A possible TEN-T Railway Core Network in Central Europe

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Abstract: A main option of the review of the trans-European networks of transport is the creation of a core network as a step forward from the loosely connected 30 priority projects being its base until now. This paper presents a proposal for the Central European part of a railway core network based on various established networks and evaluation and calculation methods.

Keywords: TEN-T, core network, railway network, Central Europe

1. Introduction

During the beginning of the year 2009 the European Commission launched a green paper (discussion document) on the policy review of the Transeuropean Network of Transport (TEN-T) [4]. A main option of the Green Paper was the creation of a core network within the TEN-T as a step forward from the loosely connected 30 priority projects being the base of TEN-T until now [7]. Here in this paper a proposal for the Central European part of a railway core network is presented. The reason why only the rail network is regarded at is that for this mode a real European transport infrastructure concept is needed most. While it is hardly a problem for goods to cross borders on roads, this is still not the case for rail freight. Cargo rails still loose much time on borders for technical (e.g. different voltage systems) and operational reasons (e.g. labour laws), thus interoperability is still piecemeal. Recently the European Commission published its newest White Paper on transport with many encouraging proposals regarding the support of railway infrastructure [8].

In the last two years two important documents were produced on the topic of the TEN-T core networks for all modes. The first one in December 2009, the TENconnect report which was released by an international partner consortium [15] and the second one in spring 2010, a proposal on TEN-T network planning set up by an expert group [13]. TENconnect mainly works with TRANS-TOOLS models and various scenarios and forecasts on traffic flows from which it identifies the bottlenecks and corridors and present concrete core network proposals (pp.104-107). The expert group was set up by the European Commission and is made up of external experts and has the mandate to elaborate a core network planning methodology. Its assessment is be based upon parts of a cost-benefit and multi-criteria analysis as well as spatial computed general equilibrium and system-based models.

This paper, however, tries to offer a quiet simple, traceable and transparent methodology for generating a railway core network, which does not depend on extensive modelling and forecasting, as this always includes large portions of uncertainty. Furthermore, in this quite political decision process like the TEN-T review, it is beneficial to base the method on established concepts and present traffic conditions. Thus, this method includes existing networks as well as relatively straightforward calculation and evaluation methods of the current traffic and socio-economic situation.

The core network of this paper is based on the methodology presented during the 3rd SoNorA (South-North Axis EU Interreg project) Think Tank conference where these existing TEN-T priority projects are extended by an overlapping of the other high level networks which are the technology-driven ERTMS (European Rail Traffic Management System) corridors, the market-driven RailNetEurope network as well as the Pan-European Transport Corridors of railways [19]. Furthermore the passenger-oriented Railteam-Network, as well as the possibility of high-speed rail service were added to the analysis. This first part of the methodology is oriented on already established networks. In the second part of the analysis for a core network, the methodology involves various evaluation systems like the track status and the aspect of European integration, represented by cross border sections as well as calculation systems based on air traffic, linked population, linked harbour goods and linked GDP (gross domestic product), which were also included to the network selection process.

The aim of the paper is to present a proposal for the Central European part of the railway core network based on existing and established networks as well as additional priority calculations resulting in different levels of priority for each observed railway section. In this paper the EU definition within the European Territorial Co-operation is used for Central Europe.

2. Existing TEN-T priority projects

In 2004 a list of 30 TEN-T priority projects was published by the European Commission [7]. These loosely connected projects rarely form a network as they were agreed upon on more political than network oriented transport reasons. Nevertheless these projects are an important starting point for a core network as these corridors were selected in consensus and are all essential for the core network but not sufficient. It is obvious that still several important connections are missing.

Out of the 30 projects, there are seven rail priority projects (PP) which are relevant for Central Europe (sections outside Central Europe in brackets):

- PP1: Berlin-Munich-/Milan-Bologna-(Palermo)
- PP6: (Lyon)-Turin-Trieste-Koper-Ljubljana-Budapest-Ukrainian border
- PP17: (Paris)-Stuttgart-Munich-Vienna-Bratislava
- PP22: Dresden/Nuremberg/Linz-Prague-Budapest-(Arad-Athens/Constanța)

- PP23: Gdańsk-Katowice-Vienna/Bratislava
- PP24: Genoa-Novara/Milan-(Basel)-/(Lyon)-Karlsruhe-(Frankfurt-Rotterdam/Antwerp)
- PP27: Warsaw-(Vilnius-Helsinki)

See figure 1 for more details, with railway lines in red.

In chapter 3 the missing sections should be evaluated and added to accordingly form a coherent core network in chapter 4.

Figure 1. The TEN-T priority projects in Central Europe. Rail sections in red [6]

3. From the TEN-T project list to a core network

3.1. Methodology

The starting point is the methodology of Reents [19] presented during the 3rd SoNorA Think Tank conference, where the existing TEN-T priority projects are extended by an overlapping of the other high level networks, which are the technology-driven ERTMS corridors, the market-driven RailNetEurope network as well as the Pan-European Transport Corridors of railways. As a next step, the passenger-oriented Railteam-Network, as well as the possibility of high-speed rail service within 2020, were added in the definition process for a core network, thus completing the part representing the established networks.

The second step included evaluation and calculation methods, like the current track status and the aspect of European integration, represented by cross border sections as well as several calculation systems based on air passenger traffic, linked regional population, harbour goods linked to regions and linked regional GDP, which were also incorporated to the core network selection process.

The following sub-chapters will deal with these different criteria leading to a calculation method in chapter 4. In general the various analyses do evaluate each railway section listed in chapter 4 (Table 1) in a range of 5 to 1, with 5 representing the highest value and 1 the lowest. The evaluated railway sections are part of the general high level European railway network and are reaching from one larger urban area to the next, or to an important railway junction.

3.2. Established networks

3.2.1. ERMTS Corridors

The first corridors relevant for a possible extension of the seven Central Euroean TEN-T priority projects are the ERTMS corridors. The European Rail Traffic Management System is an initiative of the EU to improve the cross-border interoperability and signalling procurement by creating a single Europe-wide standard for train control and command systems. In order to foster the employment of ERTMS in the EU six emphasised freight corridors (A-F) were selected [3].

The five relevant corridors for Central Europe are:

- A: (Rotterdam-Frankfurt)-Karlsruhe-(Basel)-Novara/Milan-Genoa
- B: (Stockholm-Göttingen)-Würzburg-Munich-Bologna-(Naples)
- D: Budapest-Győr-Koper-Trieste-Turin-(Valencia)
- E: Dresden-Vienna/Bratislava-Budapest-(Arad-Constanța)
- F: Terespol-Warsaw-Berlin-/Legnica-Magdeburg-(Aachen)

Thus, sections being part of the ERMTS-Corridors are prioritised for entering in the core network (see chapter 4). See Figure 2 for more details.

Figure 2. ERTMS-Corridors in Central Europe. Main lines in red-yellow [5]

3.2.2. RailNetEurope

RailNetEurope (RNE) is a common organisation of 38 rail infrastructure managers with the aim to harmonise conditions in rail infrastructure and to improve operational issues in international rail traffic. For this purpose RNE defined ten corridors which are cared by a corridor manager [16].

In 2009 the seven relevant corridors for Central Europe were:

- No 2: Genoa-Novara/Milan-(Basel)-Karlsruhe-(Frankfurt-Rotterdam/Antwerp)
- No 3: Warsaw-Berlin/Kattowice-Leipzig-(Hamburg/Bremerhaven/ Rotterdam/Antwerp)

- No 4: Vienna/Verona-Nuremberg/Munich-Gemünden-(Bremerhaven/Lübeck)
- No 7: Gdynia/Białystok-Katowice-/Čierna-Vienna-Trieste/Koper
- No 8: (Lyon)-Turin-Trieste-Koper-Ljubljana-Budapest
- No 9: Vienna-Budapest-(Arad-Constanța/Varna/Burgas/Svilengrad/Kulata)
- No 10: Hamburg-Berlin/Leipzig-Prague-Budapest
- No 11: Munich-Ljubljana-(Belgrade-Istanbul)

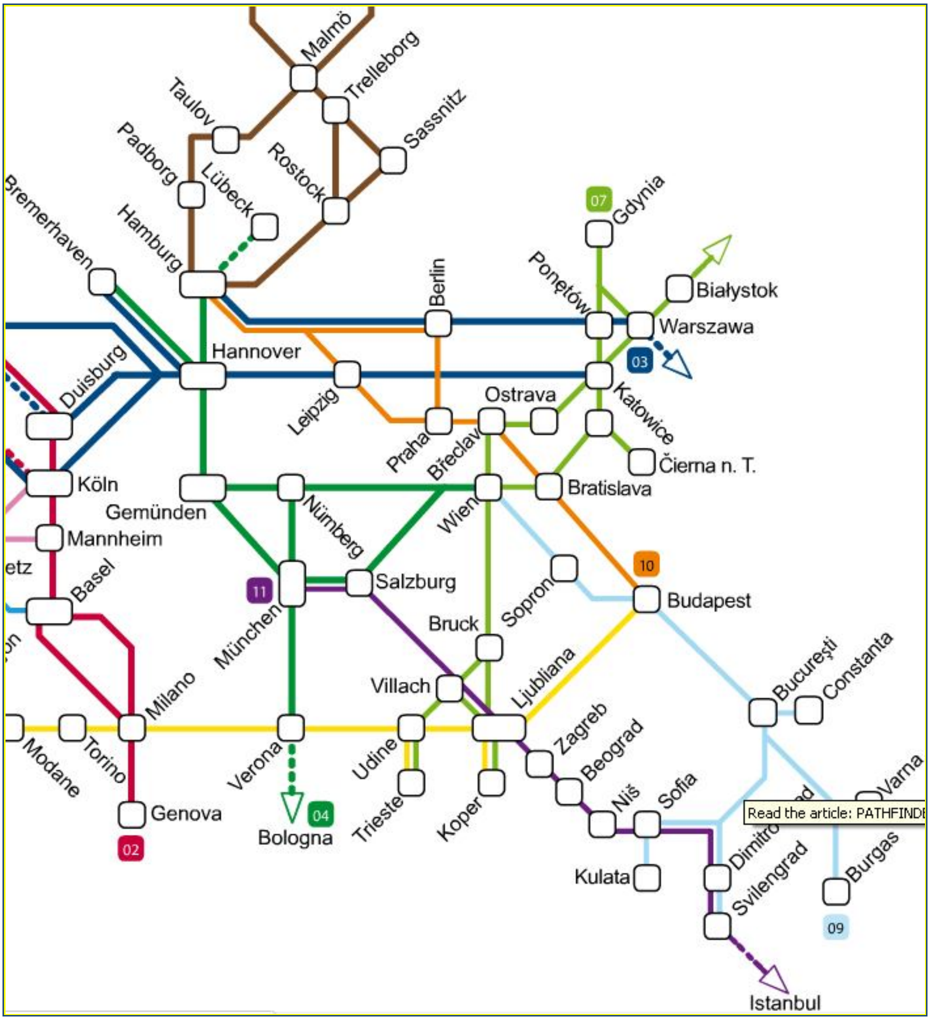

Figure 3. RNE-Corridors in Central Europe [16]

Again, the lines being part of RNE do have a higher chance for being part of the core network calculation in chapter 4. For an overview of the RNE-Corridors see Figure 3. Recently, RailNetEurope restructured some of the existing corridors and added a new corridor No 11 reaching from Munich over Salzburg-Villach-Ljubljana-Zagreb-Belgrade to Istanbul [16].

3.2.3. Railteam-Network

Next to the rail freight cooperation seven European rail companies have formed an alliance dedicated to passenger transport called Railteam. The main aim of Railteam is to develop a high-speed network, to improve travel information and to better connect the national railway systems [17]. Railteam also defined a network whose Central European part can be seen in Figure 4. Although only a few lines of Central Europe are part of the Railteam-Network, these are preferred in forming the core network.

Figure 4. Railteam network map [18]

3.2.4. Pan-European Transport Corridors

In parallel to the TEN-T priority projects the European Commission developed various Pan-European Transport Corridors (PETC) in the Central and Eastern part of Europe

[14]. Some of these corridors are partly identical to TEN-T priority projects, whereas others form important extensions and thus if sections are part of PETC they have a higher chance to constitute the core network.

Figure 5: PETC rail corridors in Central Europe [14]

For Central Europe the following seven rail corridors are relevant:

- PETC I: Gdańsk/Warsaw-(Tallinn)
- PETC II: Berlin-Warsaw-(Nizhniy Novgorod)

- PETC III: Berlin/Dresden-Krakow-Rzeszów-(Kyiv)
- PETC IV: Dresden/Nuremberg-Prague-Budapest-(Arad- Constanța/Istanbul/ Thessaloniki)
- PETC V: Venice/(Rijeka)/(Ploče)-Budapest-/Bratislava-(Lviv)
- PETC VI: Gdańsk-Katowice-Žilina/Břeclav
- PETC X: Salzburg/Graz-(Zagreb)-/Budapest-(Belgrade-Sofia/Thessaloniki/Florina)

See Figure 5 for more details.

3.2.5. High-speed rail

The construction of high speed rail tracks (> 200 km/h) is not rentable in all regions, but for the connection of metropolitan areas of Central Europe an adequate and fast rail system is necessary in order to compete with car and air traffic. Thus, in the creation of the core network this factor is included, i.e. a section which is already capable for high speed rail above 200 km/h or will be until 2020 under current plans, is getting a higher value for the calculations.

See Figure 6 for high speed rail lines, with the existing lines in red-orange-yellow and lines under construction or in planning phase with completion time before 2020 in black.

3.3. Evaluation and calculation methods

3.3.1. Cross border lines

In order to adequately represent EU integration as an important factor for the rail core network cross border lines are emphasised in a special manner. To support the European aspect of the core network, cross border sections are given a value of “5” in chapter 4. The core network should not be a mere addition of national core networks, thus national sections get a value of “1”.

3.3.2. Air traffic in Central Europe

An important aim of the improvement of the rail infrastructure in Europe is the modal shift from air passenger transport to rail transport. In order to analyse the potential for air-rail modal shifts the amount of air passenger traffic within broader Central Europe was observed. Figure 7 gives an overview of the flight pairs with over 100,000 passengers in one direction in 2008 [12].

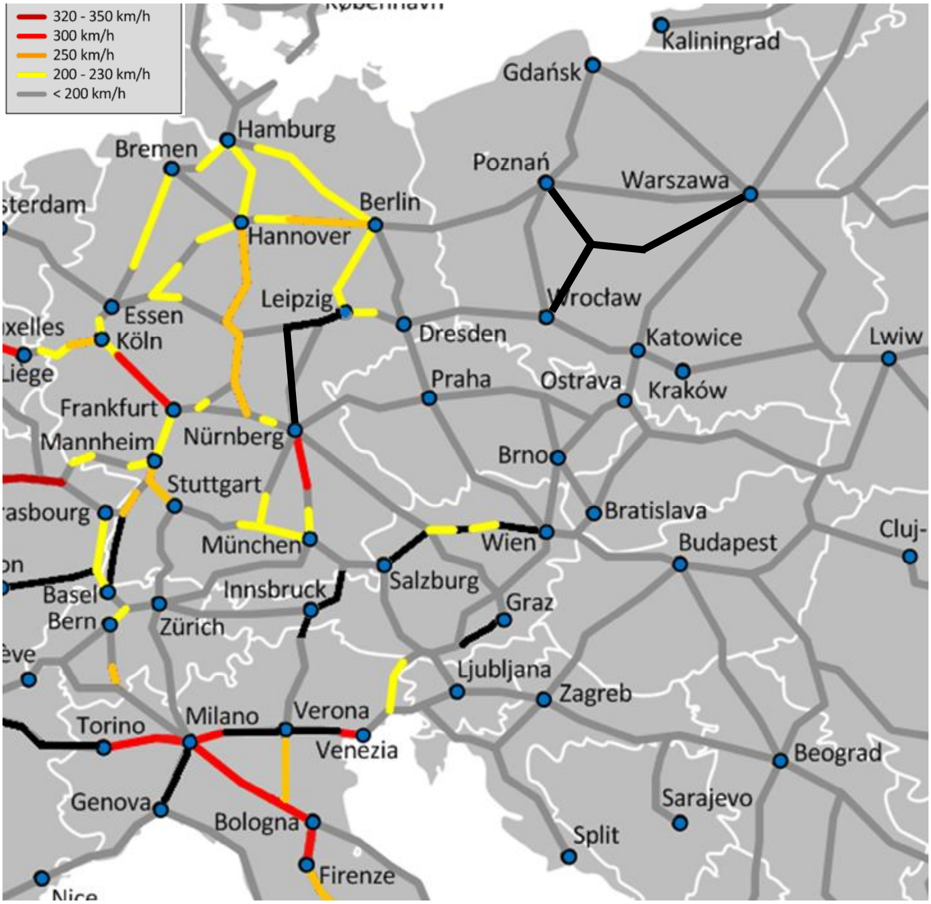

Figure 6. High-speed rail in Central Europe 2011. Lines planned or under construction with completion time before 2020 in black (modified map from [1])

The main aim of the map is to show where most air passenger traffic takes place in Central Europe. The map shows air traffic within broader Central Europe, i.e. the cities found on the map. For the purpose of a better overview the following air traffic flows are not included on the map: Intra-German, intra-Italian, Benelux to/from West-Germany/Denmark, Denmark to/from Germany outside Central Europe and French traffic. Although these lines are not shown in the map, they were included in the calculations in chapter 4.

Major air-traffic exists within Germany and Italy (not shown on map). Highest amount of international air traffic within Central Europe is generated along the corridor Benelux-Frankfurt-Vienna-Budapest-Bucharest as well as between Switzerland-Benelux-Austria-Germany. Numerous air traffic is also found to and from Rome, Warsaw and Bucharest.

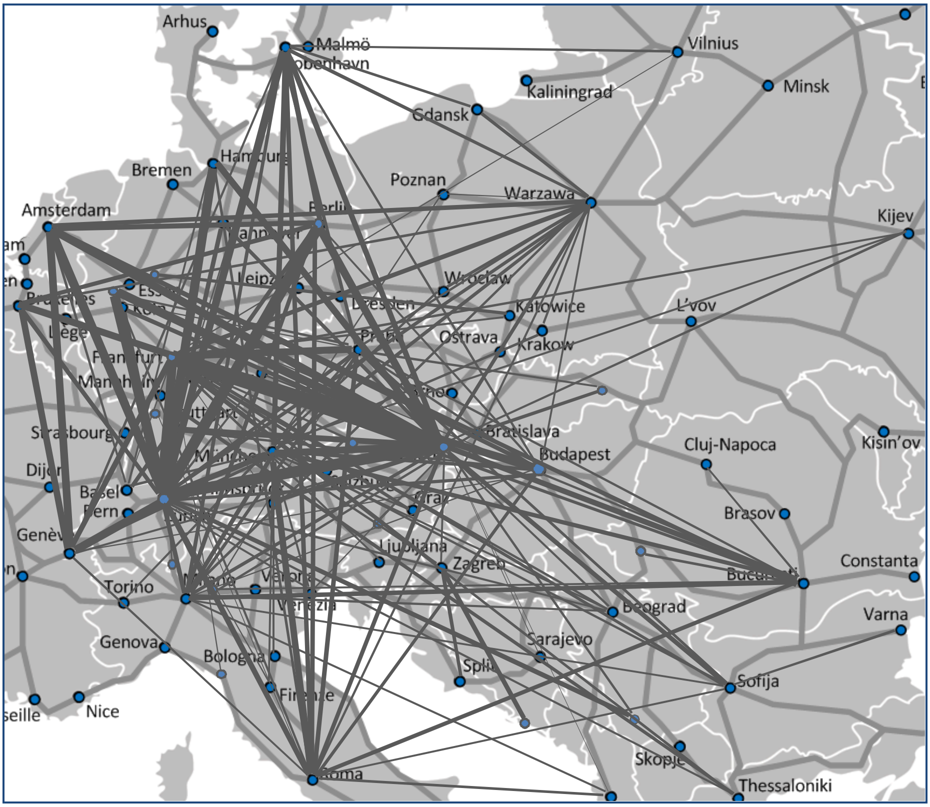

Figure 7. Air traffic (>100,000 passengers one-way) in broader Central Europe without intra-German and intra-Italian traffic in 2008. For more details on selected lines see text (own illustration with data from [12] on base map from [1])

In order to calculate the importance of a rail section for air traffic modal shift, for each section it was analysed how much air passengers could use this railway line. If a rail section is suitable (parallel) to a air connection which is shorter than 400 km it is assumed that a 100% of the air passengers could use rail if a proper service is offered. For a distance between 400 and 500 km a modal shift of 80% is considered realistic. This happened with Paris-Lyon where non-transfer air traffic ceded almost completely after full TGV services were established. For larger distances the following shares of modal shift were used:

up to 400 km	100%	800-900 km	20%
400-500 km	80%	900-1000 km	10%
500-600 km	60%	1000-1250 km	7.5%
600-700 km	45%	1250-1500 km	5%
700-800 km	30%	over 1500 km	0%

In the calculations for each rail sections the number of passengers on air traffic connections which could use this sections were multiplied with the modal shift distance factor and then summed up. Thus e.g. for calculating the air traffic value of the Brno-Bratislava rail section, the air passenger numbers of Berlin-Budapest (20%), Prague-Budapest (60%), Prague-Sofia (5%), Prague-Bucharest (5%) and Copenhagen-Budapest (5%) where summed up after multiplication with the modal shift factor in the brackets [12].

By this method each rail section gets a specific air traffic modal shift value. This value then was scaled by extracting the square root to distribute the values more equally and standardizing it between 5 and 1, with 5 representing the highest potential air traffic modal shift. Sections with high values are more likely to enter the core network and the results are shown in chapter 4.

3.3.3. Linked regional population

This category shows the amount of population which is connected by the specific railway section. The populations of the two NUTS-2 regions (2nd level statistical regions of the EU) linked by the section were multiplied. Of this result the square root was extracted and classified in 5 groups, with “5” for “high number of linked population” and “1” for “low number of linked population”. 2008 population data was extracted from Eurostat [11]. A division by the distance was not performed in order to not prefer short national sections and because most sections link neighbouring larger urban areas within similar distances. Results are shown in chapter 4.

3.3.4. Harbour goods linked to regions

This indicator approximately shows the importance of the section for the harbour-hinterland transport. Firstly it is observed in which port’s hinterland the railway section is located, then if harbour goods could use the route along this section and finally which end of the section is farer from the port. The goods transloaded in this harbour(s) in tons were multiplied with the GDP (in purchasing power parity, PPP) in the NUTS-2 region in which the end of the section farer from the port is located. This value then is divided by the squared (average) distance between the port(s) and the farer end of the section. The formula is:

Harbour goods (tons) × GDP (in PPP) / (d port ↔ far end of section)2

Of this result like in 3.3.2 the square root was extracted and classified in 5 groups, with “5” for “high number of linked harbour goods” and “1” for “low number of linked harbour goods”. 2006 GDP data and 2007 harbour data was extracted from Eurostat [9] [11]. The results are included in chapter 4.

3.3.5. Linked regional GDP

For this indicator the GDP (in PPP) of the two NUTS-2 regions linked by the section were multiplied. Of this result the square root was extracted and classified in 5 groups, with “5” for “high value of linked GDP” and “1” for “low value of linked GDP”. The

2006 GDP data was extracted from Eurostat [10]. As above a division by the distance was not performed in order to not prefer short national sections and because most sections link neighbouring larger urban areas within similar distances.

3.3.6. Track status

This indicator shows the current status of the tracks [2]. If the status is very good, i.e. the track is double-lined and electrified a value of "5" is given. Very bad track conditions like single-lined and non-electrified get a "1". Values in-between are given accordingly, e.g. a 50% double-lined and 50% electrified section gets a value of "3".

4. Analysis of sections

In order to add the most relevant sections to the 30 TEN-T priority projects the eleven values of each section where calculated. For each section the average of the eleven values being between 5 and 1 was extracted. On the one hand, the analysis bases on existing and established networks (chapter 3.2), and on the other hand it includes various calculation and evaluation methods (chapter 3.3).

Table 1 shows the values of all of the 67 rail sections of Central Europe, including sections reaching out of Central Europe in brackets. The sections are sorted according to total priority listed in the last column.

Three lines do have an extremely high priority with a value of above 3.5, which form the important corridor Hannover-Berlin-Poznań-Warsaw and should be primarily included in the core network together with the branch reaching to Brest in Belarus. Further important sections start from Linz over Nuremberg to Frankfurt/Benelux and Hannover/Hamburg as well as from Hamburg over Berlin and Wroclaw to Katowice reaching to Kiev. The high-priority sections have a value of higher than 2.40 and include also Brno-Bratislava-Budapest, Gdańsk-Łódź-Katowice, Stuttgart-Zürich, Munich-Zürich as well as Graz-Maribor and Villach-Ljubljana. The next class of sections do have a value from 2.20-2.40 and the third one from 2.00-2.20 (see also Figure 7 in chapter 5).

