enough (but not too much) time available for reversal at Celldömölk (every time) but they have more than one and a half hours in Győr (every time). The latter is obviously not favourable.

Before taking a step ahead, I must emphasize that one of the most important purposes of the clock-face schedule is the creation of a "pók" in the junctions. Here I can say only a few words about the connection systems. The "pók" is the encounter of multiple trains from multiple lines and directions (and it supports multiple transfer opportunities) in a junction. Because everything is clock-faced, the "pók"s are clock-faced too, they occur hourly, or once in two hours. Figure 2 shows an exemplary "pók" in Celldömölk, because the passenger trains arrive from Győr not long before each odd hour and the arrows show that simultaneously, other trains arrive from other directions and they leave not long after each odd hour. This is called connection system. [2]

It is easy to see that a "pók" can strongly support the creation of a vehicle schedule, but quite often, no ideal "pók" can be made (an example for this is Győr's current schedule and the extract in Figure 3, that shows the schedule of Győr's arriving and departing passenger trains, in an unfortunate timing).

This problem can often be solved with "software", that is, schedule changes, but sometimes a perfect solution requires an intervention that concern the "hardware", that is, infrastructure. [3]

In order to see the impact of this, we have to consider one of the rules of the clock-face schedule: the tuning of the symmetry axis of the train pairs to whole hours (this rule allows for the widespread use of "pók"s.) The symmetry axis can be of great help at other times (e.g. at the planning of "cross rotations" as well. The departing and the arriving trains of the pair have the same time difference from the symmetry axis, that is from the full hours. If the departing trains departs at hour: 44 then the next arriving one will arrive at around hour: 15. If the running time between 2-3 stations increases in one direction because of the lack of maintenance (that is, the train arrives not earlier than hour: 22,) then the running time of the departing train has to be increased as well (that is, it must be started earlier, at around hour: 37). The same holds if the running time is reduced.

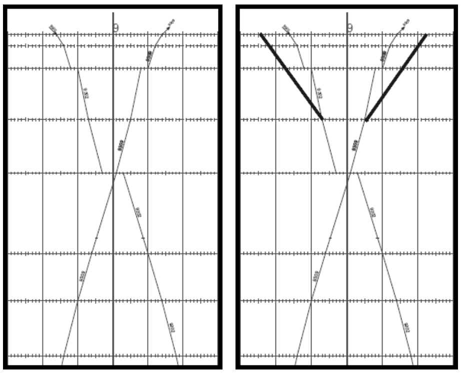


Figure 3. The symmetry axis between two lines, when the schedule of one of them changes, the reverse direction's schedule changes symmetrically (this figure shows running time increase)

One intervention, for example, the fixing (line maintenance – the hardware way) of a certain slow zone (a section of a line that can be used with reduced speed because of technical reasons); or the skipping of an unused stop in a schedule (the change of schedule – the software way) etc.) can significantly influence the schedule. That is, purposeful maintenance of the infrastructure or the change of schedule can support the effective organization of vehicle journeys (too) and can result in cost reduction.

Another possibility is cross rotation, that is a widely used method, and additionally, clock-face schedule and the observance of the rule of symmetry axis can be very helpful. Cross rotation means that a train, arriving to a junction, for which that junction is the last station, does not depart towards its station of origin but continues its way in another line. With this, the trains of two different lines are cross rotated. I will mention other examples for such a solution later.

Now let us consider a schedule designed for a network section, that is made for a future developed network section (the schedule is going to be constructed int he framework of a thesis). Based on the schedule, it may be beneficial to change some features of the improvements to be expected. In addition, it is necessary to select a few short segments that must be slow zone-free, and select the segments that are less sensitive to the lack of maintenance.

3. Possibilities to developing in the Győr – Nagykanizsa regions railway

When editing vehicle schedules, let us use the modern multiple units' uniform, 5 minute reversal procedure time demand taking the large-scale fleet acquisition into account.