Table 1. Rail sections with the 11 values and the total core network priority

	ERTMS-Corridors	RailNetEurope	Railteam-Network	Pan-ETC	High-speed before 2020	Cross border	Air traffic	Linking population	Linking harbour goods	Linking GDP	Track status	**Total priority**
Poznań-Berlin	5	5	1	5	1	5	1.7	4.9	2.8	3.1	5.0	**3.59**
Poznań-Łódź-Warsaw	5	5	1	5	5	1	1.9	4.6	2.3	2.9	5.0	**3.52**
Berlin-(Hannover)	1	1	5	1	5	1	4.7	4.0	3.4	3.5	5.0	**3.15**
Berlin-(Hamburg)	1	5	1	1	5	1	2.2	3.7	4.2	4.0	5.0	**3.01**
Nuremberg-(Fulda,DE)	5	5	1	1	5	1	3.3	1.9	2.1	2.1	5.0	**2.94**
Węgliniec,PL-Wrocław	5	5	1	5	1	1	1.6	3.3	2.5	1.9	5.0	**2.93**
Linz-Nuremberg	1	5	5	1	1	5	2.8	2.0	1.8	2.2	5.0	**2.89**
Warsaw-(Brest,BY)	5	1	1	5	1	5	1.2	3.2	1.8	1.9	5.0	**2.82**
Bratislava-Galanta-Budapest	5	5	1	1	1	5	1.8	1.8	2.3	1.9	5.0	**2.80**
Zidani Most,SI-(Zagreb)	1	5	1	5	1	5	1.9	1.8	1.7	1.4	5.0	**2.72**
Munich-(Zurich)	1	1	5	1	1	5	2.9	2.8	2.0	3.9	4.4	**2.72**
Legnica,PL-Berlin	1	1	1	5	1	5	1.0	4.6	2.6	2.9	4.2	**2.67**
Nuremberg-(Frankfurt)	1	1	5	1	1	1	5.0	3.0	2.8	3.5	5.0	**2.66**
Brno-Bratislava	5	1	1	5	1	5	1.8	1.5	1.6	1.4	5.0	**2.66**
Węgliniec,PL-Elsterwerda,DE	5	5	1	1	1	5	1.0	2.4	2.4	1.7	3.4	**2.63**
Wrocław-Katowice	1	5	1	5	1	1	1.4	4.1	2.0	2.2	5.0	**2.62**
Dresden-Węgliniec,PL	1	5	1	5	1	5	1.6	2.6	1.4	1.8	3.2	**2.60**
Stuttgart-(Zurich)	1	1	5	1	1	5	2.0	2.7	2.1	3.5	4.2	**2.59**
Villach-Ljubljana	1	5	1	5	1	5	2.0	1.2	2.4	1.2	3.4	**2.56**
Bologna-Padova	1	1	1	1	1	1	3.0	5.0	4.0	5.0	5.0	**2.54**
Magdeburg-(Hannover)	5	5	1	1	1	1	1.0	2.7	2.8	2.4	5.0	**2.54**
Graz-Maribor	1	5	1	5	1	5	1.0	1.6	2.3	1.4	3.5	**2.53**
Gdańsk-Łódź-Katowice	1	5	1	5	1	1	1.0	3.7	1.7	2.0	5.0	**2.48**
Katowice-(Lviv)	1	1	1	5	1	5	1.2	3.9	1.6	1.6	4.8	**2.47**
Magdeburg-Elsterwerda,DE	5	5	1	1	1	1	1.0	2.3	2.4	1.8	5.0	**2.41**
Graz-Villach	1	5	1	1	5	1	2.1	1.3	2.3	1.3	5.0	**2.36**
Villach-Udine	1	5	1	1	1	5	1.9	1.3	2.5	1.3	5.0	**2.36**
Berlin-Magdeburg	5	1	1	1	1	1	1.0	4.2	2.2	3.2	5.0	**2.33**
Frankfurt(Oder)-Wroclaw	1	1	1	1	1	5	1.0	4.6	2.0	2.9	5.0	**2.32**
Venice-Udine	1	5	1	1	1	1	1.9	2.9	2.8	2.9	5.0	**2.32**
Žilina-Čierna,SK	1	5	1	5	1	1	1.8	1.9	1.6	1.2	5.0	**2.32**
Rostock-(Hamburg)	1	5	1	1	1	1	1,0	2,2	5,0	2,3	5,0	**2.32**

	ERTMS-Corridors	RailNetEurope	Railteam-Network	Pan-ETC	High-speed before 2020	Cross border	Air traffic	Linking population	Linking harbour goods	Linking GDP	Track status	**Total priority**
Budapest-(Zagreb)	1	1	1	5	1	5	1.4	2.6	2.0	2.1	3.2	**2.31**
Salzburg-Villach	1	5	1	5	1	1	2.3	1.0	1.9	1.1	5.0	**2.31**
Berlin-Elsterwerda,DE	1	5	1	1	1	1	2.2	3.3	2.1	2.6	5.0	**2.29**
Innsbruck-Zurich	1	1	5	1	1	5	2.1	1.4	1.0	1.8	4.8	**2.28**
Budapest-(Subotica,SRB)	1	1	1	5	1	5	1.5	2.9	1.5	1.8	3.0	**2.25**
Vienna-Graz	1	5	1	1	1	1	2.3	2.4	2.4	2.5	5.0	**2.24**
Salzburg-Innsbruck	1	5	5	1	1	1	2.1	1.1	1.2	1.3	5.0	**2.24**
Prague-Regensburg-Munich	1	1	1	1	1	5	2.1	3.7	1.7	4.1	3.0	**2.24**
Magdeburg-(Hamburg)	1	5	1	1	1	1	1,0	2,5	3,4	2,7	5,0	**2.24**
Szczecin-Berlin	1	1	1	1	1	5	1.0	3.6	3.3	2.3	4.0	**2.20**
Udine-Trieste	1	5	1	1	1	1	1.0	1.7	4.8	1.7	5.0	**2.20**
Genoa-(Nice)	1	1	1	1	1	5	1.8	3.2	1.0	2.9	4.5	**2.14**
Elsterwerda,DE-Dresden	1	5	1	1	1	1	2.2	2.0	2.4	1.7	5.0	**2.11**
Pivka,SI-(Rijeka)	1	1	1	1	1	5	1.0	2.2	5.0	1.6	3.0	**2.07**
Turin-Alessandria,IT-Genoa	1	1	1	1	1	1	1.3	3.1	4.2	2.9	5.0	**2.05**
Wroclaw-Łódź	1	1	1	1	5	1	2.0	3.2	1.0	1.7	4.7	**2.05**
Gdańsk-(Kaliningrad)	1	1	1	5	1	5	1.0	1.9	1.1	1.1	2.6	**1.97**
Stuttgart-Nuremberg	1	1	1	1	1	1	2.7	3.1	1.9	3.4	4.5	**1.97**
Warsaw-(Kovel,UA)	1	1	1	1	1	5	1.0	2.8	1.6	1.5	4.5	**1.94**
Berlin-Rostock/Sassnitz	1	1	1	1	1	1	1.0	3.6	2.6	2.7	5.0	**1.91**
Erfurt-(Fulda,DE)	1	1	1	1	1	1	3.0	2.1	2.7	1.9	5.0	**1.89**
Dombovár,HU-(Osijek)	1	1	1	5	1	5	1.0	1.6	1.4	1.0	1.7	**1.88**
Bologna-(Ancona)	1	1	1	1	1	1	1.9	3.0	1.8	2.9	5.0	**1.88**
Wroclaw-Brno	1	1	1	1	1	5	1.0	2.6	1.5	1.7	3.0	**1.80**
Vienna-Nagykanizsa,HU	1	1	1	1	1	5	1.9	2.3	1.5	1.9	2.0	**1.78**
Poznan-Wroclaw	1	1	1	1	1	1	1.0	3.6	1.9	2.0	5.0	**1.77**
Nagykanizsa,HU-(Zagreb)	1	1	1	1	1	5	2.0	1.7	1.4	1.3	3.0	**1.77**
Prague-Wroclaw	1	1	1	1	1	5	1.0	3.1	1.5	2.3	1.5	**1.76**
Genoa-(Pisa)	1	1	1	1	1	1	1.7	2.9	1.0	2.7	5.0	**1.76**
Leipzig-Dresden	1	1	1	1	1	1	2.6	1.8	2.0	1.5	5.0	**1.72**
Poznan-Inowroclaw,PL	1	1	1	1	1	1	1.0	3.1	2.0	1.7	5.0	**1.71**
Szczecin-Poznan	1	1	1	1	1	1	1.0	2.8	1.9	1.6	5.0	**1.66**
Nuremberg-Dresden	1	1	1	1	1	1	2.2	2.1	1.4	2.0	4.0	**1.62**
Leipzig-Saalfeld,DE-Nuremberg	1	1	1	1	1	1	1.0	1.8	1.7	1.8	5.0	**1.57**
Boba,HU-Győr	5	1	1	1	1	1	1.0	1.4	1.5	1.1	1.8	**1.54**
Linz-Leoben,AT	1	1	1	1	1	1	1.0	1.8	1.6	1.8	4.0	**1.47**
Regensburg-Hof-Leipzig	1	1	1	1	1	1	1.0	1.5	1.3	1.5	3.5	**1.35**

5. A possible railway core network for Central Europe

This chapter integrates the results of chapter 4 and presents them in a map. Firstly, in Figure 8 the 30 TEN-T priority projects are shown as well as the sections with a core network value of higher than 2.0. Sections with a priority value higher than 2.4 should enter directly in the railway core network. The sections with values between 2.4 and 2.2 should only enter in the core network if there are special network reasons.

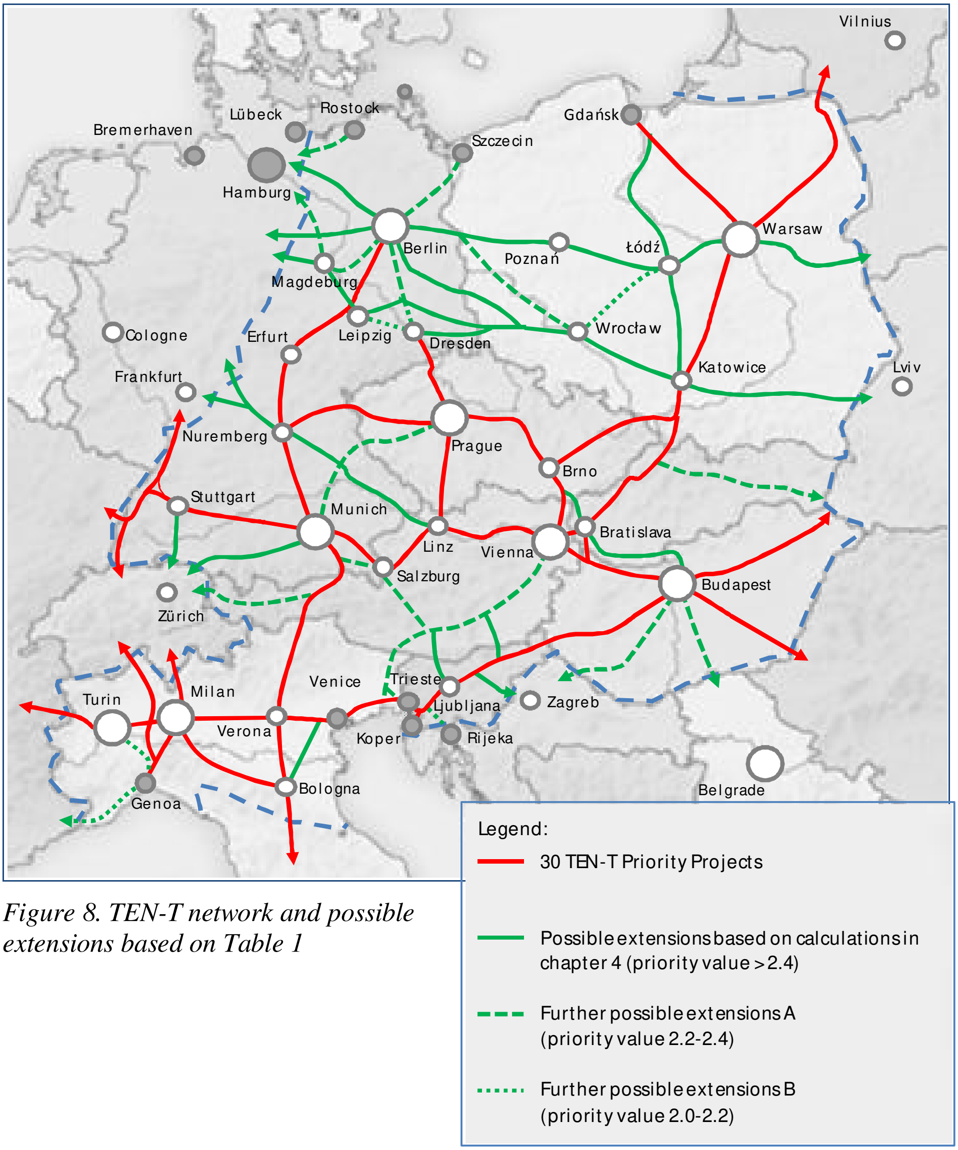

Figure 8. TEN-T network and possible extensions based on Table 1

Figure 9 shows an option for a Central European core network, based on the calculations of chapter 4 and Figure 8. Firstly, the 7 Central European TEN-T priority projects were included as well as all railway sections with a core network priority value higher than 2.4 (chapter 4). Out of the sections with a value between 2.4 and 2.2 four have been selected for the following reasons:

- Vienna-Udine-Venice, Salzburg-Villach: Linking Vienna and Munich to the Adriatic
- Szczecin-Berlin-Dresden, Rostock-Hamburg, Pivka(SI)-Rijeka: Linking the port cities to the network
- Budapest-Zagreb: Better linking of Croatia to the core network, probably a new EU member state in 2012/2013
- Budapest-Subotica-Belgrade: Linking the Balkans to the core network.

Figure 9. An option for a Central European railway core network

6. Conclusion

It is of high importance to create a good and feasible railway network in Europe and especially in Central Europe in order to achieve a modal shift from air and road traffic to the more environmentally friendly rail traffic mode. The member states of the EU should work together to build up a common European railway system with a high level of cooperation and interoperability, both for passenger as well as cargo transport.

The method presented in this paper aims at presenting a core network for Central Europe in a time when the European Commission is working on the revision of the TEN-T guidelines. This method is based on established networks as well as new calculation processes and thus generates a transparent way in prioritising European railway sections.

References

[1] Bernese media: *High Speed Railroad Network in Europe in 2011,* (2011), http://en.wikipedia.org/wiki/File:High_Speed_Railroad_Map_Europe_2011.png

[2] Büker, T.: *Maps of Railway-Networks*, (2011), www.bueker.net/trainspotting/maps.php

[3] Commission of the European Communities: *Commission decision of 22.7.2009 amending Decision 2006/679/EC as regards the implementation of the technical specification for interoperability relating to the control-command and signalling subsystem of the trans-European conventional rail system,* C(2009) 5607 final, (2009).

[4] Commission of the European Communities: *Green Paper. TEN-T: A policy review. Towards a better integrated transeuropean transport network at the service of the common transport policy*. 4.2.2009, COM(2009) 44 final, (2009).

[5] DG TREN: *European Deployment Plan for ERTMS,* (2009), http://ec.europa.eu/transport/rail/interoperability/ertms/doc/edp/ertms_map_10_07_2009.pdf

[6] DG TREN: *Trans-European transport network (TEN-T). Priority axes and projects (2020 horizon),*(2010), http://tentea.ec.europa.eu/download/maps/overview/tent_and_pp30_updated_links_20100519_galileo.pdf

[7] European Commission: *Trans-European transport network. TEN-T priority axes and projects 2005,* (2005).

[8] European Commission: *White Paper. Roadmap to a Single European Transport Area − Towards a competitive and resource efficient transport system*, (2011).

[9] Eurostat: *Maritime transport - Goods (gross weight) - Quarterly data - Main ports,* (2009), http://epp.eurostat.ec.europa.eu/portal/page/ portal/transport/data/database

[10] Eurostat: *Regional demographic statistics - Gross domestic product (GDP) at current market prices at NUTS level 2,* (2009), http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/regional_statistics/data/database

[11] Eurostat : *Regional demographic statistics - Population,* (2009), http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/regional_statistics/data/database

[12] Eurostat: *Detailed air passenger transport by reporting country and routes,* (2010), http://epp.eurostat.ec.europa.eu/portal/page/portal/transport/data/database

[13] Expert Group Methodology for TEN-T Planning: *Draft Proposal on Core Network Planning (status after 3rd Meeting),* (2010).
[14] HB-Verkehrsconsult GmbH & VTT Technical Research Centre of Finland: *Pan-European Transport Corridors and Area Status Report,* (2005).
[15] Petersen, M.S., Bröcker, J., Enei, R., Gohkale, R., Granberg, T., Hansen, C.O., Hansen, H.K., Jovanovic, R., Korchenevych, A., Larrea, E., Leder, P., Merten, T., Pearman, A., Rich, J., Shires, J., Ulied, A.: *Report on Scenario, Traffic Forecast and Analysis of Traffic on the TEN-T, taking into Consideration the External Dimension of the Union – Final Report,* Funded by DG TREN, (2009).
[16] RailNetEurope: *RailNetEurope,* (2011), www.railneteurope.com
[17] Railteam: *About us,* (2011), www.railteam.co.uk/about-us
[18] Railteam: *Network Map,* (2011), www.railteam.co.uk/travel-information/network-map.php
[19] Reents, M.: *Creation of a "Core Layer" within the Trans-European Transport Network (TEN-T) − The case of the Via Regia area, TEN-T core network & European and national railway policies,* in Proceedings of the 3rd SoNorA University Think Tank Conference, Potsdam, (2009), pp. 79–88.

Potential Role of Regional Railways in Regional Transportation

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Abstract: Beside Hungarian Railways Plc (MÁV) and other railway companies, local railways companies contributed to forming the railway network in Hungary. The establishment of local railways was legally supported by the Article XXXI/1880 and Article IV/1888. The operation of local railways between Arad – Körös region was allowed before these laws came into effect. The constructions of local railways had a considerable pace as 57% of them were built by local railway companies in 1918. The laws set simple technical conditions to start the constructions resulting in lower construction costs. The lines built with lower technical quality still met the requirements of local transport. Local railway companies became completely state owned after 1945, except for Local Railways Plc of the Fertő region. However, many of the former local rail lines were closed. Most of the currently functioning branch lines are actually the former local railways. The railways which had not been closed had worse and worse technical conditions with a declining number of passengers. In most of the cases the solution was to close rail lines with bad infrastructure parameters. The present study outlines a model appropriate for a complex analysis of problems of branch lines while considering potential roles of rail lines in regional transport.

Keywords: local railway lines, railway act, rail regionalization, branch lines

1. Past and present of regional railways

At the time of flourishing railway transport in Hungary 50% of the railway network were local railways. Since the Trianon Treaty and due to attempts to solve the problems this rate has decreased to only about 30%, nevertheless, local railways are major problems in railway traffic in Hungary even today.

Originally, there was no national interest in local railways. The Article XXXI/1880 mentioned above defines local railways as follows: 'railways which aim at meeting transport and economic requirements of a region.' Discounts and allowances involved in the Article did not apply to railways connecting two railways or serving as supplementary lines to major lines. The amendment of the Article XXXI/1880, that is Article IV/1888 also mentioned above, declares that starting local railways which are planned to be extended to the borders of Hungary or which connect railways with waterways used by steamships, is subject to legislation. The former term, local railways, is equivalent with the present term of regional railways.

The terms local railways and regional railways are often used as synonyms. (According to community law the term regional railways is equivalent with the term local railways, considering the Hungarian railway system.) The local railways are connected to the major national railway network. The criteria to set up local railways are defined in the law in force CLXXXIII/2005:

- The railway system is established to assure local transportation. Its role in national transportation is eligible.
- The local governments involved take the responsibility voluntarily to develop services of local interest.
- The railway network to be established can be made with narrow-gauge.

The local railway network is designated by the National Transport Authority, right after the application on the operation of the railway network is approved. However, the local railway network is allowed to operate in at most 3 counties or the network length must not exceed 400km.

1.1. The golden age

The above mentioned two laws made the establishment of local railways much easier. The permission to construct local railways in jurisdiction of the laws was issued by the Minister and not the Parliament. The Hungarian local railways had their longest network in 1918 when local railway companies constructed 13,000km of the 23,000km long network. 11.7% of the 13,000km were run only by local railway companies. The local railways were constructed in the frame of concession public limited companies and were mostly run by the Hungarian Railways company. After the expiry of concession the state of Hungary got the right of ownership, but in practice, due to financial problems the state had got the right of ownership well before the concession expired. It is important to note that the local railways were always constructed by taking only local interest into account and neglecting any national conception [1]. In Transdanubia (West of the river Danube) in Hungary a local railway network of more than 2,100km was built. The first line (between the cities Szombathely and Kőszeg) was launched as early as 1883 [2]. Most railway lines were built in the region of the city Kecskemét located in the region between the rivers Danube and Tisza. The local railway Kecskemét-Tisza Company opened its first railways between the cities Kecskemét and Tiszazug which was extended up to the city Kunszentmárton. In the region West of the river Tisza in Hungary the local railway company Arad-Kőrösvölgy had already been established before the law concerning local railway companies was accepted. The railways of the company had a network throughout the region West of the river Tisza in Hungary, Partium and Trasylvania. The biggest junction of the region West of Hungary were the cities

Debrecen and Nyíregyháza. Simultanously with the construction of railways with normal gauge three railway companies started building important railways with narrow-gauge in the region West of the river Tisza in Hungary. In the North of Hungary railway construction was determined by the special geographical features, mines and location of industrial areas. Thus, the shortest railway lines were built in this region. And also, there were construcion works in the regions Sub-Carpathia, between the rivers Sava and Drava, Transylvania, Partium, Bácska and Bánát. During local railway constructions lasting till the First World War railway station buildings were built based on standard plans. These buildings were ranked in four groups. A lower ranked building could be developed and extended in some steps based on the theory of developing buildings [3].

1.2. After the First World War

The railway network in Hungary developed until the First World War. The first and biggest hit on the network was made by the peace treaty of Trianon. The new borders crossed and cut 52 railways (on the open ways between stations) which resulted in ending of transportation. The new border made especially great damages to local railways by isolating agricultural lands from markets, and mines from proceeding industry. The railways at the border region were located on territories of the neighbour countries. Railways right at the borders connected the former Czechoslovakia, Rumania and Yugoslavia. For data on the Hungarian railway network before and after the Trianon treaty see Table 1 and 2.

Table 1 Data on the Hungarian railway network in 1918[1]

Name	Operation length, km		
	Normal	Narrow	Total
	Gauge		
Hungarian Railways Company ownership	8 279	37	8316
Community major railways	1 333	-	1333
Local railways line	11 475	1574	13 049
Other/foreign railways and peage line	171	-	
			171
Total	21258	1611	22 869

[1] Source: Fejezetek a 150 éves magyar vasút történetéből (Chapters from the history of the 150-year-old Hungarian railways)

Table 2: Data on the Hungarian railway network in 1920[2]

Name	Operation length, km		
	Normal	Narrow	Total
	Gauge		
Hungarian Railways Company ownership	3068	-	3068
Community major railways	780	-	780
Local railways line	4530	268	4798
Other/foreign railways and peage line			
	59	-	59
Total	8437	268	8705

1.3. After the Second World War

Between 1938-41 the railways which were cut by the Trianon treaty were united again due to the territories regained. Furthermore, new railway lines were built in order to improve railway connections. In the 1950's new plans were made to build new railway lines and some of them were even carried out. There was also a complex plan to build a major railway line of the direction East – West between the cities Solt and Szarvas, which was just partly carried out. Some decades later there was an intention to build a railway roundabout line right outside Budapest [4]. Several plans were examined. For the plans see Figure 1. One line could derive from the railway line Budapest – Hegyeshalom at the town Szár and connect to the Budapest – Záhony railway line at around the city Cegléd by running over the new Danube Bridge at the Csepel island. According to the second version the roundabout rail line could have a branch line deriving at Rétszilas from the railway line Gyékényes- Kaposvár- Budapest and after running over the Duna Bridge and via Kecskemét it connects to the Budapest – Záhony line at around Cegléd. This is also a current issue as there is a need for improving and strengthening railway connections between the West and the East, the North and the South without travelling through Budapest.

Closing down rail lines started at the turn of the 50's and 60's. As a first step branch lines cut as a result of the Trianon Treaty were closed at the border line. The transportation policy in 1968 triggered closing down a number of railways. The former local railways were also subject to this process. However, the policy ignored several factors, such as the secondary effects of closing railway lines. Due to the transport policy the railway in the Őrség region (between towns Zalalövő – Bajánsenye) was closed down, which was later still rebuilt as part of the Corridor V and was conveyed for transport in 2000. As a result of the transportation policy the railway closing process took place between 1968 and 1982, involving 1900km long railways of normal and narrow gauge. From March 2007 passenger transport was banned on 14 railway lines.

[2] Source: Fejezetek a 150 éves magyar vasút történetéből (Chapters from the history of the 150-year-old Hungarian railways)

After changing the time table of 2009/2010, 24 railway lines were closed from passenger transport. In 2010 passenger transport started again on 10 lines of 380km altogether.

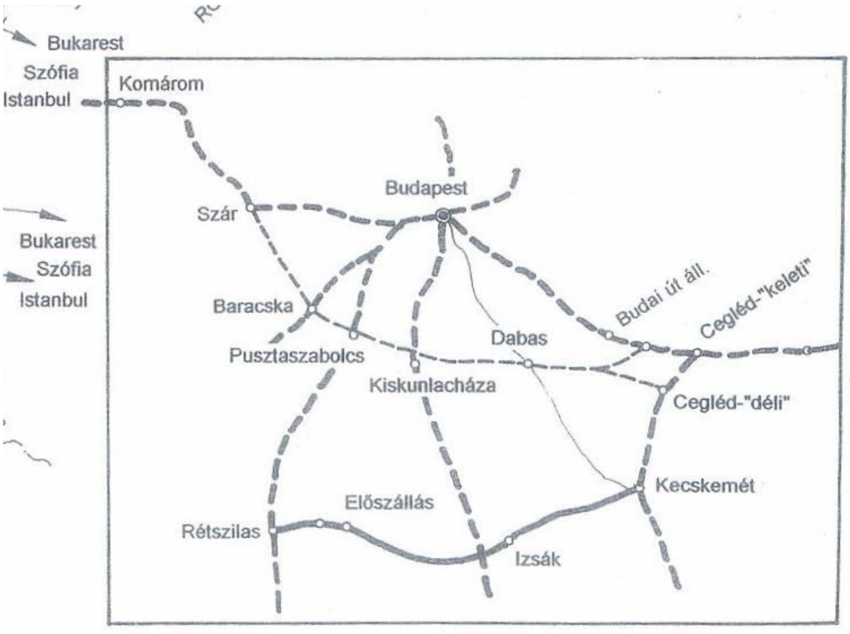

Figure 1 Railway line construction plans[3]

2. Problem solving attempts without closing any railway lines

The reconstruction of local railways with low quality technical features did not take place. Due to this fact travel time increased and comfort of passengers got much worse. The process of closing and reorganizing big companies contributed to a lower number of passengers, as well. Originally, the local railway lines were built regarding only economic needs and their distance from cities and major towns was down at list of priorities. Consequently, many railway stations are located far from towns or town centres which deteriorates the competitiveness of railways. Furthermore, the state and quality of station buildings is distressing. Bus transportation connecting towns with railway stations and introduction of reasonable time tables of branch lines are not really costly [5]. The former local railways are ranked in line category III. For their percentage see Table 3.