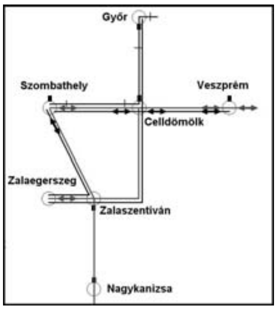


Figure 4. Póks formed at even hours

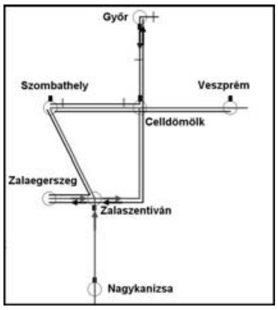


Figure 5. Póks formed at even hour: 30 minutes

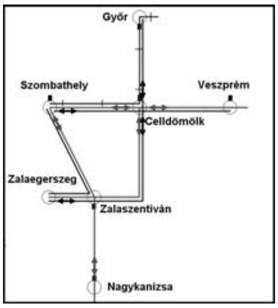


Figure 6. Póks formed at odd hours

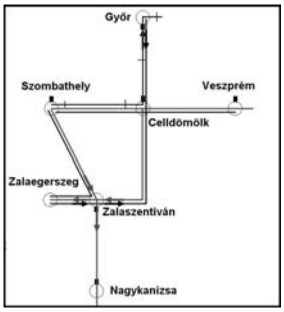
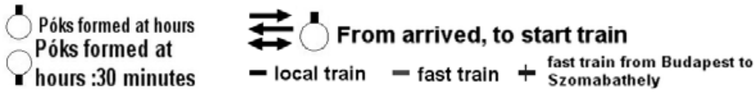


Figure 7. Póks formed at odd hour: 30 minutes



Lines in the schedule (settlements not included are in brackets):

- (Budapest –) Győr – Szombathely express (striped gray)
- (Budapest –) Veszprém – Boba – Celldömölk – Szombathely express (red)
  – Zalaszentiván – Zalaegerszeg express (gray)
- Szombathely – Zalaszentiván – Nagykanizsa (– Pécs) express (gray)
- Győr – Celldömölk local train (black)
- Zalaegerszeg – Zalaszentiván – Celldömölk local train (black)
- Szombathely – Celldömölk – Veszprém local train (black)
- Szombathely – Zalaszentiván – Zalaegerszeg local train (black)

Now I will introduce the schedule figures in small size and highlight the necessary data in a table format. The data we need are the arrival and departure times of the trains in each terminal because the data from this will be needed for the creation of a vehicle schedule. Now we will not deal with the vehicle schedule of the express trains running on lines Szombathely – Győr – Budapest and Szombathely – Veszprém – Budapest therefore I will not introduce their timing data either. However these trains are present in the visual schedule figures of course. (Szombathely – Győr – Budapest is blue, the rest of the express trains are red, local trains are black).

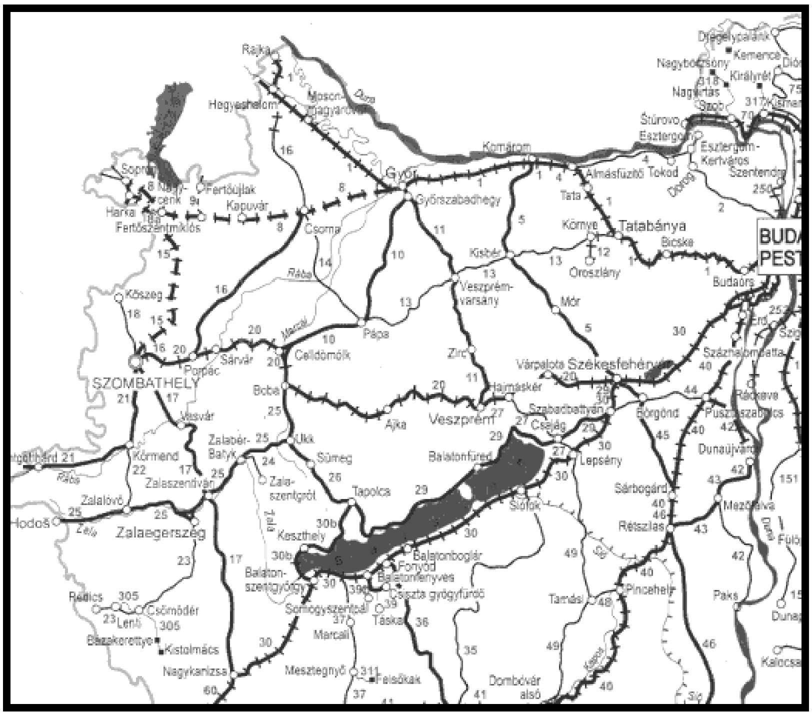


Figure 8. The railway map of North-Transdanubia

The abbreviations are: "po" – even hour, "pt" – odd hour, "mo" – each hour. The settlements in the figure titles are depicted in the Y-axis of the schedule, starting from the top, towards the bottom.