[3] Source: Fejezetek a 150 éves magyar vasút történetéből (Chapters from the history of the 150-year-old Hungarian railways)

Table 3 Percentage of railway line types[4]

Railway line type	National (%)	Region (%)	
		Transdanubia	Great Hungarian Plain
I.	35	44	23
II.	30	39	24
III.	35	17	53

The Hungarian Railways company had several attempts to manage problems concerning branch lines. In 1995 it established independent railway organizations and urged transportation authorities of the government to finance investments aiming at cost cutting. These investments focused only on decreasing number of human work force. Dismission of workers was a result of organization rearrangements and application of new technologies. There were hardly any real investments. In 1995 three regional railways were established, and 17 in 1996. So, the regional railways took 30% of the whole network system. These regional network systems were not spread equally in Hungary. 14 railways out of 17 worked in the East of Hungary, serving the less developed regions. When setting up regional railways which operated within the network of Hungarian Railways the following aims were set:

- Greater independence in contact with forwardig companies
- Greater independence in making time tables
- Right to start special trains
- Greater independence of decision on issues concerning railway services
- Significant decreasing of costs

Most of these aims were not carried out. Operation of the regional railways was significantly restricted, compared to original ideas. The fact that the local railways are run within the Hungarian Railways company, contributed to failure of local railways. In 1998 the system failed as the Hungarian Railways company deprived operation rights from local railways [6].

In 2000 the Hungarian Railways company drafted a proposal to rationalize the railway network in charge of the Ministry. The proposal involved closing railway lines of some hundred kilometers, mostly those not used at all, and also, establishment of 4 independent railway networks. Later these lines were referred to as regional railways. Two regional railways of 372km (Regional Railways of Vésztő and Regional Railways of the Region Nógrád) were launched as an experiment from 1 January 2005. In spite of proposals of the Hungarian Railways company these two railways operated within the Hungarian Railways company. Nevertheless, they could not have an independent economic basis. To have a successful economy, beside attaining independence the regional railways should have introduced a series of arrangements in order to increase income and cut costs. The pilot project resulted in various experience:

[4] Source: made by the author

- Lack of independence
- Problems with time tables due to lack of independence
- Passenger complaint about comfort level
- Neglected infrastructure
- Weak cooperation with bus transportation companies
- Relation with local governments improved
- Insufficient spheres of authority to meet local needs

3. Analysis of social economic effects of regional railways by making a conceptual model

3.1. Functions of regional railways

Recent practices regarded annual income and operation costs as a basis when a decision had to be made on a branch line serving regional interests. The former regional railways have several functions which require considering social costs and benefits by decision making. These functions are related with network, regions, and natural environment [7].

- A connected network of regional railway lines can be a basis of a regional network
- A roundabout railway line within the network
- Some branch lines serve as a basis of connection to the national railway network to be developed later
- Role of leading to and off the major railways
- Improving former relations of crossborder railways
- Branch lines can attract settlers in less developed regions
- Branch lines are potetials to affect transportation policy of sharing transportation tasks
- Some railway lines are likely to cross areas to be under natural protection where there is an enormous need for restricting public road transport

3.2. A large scale description of the model

It is deemed to set up a model which allows decision making from a complex aspect and reflects the complexity of the branch line issue (Figure 2). By using the conceptual model there are several scenarios made to manage branch line related problems. By modelling, a simplified copy of a partial network system is made, including the determining features necessary for analysis [8]. Features not necessary for analysis can be ignored as they would complicate analysis without providing any useful information.

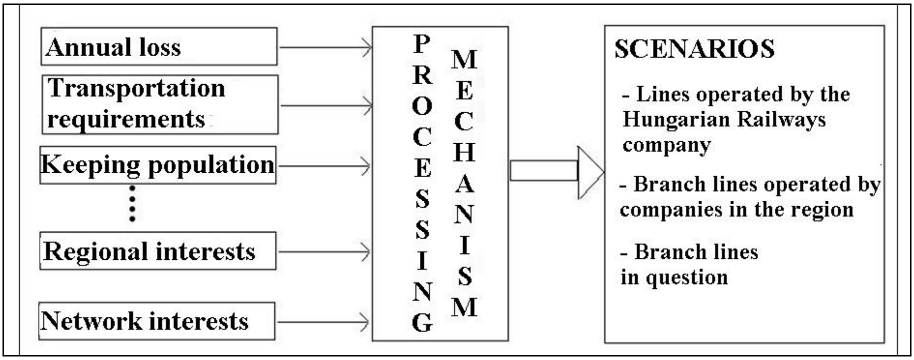

Figure 2 Conceptual model for social economic efficiency analysis of regional railways[5]

The most important inputs of the model are described in forms of natural units of measurement which affect regional railway transportation. For example:

- Railway connections of small regions
- Annual losses of the railway line
- Transportation needs
- Providing basic transportation services
- Power of keeping population
- Regional interests
- Network (connection) interests

These indicators can be expressed in sums of money or any other ways. Concerning an indicator the best value is 100 and the worst is the minimum value of the very scale. The value of indicators with different dimensions can be defined by beneficiary indicators.

$$I_{ix}=\{1-[\frac{Z_{ix}-Z_{\min i}}{Z_{\max i}-Z_{\min i}}\times(1-\frac{Z_{\min i}}{Z_{\max i}})]\}\times 100 \quad (1)$$

where:

I_{ix}: points of input i.

Z_{ix}: actual value of input i.

Z_{mini}: minimum value of input i.

Z_{maxi}: maximum value of input i.

An independent organization makes a preference ranking for each input and finally, it makes a group ranking by uniting single preferences. This ranking will be the basis of determining preference values. It is important to note that aggregating single

[5] Source: made by the author

preferences into group preferences is a broad and complex issue. It is recommended to use a methodological approach to set up a model. It could be an overwhelming task to analyze the social, psychological aspects of decision making on groups. In the process actually voting takes place whereby experts work out their ranking and later they do not make any changes to this rank of preferences. Aggregation of input indicators is carried out by using preference values.

$$AI_{xsz}=\sum_{i=1}^{n} I_{ix}\times S_{szi} \tag{2}$$

where:

AI_{xsz}: aggregated value of inputs

I_{ix}: points of input i.

S_{szi}: preference value of input i. from the aspect of the expert team (sz)

The aggregated value can be regarded as the utilization value of the regional railways. This value determines the potential scenario. Potential scenarios:

- Lines operated by the Hungarian Railways company
- Branch lines operated by companies in the region
- Branch lines still in question

It is necessary to note that after closing down railway lines their reconstruction is almost impossible due to extremely high construction costs. There is no possibility to build lines with simplified technology, as it was permitted by the law at times when regional railways were built first. Based on recent experience, on railway lines without any traffic it is highly required to spend on guarding assets and equipment.

In case one or more branch lines are opened for transportation based on the model and operated by a company in the region, further activities occur:

- Contracts
- Separated accounting required
- Criteria of railway security certificate and permission
- Criteria of operation certificate
- Designating regional railway network

The present law concerning railways allows different companies to operate railway branch lines. Beside the central budget other resources (private resources, tenders) become available. Regional operation makes it possible for local governments to negotiate directly and adjust railway passenger transport to local features and needs.

Summary

Due to specific railway network features in Hungary branch lines have got a main role in organizing railway transportation. The history of branch lines is rooted in the XIXth century. To differentiate them from major railway lines the term local railways, also used in other countries in Europe, was used for them. These railways were built with lower level technology; however, the railway system was really sufficient in Hungary, even compared with other European countries. The technological parameters and lack of renovation works for decades have made it urgent to solve the problems concerning branch lines. To make a proper decision on the branch lines it is practical to use the results of a complex model which is not merely based on annual losses. If the output confirms the idea of operating branch lines by companies in the region, several questions (maintenance of railways, organizing and accounting passenger transportation, human political issues etc.) are expected to be answered.

References

[1] Mezei, I., Somogyi. Á.(szerk.): *Fejezetek a 150 éves magyar vasút történetéből,* MÁV Rt., (1996).
[2] Majdán, J.: Helyi *érdekű vasutak és kiépülésük a Dunántúlon, MÁV Rt.*, (1996).
[3] Kubinszky, M., Gombár, Gy.: *Vasútállomások Magyarországon 1846-1988*, Népszava kiadó, (1989).
[4] Kovács, L.(főszerk.): *Magyar Vasúttörténet 2. kötet*, MÁV Rt., (1996).
[5] Felsmann. B.: *Mellékvonalak működtetése térségi vasúti társaságokon keresztül http://www.khem.gov.hu/data/cms1553487/vasarosnameny.pdf*
[6] Ercsey, Z., Felczán, M., Szedlák. Zs.: *A regionális vasúti közlekedés fejlesztése,* MÁV FKI évkönyve (2003), pp. 57-78.
[7] Rixer, A.: *A kisforgalmú vasúti mellékvonali probléma alapjai és megoldásának elemei*, MÁV Rt. FKI évkönyve(1991-1993), pp. 53-84.
[8] Pokorádi, L.: *Rendszerek és folyamatok modellezése*, Campus kiadó, (2008).
[9] Temesi, J.: *A döntéselmélet alapjai*, Aula, (2002).

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Planning and Timing in Inland Navigation

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Abstract: Hungary has a central position considering both geographical position and waterway networks, so changes in the inland waterway transport tendencies can be obviously experienced. In Middle-Europe the traffic outputs don't reflect the theories of conception on sustainable transport. The dividend of inland navigation from total modal split is insufficient. What are the reasons of the state of being slighted? How can be enforced the well-known ecological and economical advantages of shipping? It is important to gauge the specialities of river transport planning. Due to transformation of shipping market and disproportional module differences, forecasts are strongly focused on. Beside network development, infrastructural modernising and a suitable charging policy it is important to improve reliability if you wish to take the advantages of waterway transportation. As a basis for this you need an appropriate transportation planning system.

Keywords: planning process, structural model, general process model, timing, dynamic calculation

1. Advantages vs. performance

In spite of the well known fact that shipping has many advantages as it is economical, environmental friendly and safe, its modal split rate is quite low. The Netherlands are kind of exception with their 40%. Even on the waterway system of the river Rhine a rate of 20% is achieved only in few countries [5]. To reach this rate on the Danube seems a utopist idea. This may be an astonishing fact knowing that shipping is a proper way of transporting big masses to far distances. When defining transportation performance you need to form a product of much bigger elements. The basic formula [6] for a vehicle fleet in a selected period of time is the following:

$$P = \sum_{i=1}^{x} \sum_{k=1}^{z} M_{i,k} \times D_{i,k} \tag{1}$$

where: P: total transportation performance
$M_{i,k}$: mass transported by vehicle number i on its transportation route number k
$D_{i,k}$: the distance covered by vehicle i on the transportation route number k
x: number of transportation vehicles used

z: number of routes in a selected period of time

As M and D are high numbers, a low level of total P, compared to other fields, is caused by the low level of x and even more that of z. Consequently, there are few ships and they have hardly any transport which results in a very low transportation frequency. As a result, P is low, too.

Shipping is claimed to be slow, so it is often ignored. Insufficient technical speed is a solid feature that cannot be improved. However, due to its trading (forwarding) speed shipping is competitive when it comes to transporting big masses to far distances. For example, 10,000 tons of load is transported from Austria to the Black Sea within shorter period of time on a pushed ship of craft than doing so by using the vehicle fleet of a road transportation company.

The other major problems are spatial availability, the limited network system and the really low number of proper ports. As a result, shipping is involved in combined transportation chains. With combined technology on- and off-transportation are easy to plan and organise. Nevertheless, it is still shipping that takes the most time and distance in the transportation process. Due to external natural effects shipping is the least reliable way of transportation considering punctuality. That is why the shipping route section requires the most appropriate calculation, timing, planning and organizing to carry out bimodal transportation tasks properly. You can improve reliability by competent planning which may result in a more widespread use of waterway transportation.

The aim of the present study is also to contribute to improving waterway transportation by optimizing transportation task planning.

2. The transportation planning process

Waterway transport scheduling involves operational, nautical and economic issues which are mostly strongly related. Concerning the hierarchy structure of methods there are vertical - layered -, and horizontal - independent - planning methods.

The planning process consists of structural and action phases. Concerning structure, we are in process of preparation-elaboration-completion. Action consists of the following steps:

- defining tasks
- defining system elements
- revealing influencing factors
- matching
- modifying
- developing versions
- checking
- completion.

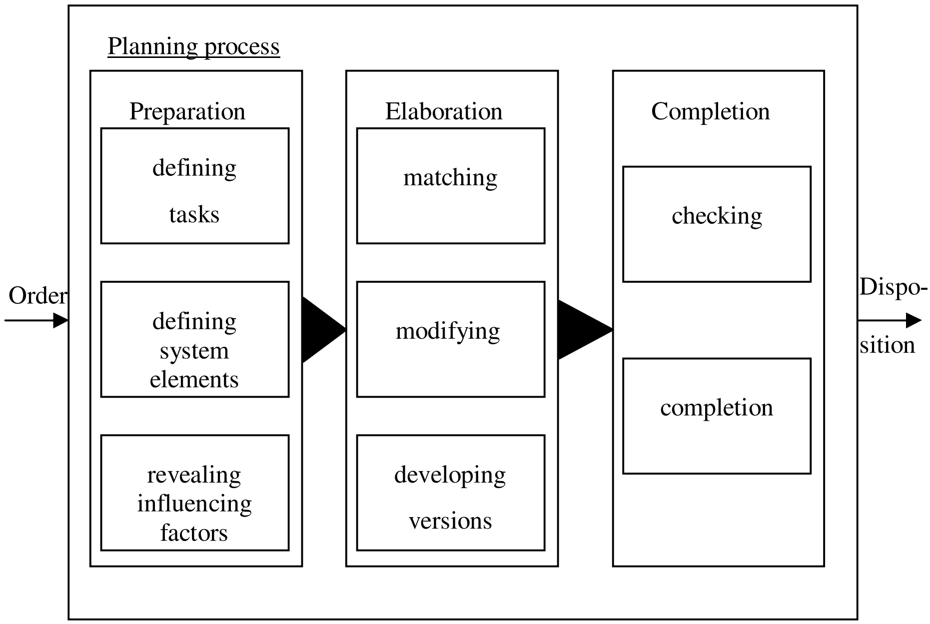

Figure 1. Structural model of transportation planning

2.1. Phase 1: Preparation

The role of preparation of planning is to reveal the bases of a transportation task and detail basic data.

Based on orders the task can be defined. Firstly, you define the character of transportation (if you transport people or goods). If you transport goods you have to define the character of joining the transportation chain (if you transport only by ship or it is a combined bimodal or trimodal process). All these characters affect the application.

Elements of transportation task:

- goods
- vehicle
- relation
- period

The load, the on- and off-loading station and transportation deadline are set according to the needs of the contractor [1].

The transportation vehicle is usually provided from the ship fleet of the transporter. In case of leasing vehicles from an extern company the vehicle fleet is obviously extended.

The transportation route on river waterways (from the starting point to the destination) is mostly given, there are alternative option routes only in the region of the river Rhine.

You can define the influencing factors of the single system elements.

Influencing factors of transporting goods:

- type (piece or bulk goods)
- physical condition (liquid or dry goods)
- specific density and loading co-efficience
- size and geometry of a loading unit
- way of storing and packaging
- amount

Required features of ships:

- type (according to loading and shipping technology)
- capacity (data on volume and mass)
- data on extern size
- store geometry

Input data on relation:

- spatial features (ends, distance, inner section size)
- features of hidrology and
- hydraulics

The transportation period can change the meteorological and hydrological conditions on the route.

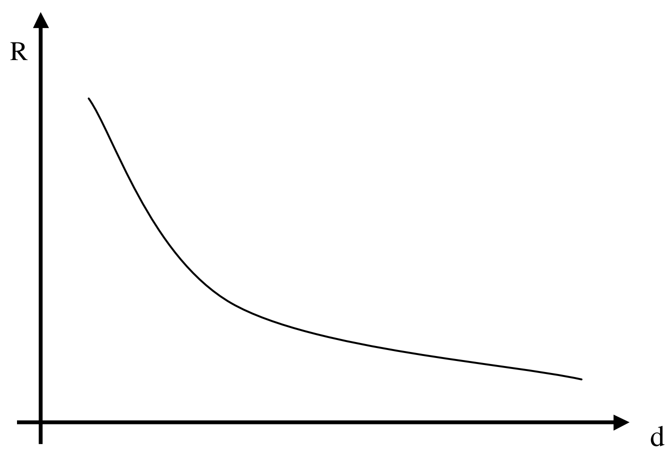

Figure 2. Reliability of waterway transportation against distance

The increasing transportation distance, the variable shipping route, the fluctuating streaming speed and the ever increasing number of various shipping actions have a degressive effect on the reliability of waterway transportation (see Figure 2).

Various spells and seasons may disturb planning and calculation (see Figure 3): spells with water level changes, ice and floods.

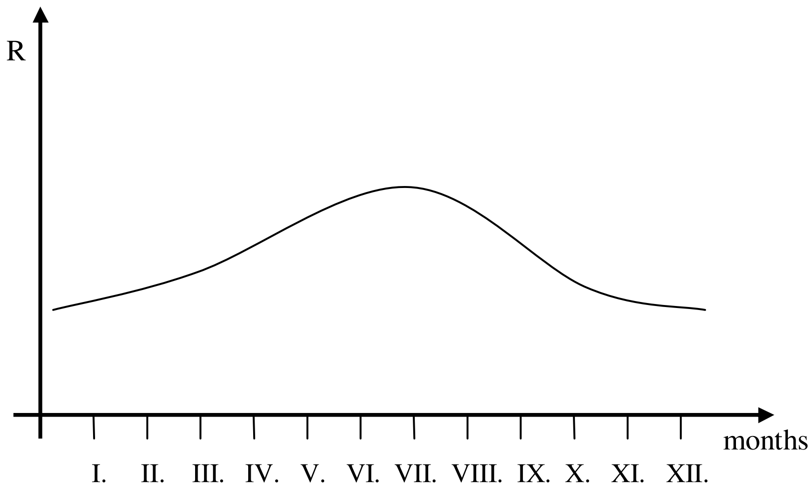

Figure 3. Reliability of river transport by seasons

2.2. Phase 2: Elaboration

During elaboration we follow some earlier defined aspects to fulfil the set aims. Planning has operational and nautical aspects.

Operational aspects:

- harmonizing load and vehicle (according to type, amount and other features)
- considering range of engine ship (fuel and food supply, technical service)
- adjustment to operating time of ports and sluices

Nautical aspects:

- calculating hydrological conditions
- application of vehicles adapted to shipping route features
- considering transport restrictions.

Major purposes of planning:

- best utilization of ships (concerning mass and/or volume)
- with the right trimm position and
- suitable stability,

- keeping load safe (by proper loading and storing)
- minimizing transportation time [3].

The input elements are adjusted by matching the above listed aspects and purposes. Since both the elements and factors are complex, it is almost impossible to carry out a perfect adjustment. You can solve this problem by making a list of preferences with varied options.

Basic prearrangements in the first phase are:

- Selecting appropriate vehicle, that is, matching the loading and the transportation vehicle (character of goods – suitable ship, quantity of goods – transport capacity, matching in ‘space and time’)
- Maximizing ship load utilization (concerning plimsoll limit of load volume - and store size and amount of goods)
- Calculation of machinery power required
- (enough power considering the amount of load and ship type, based on the nautical and hydraulic conditions of the transportation way)
- Amendments to waterway parameters (calculations on gauge based on hydrological and geometrical features)
- For regular, long term transportation: setting annual utilization time, setting time basis
- For new enterprises: calculation of returns, calculation of economical utilization

It is important to note that it is not necessary to check stability when fixing suitable trimm position, while considering dynamic effects is needed with maritime navigation.

The task is even more difficult if you have to plan and organise transportation with a formation of several ships. Beside criteria applying to single ships you have to take a set of criteria into consideration when forming ship caravans:

- an optimum size according to the waterway capacity
- sufficient engine ship performance to enable special movements, manoeuvres
- obeying official restrictions applying to any waterway section
- creating up- and downhill forms according to actual direction
- positioning in the caravan according to load line
- connecting ships considering destination port
- separation of dangerous goods.

It is not possible to meet each criterion at the same time, thus, it is advised to make a list of priorities. Although you usually have to meet only one or two of the criteria, planning still gets divergent [4].

Calculation has special position in range of shipment tasks. The single phases of its analysis are logically related. The system model of the planning process is based on these phases (see Figure 4).

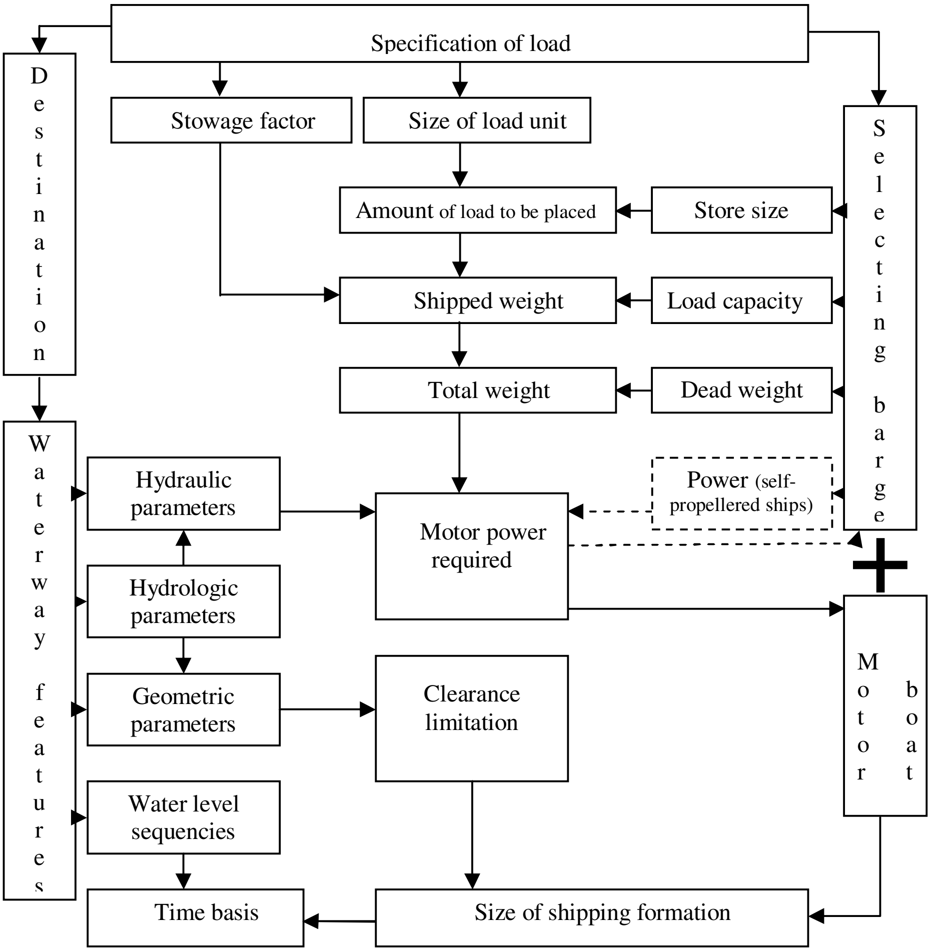

Figure 4. Process model of transportation planning

2.3. Phase 3: Completion

The single versions must be checked concerning all the transportation relation. In case of any differences new amendments actions and checks are necessary until differences disappear. It is especially difficult to forecast changes that occur during the transportation process. Being a major issue, the time factor needs high consideration. By doing so, and after a repeated check and realization of the required amendments, it is possible to make the final version of the plan, and also issue the executive order to start transportation.

3. The roll of time in planning

Transportation on river waterways can be regarded as a reliable service if you are well prepared for occasional and unexpected conditioins on the way. While planning the transportation process, you can select stable elements, like type of ship, loading machine. However, different positions of the transportation vehicles and various features of the waterway require considering time factor for the single phases. There may occur static and dynamic effects. You need to take the positioning list into consideration only to calculate starting time of the ship, though, the waterway features continuously fluctuate during a long transportation process. The time factor has direct and indirect affects on elaboration of the transportation process (see Figure 5).

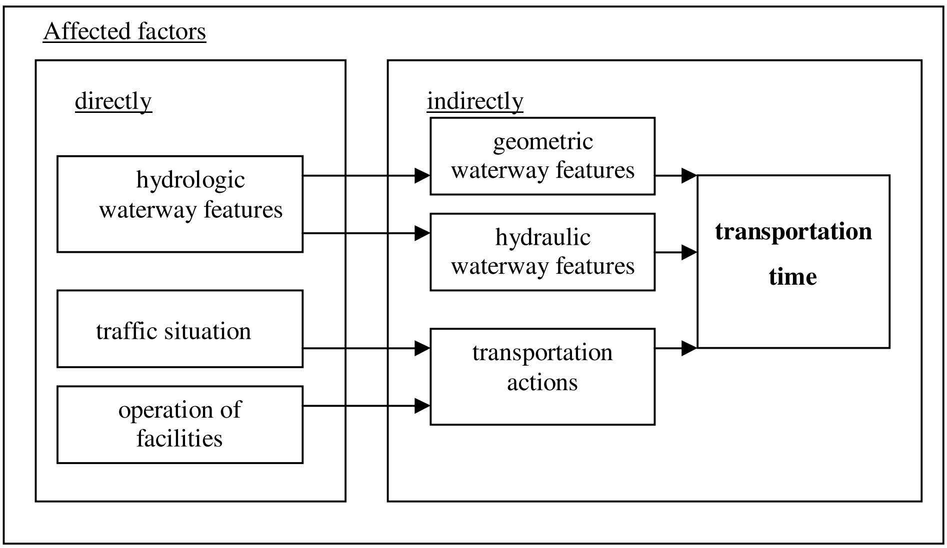

Figure 5. System of time affected factors

Technological development allows more and more reliable solutions for calculating changing circumstances. Earlier you could base your calculation on own experience, then it was possible to get reports on daily water level and shipping positions. Today it is possible to be informed about any required data any time.

3.1. Static calculation

With classical calculation you determine the inner section size and streaming characteristics based on available water level data. Loading, load level and and hight of ships is adjusted to the most crucial points of the whole transportation way. Starting parameters are usually calculated with statistical methods using water level measurement functions. It is not possible to establish any deterministic relation between the single way, and also, the available relations are only effective under stable hydrometeorological circumstances. In case of up-swollen waterway sections natural waterstream relations are irrelevant. The waterway characteristics are determined by the operation schedule of power stations and flood prevention management. Classical calculation for these areas is only possible by approximation. As a result, ships are forced to stop and wait during transportation. Major reasons:

- oneway traffic in narrow waterways
- limited depth in swallows
- partial passing of big ship formations at locks
- compulsary use of a towboat at sections with heavy streams.