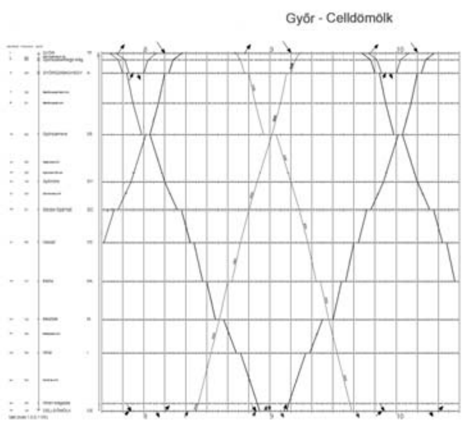


Figure 9. Győr – Celldömölk

trains of 9. 10. 12. figures

Győr
local train arrives from Celldömölk – po: 18
local train departs to Celldömölk – pt: 44

Celldömölk
local train arrives from Zalaegerszeg – po: 53
local train arrives from Győr – po: 55
local train departs to Zalaegerszeg – pt: 07
local train departs to Győr – pt: 08

Trains of figure 10.

Veszprém
local train arrives from Szombathely – pt: 44
local train departs to Szombathely – po: 15

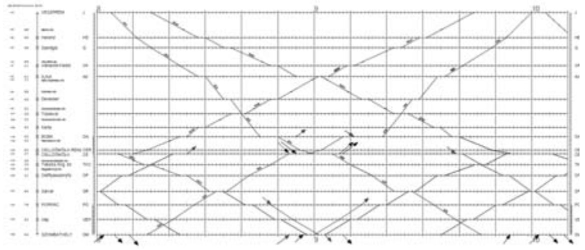


Figure 10. Veszprém – Celldömölk – Szombathely

Trains of figure 10 and 11.

Szombathely
local train arrives from Zalaegerszeg– po: 02
local train departs to Zalaegerszeg – po: 09
fast train arrives from Pécs – po:53
local train arrives from Veszprém – po: 57
fast train departs to Pécs– Pt: 02
local train departs to Veszprém pt: 13

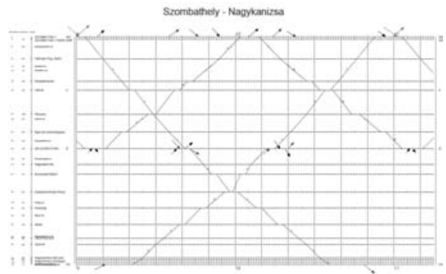


Figure 11. Szombathely – Zalaszentiván – Nagykanizsa

trains of the 12. figure

Zalaegerszeg
local train arrives from Celldömölk – po: 28
local train departs to Szombathely – po: 58
local train arrives from Szombathely – pt: 17
local train departs to Celldömölk – pt: 29

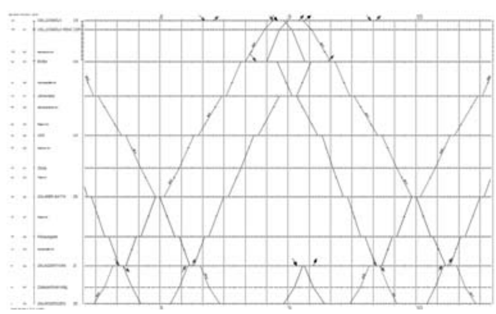


Figure 12. Celldömölk – Zalaszentiván – Zalaegerszeg

Table 1. The current data/data after the expected development of the network section we deal with; the suggested developments not present in the plans are in brackets; Between Boba and Celldömölk, the speed limit of the two tracks are separated by semicolon.

Line	Max speed	diesel/electric traction	number of rails
Győr – Celldömölk	100/120	diesel traction /electric traction	1
Szombathely – Vasvár	100	diesel traction	1
Vasvár – Pácsony	80/(100)	diesel traction	1
Pácsony – Egervár	100	diesel traction	1
Egervár – Zalaszentiván	80/(100)	diesel traction	1
Zalaszentiván – Gelse	100	diesel traction	1
Gelse – Nagykanizsa	80	diesel traction	1
Veszprém – Hajmáskér	80/120	electric traction	1
Hajmáskér – Herend	100/120	electric traction	1
Herend – Ajka	80	electric traction	1
Ajka – Boba	80/160	electric traction	1
Boba – Celldömölk	100; 60/(100; 100)	electric traction	2
Celldömölk – Porpác	100	electric traction	1
Porpác – Szombathely	100; 100	electric traction	2
Boba – Zalaszentiván	100/160	electric traction	1
Zalaszentiván – Zalaegerszeg	80/160	electric traction	1

Knowing these data, we can create the vehicle schedule outline. The solution is obvious in some junctions (e.g. Celldömölk and Veszprém,) but 2 stations require optimization.

Győr

There is a one and a half hour time gap between the arriving and the departing train, which is a big one, moreover, for some reasons, cross rotation is not possible (e.g. towards Hegyeshalom). The disadvantageous influence can be reduced by connecting the Győr – Celldömölk line with the Celldömölk – Zalaegerszeg line (that is, to cross rotate the two lines in Celldömölk), so more trains will share the longer idle time in Győr. This is beneficial because this shares out not only the disadvantageous effect (the reduction of load factor) but also the positive effect (time to clean trains, spare time: the delay of the arriving train is not transmitted to the departing train).

Zalaegerszeg

1. There are two problematic lines in Zalaegerszeg but there are 2 other lines not mentioned yet.

The solution is cross rotation in each case. We also suppose that Zalaegerszeg station is relocated to Zalaegerszeg – Ola stop (a plan that has been considered and is probable).

In Zalaegerszeg, there is a 01:03 time gap between the train arriving from Celldömölk and the one departing to Celldömölk. The solution is the cross rotation of trains with the Zalaegerszeg – Zalalövő line. The travelling time is 31 minutes now, but after the installation of ETCS II signal posting tool, the speed limit will be 160 km/h, and as a result, the Zalaegerszeg – Zalalövő line can covered in about 20 minutes by passenger trains.

The trains have 20 minutes to stay in Zalalövő. The train fits the parameters of both lines, therefore cross rotation is possible. Notice that with the cross rotation in Celldömölk, mentioned not long ago, and the cross rotation in Zalaegerszeg, a new, longer Győr – Zalalövő line is created.

2. The Szombathely – Zalaegerszeg line has a 1:40 minutes time gap in Zalaegerszeg. The train can be forwarded to Rédics, the time needed to cover the Zalaegerszeg – Rédics line is 1:18 minutes, but with the relocation of the station to Zalaegerszeg – Ola stop there is an additional 10 minutes travelling time. The train arriving at pt:17 continues its way to Rédics (arrives at around even hour: 35) and departs back from Rédics at pt: 30 (with about 1 hour idle time) to arrive at even hour: 58, when it continues its way to Szombathely. So there is a Rédics – Szombathely line created.

Let us take a look at the vehicle schedules:

Table 2. The main data of vehicle schedule created for the schedule [3]

Line	Time one of one service journey	Waiting times	The number of service journeys to be made by each train	Service time
Győr – Zalalövő; Zalalövő – Győr	03:06	Zalalövő: 00:20 Győr: 01:30	4; 4; 4; 4;	12:24; 12:24; 12:24; 12:24;
Szombathely – Veszprém; Veszprém – Szombathely	02:42	Szombathely: 00:16 Veszprém: 00:31)	5; 5; 4;	13:30; 13:30; 10:48;
Szombathely – Pécs; Pécs – Szombathely fast train	04:36	Szombathely: 02:10 Pécs: 00:30	3; 3; 3; 3;	13:48; 13:48; 13:48; 13:48;
Szombathely – Rédics; Rédics – Szombathely	02:29	Szombathely: 02:07 Rédics: 00:55	4; 4; 3; 3;	11:56; 11:56; 08:57; 08:57;

It is important to take into consideration that in lines that take a longer time to cover, it is not enough to start and accept trains in the two terminals. For example, in the

Szombathely – Pécs line, there is a train departing from Szombathely to Pécs, from Nagykanizsa to Pécs, from Pécs to Szombathely, and from Nagykanizsa to Szombathely in the morning. The same is true for arrivals. Therefore, there are two “halves” for two trains, that can be counted as one. The same is true in the Győr – Zalalövő line.