All these constraint actions and waiting time can even exceed expected transportation time by 20-70%. This time is extremely long due to miscalculated swallow depth values. In critical cases ships can travel on by reducing weight of load.

3.2. Dynamic calculation – 4D-planning

The most crucial points of planning transportation are the changing parameters concerning time and space. The most effective way the situation can be improved on frequently changing waterway sections (like that on the river Danube in Hungary) is waterway development and maintenance. Without these planning needs bigger consideration.

You can solve the problem of time changes in several steps.

1. Firstly, you need to specify data on starting time. You have to switch from static to dynamic state evaluation. The expected waterway parameters can be adjusted according to the time the parameter is expected to be relevant. To do so, you need to calculate with transportation time and passing of water output.

The size of inner sections can be harmonized with load and size of the ship. Selecting the most appropriate ship is of great importance, as we cannot expect any changes of the size of the selected ship during the transportation process. Potential actions in case of negative forecast:

- change starting time (if transportation deadline allows it)
- use smaller vehicle units (if available)

2. Secondly, accurate timing requires considering time factor. 4 dimension shipping enables you to trace occasional changes of restrictive cross-sections during the whole transportation process. If changes are negative, the most evident solution is to postpone passing on. If you are aware of changes well in time, prevention is possible. Potential adaptation options for ships of given size on the waterway:

- timing of passing on at critical sections considering flexibility of travel speed, $v_1 \rightarrow v_2$ (with a towboat if economical) (Figure 6/1)
- decreasing former usual waiting time $t \rightarrow t'$, if possible (Figure 6/2)

- preference of arranged facilities [2] , e.g. passing at locks $w_i \rightarrow w'_i$ (Figure 6/3).

Electronic information technology support allows continuous information flow on ships, as well. Before, shipping was conducted based on indirect central orders and today you get up-to-date direct information during shipping. It is easier to take responsible operative measures having reliable and fast resources of information.

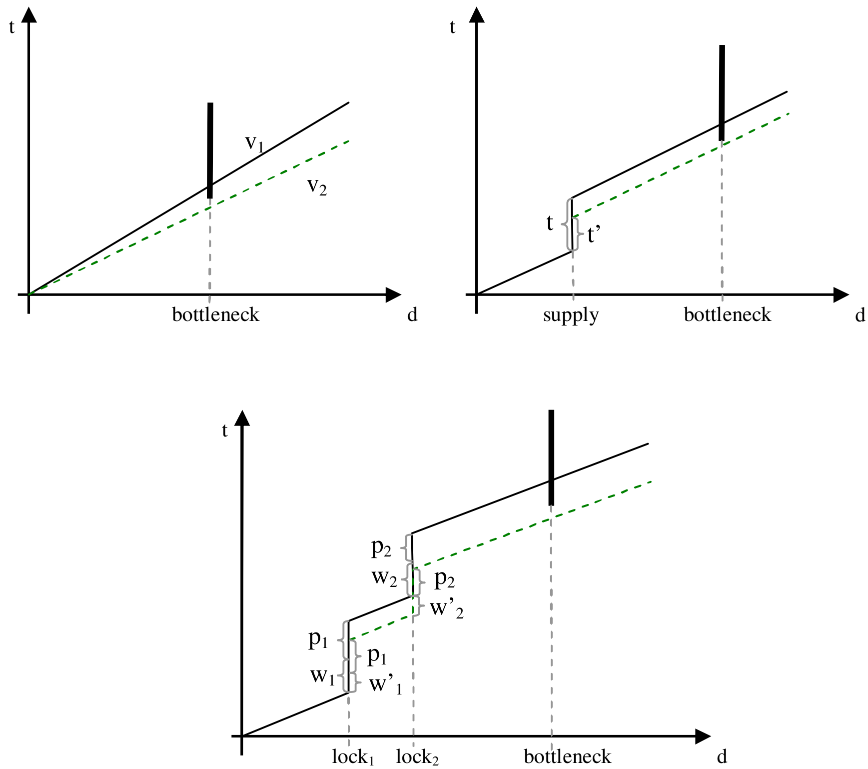

Figure 5/1-3. Adjustment / timing on the way

3.3. Measurable effects

Planning transportation tasks on river waterways traditionally is carried out by calculating parameters. Data are regarded as something static when you forecast waterway conditions based on the actual data at the time of planning.

Planning with a dynamic approach takes shipping time into account at time of the planning phase to have up-to-date data on size of inner sections. Further improvement is expected with applying potentials of 4D-shipping, which allows adjustment according to information gained during shipping.

For differences between the process and the expected results of traditional and dynamic planning see and compare Figure 6/1 and Figure 6/2.

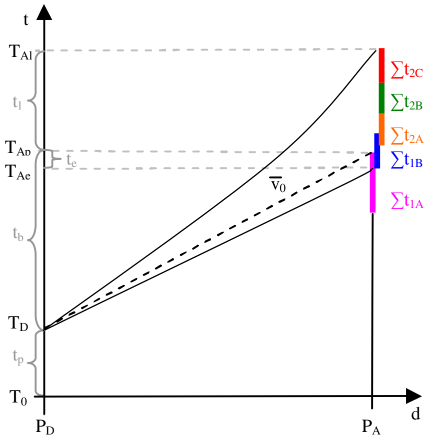

Figure 6/1. Result of static planning

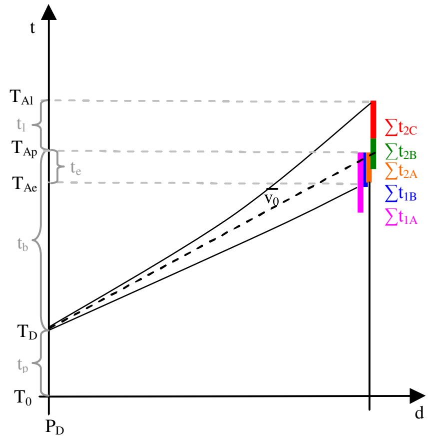

Figure 6/2. Result of dinamic planning

where: P_D: port of departure
P_A: port of arrival
T_0: time of beginning to plan
t_p: planning time
T_D: time of departure
T_{Ap}: time of planned arrival
T_{Ae}: time of earlier arrival
T_{Al}: time of later arrival
t_e and t_l : time differences at earlier (-) and later (+) arrival
v_0: average shipping speed at planning

The types of factors affecting differences between optimum and real shipping time are as follows:
1/A: existing at the planning phase
1/B: calculable at the planning phase
2/A: occuring during shipping and can be completely avoided
2/B: occuring during shipping that can be decreased and partly avoided
2/C: occuring during shipping but cannot even be resolved
by using prognoses.

Classical static planning is based on types 1/A and 1/B. Without any available updated information a partial solution of problems type 2/A is only possible during transportation.

4D-shipping may be affected only by factors 2/C, by using real time data, and there is a high probability of preventing any other kind of problems.

The difference between optimum and real shipping time reflects much bigger deviation with classical planning.

4. Conclusions

Neglection of inland waterway shipping is caused by spatial and time variabiltiy and unreliability of the waterway section. Complex analyses serve as a solid basis for carrying out shipment tasks. There may be differences in the single tasks at some points; nevertheless, the whole process is unique.

The present study is about to demonstrate a solid basis by setting a model. Transportation planning has great responsibility in economical supply and keeping deadlines. Considering time factor during the elaboration of the transportation task can really improve the expected result of better utilization of ships, shorter shipping time and more accurate arrival time. 4D based shipping contributes to a further increased quality.

Consequently, up-to-date, modern planning methods have an improving affect on efficiency of transportation. A better utilization of ships and reliability makes shipping both for tranporters and contractors a more attractive and respectful option of transportation.

References

[1] Branch, A.: *Elements of shipping*. New York: Chapman and Hall (1989).
[2] Bayart, P., De Clercq, B. Adams, R.: *A new numerical lock model applied in a lock capacity analysis*. Baja: EIWN Conference (2010).
[3] Hadházi, D.: *Tengeri rakodástechnika gyakorlatok*. Budapest: Tankönyvkiadó (1992).
[4] Horvath, G.: *Methodology of ro-ro transport planning*. Portoroz: ICTS Conference (2009).
[5] http://epp.eurostat.ec.europa.eu
[6] Ugróczky, L., Fülöp, G.: *Közlekedési üzemtan I.*,Győr: SZIF. (1999).

Acknowledgement

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Road Safety Situation of Hungary Reflected by National and International Objectives

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Keywords: road safety, economic crisis, performance indicators, methodology, definitions

1. Some national and international time series

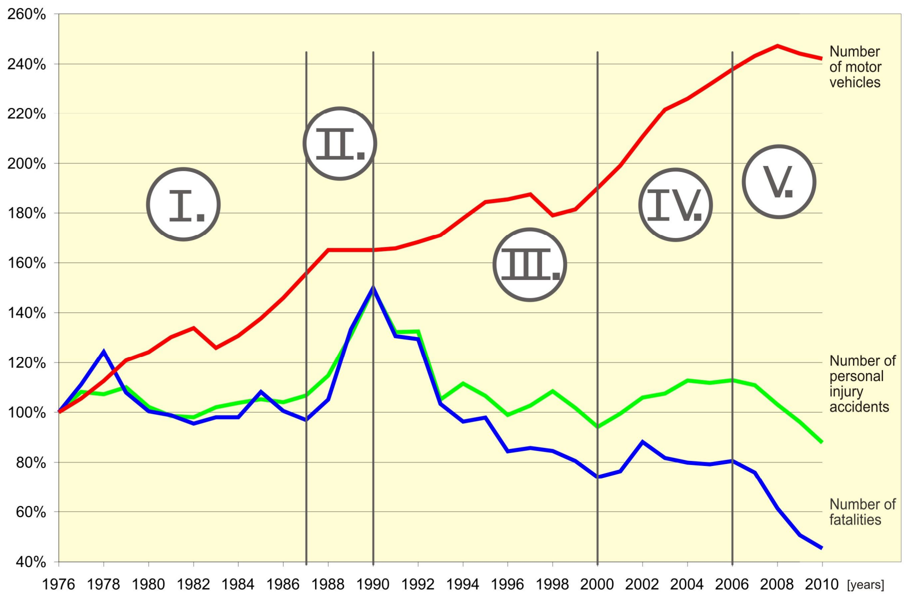

Figure 1: Number of road motor-vehicles, personal injury accidents and of fatalities. Main periods of the national road safety

In Figure 1 one can observe the development of the number of road motor vehicles, personal injury accidents and fatalities in the period between 1976 and 2010. The Figure also shows distinctive periods of the national road safety situation. (Data before 1976 are also illustrated in the time series applied by some authors, however it must be borne in mind that at that time the 48-hour- and not the 30-day-definition was in force for those killed.) For the time being particulars for different periods have not been detailed but we note that – apart from phase I, apparently stable – periods of improvement and deterioration of different length alternate with each other. At present – as from 2006 – national road safety is improving, which is also continuing in 2010.

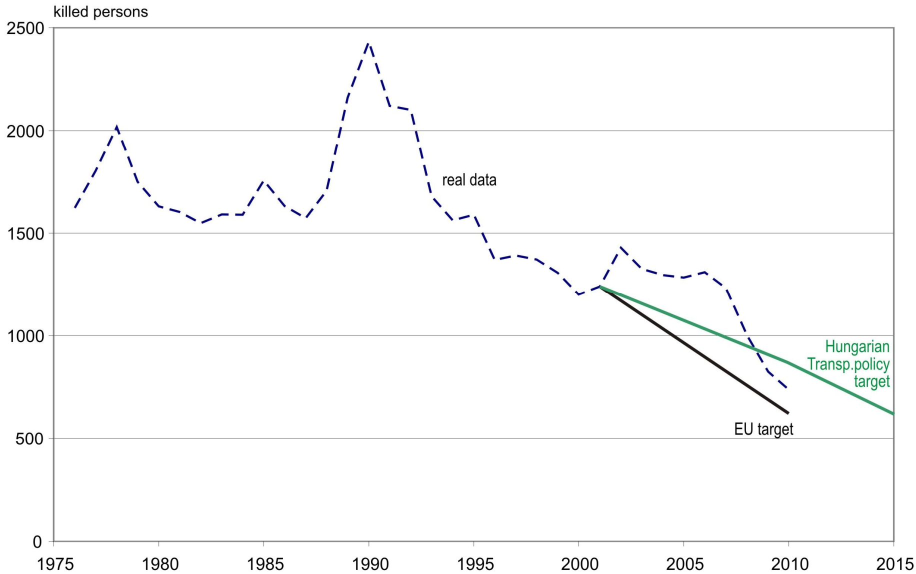

Figure 2: Number of fatal victims of road accidents in Hungary in the years between 1976 and 2010 as reflected by the objectives of transport policy in the EU and Hungary

In Figure 2 the number of fatal victims of road accidents between 1976 and 2010 in Hungary is shown as reflected by the transport policy objectives of the EU and Hungary.

2001 being the basis year of the objectives, the number of fatal victims of road accidents should have been reduced either to 620 (–50%, EU White Paper) or to 867 (-30%, Hungarian transport policy) by 2010.

Since in 2009 this number decreased already to 822, one can say that the objective of the national transport policy has been „over-fulfilled". According to the final data of KSH (Hungarian Central Statistical Office) [1] in 2010 in Hungary 739 persons were killed in road accidents. This means that in comparison with 2001, more than 40% reduction could be achieved. 739 is almost the arithmetical mean (744) of the objectives of the EU (620) and of the national transport policy (867).

Following the significant improvement in the years 2008 and 2009, in 2010 [1] the number of:

- personal injury accidents decreased by 8.7%,
- killed decreased by 10.1%,
- serious injuries decreased by 12.0%,
- slight injuries decreased by 9.4%.

In the same period the number of accidents caused by drivers under the influence of alcohol decreased by 17.2% in comparison with the previous year. The real and the “planned” development of the number of fatal victims of the road traffic accidents can be seen in Figure 3 in the period between 1990 and 2010 in the EU member states.

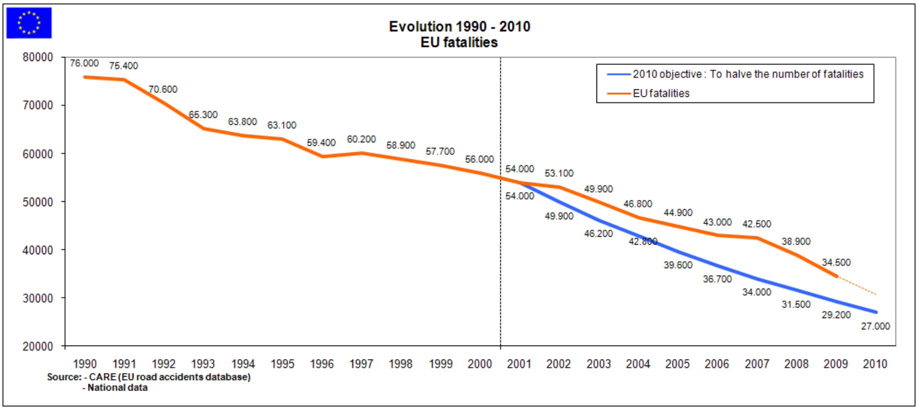

Figure 3: Real and „planned” development of the number of fatal victims of road accidents between 1990 and 2010

From 2001 until 2009, overall the number of fatal victims of road accidents lessened by 36% (from 54,000 to 34,500) in the EU member states.

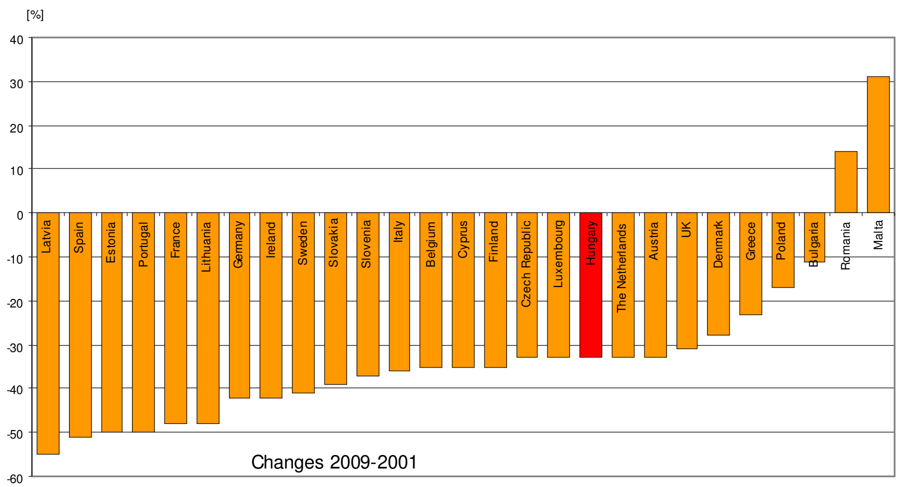

Figure 4: Change in the number of killed in road accidents between 2001 and 2009 in the EU member states

In the same period in Hungary this reduction equalled to 34.0% (from 1,239 to 822). This is all the same more noticeable, because essentially in Hungary in 2 years the reduction achieved in the number of killed equalled to the other countries’ 8 years’ achievement.

This, as well as the ranking of different countries is well demonstrated on the basis of the change resulting from the number of killed due to road accidents. (Figure 4).

2. How many years should we „go back" in time when the number of fatalities was as low as in 2010?

Since 22 February 2011 the final statistics for 2010 are also available: in 2010 739 persons were killed in road accidents. The 30-day-definition for road accident fatalities has been used since 1976 in Hungary. Before 1976 only the 48-hour-outcome was in force. After 1976 both data were recorded for a long time; accordingly from these data the so-called correction coefficient could be determined. This was used as a multiplier of the 48-hour-figure. So the 30-day-numbers for the periods before 1976 could be "produced" as well. In the database of the OECD member countries, the IRTAD (**I**nternational **R**oad and **T**raffic **A**ccident **D**atabase) this coefficient is 1.2. I.e. the number of 30-day-fatalities is usually higher by 20% in comparison with that of the 48-hour-cases. For example the 48-hour-figure was 1398 in 1975.

The 30-day-data estimated for the same year was: 1398 × 1.20 = 1678 persons

Making calculations for the previous years:

	Number of deaths after 48 hours	**Estimated number of deaths after 30 days**
1974	1353	1624
1973	1419	1703
1972	1507	1808
1971	1527	1832
1970	1356	1627
1969	1130	1356
1968	1013	1216
1967	784	941
1966	761	913
1965	725	870
1964	859	1030
1963	763	916
1962	685	822
1961	622	**746**
1960	558	670

Consequently, it was in 1961 when the number of road accident fatalities (746) was only by 7 higher than in 2010 (739).

The fact itself, that it was exactly a half century ago (in 1961) when seven more people died (746) in road accidents than in 2010, is a **huge result**.

However one must not forget, that reduction of fatalities to almost the level of the 50 years earlier period was mainly due to immense progress achieved by vehicle technology. Significant increase of the occupants' passive safety provides for survival even in cases, which seemed unimaginable before.

(Airbags, automatic safety-belts with tensioners, vehicle bodies tested with crash tests, with energy impact zones designed with survival spaces, etc.)

Of course, during such a long time the process of accident severity has been affected favourably, too by the huge progress achieved in the rescue work, and by medical sciences. After studying Figure 1, one may draw the conclusion that not the number of personal injury accidents but that of their fatal victims slackened significantly. I.e. in the last decades it was not the active safety that mainly improved, nor the accident risk that outstandingly decreased, but the outcome, the accident severity. Not only fatal injury, but also the risk of personal injury lessened, even if not to the same degree as the number of killed did.

To sum it up: **accident severity** decreased decisively.

As injury risk lessened, the number of registered (personal injury) accidents reduced as well, although in a lesser degree than that of people killed.

3. Has economic crisis any role in road safety improvement?

Several researches [2], [3], [4] demonstrated that economic revival or recession (the rate of the GDP) may influence directly road traffic and through it the road safety trends.

According to annual KSH figures in 2009 [5] as compared to 2008 the following declines were experienced:

- **mass of goods** carried by **road in domestic traffic**, by **12.9%;**
- **performance of goods ton-kilometres** in domestic road traffic by **6.7%;**
- **number of bus-passengers** transported in interurban domestic traffic by **6.2%;**
- **performance of passenger-kilometres** in interurban domestic traffic by **5.0%;**
- **number of bus-passengers** in local domestic traffic by **6.4%;**
- **performance of bus-passenger-kilometres** in local domestic traffic by **7.0%.**

In 2009 in Hungary the number of road motor vehicles with first **registration** (entry into traffic) was 106343, **by 53% less** than in 2008 (227251).

Since a long time it was in 2009 that for the first time the national fleet of road vehicles **decreased** as well. While in 2008, at the end of the year the registered number of road vehicles was 3685677, this number declined to 3640115 in 2009.

In comparison with the same period of the preceding year, in 2010 the following changes could be observed [6]:

- **mass of goods** transported by domestic **road** traffic decreased by **15.1%**;
- **performance of goods ton-kilometres** in the domestic road sector decreased by **6.8%**;

- **number of bus-passengers** transported in interurban domestic traffic increased by **3.2%**;
- **performance of bus-passenger-kilometres** in domestic interurban traffic increased by **4.5%**;
- **number of bus-passengers** in local traffic decreased by **6.3%;**
- **performance of bus-passenger-kilometres** in local traffic decreased by **5.7%**.

In Hungary the number of road motor vehicles with first **registration** (entry into traffic) in 2010 was 88463, which in comparison with the data registered in 2009 (106348) indicates a **decrease** of 16.8 %.

The national motor vehicle fleet was 3608834 in 2010, less by 31281 than in 2009 (3640115).

4. Conclusions

Between the years 2001 and 2009 in Hungary and in all EU member states the number of fatalities resulting from road accident decreased by 34% and 36%, respectively.

In 2008 a real breakthrough was achieved in road safety improvement, which continued in 2009 and in 2010, too.

The breakthrough (2008) was mainly the result of consistent and strict measures (so-called “objective” responsibility (owners’ liability) , “zero-tolerance” against drinking and driving, rendering more stringent demerit point system, automated speed cameras, etc.), admitting that economic recession also contributed to this improvement, especially in 2009, but in 2010, too, although in a lesser extent.

During evaluation a special attention should be paid to the methodological questions as well (e.g. the difference between the 48-hour- and the 30-day-outcome.)

References

[1] Személysérüléses közúti közlekedési balesetek, 2010. I-IV. negyedév. *A Központi Statisztikai Hivatal legfrissebb adataiból,* Gyorstájékoztató, sorszám: 28, közzétéve: 2011. február 22.

[2] Partyka, S.C., 1984. *Simple models of fatality trends using employment and population data.* Accident Analysis and Prevention 16, 211-222.

[3] Partyka, S.C., 1991. *Simple models of fatality trends revisited seven years later.* Accident Analysis and Prevention 23(5), 423-430.

[4] P.Holló, V. Eksler, J. Zukowska: *Road safety performance indicators and their explanatory value*: A critical view based on the experience of Central European countries, Safety Science, 2010. (Megjelenés alatt).

[5] Szállítási teljesítmények, 2009. *A Központi Statisztikai Hivatal legfrissebb adataiból*, Gyorstájékoztató, sorszám: 33., közzétéve: 2010. február 25.

[6] Szállítási teljesítmények, 2010. I. félév. *A Központi Statisztikai Hivatal legfrissebb adataiból*, Gyorstájékoztató, sorszám: 132., közzétéve: 2010. augusztus 26.

Effects of Motorization Development on the Usage Level of Local Public Transport

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Abstract: Department of Transport at the Széchenyi István University participated in 27 research projects on local public transport systems in Hungary between 1992 and 2009. This paper presents the main results of these surveys showing how the development of motorization drives public transport into the background. Typical trends and consequences are analysed based on the data gathered through the former surveys.

Keywords: Hungary, motorization, public transport, passengers, occupancy rate

Introduction

Department of Transport at the Széchenyi István University as well as its legal predecessor have been analysing the local public transport system of Hungarian settlements since the establishment of the department. The number of surveys of this field has significantly grown since the early 1990's. The department has participated in 27 similar projects between 1992 and 2009 [1] [2] [3] [6] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] (see Figure 1). Most of these works were based on counting public transport passengers, however some of them also included an origin-destination analysis and a passenger satisfaction survey, too.

Data gathered through these surveys can be used excellently for showing that public transport has been driven into the background as motorization grew and this tendency is going to be continued unless efficient solutions are introduced to improve the service quality of public transport.

Most surveys examined the following characteristics of local public transport systems:

- number of services (departures);
- service km;
- number of passengers (boardings);
- number and ratio of unutilized services;
- number and ratio of crowded and overcrowded services;
- number and ratio of unpunctual (delayed and early) services;
- capacity km;

- passenger km;
- static and dynamic occupancy rates and their ratio;
- average trip length;
- motorization (daily number of trips/number of inhabitants);
- average number of passengers/service.

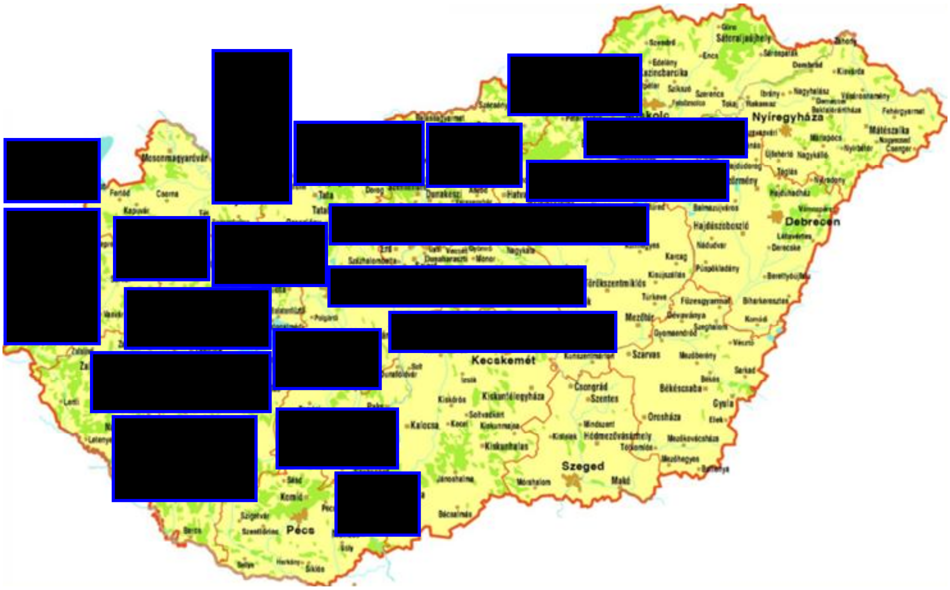

Figure 1. Surveys by the Department of Transport, Széchenyi István University [32]

The structure of this paper is as follows. Section 1 provides an overview of motorization development in connection with the changes in the usage level of local public transport in Hungary. Section 2 shows details based on the example of Győr as the results of six different surveys (including other works [7] [31]) are available for this city. Examined cities are divided into three groups based on their population size in Section 3 and characteristics of these groups are analysed. Occupancy rates on different day types (school and non-school working days, Saturdays, Sundays) are compared in Section 4. Finally results are summarized and evaluated.