It is also important to mention that to the Szombathely – Pécs line it is suggested that only 4 trains be assigned because it is enough to provide 6 pairs instead of the 8 pairs providing continuous 2-hour headways. So there is a 4-hour long period without express trains in each direction, which may be scheduled to the time period between 10 a.m. and 2 p.m.

4. Summary and results

It is important to highlight that the schedule introduced presupposes the availability of a certain number of new and old vehicles. The aim is to make certain vehicle journeys very efficient while the efficiency of other vehicle journeys including less preferred trains does not make a difference because the load factor of the vehicles that have low maintenance and high operating costs does not influence the railway’s costs as much.

For comparison, let us take a look at some of the details of the vehicle schedule of the 2009/2010 schedule in line Győr – Celldömölk (line #10).

Table 3. The details of the passenger train vehicle schedule on the Győr – Celldömölk line for one day based on the 2009/2010 schedule; the details of developed schedule periodic roundtrip for one day on the Győr – Celldömölk line.

Line #10 2009/2010 schedule details			
train	Service time [h]	Service journeys [#]	distance [km]
1	5:45	4	288
2	9:10	6	432
3	5:00	3	216
4	8:30	5	220
average:	7:10	4.5	289

Line #10 developed schedule details			
train	Service time [h]	Service journeys [#]	distance [km]
1	12:24	6	660
2	12:24	4	660
3	12:24	4	660
4	12:24	6	660
average:	12:24	5	660

The table contains those trains in the line which make the most trips in the Győr – Celldömölk line (one train, train #4 makes 2 trips in another line, so its details slightly modify the details belonging to that line) and the number of trips is the same as the number of the trips in the clock-face schedule just introduced. There were 10 additional trips in the 2009/2010 schedule (not included in the table) which trains predominantly ran on different lines, and made only 1 to 2 trips in the Győr – Celldömölk line (that is they are not part of the base schedule, they are additional trains, so I will not deal with them in this article).

The comparison does not show how much the developed schedule’s average details would deteriorate with additional trains (however it could be expected to deteriorate significantly). But because it is practical that the additional trains are not made up of new vehicles, but old vehicles that are cheap to maintain but expensive to operate, their load factor is not as important as the those vehicles' that run according to the clock-face schedule.

The load factor of the vehicles running on the example line I analyzed (Győr – Celldömölk) measured in time is 70% and its running performance is increased by 100% a day.

Certainly, these data do not hold for every line (for example a much smaller degree of improvement can be expected in the Szombathely – Rédics line) but they provide some information about the degree of improvement that can be expected.

Better load factor is not only important because of the costs in connection with the vehicles but it also decreases the costs of the personnel. This may be up to 200 000 HUFs adding up the salary and additional costs, education, and medical attendance etc.

Although a full cost analysis cannot be made without appropriate data, it can be said in summary, that the purposeful maintenance and development of infrastructure can hugely support the creation of effective vehicle schedules.

References

[1] Ercsey, Z., Gittinger, T., Kisteleki, M., Vincze, T.: *Hogyan lehet és hogyan nem szabad a magyar vasút költségeit csökkenteni?*, Közlekedéstudományi Szemle 2009/4.
[2] Borza, V., István, Gy., Kormányos, L., Vincze, Gy. B.: *Integrált Ütemes Menetrend I.*, Közlekedéstudományi Szemle 2007/november.
[3] Borza, V.: *Átszállási rendszerek az Intergált Ütemes Menetrendben*, – www.itf.hu
[4] www.vpe.hu, Network terms and annex (5.4.4.1; 3.3.1.3; 3.3.1.1).
[5] The schedules are made by Takt program free demo version (Takt 1.0.XX. version).