1. Development of motorization in Hungary

Figure 2 shows the development of motorization (number of cars/1000 inhabitants) from 1960 to nowadays in Hungary. It can be seen that this value is monotonously increasing: there is a slight fallback only at the time of the regime change (1989) and at the and of the 1990's. On the other hand, Figure 3 shows the changes in the total number of passengers of local public transport in Hungarian settlements: increase is monotonous until the regime change, too, however it is followed by a drastic fallback and then a slowing but continuous decrease.

Figure 2 and 3 illustrate excellently the phenomenon of modal shift: the share of individual motorized transport is increasing whereas the usage of public transport is decreasing.

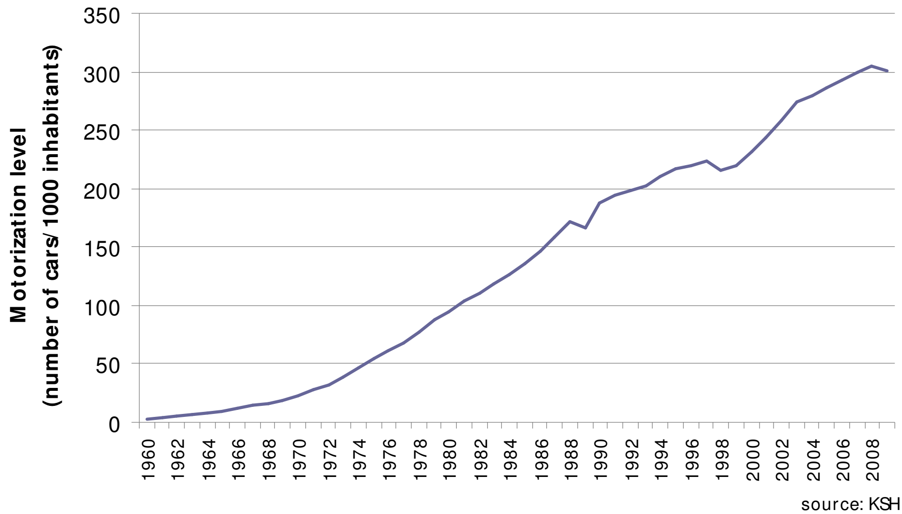

Figure 2. Development of motorization in Hungary [5]

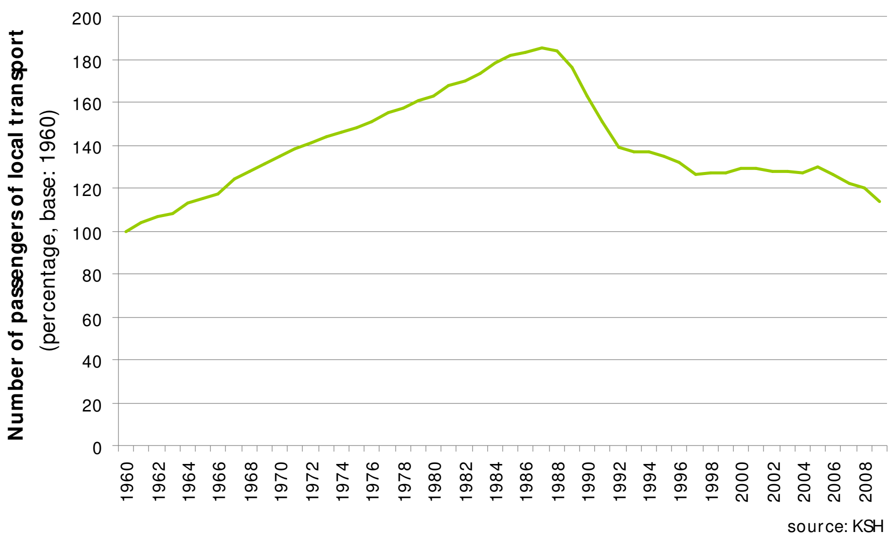

Figure 3. Changes in the number of passengers of local public transport in Hungarian settlements [5]

2. Relationship between motorization and public transport based on the example of Győr

Győr is the sixth largest city of Hungary: it is an important industrial, educational cultural and tourism centre. The public transport system of the city has been analysed not only by Széchenyi István University [1] [13] [14] [19] but former results were also available [31] and the local transport service provider company, Kisalföld Volán Zrt. made a survey in 2008, too [7]. Table 1 and Figure 4 show the changes in the most important characteristics of the system between 1985 and 2008.

Table 1. Characteristics of the public transport of Győr based on surveys 1985–2008 (school days, n/a = not available)

Year	Number of services	Service km	Number of passengers	Capacity km	Passenger km	Dynamic occupancy rate	Avg. trip length (km)	Number of inhabitants	Number of cars	Mot. level (num. of cars/ 1000 inh.)	Avg. number of trips/ inhabitant	Avg. num. of pass./ service
1985	2,726	n/a	142,596	1,438,243	384,011	26.7%	2.69	129,116	n/a	n/a	1.10	52.3
1992	2,519	15,589	129,449	1,464,673	354,451	24.2%	2.74	131,551	34,109	259	0.98	51.4
1997	2,481	15,731	129,954	1,490,601	392,137	26.3%	3.02	130,241	34,270	263	1.00	52.4
2002	2,618	17,569	113,135	1,664,880	365,668	22.0%	3.23	128,913	39,076	303	0.88	43.2
2004	2,240	16,397	105,805	1,553,819	346,094	22.3%	3.27	127,594	41,618	326	0.83	47.2
2008	2,189	16,227	92,404	n/a	n/a	n/a	n/a	130,476	43,447	333	0.71	42.2

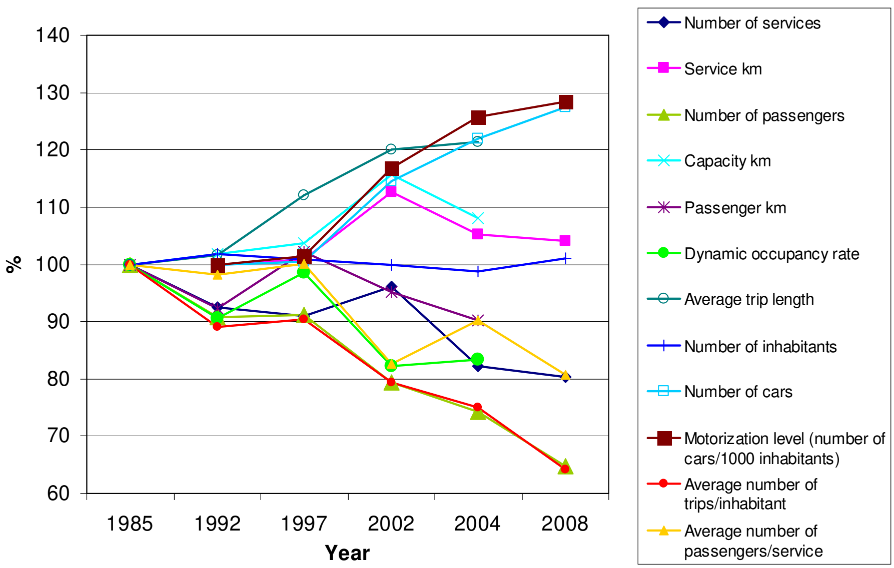

Figure 4. Changes in the local public transport of Győr based on surveys 1985–2008 (school days, base: first available data)

It can be seen that the number of cars (and therefore the motorization level) shows a monotonous increase in Győr, too. Compared to Figure 2, it can be found that the level of motorization was on the average 18% higher than the national value in the examined years which implies that the effects of this tendency appear to a greater extent in Győr.

The number of local public transport passengers is continuously decreasing, just as in other settlements of the country, however the amount of passenger kilometres used to be growing until the end of the 1990's. This can be explained by the increase of the average trip length which was caused by new industrial investments (factories built further from the city centre) as well as suburbanization.

However, the supply of public transport (service kilometres, capacity kilometres) increased until 2002 which caused a significant decrease of occupancy rate. This trend caused a greater financial loss: as a consequence, the local government decided to narrow the supply. Service was decreased in two steps between 2003 and 2004: this caused that service kilometres and capacity kilometres also showed a decreasing tendency from 2004. On the other hand, this fallback of service quality (service frequency was reduced and some routes were completely stopped) has led to further decrease of the number of passengers. This illustrates the "vicious circle" of public transport: lower service quality attracts fewer passengers which implies another decrease of supply. This leads to a never-ending degradation spiral. The only way to stop this trend is keeping or developing service quality, however financial problems need to be solved.

3. Characteristics of public transport in different sized settlements

Figure 1 shows that the Department of Transport at the Széchenyi István University dealt basically with the local public transport of small and medium sized settlements. The examined cities can be grouped based on the number of their inhabitants as follows:

- between 20 and 35 thousand inhabitants (Dombóvár, Várpalota, Siófok, Esztergom, Gyöngyös, Pápa, Vác);
- between 35 and 60 thousand inhabitants (Baja, Salgótarján, Dunaújváros, Nagykanizsa, Sopron, Eger);
- between 60 and 130 thousand inhabitants (Zalaegerszeg, Veszprém, Tatabánya, Szombathely, Székesfehérvár, Győr).

Values directly connected with settlement size (service kilometres, number of passengers, capacity kilometres, passenger kilometres) are implicitly higher in larger cities. Occupancy rate is usually also higher in larger cities, however there are some exceptions, too.

There is a quite regular, logarithmic relationship between the number of inhabitants and the mobility level for public transport (daily number of trips/number of inhabitants, see Figure 5) as well as the daily service km/number of inhabitants (see Figure 6).

Figure 5 shows that mobility level for public transport is higher in larger settlements. This is partly caused by the higher ratio of transfers, partly explained by larger distances where walking and cycling are no alternatives. Furthermore, higher service quality can attract more passengers (reverse "vicious circle").

This implies that service km/number of inhabitants is necessarily higher in larger cities. Estimating the required amount of service kilometres (which depends on many factors) as a linear function of the number of inhabitants is therefore a wrong principle.

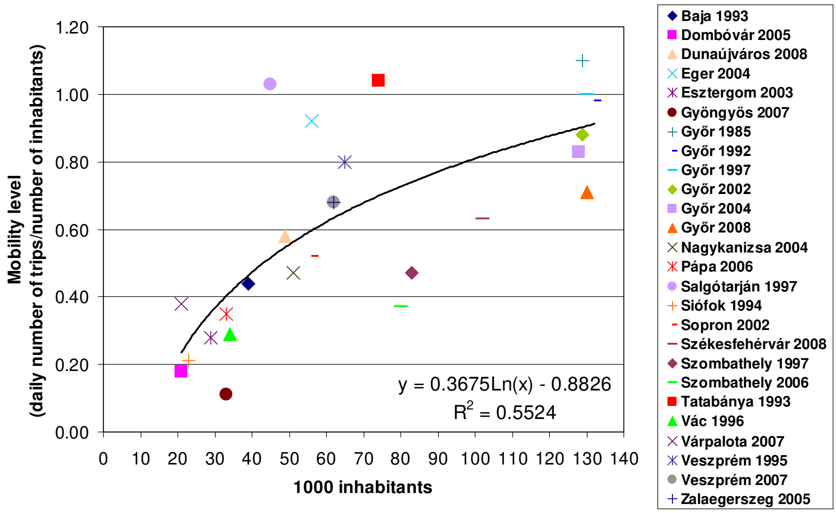

Figure 5. Mobility level for public transport (daily number of trips/number of inhabitants) depending on the number of inhabitants (school days)

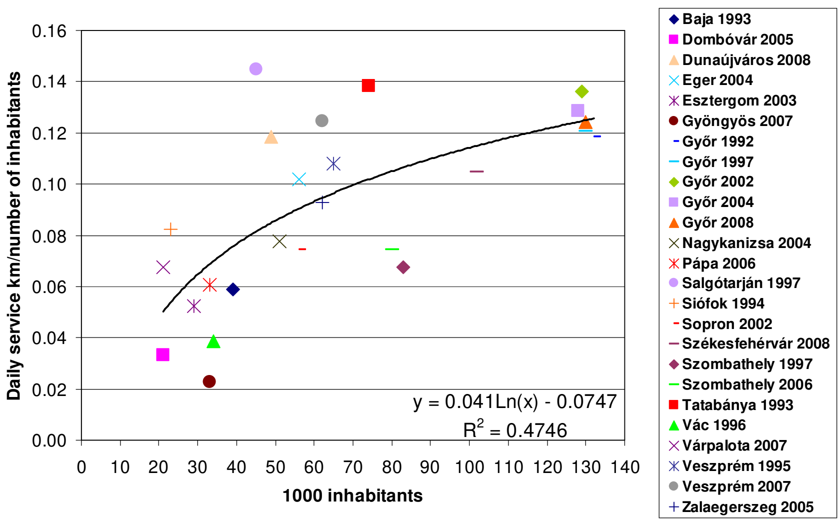

Figure 6. Daily service km/number of inhabitants depending on the number of inhabitants (school days)

It is interesting that the average trip length for public transport does not show a significant difference in the examined settlement groups: it is between 2.35 km and 3.82 km in all surveys.

4. Occupancy rates on different day types

Surveys typically involved the following day types:

- school days (working days, Mondays to Fridays)
- non-school working days (Mondays to Fridays);
- Saturdays;
- Sundays (public holidays).

School days were examined in all cases, other day types were or were not examined based on the demands of the procurers.

Table 2 contains the occupancy rates (passenger km/capacity km) for different day types as well as their ratio to school day values. It can be seen that occupancy rates on non-school working days are only 59.2–85% of school day values. This ratio is 64.3–91.7% for Saturdays and 44.7–74% for Sundays. The same problem is illustrated by Figure 7 which shows the ratio of non-school service km and that of the number of passengers to school day values based on four surveys. Despite service kilometres decrease by less than 10% on non-school working days, the number of passengers does not reach 75% of the values on school days.

Table 2. Dynamic occupancy rates on different day types and their ratio to school day values (n/a = not available)

Year	Settlement	School day	Non-school working day	Non-school/ school day	Saturday	Satur-day / school day	Sunday	Sunday / school day
1993	Tatabánya	22,4%	n/a	n/a	18,7%	83,3%	16,6%	74,0%
1997	Szombathely	17,9%	n/a	n/a	12,9%	72,1%	8,0%	44,7%
1997	Győr	26,3%	n/a	n/a	21,1%	80,1%	18,0%	68,6%
2004	Nagykanizsa	16,3%	12,0%	73,5%	12,6%	77,3%	11,3%	69,3%
2005	Zalaegerszeg	21,1%	18,0%	85,0%	15,5%	73,4%	13,2%	62,6%
2006	Pápa	15,4%	9,1%	59,2%	11,2%	73,1%	8,8%	57,5%
2006	Szombathely	13,5%	n/a	n/a	12,4%	91,7%	n/a	n/a
2007	Várpalota	19,6%	16,5%	84,1%	17,1%	87,6%	13,2%	67,4%
2007	Gyöngyös	15,7%	n/a	n/a	11,9%	75,4%	n/a	n/a
2007	Veszprém	15,7%	n/a	n/a	12,1%	77,3%	10,9%	69,5%
2008	Székesfehérvár	19,2%	n/a	n/a	12,3%	64,3%	10,0%	51,8%
2008	Dunaújváros	13,3%	n/a	n/a	10,0%	75,5%	8,9%	67,4%

It can be questioned why the decrease of the number of passengers is not proportionately followed by the capacity. This can be explained the following two ways. Firstly, the ratio of solo and articulated buses is determined based on the requirements of peak hours. Therefore it can happen that there are not enough solo buses for non-school working days, Saturdays or Sundays and articulated buses have to be used even when it is not reasonable. However the operation of more buses would increase costs to an even greater extent. Another aspect of this phenomenon is the minimum level of service quality: all parts of the settlements must be served with a specified minimum frequency in order to provide inhabitants with the right of mobility even if the number of passengers is low. Furthermore, infrequent service would decrease the attractiveness of the system which would cause further loss of passengers. This implies that lower occupancy rates in off-peak hours are usually necessary.

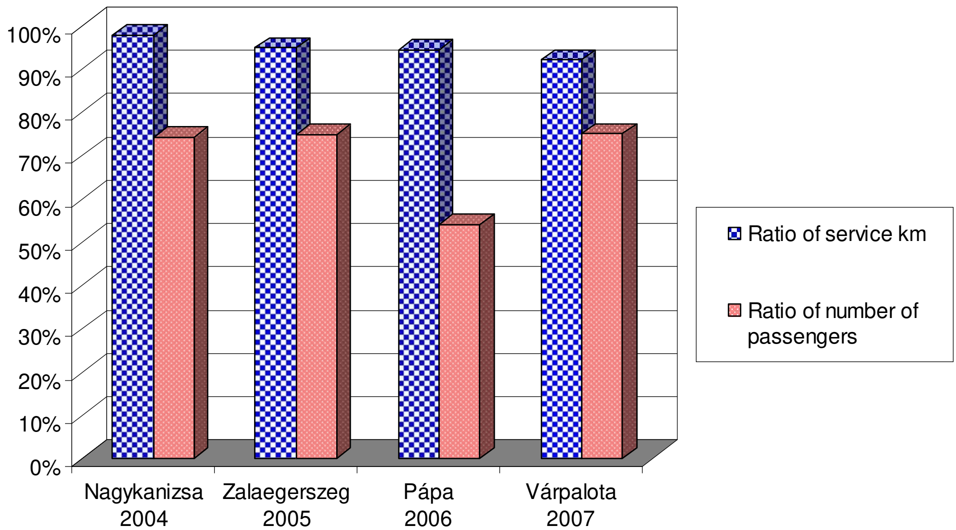

Figure 7. Ratio of non-school service km and number of passengers to school day values

Conclusion

This paper presented the surveys of the Department of Transport at the Széchenyi István University between 1992 and 2009 on the local public transport system of Hungarian settlements. The results show how the development of motorization drives public transport into the background.

Unfavourable consequences of this phenomenon are known for all of us: there are congestions on the roads, environment is polluted and it is a serious problem for local governments to finance local public transport. Stopping or at least slowing this negative trend is only possible through the development of the service quality of public transport even if it needs more investments in the short run.

References

[1] Fülöp, G. et al.: *Győr város helyi tömegközlekedésének fejlesztése*, (1992).
[2] Fülöp, G. et al.: *Szombathely megyei jogú város tömegközlekedésének helyzetértékelése és fejlesztése*, (1997).
[3] Fülöp, G. et al.: *Dombóvár város közforgalmú helyi közlekedésének forgalomfelvétele, a forgalomfelvétel adatainak feldolgozása és kiértékelése*, (2005).
[4] Fülöp, G., Winkler, Á.: *A motorizációs fejlődés hatása a helyi közforgalmú közlekedés igénybevételi szintjére*, in Közlekedéstudományi Konferencia, Győr, (2011), pp. 86–96.
[5] Horváth, B.: *Személy / autó / busz / megálló: a közforgalmú közlekedés szerepe a városok életében*, jUNIor egyetem, Széchenyi István Egyetem, Győr, (2011).
[6] Kálmán, L., Prileszky, I. et al.: *Szombathely Megyei Jogú Város helyi tömegközlekedésének átszervezése*, (2000).
[7] Mihályka, I., Kovács, M., Winkler, Á.: *Győr Megyei Jogú Város közösségi autóbusz-közlekedésének utasforgalmi felmérése, kiértékelése, menetrend-racionalizálási javaslatok*, Kisalföld Volán Zrt., Győr, (2008).
[8] Prileszky, I. et al.: *Baja város tömegközlekedésének helyzetértékelése és fejlesztése*, (1993).
[9] Prileszky, I. et al.: *Tatabánya város tömegközlekedésének helyzetértékelése és fejlesztése*, (1993).
[10] Prileszky, I. et al.: *Siófok város tömegközlekedésének helyzete, az önkormányzat és a közlekedési vállalat kapcsolata*, (1994).
[11] Prileszky, I. et al.: *A helyi tömegközlekedés üzemeltetési rendszerének megváltoztatása Veszprém városban*, (1995).
[12] Prileszky, I. et al.: *Vác város tömegközlekedésének helyzetértékelése és fejlesztése*, (1996).
[13] Prileszky, I. et al.: *Győr Megyei Jogú Város tömegközlekedésének helyzetértékelése és fejlesztése*, (1998).
[14] Prileszky, I. et al.: *Győr város helyi közlekedésének forgalomfelvétele és értékelése*, (2002).
[15] Prileszky, I. et al.: *Sopron Megyei Jogú Város közforgalmú helyi közlekedésének forgalomfelvétele, a forgalomfelvétel adatainak feldolgozása és kiértékelése*, (2002).
[16] Prileszky, I. et al.: *Esztergom helyi autóbuszhálózatának átszervezése, (2003).*
[17] *Prileszky, I. et al.: Nagykanizsa Megyei Jogú Város közforgalmú helyi közlekedésének forgalomfelvétele, a forgalomfelvétel adatainak feldolgozása és kiértékelése*, (2004).
[18] Prileszky, I. et al.: *Eger Megyei Jogú Város közforgalmú helyi közlekedésének vizsgálata*, (2004).
[19] Prileszky, I. et al.: *Győr Megyei Jogú Város közforgalmú helyi közlekedésének vizsgálata*, (2004).
[20] Prileszky, I. et al.*: Zalaegerszeg Megyei Jogú Város közforgalmú helyi közlekedésének vizsgálata*, (2005).

[21] Prileszky, I., Fülöp, G., Horváth, G., Szabó, L., Pusztai, P.: *Pápa város helyi tömegközlekedési szolgáltatásának racionalizálása, fejlesztése*, (2006).
[22] Prileszky, I., Fülöp, G., Horváth, G.: *Szombathely megyei jogú város helyi közforgalmú autóbusz-közlekedésének átalakítási tervkoncepciója*, (2006).
[23] Prileszky, I., Fülöp, G., Horváth, G., Pusztai, P.: *Utasáramlási adatfelvétel elvégzése reprezentatív módszerrel Tatabánya helyi autóbusz-hálózatán*, (2006).
[24] Prileszky, I., Fülöp, G., Horváth, G., Pusztai, P.: *Várpalota Város helyi tömegközlekedési szolgáltatásának racionalizálása, fejlesztése*, (2007).
[25] Prileszky, I., Fülöp, G., Horváth, G., Pusztai, P.: *Gyöngyös Város helyi tömegközlekedési szolgáltatásának racionalizálása, fejlesztése*, (2007).
[26] Prileszky, I., Fülöp, G., Laki, R.: *Tatabánya Megyei Jogú Város helyi tömegközlekedési szolgáltatásának fejlesztése*, (2007).
[27] Prileszky, I., Fülöp, G., Horváth, B., Horváth, G., Farkas, I., Laki, R.: *Veszprém város helyi tömegközlekedési szolgáltatásának javítása komplex hatékonysági kritériumok alapján*, (2007).
[28] Prileszky, I., Fülöp, G., Horváth, B., Horváth, G., Farkas, I., Winkler, Á.: *Székesfehérvár város helyi tömegközlekedési szolgáltatásának javítása komplex hatékonysági kritériumok alapján*, (2008).
[29] Prileszky, I., Fülöp, G., Horváth, B., Horváth, G., Farkas, I., Winkler, Á.: *Dunaújváros helyi tömegközlekedési szolgáltatásának fejlesztése komplex hatékonysági kritériumok alapján*, (2009).
[30] *Salgótarján város közforgalmú közlekedésének vizsgálata*, (1997).
[31] *Utasszámlálás Győr város helyi közforgalmú közlekedésében*, (1985).
[32] Zentai, L.: *Magyarország térképe (Map of Hungary)*, Digitális Képarchívum, http://keptar.oszk.hu/000300/000385/mo-terkep_nagykep.jpg

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From Inter-modal Transport Services to Integrated Common Objectives

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Abstract: The article starts from the paradigm of modernity and its connection to the technological basis with special regards to the technological determinations in the development of the transport modes. As a contrast to the approach, the next parts deal with the excess of the barriers at a paradigm level, introducing the connection of the problems with the different integrations. Integrations mean here both the common planning of the city with the conurbation area (territorial integration), the common handling of different transport modes (inter-modality, co-modality) and the transfer between technological platforms (interoperability). As a representation of the problems, the article presents and interprets the recent development of the plans for the public transport backbone network of Budapest and its environ. A further case for the integrated approach is the new integrated transport strategy for Hungary: where just the preparation phase begins in this year.

Keywords: inter-modal, co-modal, integrated transport, modernity, post-modern, multi-level transport system

1. Introduction

It is a commonplace now-a-days that there is a need for inter-modality / co-modality – that is the co-operation of the different transport modes – in the transport system. The target is not really debated at that general level – while it is much less evident, how, in which steps a common transport system can be formed. One option is the growing cooperation between the existing transport technologies, another gives more emphasis to searching new co-operation technologies to newly established transport objectives.

In the latter approach the problem is not a specific transport issue any more, but rather a wider social context that touches the fundament of the expectations towards the transport systems. The article supports this more general understanding of the integration issue.

The structure of the paper is the following. The first chapter explains the rise of the "modernity" approach and also the changes in our thinking to exceed those barriers the approach would mean now-a-days. The next chapter presents the regular appearance of the new transport modes in the history that typically took the dominance from the previous ones earlier in leader position. In the future we expect a change in that respect towards the use of an integrated mix of the different transport modes. The final part of the paper shows the possibilities and the dangers in two planned case of the modal integration: one in the urban public transport system in the Budapest area and another in an integrated transport policy level.

2. The rise and fall of the idea of modernity

From 1928 on the CIAM (*Congres Internationaux d'Architecture Moderne*) was operating through three decades, with architecture congresses organised about three-annual. The group declared the adjective *Modern* also in its name, and the Athens Charter that was formulated in 1933 on the fourth congress of the CIAM summarises very well the essence of that school (*Kubinszky 1978*). The starting point of the thinking was the solution of the housing problem, especially the mass housing building achieving to the construction of the housing estate (=industrialised mass-production of uniformed flat-boxes). From here the next step was adjusting the city to the philosophy of the mass-production. The invention was the functional city, dividing the towns to big, functionally homogeneous quarters as dwelling zone, industrial zone, business district, recreation area – and naturally to intensive transport area that is able to connect the separated zones. Behind this idea the basic principles were the efficient mass-production, the economy of scale, the rationality, the standardisation/uniformisation and the planning.

Our first thought could be that in the transport services that background is very advantageous for the development of the public transport – based on the concentrated passenger flows between the quarters. Still, the dominant transport characteristic of the period is the rise of the road traffic, where the use of the small uniform boxes spreads over. The planners begin to create the possibilities of the industrialised and mass transport for these units. The main task is to make room for the cars in the city: it is necessary to remove everything that would hamper the motion of the cars, at least on the surface. Such barriers are the trams, even more the stops near the road crossings, the trees, the pedestrians etc. Sometimes it is necessary to occupy a part of the sidewalk, sometimes to push it under the houses (arcades). The general feeling was, that "there is not enough room, we need more for the cars".

Looking back from our days perhaps such summary of those activities seems a bit caricature-like, still it is important to flash on the post-industrial, post-modern turn that rose up just on the denial of the principles enumerated above.

It is not the circumstances, the society, the urban life, the environment that we should adjust to our planned systems but vice-versa: we should create systems that are able to respect the existing patterns, activities, the life. Instead of the keywords used like *effective, uniform, homogeneous, optimal, calculated* the new ones are *co-operative,* *partner, integrated, adjusted, adaptive, networked* etc. The latter features can make possible the adaptation to the existing or changing conditions, even to those not calculable in advance.

It is that context where we can interpret the new urban policy documents like the Leipzig Charter (2007). Its main principle is the integrated approach, the mixed use instead of a spatially homogenised one. Multifunctional neighbourhood units instead of a macro-level functional divide of the urban space; small towns within the big cities, mixed zones, everyday target-points should be accessed by walking: city of small distances etc.

One of the lessons of the transport planning now is to give back a part of the public space to the different slow movements attaching to houses-sidewalks-local activities, that is to walking, staying non-motored moving. As Salingaros (2000) explained it, the coherent urban texture must have strong links in small scale while weak links in big scale. If we don't keep ourselves to that rule, we may tear out the roads from its urban context and force those living in the houses to turn back to the street and also to their environment by that.

3. Marked periods of the transport: the technological dominances

Until the middle of the 19th century the rivers and channels were the main axes of the inland transport. The alternative was the carts pulled by horses or other animals (beasts of burden).

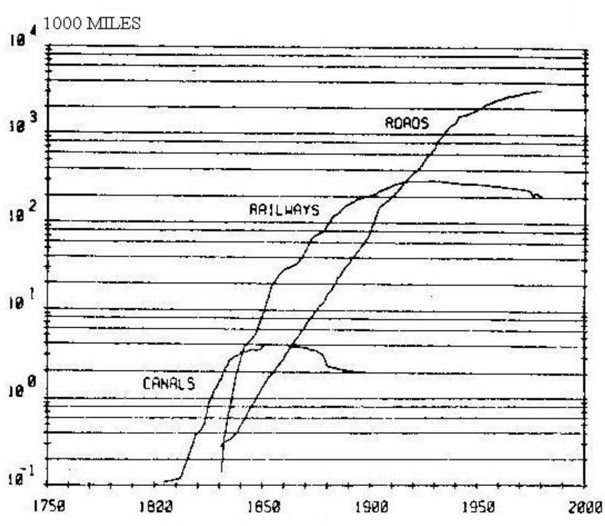

Figure 1. The length of different transport infrastructures in the United States between 1800 and 1980[1]

[1] Source: Nakicenovic 1988

Based on the statistics of the United States, *Figure 1.* presents how the rail or the paved road (and the automobile) appeared as a new technical invention, offering a possibility to take over the tasks from the previous actor, even to spread the transport provision to larger and larger areas.

The pre-industrial period can be characterised by the construction of the canals. The goods are transported on water, the ships are made of wood, driven by the wind (wind–wood–water period). The industrial revolution brings the dominance of the rail (coal–steel–rail), while the times of modernisation is accompanied by the glory of the car (oil–bitumen–motorway). What composition can come next?

In the history of the past two centuries of transport, there was always a dominant transport mode (changing from time to time) and an infrastructure based the given mode and determining the possibilities of the transport. In *Figure 2.* the different curves present the proportion of the built length of a single mode relative to all the other modes existing at the given moment. The period following the year 1985 shows the hypothetical expectations of the author of the figure.

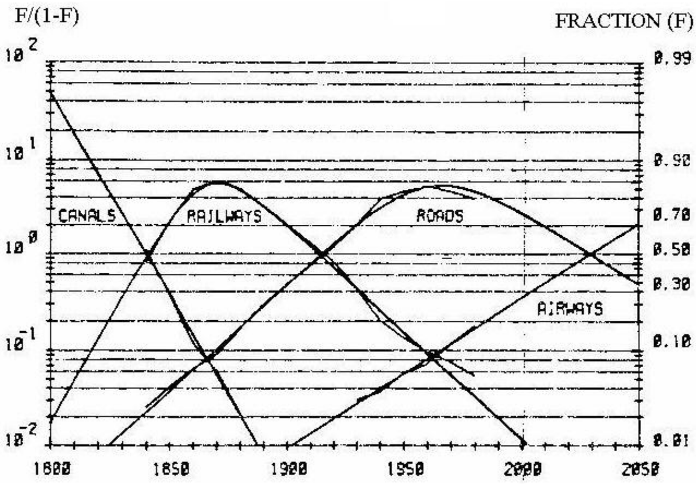

Figure 2. Transport infrastructures in the United States between 1800 and 2050 – first substituting the previous one and gradually taking over the place from each other[2]

Whether we have to accept the presumption of Nakicenovic presented in Figure 2., namely that we have to wait for a new dominant transport mode able to take over the service from the previous one? Really that would be the future, just looking on how the systems developed earlier extinct to give their place to a new and better solution?

Instead of the relative proportions of the different transport infrastructures, Ausubel et al (1998) present the trend of the growth rate of the same transport networks (see the right upper corner of *Figure 3*). This could be considered as the derivative of Figure 1

[2] Source: Nakicenovic 1988

(if it weren't a schematic diagram) the tangent showing the measure of the rising in Figure 1 appears as y value in Figure 3. This latter figure also presents that those transport modes (new technologies) starting later are developing for a longer time and still their relative dominance to the other modes is decreasing. It is worthy to note that the figure is not only schematic but also ignores to present that the growth rate can also be negative (we could see in Figure 1 that the lengths of the canals and rails both begin to decrease at a given phase.)

Based on the figure of Ausubel et al, we made slight modifications on *Figure 3* (main diagrams). Instead of the growth rate, let us consider the diagrams rather to the proportion of the investments into the given network (by that we could give sense to its non-negative value range). We completed this approach to a hypothesis that the investment to the older ('outmoded') transport modes is not necessarily closes its cycle to zero, but the developments can be stabilised at a low, still not zero level. This means, that we could recognise a transport segment that can continue to be supplied best by the given mode and in that segment this mode keeps on developing.

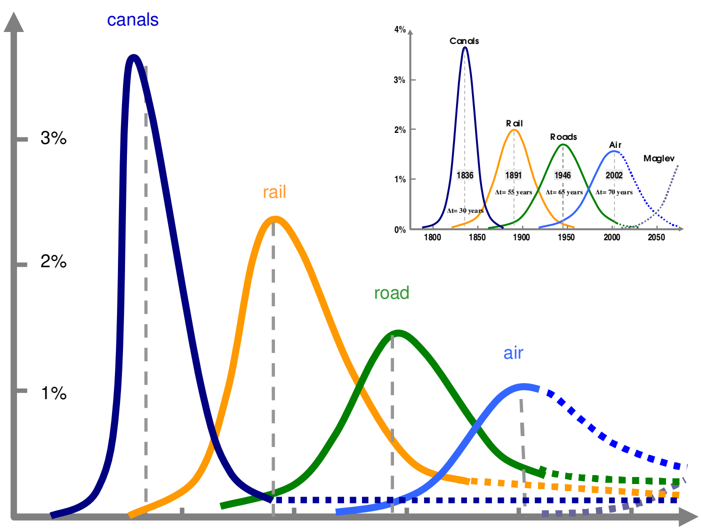

Figure 3. Supposed co-operation of the transport modes in the 21th century[3]

We expect an evolution of the mixed use of the different transport modes by the 21th century, where all modes can serve a specific segment in the supply of the total transport needs, without any of them getting excessive dominance over the others. This approach fits very much into a post-modern paradigm, where it is a general rule that the elements of the accumulated heritage can be coupled with new innovative solutions; and where the new technologies also have to serve the possibility that the different segments could be associated to a well-operating whole. In our case it is the task of the transport

[3] Source: Rodrigue J-P. 1998-2010 (right upper corner) referring to Ausubel et al 1998

policy to promote and assure the co-operation of the different transport modes into an integrated and co-modal transport system.

4. A practical case: local and commuter train system in Budapest and the conurbation area

The spatial service of the different sites of the city and the conurbation area by public transport is an important and difficult challenge. As for the Budapest area, there was a significant development, rather a paradigm-change in the support of this task with networks in the recent years – at least at the planning level. We can well monitor this change by comparing the earlier (2001) and newer (2008) version of the Development Plan for the Transport System of Budapest (BKRFT): more exactly the plans BKRFT 2001, S-Bahn 2007 and BKRFT 2008.

Important historical background was the transformed public transport system of the 1970s, with the completion of the east-west and north-south underground lines supplying the inner third core of the Great-Budapest area. These lines were built with many and dense stations aiming at a direct service to the areas crossed, while the surface public transport system was converted (disintegrated, fragmented) at the same time to formulate short lines, direct feeding the underground stations and ceasing those lines parallel with the underground.

The BKRFT 2001 development plan was formulated during the nineties after extended consultations. As for its philosophy for the public transport, there was a sacred and central element of it: the Metro 4 – the relating plans were ready and basically followed the earlier planning pattern: a line crossing the very centre of the city, with end-points at the border of the inner core of the city and also with many short-distance stations.

The BKRFT 2001 plan formed big intermodal hubs at the end-points of the metro lines, holding up at the same place also the commuter trains, inclining by that to force all passengers to change. Such operation of the change points copied the principle of the freight distributing hubs (and also the operation of the already existing metro end-points) with technocratic rigidness. Just because of the earlier adverse experience, specific attention has been paid on the development of use of the the changing points, to promote the comfort of the transferring passengers. The ambition naturally approved, the fluent operation of the intersections is important. The problem was that this intention totally overshadowed the fact that a high proportion of the changes could have been avoided – they were created by the planners when they built their plans around the idea of the development of the big inter-modal hubs, endpoints of the arriving lines. For the passenger the comfort is not the possibility that s/he can chose among 22 directions at a huge omnipotent junction, but rather the journey that need no changes or less and simple changes.

Today it is already easy to describe the new principles, and it is not necessary to invent the base of the up-to-date move of the passengers in Budapest either. In 2007 practically the same planner group elaborated it for the commuter train system of the capital (S-Bahn 2007).

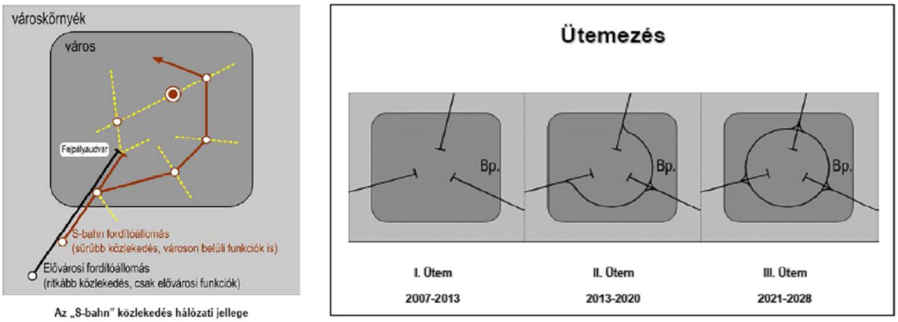

Figure 4. Scheme of a rail network that is passing nearby the city centre offering many connections. (The final plan in the last phase connects head-stations with tunnel differing from the original scheme)[4]

The essence is to work out a common transport system for the conurbation zone, for the outer districts of the capital and for the inner core of the capital, that is abandoning the earlier obligate and sharp separation of the 'out' and 'in' and also the accentuated technical separation of those braking line in the transport (*Figure 4.*). The commuter train is not something to turn back and keep far away from the city any more, but the backbone of the passenger transport to be continued in the city, part of a system that serves both conurbation and urban main traffic hubs.

With that S-Bahn plan the theoretic base of a two-level public transport for the capital and its conurbation was born. One level is the backbone network covering both the urban area and the conurbation with long overlapping lines, offering to all zones of the area an easy accessibility from each other with few changing. The other level is the traditional public transport with dense stops, offering a more fine covering within and between the single zones.

The new BKRFT 2008 prepared in the next year already contained the S-Bahn concept, but it remained a separated technological segment ('rail') within the plan, instead of adapting the new principles to the whole plan. There is no plan yet for the whole rapid-transit level of the public transport of the area, interconnecting the zones, where beside the rail also the elements of other modes – local train, metro, rapid-tram, rapid-bus – that could serve the same level would appear in a single system. Similarly, there is no general concept in the plan yet for the link of this level to the traditional level of the transport. While the territorial integration (urban and surrounding area) is already represented, the modal integration stuck in an outmoded old form.

In spite of all these shortcomings, it is important to note that the fundaments of a new networking principle have been born in the recent years. Care should be taken to make the principles more conscious and known, promoting that no project could be prepared based on the old, contradicting views. Instead a new transport development plan for

[4] S-Bahn 2007 http://www.fomterv.hu/hun/sbahn/koncepcio_osszefoglalo.pdf

Budapest and the conurbation area should transform the multilevel transport network to the fundament of the future transport of the area.

5. Another future case: outlines of a new integrated Hungarian transport policy

It is a relative new decision that the Hungarian government begins the preparation work of an integrated transport strategy (=covering all transport sub-sectors in one strategy). Naturally it is not the first attempt to develop such a strategy, actually at least three documents exist and valid to cover that area.

The oldest in the row among the still valid strategies is the Hungarian Transport Policy ([A] Magyar közlekedéspolitika 2003-2015. [2004]) approved by the parliament in 2004, and never was declared, that its 2015 horizon would be shortened. There were also no modifications approved by the parliament relating to this document. The policy covered all modes, but this statement could have been more authentic if the separated Motorway Act hadn't been approved by the parliament just three months before the transport policy.

Shortly later a new development plan (ÚMFT 2007) and sector-specific operative programs were prepared, covering all those projects that are supported from EU development funds. One of those was the transport operative program for the EU 2007-2013 planning period (KözOP 2007). This program was based on an integrated approach, as the main priority blocks are (1) the external accessibility of the country and its regions, (2) the accessibility within and between the regions, (3) the intermodal freight hubs and (4) the public transport hubs – cities and conurbation. However, the selection of the projects didn't follow too strictly this structure; the priorities were rather filled up from the old sub-sector projects.

The operative program had to be also approved by the EU Commission, and as a condition for that the Commission assessed the preparation of a single transport development strategy to show that the projects in the operative program all fit to a wider transport strategy of the country. These strategy documents were very quickly prepared first as single (all-transport) green, later white papers; (EKFS Zöld 2007) (EKFS Fehér 2007) and finally also a sector program was issued (EKFS Ágazati 2008). The integrated strategy was built up on four pillars: passenger transport, freight transport, transport infrastructure, and horizontal issues like safety or institutions. Somehow, the consequences of the strategy brought no new invention, but proved the choice of the earlier projects in the operative program as they were already accepted.

In 2011 a new general development strategy was approved by the Hungarian parliament (Új Széchenyi Terv 2011) with a transport chapter in it, declaring to overwrite the 2007 development strategy, (UMFT 2007) but not really its part, the transport operative program that is valid until 2013 (with time-to time modifications).

That is the moment, when the preparation of a new national integrated transport policy has been decided. As not more than verbal presentations were until now seen from this future document, the short comment below is a warning to possible dangers rather than criticism based on facts.

As we could see, the earlier integrated strategies followed different starting logics, all of them can prove to be a good structure. On the other hand a second and common feature was of all the earlier documents, that the strategy built up carefully wasn't consequently followed by subordinated second-third level goals that could have designate those tasks and programs that are suitable to achieve the general objectives. Instead it was always considered evidence that the projects decided beforehand in the different sub-sectors are just the best in the context of the new strategy too.

Now, the first signals show that those preparing the new strategy, announce a kind of 'bottom-up' principle, that really sounds very democratic, excluding, if the bricks at the bottom are not people or their organisations but sub-sector strategies. The decision that the integrated transport strategy should posteriorly balancing between separately elaborated sub-sector strategies seems to be the misunderstanding of the task of an integrated transport strategy. It is even worse that the different sub-sectors are very differently supplied by their own strategies, the preparation of the railways strategy has slowed down, perhaps stopped while the development plan for the motorways and main roads has just been finished and the transport authority intends to pin down it by a parliament order creating a fait accompli situation for the integrated strategy.

To avoid any misinterpretation of the preparation process of an integrated strategy, here *Figure 5* displays an empty frame just to demonstrate how the general objectives can gradually be enforced in the sub-sector strategies in an iterative process.

The small boxes can represent modes (inland waterways, rail, road, aviation, local transport) while the longer boxes show that during the process the integrated analysis of the achieved results and the integrated elaboration of the next activities is necessary several times.

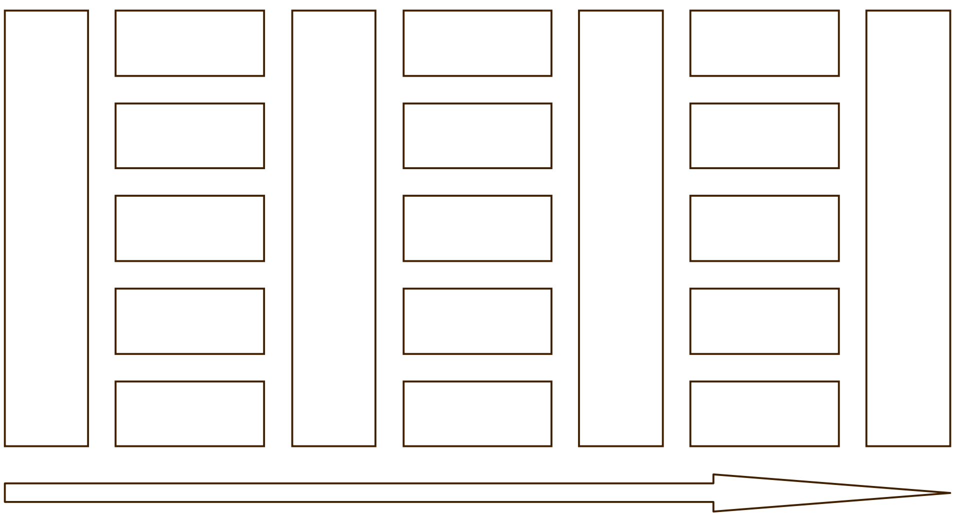

Figure 5. The suggested iterative set-up of the integrated transport strategy

The first block is integrated and can set general environmental, social, macro-economic objectives the transport sector has to serve. From that base also a commonly decided instruction can define the common structure of the analysis of the starting positions and the situation. The evaluation of the starting status is again a common block with the preparation of a problem-map and pointing at the causing mechanisms. By that way step-by-step the process can form the general transport goals to help to achieve the first level social objectives, then the programs to achieve this goals etc. What is important, the sub-sectors can't inject directly prefabricated projects into the last (right) boxes but they have to lead their targets through the whole process, and adjust the projects to the proven goals, not vice-versa.

Conclusions

The article gives a general introduction to the integrations and co-operations trying to avoid a simplified view as if establishing co-operation between the different transport modes could be based on the willingness of existing (rigid) transport systems to understand each other. The presentation of the modern and the contradicting (post-modern) values and key-words first of all want to show that the biggest revolution occurred in our use of the space (urban space or land) together with our relation to the city and to the public space in our living area. The developments, also the transport developments have to serve, follow and promote this great change.

The co-operation between the transport modes is a small element in that whole frame, and the viewpoints towards that have to be filtered through the all-transport considerations: the integrated transport system transmits the social expectations. The integrated transport system unifies several different integrations: one part of them is external: as the integration between the transport and the other economic sectors, or between the transport and the dispersed users of the transport. A second block is the internal integration within the transport system as the spatial integration (local / trunk) and the modal integration.

The preparation of the transport strategies and the activity of the transport planning both have to be placed within that wider frame, to understand the more general social and economic macro-level objectives that the transport system has to serve.

References

[1] Ausubel, J.H., Marchetti, C., Meyer P.: *Toward green mobility: the evolution of transport,* European Review, Vol. 6, No. 2, (1998) pp. 137-156. Átvette Rodrigue J-P (1998-2010)

[2] BKRFT 2001 *Budapest Közlekedési Rendszerének Fejlesztési Terve*. Budapest, Főmterv 1997, 2001

[3] BKRFT 2008 *Budapest Közlekedési Rendszerének Fejlesztési Terve*: Távlati koncepció és a 2020-ig javasolt fejlesztés terve. Budapest, 2008 december, FKT. URB. Konzorcium.

[4] EKFS Fehér (2007) Egységes Közlekedésfejlesztési Stratégia 2007–2020. Fehér Könyv. Gazdasági és Közlekedési Minisztérium 100 p. [dátum, verziószám, kolofon nélkül] http://www.gkm.gov.hu/feladataink/kozlekedes/kozlekedespol/ekfs.html http://www.gkm.gov.hu/data/cms1461000/EKFS.pdf (Loaded January 28, 2008)

[5] EKFS Zöld (2007) Egységes Közlekedésfejlesztési Stratégia 2007–2020. I. Zöld Könyv. Gazdasági és Közlekedési Minisztérium 83 p. [with no date, version number, impressum] http://www.gkm.gov.hu/feladataink/kozlekedes/kozlekedespol/ekfs.html (dated September 10, 2007. several times modified since) http://www.gkm.gov.hu/data/cms1460999/ekfs_0907.pdf

[6] EKFS Ágazati 2008 *Az Egységes KözlekedésFejlesztési Stratégia célkitűzéseit megvalósító alágazati stratégiák 2008-2020*. KHEM n.a., 125 p. http://www.khem.gov.hu/data/cms1791750/EKFS_Al__gazati_fejleszt__sek_HU_0902.pdf (Last loaded June 2010)

[7] KözOP (2007) *Közlekedés Operatív Program* (KÖZOP) 2007. július 111 p. Az operatív program hivatkozási (CCI) száma: 2007HU161PO007 A Magyar Köztársaság Kormánya. http://www.nfu.hu/umft_operativ_programok Version: KÖZOP_070712_hu.doc

[8] Kubinszky Mihály (ed.) 1978. *Modern építészeti lexikon*. Budapest, Műszaki Kiadó ISBN 963-10-1780-X

[9] *Leipzig Charter on Sustainable European Cities*. (2007) 7 p. http://www.eu2007.de/en/News/download_docs/Mai/0524-AN/075DokumentLeipzigCharta.pdf

[10] *[A] Magyar közlekedéspolitika* 2003-2015. [2004] Magyar Köztársaság. 45 p. http://www.gkm.gov.hu/data/cms18631/k_zlpol_nyomt.pdf

[11] Nakicenovic, N. 1988 *Dynamics of change and long waves*. IIASA Working Papers 1988

[12] Rodrigue J-P. 1998-2010 Centre for Research on Transportation of Université de Montréal. Web server provided by Hofstra University. in "*Transport Geography on the Web*" http://people.hofstra.edu/geotrans/eng/ch1en/conc1en/ustrspgrowth.html (loaded January, 2010)

[13] S-Bahn 2007 *A Budapesti Regionális Gyorsvasúti Rendszer koncepciója* FŐMTERV-KÖZLEKEDÉS Konzorcium 2007. október hó http://www.fomterv.hu/hun/sbahn/koncepcio_osszefoglalo.pdf

[14] Salingaros, Nikos A (2000) *Complexity and Urban Coherence*. Journal of Urban Design, Vol. 5. pp.291-316.

[15] ÚMFT 2007 *Új Magyarország Fejlesztési Terv. Magyarország Nemzeti Stratégiai Referenciakerete 2007-2013*. Foglalkoztatás és növekedés. Magyar Köztársaság Kormánya http://www.nfu.hu/download/479/UMFT_HU_NSRK-hun_Accepted.pdf (loaded in April, 2011)

The Implementation of Public Transport Data Models in Hungary

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Abstract: The article focuses on the reasons behind the recent nationwide implementation of the European reference data model for public transport, TRANSMODEL and the service interface for real time information, SIRI in Hungary. It analyses the operational and institutional background, presents a brief introduction and their role in public transport management with application examples, particularly the liaison between TRANSMODEL and the location identification and coding rules of ELEKTRA Hungaria, the national chip card system.

Keywords: *transmodel, siri, elektra, data model, geodatabase, transport, network*

1. Introduction

The **New Széchenyi Plan** identifies the development of transport as an outbreaking direction and within it "the reorganisation of public transport system, the modernisation of its structure and financing" is a stressed horizontal issue. [1.] The **key to the successful implementation** of these measures **is the development of coherent public transport systems and databases**, built with unified terms, logic and content in the bottom line of mind. The preparatory works and the supervision of the development are the duties of the Ministry.

Understanding the importance of the standards and reasons behind their application the use of these standards is a definite requirement in the Regional Operational Programmes. [2.]

In the early stage of their implementation **a number of questions were raised** in connection with the standards forming some concerns of the adequacy and use. Behind the question a number of reasons can be identified among which the following should be listed:

- the implementation of the standards is a tool and not a goal, thus the call writers did not devote too much explanation to the exploitation of the data models;
- the applicants understood the implementation of the standards as a challenge in informatics however the real goal was to support traffic management processes;

- for a long time the national traffic management and planning system were common in refusing the spatial representation and modelling of the network in spite of the fact that the know-how was available since 1980'ies also in Hungary;
- the translation and the transposition of the standards did not happen in the past, since the demand for that became clear just during the recent implementation works.

The goal of this article is not to give an in-depth introduction of the standards, which wouldn't make sense in such extent anyway, but stressing the key role of standards in traffic management, operational planning, passenger information, ticket selling and network planning.

Definitions of database

Before going in details it is important to clarify some misunderstandings and misconceptions – that do exist according to the present practice. The easiest way of doing this is to give exact definitions.

The **definitions of the following terms are necessary**:

- **Data:** Refers to factual figures with definition and unit that are measured or recorded during the operation of public transport.
- **Jumble of data:** The electronic storage place of data, typically arrange into datatables.
- **Database**: Data of a common nature and collected in a common logical system.
- **Relational database:** The structured, logically managed and connected storage architecture of data, of which information (knowledge!) can be derived.
- **Geodatabase:** A database in which the data have spatial reference and the geographic and describing attributes and their logical connections – including spatial ones (like adjacency) – are recorded together and managed commonly. Its key benefit is the redundancy free data storage.
- **Data model:** The relational and interpretation system that defines the logical description of the database, containing constructional and operational elements.

Giving **a practical example**: the departure time of a given public transport service is a datum (transferring to the passengers is information); the datasheet containing all departures of a day is a jumble of data (the timetable is a logical term!); in a relation database this data sheet is a table interpreted in a connection system; in a geodatabase these departures have spatial references (can be presented on a map and spatially analysed). In most cases the mixture of the above terms is typical; e.g. the collection of Excel data sheets is called database. A similar mistake is to say geodatabase when we have only a table in the database containing the stop coordinates or even the vertex coordinates and we can have a plot of the services.

It is important to emphasise that **data model does exist in any database** independently from its direct presentation during software planning and from having a conscious design with users.

The data connection model called data block diagram can be derived from an existing database as well (reverse engineering).

The base of the state-of-the-art software design is the establishment of a data model, in which the logical model, the data connections and external references of the stored data as well as the operational rules are defined. It is forbidden to mix these later ones with the physical database operations like insert or delete.

The present practice says that in spite of the fact that the transport and its connected processes (like trip or journey) and events (like departure) are heavily connected to spatial description and movements the geodatabase and **the systems that can handle spatial connections and operations are quite rare** (they are preliminary at planning institutions). This poor availability of spatial management caused and still causes clear decrease in service efficiency and quality (it is enough to mention the poor handling of changing – if the name of the stops are different the systems usually do not recognise the possible changes).

Interpreting the abovementioned definitions **the standards that were put as requirement in the calls of the regional operational programs** is **not more just the clear definition and demand on the common terminology and data model**. Additionally **it takes the duty and costs of one of the most important design phases** which require the broadest knowledge in transport operation – therefore causing the most troubles handling it as a simple software definition task. This is extremely important since it not just a financial tool for software development but **a chance for a quality upgrades**: the recent traffic operation and management can be supported with spatial domains – since typically the ground vehicles will be equipped with GIS; this inevitably leads to new data models at those companies that had lack of spatial database.

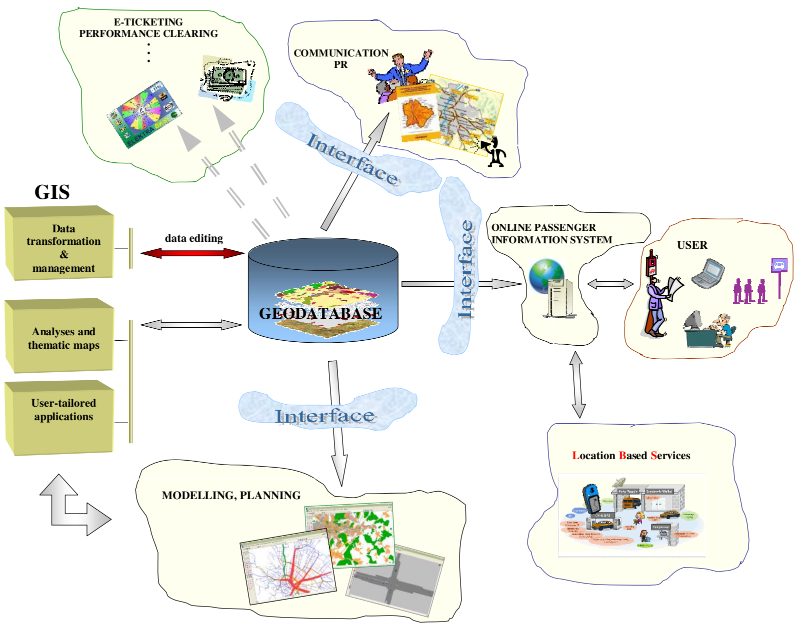

Figure 1: Sketch of business and passenger information systems (Berki [4.])

Additionally, it should be mention that **these systems will serve a number of other applications** directly connected to public transport operation (e.g. e-ticketing system, see Figure 1) – thus their requirements should be incorporated in the data model, which – regarding the fact that the companies have very limited experience in these fields – practically would mean an infeasible task for software engineers!

2. The role of public transport network representation

It is crucial to consider the following integrated aspects at transport network database building in connection with public transport:

- **planning of the public transport network**; calculation of the passenger demand loads, the optimization of the alignment of the lines with the impact assessment,
- **service planning**; timetable and service calendar planning, making of the crew and vehicle scheduling,
- **assisting traffic control**; assisting operation tasks by involving spatial information and spatial connections, efficient handling of incidents,
- **developing passenger information system**; provision of timetable based route guidance calculated with the real availability of services for several kinds of end-user devices (e.g. internet, mobile equipments),
- **application of electronic chipcards**; the positioning of the different network elements and equipments (e.g. validators); the description of timetable supply according to intended travel relations of passengers for the loading onto the cards,
- **recording and presentation of performances**; for the periodic recording of the passenger-, deployment-, vehicle and staff performances based on network points and lengths and for the reporting on area/line based results.

An information system built with these considerations in mind could assist the complex planning and decision making processes of public transport companies. For these tasks the only common solution is to build a **geodatabase**.

The transport operation processes that can capitalize on geographic information systems are pretty wide (see Figure 2**). The common feature of these processes is that without using localisation we could get only partial information from them**, therefore the user should – usually in mind with verbal or tabular information – combine them. In the latter case there are trivial problems; it is enough to mention the liaison between service planning and demand in strategic planning or at passenger information the bundling of the route and validity (e.g.: the route could be different on weekdays and weekend days).

The **service data** of the operators in a database system **are collected in clearly defined logical association groups** (categories) of which the following ones are the most crucial:

- identification of line/service patterns/runs;
- defining of routes, stops, route sections and internal junctions;
- the schedule and vehicle type of valid and planned runs.

In brief we can state that **the fundamental requirement** of a geographic information system **is to represent the conceptual range of the operators** and be capable to join the data with their validity, including versioning and geodatabase rules.

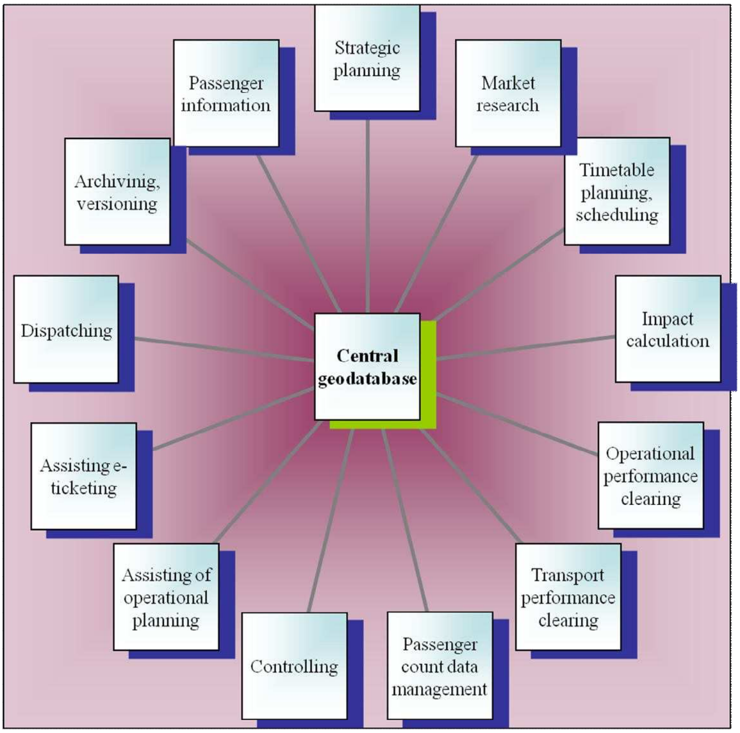

Figure 2: Transport operation processes that can capitalize on geographic information systems (Berki)

3. Standards and business processes

The launching procedure and existence of standards is not an art for art's sake but they are the keys for successful implementation of the business processes. This fact is further supported by the rapid development of info-communication technologies, since without standards and interfaces these systems never could be linked.

This is true for public transport operation as well. A good example is from the European Bus System of the Future (EBSF) research programme running recently (2008-2012, 47 partners, 26millió EUR budget – Budapest Transport Co is one of the partners). One of the most stressed ideas is [5.]: *"One key innovation developed in the project is the concept of integrative approach on information technologies and telematics. EBSF is developing IP communication architecture on the vehicle side as well as standard interface (like SIRI and data model like Transmodel) on the back back-office side for European buses in 2015. Integration is THE key aspect while speaking about «system» in EBSF."*

The **following EU level standards and directives** do exist related to public transport data management and data interchange:

- **TRANSMODEL** – the Reference Data Model for Public Transport; including the database schema for network description, versioning, vehicle-driver scheduling and rostering, personnel disposition, operations monitoring and control, passenger information, fare collection and management [6.];
- **SIRI** – Service Interface for Real Time Information; an XML protocol to allow distributed computers to exchange real-time information about public transport services and vehicles [7.].

TRANSMODEL is a database data model which **is due to be implemented within the Enterprise Resource Planning System** of an operator **while SIRI is supporting the connection** of distributed systems.

The national implementation of these standards has been started. As early as 2006 a study dedicated to the passenger information system of Budapest Transport Association (BTA) of TRANSMAN and CDATA has stressed to build the database by applying the TRANSMODEL standard.[8.] Later CDATA-Térképtár built a database for testing purposes for BTA by implementing TRANSMODEL standard's chapters dealing with network description [9.], and an other one for assisting the national transport count and survey program in 2007-2008. [10.][11.].

4. Network description – The key element

The central element of such databases is the network description. Its fundamentals have been developed in the 80'ies with multi-modal approach in mind. One of the pioneers was Dr. habil János Monigl who summarised these issues in his study about TRANSURS (Transport planning in urban areas) model system. [12.]

The harmony between the two aspects is evident when we compare the network schema of the two systems:

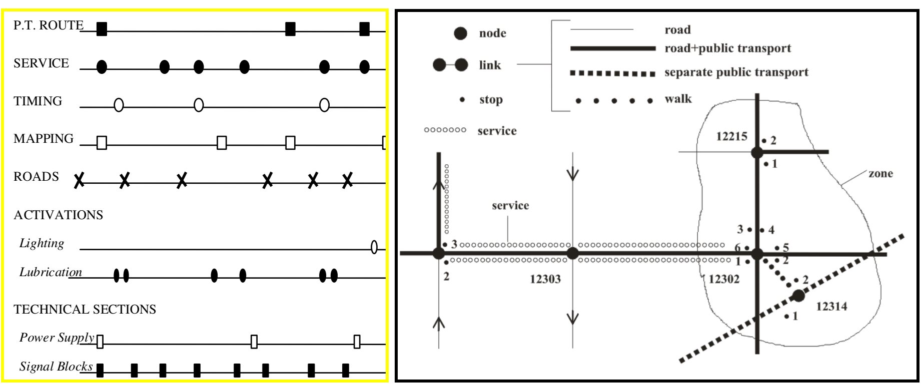

Figure 3: The transport network description (TRANSMODEL and TRANSURS)

Anyway, this is the fundamental structure of the TRANSURS transport planning software (developed by TRANSMAN) and also PTV VISUM used by TRANSMAN and FOMTERV.

Thanks to this similarity there was no need to transform the database when we shared a modelling database between these software tools. PTV VISUM is such complex that it can work as a transport database server of a city (e.g. London [13.]).

However, TRANSMODEL is only a reference data model. Adding to this a number of coordination actions are needed. Like the preparation of a national identification system and location code tables is the duty of the central government. For example in the UK the National Public Transport Gazetteer (NPTG) provides a topographic database of towns and settlements [14.] and the National Public Transport Access Node (NaPTAN) is a UK nationwide system for uniquely identifying all the points of access to public transport [15.].

A similar work has been undertaken also in Hungary in connection with the development of the national chipcard system called **ELEKTRA Hungaria** which was coordinated by TRANSMAN and led by Dr. habil János Monigl [16.]. In that project the author prepared the network database and the network based calculations [17.].

The objective of the underlying work was to provide a unified network and timetable description system which could be filled up directly by an automated manner using the existing databases of recent transport operators and could support the preparatory works of transport associations in planning phase and the operational tasks in a latter phase covering tasks from timetable planning to revenue sharing. In this workflow the **role of the spatial database** is to support the network description by providing a framework for presenting, querying and spatial analyses (like neighbouring, zone system creation) of the services and support to make a mathematic graph of the transport system suitable for path searching and network calculation (like assignment, tariff calculation). It provides a unique possibility to involve other, non-transport data sources – primarily demand related ones: population, motorisation, etc.

Table 1: The identification and code system of ELEKTRA Hungaria [17.]

Nr.	ELEKTRA Data file	File name	Size of ID
1.	ELEKTRA issuer identifyer	ISSU	1 byte
2.	ELEKTRA operator identifyer	OPER	2 byte
3.	ELEKTRA card identifyer	CARD	1+4 byte
4.	Card delivery office identifyer	OFFI	2+1+2 byte
5.	Reload device identifyer	RELD	2+3 byte
6.	Validator identifyer	VALD	2+1+3 byte
7.	Controll device identifyer	CTRL	2+2 byte
8.	Display device identifyer	DPLY	2+2 byte
9	Computer identifyer	COMP	2+1+2 byte
10.	ELEKTRA location identifyer	LOCI	2 byte
11.	ELEKTRA service identifyer	SERV	3 byte
12	ELEKTRA travel identifyer	TRAV	4 byte

The fulfilment of the presented list of requirements seems to be pretty demanding but with the use of geographic information system tools it is quite easy and straightforward.

It should be stressed that the **key to the successful implementation is to have a central auditing body** to beware of the misinterpretation of the standards. This task was dedicated by the Ministry to the **VOLÁN Egyesülés (VOLÁN Professional Association)**. Its special mission is to keep and strengthen the coherent database of the national road public transport companies. [17.]

References

[1.] New Széchenyi Development Plan, 7th Transport Development Programme, http://ujszechenyiterv.gov.hu/

[2.] National Development Agency – *Call and guide for proposers in Regional Operation Programmes supporting Infrastructure Investments to Increase Public Transport Service Level (separate call for each region)*, 2009., e.g.: http://www.nfu.hu/download/20848/00_DD_Kozossegi%20kozlekedes%20090708.pdf

[3.] Berki, Zs.: *The role of Public Transport Network Description in the Implementation of the National Chipcard System ELEKTRA Hungaria*, Városi közlekedés, 2006. (46. évf.) 3. sz. 139-151. old.

[4.] Berki, Zs., Fejes, B.: *The Integrated Passenger Information System – a case study of Budapest Transport Association (BTA)*, Városi közlekedés, 2010. (50. évf.) 5. sz. 273-279. old.

[5.] http://www.ebsf.eu/index.php/news/111--6th-uitp-international-bus-conference.html

[6.] TRANSMODEL – The European Reference Data Model for Public Transport, 2001 http://www.transmodel.org/

[7.] SIRI – Service Interface for Real Time Information CEN/TS 15531 (prCEN/TS-OO278181), http://www.kizoom.com/standards/siri/overview.htm

[8.] TRANSMAN – CDATA: *Feasibility study for the on-line public transport journey planner of BTA*, Client: BKSZ Kht., 2006.

[9.] TRANSMAN – Térképtár: *Establishment of a Regional Transport Geographic Information System*, Client: BKSZ Kht., 2007.

[10.] TRANSMAN – CData-Térképtár: *Concept for a National Geographic Information System and Data Model for Public Transport compatible with ELEKTRA Hungaria*, Client: KTI Nkft., 2008.

[11.] KTI: *National Count and Survey Programme for Regional Transport*, 2007-2008, client: KHEM és Szolgáltatók, 2008.

[12.] Monigl, J., Berki, Zs., et.al.: *The Space-Time-Cost Modelling System of Budapest and its region (TRANSURS model system)*, TRANSMAN Kft, 1998.

[13.] CONDUITS – Coordination Of Network Descriptors for Urban Intelligent Transport Systems, State-of-the-art of urban traffic management policies and technologies Deliverable No. 1.2 – 1.3, 2010, page 148

[14.] NPTG (National Public Transport Gazetteer), http://www.dft.gov.uk/nptg/

[15.] NaPTAN (National Public Transport Access), http://www.dft.gov.uk/naptan/
[16.] Monigl, J., Dániel, Sz., Berki, Zs., Halász, Gy.: *The Fundamentals of ELEKTRA Hungaria National Chipcard System*, Városi közlekedés, 2006. (46. évf.) 1. sz. p. 8-27
[17.] Berki, Zs.: *The Role of Transport Model Description in the Implementation of ELEKTRA Hungaria National Chipcard System*, 2006. (46. évf.) 3. sz. p. 139-151 http://www.volanegyesules.hu/transmodel/Transmodel_ASZF_201102.PDF

Transport Costing Based on the Modelling of Technology Processes

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Abstract: Transport costing is a relatively seldom addressed topic of the researches and the literature. At the same time, its traditional methods are not always sufficient to determine the real costs of services and to support the evaluation of cost effectiveness. Thus the methodology needs to be developed significantly. This paper aims at working out a costing model which is able to enhance the reliability of transport cost calculations. The elaboration of the model makes advantages of the related research results published in the literature. On the other hand, it uses a new approach: connects cost allocations to the logic of technology processes. The model is verified through an illustration of a simple example.

Keywords: transport costs, transport performances, calculation

1. Introduction

The widely used costing regimes of the companies operating in the transport sector are often not suitable enough to support decision making on capacity allocations, pricing or business/technology process reengineering. These calculation systems rely namely on traditional accounting principles which use arbitrary approaches when allocating costs to the elementary components of transport services

The main methodological problems of current transport cost management practices can be summarised as follows:

- high level of aggregation of prime cost and profitability information;
- cost drivers are not identified;
- widespread use of simplified average values instead of detailed calculations;
- performance flows and cause-effect relationships in cost allocations are ignored [3].

These methodological problems lead to inaccurate information on the cost and profit of transport services which may result in inefficient resource allocations. Furthermore, the bottlenecks or the weak points in the technology process chain remain undiscovered which contributes to the loss-making operation of certain transport companies.

Some methodological innovations aiming to improve the procedures of transport costing can be found in the literature. The most fruitful research was carried out in the field of road haulage where a comprehensive activity-based costing model was set up and used for allocating overhead costs [1]. Other results concern logistics (rather than transport). The main tool here is activity-based costing as well. The researchers give guidance on how to apply this method in logistics [4, 6] and in distribution systems [9], or how to enhance the efficiency of logistics systems by making cost calculations more reliable [8]. Another finding is that activity-based costing can be extended even to the entire supply chain [7].

The results of relevant researches provide a sound basis for the introduction of a new transport costing model. Nevertheless, additional methodological considerations shall be explored to generalise the outcomes of the rather specified approaches. So the aim of this study is to set up a general model framework supporting the development of transport costing. A higher level of exactness is targeted by connecting cost allocations to the logic of technology processes measured through performance flows or indicators. The basic mathematical formulas of the calculation algorithm are also determined. To show the applicability of the model and the formulas a simple example calculation is conducted.

2. Principles of the calculation model

Figure 1. illustrates the model proposed for transport cost calculation based on technology processes (represented by performance flows). It consists of the following elements:

- cost objects: second level intern services ($i = 1 \ldots m$); first level intern services ($j = 1 \ldots n$); productive cost objects ($k = 1 \ldots p$);
- profit objects ($l = 1 \ldots q$);
- performance flows: second level intern services – first level intern services (ij); second level intern services – productive cost objects (ik); first level intern services – productive cost objects (jk); productive cost objects – profit objects (kl).

Cost objects are various organisation units or pieces of equipment in the transport company. They consume resources and produce performances. Some of them are responsible for providing background services, while the productive cost objects are involved in the production of the transport tasks. The resources which can not be allocated to the profit objects directly are assigned to the cost objects. The costs of consuming these resources represent the indirect costs of the transport company.

Profit objects are the transport tasks produced by the company. They create revenues while consume resources and performances. Resources which can be allocated to the transport tasks directly cause the direct transport costs. The indirect transport costs are allocated to the profit objects from the cost objects through a cause effect based calculation. This calculation is governed by the performance relations (or flows) determined in the framework model.

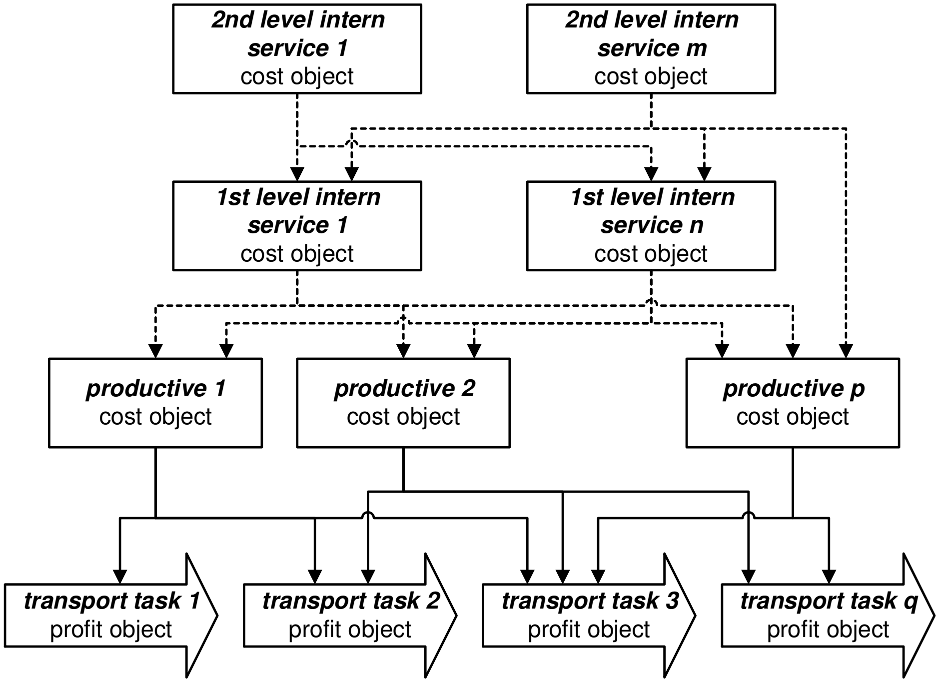

Figure 1. The basic framework of the transport costing model

The entities in the model are arranged into the following data structure:

- second level intern service cost objects: cost, performance;
- first level intern service cost objects: primary cost; secondary cost, performance;
- productive cost objects: primary cost; secondary cost, performance;
- profit objects: direct cost, indirect cost, revenue.

The secondary costs of cost objects and the indirect costs of profit objects are subject to special calculations: these performance based allocations along the logic of technology processes. The rest of the data shall be made available by the accounting system (however, some transformations may be needed here as well).

Note that the structure of the model shall be adapted to the specific features of the company examined. It means that less or more levels of cost objects can also be introduced depending on the complexity of transport technology processes. Furthermore, the interactions between the cost objects can be even more complex as in the reference model.

If using the basic framework for transport costing (as illustrated in Figure 1.) the main calculation formula can be obtained as shown in equation (1) – for the detailed methodology of deducting the calculation scheme see [2].

$$C_{po_l} = C_{po_{d_l}} + \sum_{k=1}^{p} C_{pco_{pk}} \frac{P_{kl}}{P_k} + \sum_{k=1}^{p}\sum_{j=1}^{n} C_{flisco_{pj}} \frac{P_{jk}P_{kl}}{P_j P_k} + \sum_{k=1}^{p}\sum_{i=1}^{m} C_{slisco_i} \frac{P_{ik}P_{kl}}{P_i P_k} + \sum_{k=1}^{p}\sum_{j=1}^{n}\sum_{i=1}^{m} C_{slisco_i} \frac{P_{ij}P_{jk}P_{kl}}{P_i P_j P_k} \quad (1)$$

where:

C_{po_l} : total cost of profit object l

$C_{po_{d_l}}$: direct cost of profit object l

$C_{pco_{pk}}$: primary cost of productive cost object k

P_k : total performance of productive cost object k

P_{kl} : performance flow between productive cost object k and profit object l

$C_{flisco_{pj}}$: primary cost of first level intern service cost object j

P_j : total performance of first level intern service cost object j

P_{jk} : performance flow between first level intern service cost object j and productive cost object k

C_{slisco_i} : total cost of second level intern service cost object i

P_i : total performance of second level intern service cost object i

P_{ik} : performance flow between second level intern service cost object i and productive cost object k

P_{ij} : performance flow between second level intern service cost object i and first level intern service cost object j

Note that the general formula shall be adjusted to the actual calculation framework – representing the technology processes – applied to the company investigated. If the technology structure of the company is less or more complicated the initial formula may also be changed in a flexible way.

It is possible to make formula (1) less difficult when using performance intensities (formulas (3), (4), (5), (6)) instead of performance indicators – see equation (2). The measurement of performance indicators can be ignored here: the distribution of performance consumptions between the entities – measured in percentage – is only to be elaborated.

$$C_{po_l} = C_{po_{d_l}} + \sum_{k=1}^{p} C_{pco_{p_k}} p_{kl} + \sum_{k=1}^{p}\sum_{j=1}^{n} C_{flisco_{p_j}} p_{jk} p_{kl} + \sum_{k=1}^{p}\sum_{i=1}^{m} C_{slisco_i} p_{ik} p_{kl} + \sum_{k=1}^{p}\sum_{j=1}^{n}\sum_{i=1}^{m} C_{slisco_i} p_{ij} p_{jk} p_{kl} \quad (2)$$

The performance intensities between productive cost object *k* and profit object *l*, first level intern service cost object *j* and productive cost object *k*, second level intern service cost object *i* and productive cost object *k*, and second level intern service cost object *i* and first level intern service cost object *j* respectively are the following:

$$p_{kl} = \frac{P_{kl}}{P_k} \quad (3)$$

$$p_{jk} = \frac{P_{jk}}{P_j} \quad (4)$$

$$p_{ik} = \frac{P_{ik}}{P_i} \quad (5)$$

$$p_{ij} = \frac{P_{ij}}{P_i} \quad (6)$$

If revenue data can be collected for profit objects margins become also calculable by applying formula (7).

$$M_{po_l} = R_{co_l} - C_{po_l} \quad (7)$$

where:

M_{po_l} : margin of profit object *l*

R_{co_l} : revenue of profit object *l*

3. Practical use of the calculation model

Figure 2. represents an example of the transport costing framework model. It aims to illustrate how the model can be operated in the real world. That is why the applicable technology performance indicators have also been added to the entities. The example model has been applied for public transport services as they can be regarded as complex

systems operating with a significant share of indirect costs. The results can contribute to improve the related assignment models too [5].

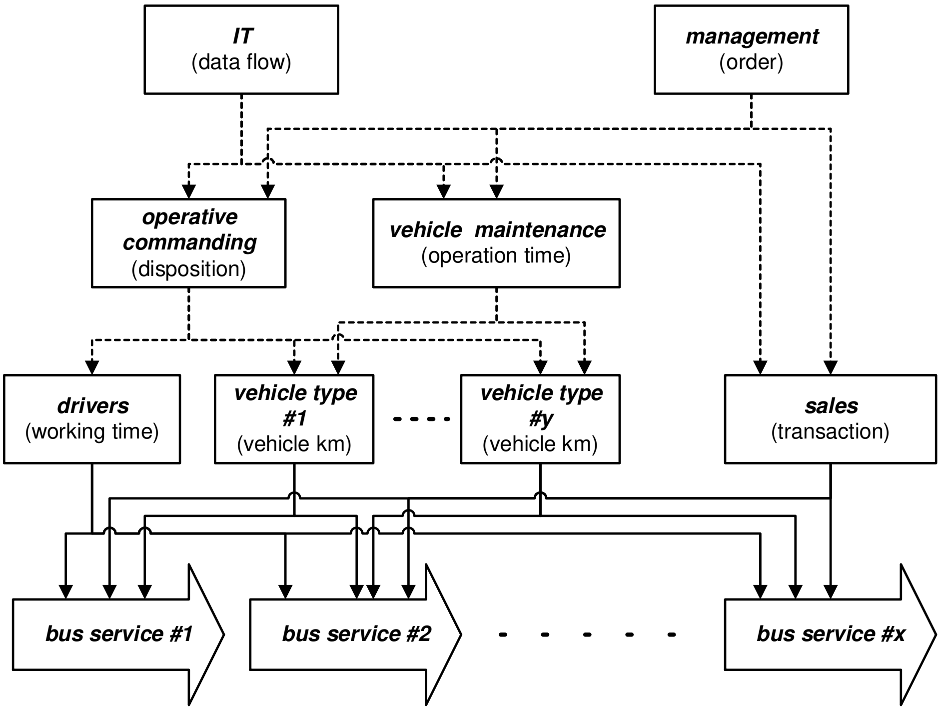

Figure 2. Example costing framework for a company operating bus services

Let us look at a pilot calculation for bus service #1 by applying formula (2). The first task is to identify the technology processes controlling the cause-effect based cost allocation. According to the framework model (Figure 2.) bus service #1 is produced by three productive cost objects: drivers, vehicle type #1 and sales. They contribute to the realisation of the profit object by providing performances measured by the indicators of working time, vehicle km and transaction. The cost objects of drivers and vehicle type #1 are controlled through dispositions of the operative commanding unit. Vehicle type #1 is served by the vehicle maintenance unit too. Here operation times shall be measured for cost allocations. The performances of IT and management cost objects are measured by data volumes and the number of orders respectively. They serve each of the cost objects of sales, operative commanding and vehicle maintenance.

Based on the identified chain of relevant technology processes the concrete calculation formula of bus service #1 can be summarised in Table 1.

The detailed calculation scheme makes it possible to determine the real cost of an elementary transport service in an exact way. Furthermore, the contribution of the various performance generators (organisational units, workforce, vehicles, etc.) to the total cost can also be identified. Adding revenues to cost data the profitability or the cost coverage of transport services become transparent too. This information is useful for setting prices or elaborating the necessary financial support granted by the state or the local authorities.

Table 1. Cost calculation for bus service #1

(primary cost of drivers) × (working time $\%_{\text{bus service \#1}}$)
(primary cost of vehicle type #1) × (vehicle km $\%_{\text{bus service \#1}}$)
(primary cost of sales) × (transaction $\%_{\text{bus service \#1}}$)
(primary cost of operative commanding) × (disposition $\%_{\text{drivers}}$) × (working time $\%_{\text{bus service \#1}}$)
(primary cost of operative commanding) × (disposition $\%_{\text{vehicle type \#1}}$) × (vehicle km $\%_{\text{bus service \#1}}$)
(primary cost of vehicle maintenance) × (operation time $\%_{\text{vehicle type \#1}}$) × (vehicle km $\%_{\text{bus service \#1}}$)
(total cost of IT) × (data flow $\%_{\text{sales}}$) × (transaction $\%_{\text{bus service \#1}}$)
(total cost of management) × (order $\%_{\text{sales}}$) × (transaction $\%_{\text{bus service \#1}}$)
(total cost of IT) × (data flow $\%_{\text{operative commanding}}$) × (disposition $\%_{\text{drivers}}$) × (working time $\%_{\text{bus service \#1}}$)
(total cost of IT) × (data flow $\%_{\text{vehicle maintenance}}$) × (operation time $\%_{\text{vehicle type \#1}}$) × (vehicle km $\%_{\text{bus service \#1}}$)
(total cost of management) × (order $\%_{\text{operative commanding}}$) × (disposition $\%_{\text{drivers}}$) x (working time $\%_{\text{bus service \#1}}$)
(total cost of management) × (order $\%_{\text{vehicle maintenance}}$) × (operation time $\%_{\text{vehicle type \#1}}$) × (vehicle km $\%_{\text{bus service \#1}}$)
Σ = indirect cost of bus service #1
+ direct cost of bus service #1
= TOTAL COST of bus service #1

4. Conclusions

The elaborated framework model and its formulas enable a more exact calculation of costs and margins of elementary transport services. Its implementation makes the cost structure of transport companies or transport service chains more transparent. Another result of the application is that the generators of transport technology performances become visible and their contribution to the costs or profits can also be identified.

The reliable information delivered by the new costing model enhances the effectiveness of decision making in transport companies. Nevertheless, the introduction or practical realisation of the improved cost management system may require considerable efforts: the accounting data shall be supplemented by performance indicators or at least their intensities. Performance data can be derived from the evaluation and measurements of transport technology processes.

The main methodological innovation of the model developed is the combination of accounting/financial information with the data describing the technology operations in transport systems. Thus this approach relies on the disciplines and tools of management-economics sciences as well as technology sciences.

References

[1] Baykasoglu, A., Kaplanoglu, V.: *Application of Activity-based Costing to a Land Transportation Company: A Case Study*, International Journal of Production Economics, Vol. 116, No. 2, (2008), pp. 308-324., doi: 10.1016/j.ijpe.2008.08.049

[2] Bokor, Z.: *Calculation Model for Transport Costing*, Periodica Polytechnica ser. Transportation Engineering, Vol. 40, No. 1, (2012), article in press

[3] Bokor, Z.: *Improving transport costing by using operation modeling*, Transport, Vol. 26, No. 2, (2011), article in press

[4] Bokor, Z.: *Implementation of Activity-based Costing in Logistics*, Acta Technica Jaurinensis, Vol. 2, No. 3, (2009), pp. 337-343.

[5] Horváth, B.: *A new public transport assignment model*, Acta Technica Jaurinensis, Vol. 1, No. 1, (2008), pp. 93-108.

[6] La Londe, B. J., Pohlen, T. L.: *Implementing Activity-Based Costing (ABC) in Logistics*, Journal of Business Logistics, Vol. 15, No. 2, (1994), pp. 11-12.

[7] Lin, B., Collins, J., Su, R. K.: *Supply chain costing: an activity-based perspective*, International Journal of Physical Distribution & Logistics Management, Vol. 31, No. 10, (2001), pp. 702-713., doi: 10.1108/EUM0000000006286

[8] Markovits-Somogyi, R., Bokor, Z.: *Efficiency in transport logistics*, Logisztikai Évkönyv, (2011), pp. 19-27.

[9] Pirtilla, T., Hautaniemi, P.: *Activity-Based Costing and Distribution Logistics Management*, International Journal of Production Economics, Vol. 41, No. 1-3, (1995), pp. 327-333., doi: 10.1016/0925-5273(94)00085-9

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Population and Modeling of Transportation Process

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Abstract: Different types of models have been in use for decades in order to describe transportation networks. These models make it possible to portray real systems using qualitative and quantitative parameters, therefore they can be examined. Conventional transportation simulation models are difficult to use in the case of complex systems as well as not or simply restrictedly containing data, which are necessary to describe the system. Urban transportation systems are often complex with many different types of parameters and their relationships. In certain cases, these systems can easily be described by system dynamics tools. This article introduces a cooperation of a system dynamics model and conventional transport planning system.

Keywords: Transport planning, System dynamics

1. Introduction

The increasing problem of modern times is the crowdedness of transport networks. Experts who deal with transportation have to give answers to more and more difficult question, which provide a compromise to the passenger the users of the service and the service provider. Besides the increasing fuel prices the increasing mobility need requires that travel need of public transport will be growing.

Transport planning assisting system usually use the conventional four-step model. The planning work with this method. In the first two step we determine the origin-destination matrix and in the next two step (mode choice, assignment) we assign each elements of origin-destination matrix to the mode and the network. With this model we can examine different ideas.

2. Why we need models

In an engineering environment models are often made in order to better understand the real world and real life. With the help of these models, problems can be simplified and the simplified models provide an opportunity for the examination of these problems as well as for the analysis of emerging ideas which can be materialized. One must strive not to lose any information, which may be important later regarding the system as a whole and how it works, via the simplification.

The description of complex systems presupposes relationships, which are based on each other, the portrayal and correct interpretation of which is important in order to understand the system.

In the first step of the four-step model[4] the population gets an important role. The assessment of the population depends on many components, so forecasting is difficult. In transport planning software the effect the elements have on each other can be described to a certain level but we need detailed a connection system when run up against a problem.

We can solve the problem with the use of different software used together. In this case we can calculate first with a system dynamics model the population and the change of the population and after with this data we can use normal transport planning software so the base of the four-step model comes from a system dynamics model.

3. The structure of the system dynamics model

A system dynamics model describes the relationship between the individual elements of the system with the help of standard elements therefore it is suitable to solve the problem. Generally the verbal description of a system can be portrayed by a causal loop diagram.

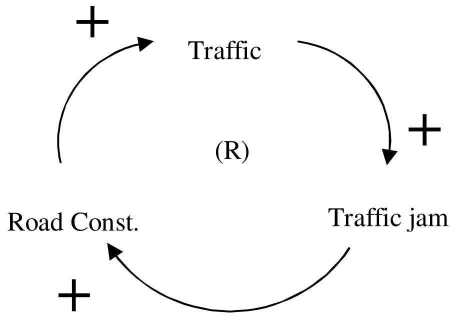

Figure 2. Causal-loop diagram

For example, nowadays traffic jams are getting to be a great problem. For a while a solution could be to build new roads but in a short while these roads also get congested. The causal loop diagram of the previous example can be seen in Figure 1.

But in real life this is not so, since many basic conditions (land use, financial situation) must be taken into consideration. A model is as precise as the number of basic conditions it is able to manage. Of course everything cannot be taken into consideration, it is the model maker's task to determine in a given case which elements and links are important that will decisively influence the functionality of the model.

The causal loop diagram can be two-directional, positive and negative. In the system dynamics literature, positive loops are sometimes called “reinforcing loops” and negative loops are sometimes called “balancing loops” or “counteracting loops”.

Positive feedback processes destabilize systems and cause them to “run away” from their current position. Thus, they are responsible for the growth or decline of systems, although they can occasionally work to stabilize them.

Negative feedback loops, on the other hand, describe goal-seeking processes that generate actions aimed at moving a system toward, or keeping a system at, a desired state. Generally speaking, negative feedback processes stabilize systems, although they can occasionally destabilize them by causing them to oscillate.

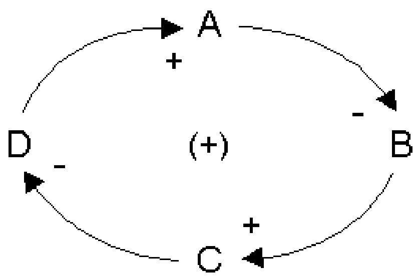

Figure 3. Positive causal-loop diagram

For example, if a shock were to suddenly raise Variable A in Figure 2, Variable B would fall (i.e., move in the opposite direction as Variable A), Variable C would fall (i.e., move in the same direction as Variable B), Variable D would rise (i.e., move in the opposite direction as Variable C), and Variable A would rise even further (i.e., move in the same direction as Variable D).

As soon as the link diagram is available, thus the functionality of the model is described, the real examination and analysis can be done via some software. The software is not necessarily a system dynamics tool, since as you will see later in the article, in fact we are talking about solving equations so even a spreadsheet software can be used. Naturally the use of system dynamics software has several advantages regarding their manageability.

The causal loop diagram must be transformed for further use. Usually a Stock-Flow diagram is made, system dynamics models also portray systems in this way.[2]

As it can be seen from its name, the diagram consists of two main elements:

- Stock: this is a stock element in which we set the elements in the model according to amount, quantity and value. Each and every element may contain its own individual characteristics.
- Flow: this is an element which affects flow. It regulates the flow of moving the content of stock elements from one to another taking into consideration the given parameters.

We can simply say that we record the starting amounts and values in the stock element, then the influence had on them will be given by the flow regulating elements. The process in Figure 1. can be portrayed by 2 stock and several flow elements. One of the stocks represent the number of roads, the other represents traffic. The flow regulating elements carry out the conditions. For example, if there is a traffic-free road, traffic may grow, if congestion has reached a certain level, a new road must be built, after which the result will be a traffic-free road and the cycle continues.

With the help of the flow regulating elements, an opportunity is made to use the values of time. The problem with these elements is that the longer the examined time interval, the greater the uncertainty of the value of the element.

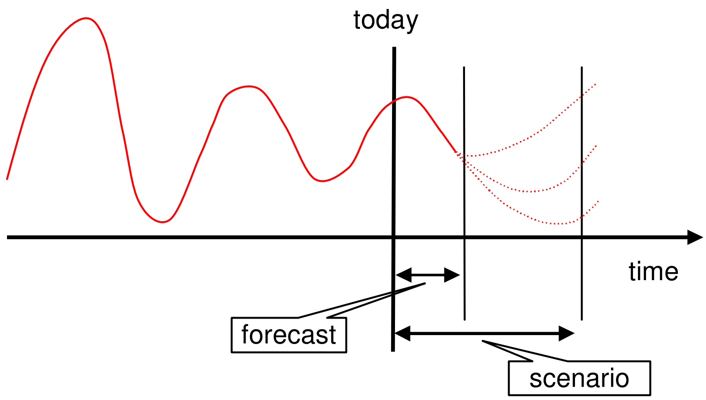

Figure 4. Forecast or scenario[1]

We can talk about a forecast with some probability for a while due to the nature of the data, then it is only possible to create different variations. As can be seen in Figure 3., the inaccuracy of the parameters lead to very different results.

The general conclusion that the reader should draw from these graphs is that real systems often generate clearly identifiable time patterns and that system dynamic models can be built to mimic the patterns.

What is necessary for the effective use of system dynamics?

- a description of the problem
- the identification of important elements
- a causal-loop diagram
- a stock-flow diagram
- system dynamics software
- an analysis of the results

4. Transport planning and system dynamics

Jay Forrester one of the creators of system dynamics dealt extensively with the question of urban transport modeling in his first work[3]. It is easy to see in Figure 4. that the population is the one of the main factors in public transport. The population are the people who use the services. The aim of transport planning is that the presented connection system works well and the examination of the reaction to the changes. The change in population is usually presented with function in transport planning system. In generation models there isn't any feedback so planning several years ahead causes problems.

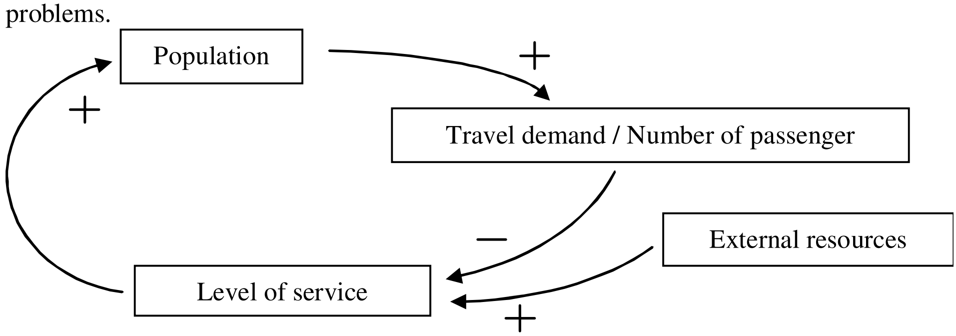

Figure 5. Simplified process of public transport

The data relating to the number of the population changes from year to year depending on several components. System dynamics model relating to population can be seen in Fig. 5.

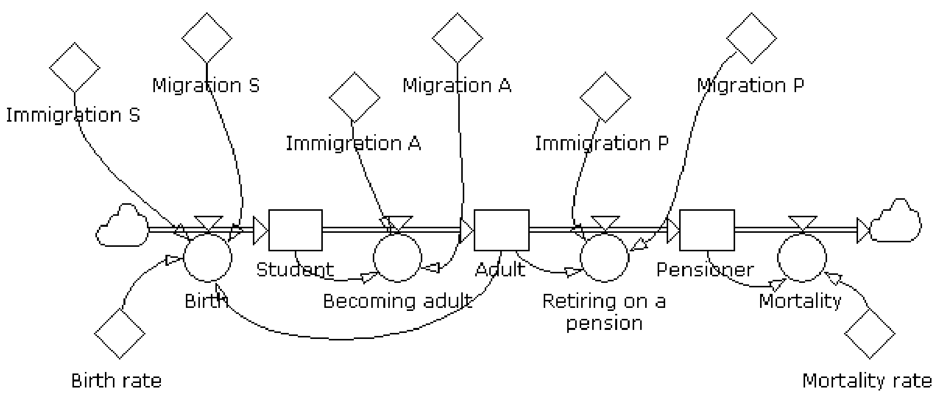

Figure 6. System dynamics model of population

The big advantage of the model is that the developed connection system can be described with functions and can be built into generation model. Another possibility is that the results of the system dynamics model are put into generation model and after assignment the results are the base of the next system dynamics cycle. With the cooperation of the two systems there is a possibility of long-term planning.

5. Conclusion

System dynamics can be successfully utilized in the case of transport problems but it is important under what circumstances it is applied. As we have seen, a basic model can be expanded in many ways with the addition of further elements, therefore the area of utilization can be quite diverse. In my opinion though, system dynamics is rather a macro tool in the field of transportation. Nowadays, we can observe representations which are quite detailed. In the case of public transport, models try to deal with each and every passenger or every event separately. This, of course, has its price: complex and difficult to use models. In these cases, the collection of suitable data is often a problem. A good solution could be to have the usual simulation procedures work together with system dynamics. Using the model built with system dynamic tools, examination of how the system works can be accomplished and the results of this examination can be used in simulation models. The construction of a system dynamics model is relatively simpler, it can be used with less data although of course its results are not as detailed as in the case of the usual simulation models.

References

[1] G. Ossimitz: *Systemisches Denken braucht systemische Drastellungsformen,* GWS-Jahrestagung-Industrieseminer der Universität Mannheim Sept. 2000

[2] *Introduction to System Dynamics – Distance Learnin Material,* http://www.systemdynamics.org/DL-IntroSysDyn/start.htm

[3] Forrester, Jay W. : *Urban Dynamics,* AIT Press (1969)

[4] Dr. Koren Csaba – Dr. Prileszky István – Dr. Horváth Balázs – Dr. Tóth-Szabó Zsuzsanna: *Közlekedéstervezés,* Universitas-Győr Nonprofit Kft. Győr, 2007. pp196 ISBN: 978-963-9819-07-8

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Implementing of Integrated Public Transport Services – Examples of Budapest Transport Association

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Abstract: This paper describes how integrated public transport system was already implemented in Hungary. The integrated public transport system organiser in Budapest agglomeration and its activity is shortly introduced. Integration of public transport system on service, tariff and information level is analysed in examples of Budapest Transport Association.

Keywords: integrated public transport, service, tariff, information level integration

1. Introduction

Subsystems of public passenger transport system do not need to compete each other but they need to cooperate, to

- supply competitive alternative solution against private car usage to receive new passengers who can choose both motorised modes of transport;
- furthermore persons without having car over waking distance satisfy their movement needs.

Other words: using synergies from cooperation of public passenger transport subsystems to be reached higher level system operation that they realize these two objectives.

Integration can be on different level of the public transport system which is described in this paper:

- service level
    - between different modes
    - between local and regional services
- tariff level
- information level

The realisation of above mentioned things can fulfil transport policy goal reserving existing modal split or in some case increasing modal split in favour of public transport in passenger transport system in order to save as a heritage an environmentally, socially and economically sustainable transport system for our children.

Transport association is an organisation of realisation of integrated public passenger transport system. Transport association is a voluntary cooperation of service providers or competent authorities or both in order to harmonise local (urban) and regional (suburban) transport tasks. Integration of public passenger transport system is introduced with realised or prepared solutions in frame of Budapest Transport Association alone inland example of creation of transport association.

2. Short introduction of Budapest Transport Association

After one and half decades of preparation Budapest Transport Association (BKSZ) was founded in 2005 by Ministry of Transport, Municipality of Capital City Budapest and Municipality of Pest county.

The 7,600 km^2 area of BKSZ consist of 193 settlements with 3.2 million citizens in the Budapest agglomeration.

The main objective of BKSZ is to harmonize and develop public transportation in Budapest and the surrounding areas and to improve the image of these services.

On the area of BKSZ, integrated public transport services are provided by the Budapest local transport company (BKV), the Hungarian state personal transport railway (MÁV-START, subsidiary of Hungarian State Railway) and several regional bus companies (main regional bus operator: Volánbusz).

First measure of BKSZ was to introduce the Budapest Combined Pass, a season ticket valid for all transport services within the boundaries of Budapest. This monthly ticket was launched in September 2005, to be followed by the year through version on 1 January 2006. The price of the Budapest Combined Pass was 10 % higher than that of the regular local pass. The new season ticket type was valid on the services of all aforementioned service providers in Budapest. Actually, this was a service extension for local passengers and a fare reduction for commuters as they only had to buy regional passes and tickets for shorter distances outside Budapest to the city boundary). This of course led to revenue losses for the regional operators and generated compensation payment obligations for the competent authorities. In January 2009, the Budapest Pass was launched. It is actually the upgrading of local passes to match the coverage of the Budapest Combined Pass. Now all local passes are valid on all services inside Budapest.

In 2011 owners of Budapest Transport Associations organiser decided to liquidate of existing company and organise the public passenger transport integration in frame of other companies and organisations in the future.

3. Public transport service integration

3.1. Rail and road service integration

Aim of BKSZ is to integrate rail and road public transport services in Budapest and its suburbs. In 2007 and 2008 BKSZ was in charge of elaboration of Budapest Regional Rail Study and Budapest Transport Development Master Plan by the competent authorities (Ministry of Transport and Municipality of Budapest Capital) In both basic development plans rapid rail (in German: S-bahn) network planned on the existing heavy rail network is the backbone of regional public transport system. According to this plans road based public transport services will be connecting to rapid rail network at intermodal nodes.

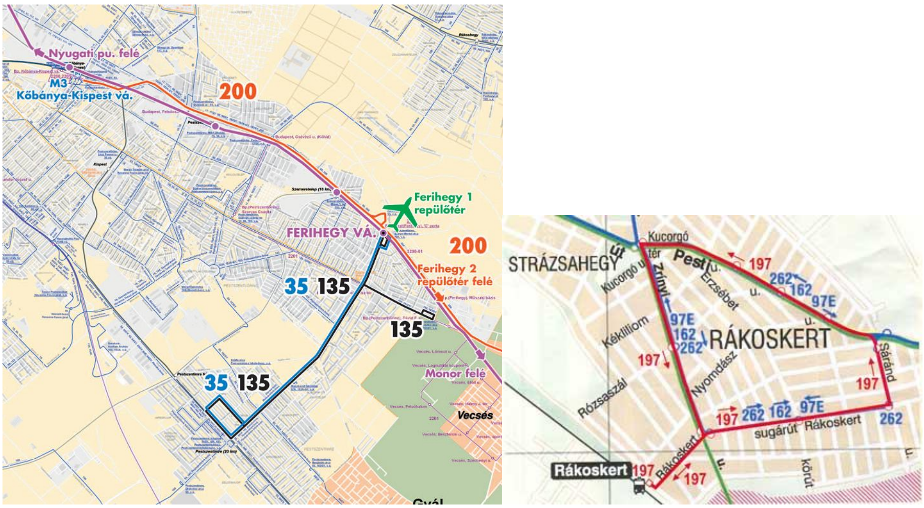


Figure 1. Local bus services connecting to railway lines in Budapest

In some cases rail and road public transport service connections are already working or will be working in near future (see Figure 1). In some outer district of Budapest local bus lines were already connected to suburban rail services of MÁV-START e.g. at railway station opened in 2007 near Airport Ferihegy terminal 1. In XVII district of Budapest between 2 railway lines going to Keleti railway terminus a connecting local bus line will open after construction of bus loops at railway stations.

In intermodal nodes P+R facilities also will be constructed. At 6 rail stations situated in outer districts of Budapest and 13 settlements in suburb P+R and B+R facilities and in some cases also bus loops will be constructed until 2010 using EU founds.

3.2. Local and regional service level integration

Aim of BKSZ is to integrate local and regional services in Budapest. It means that beyond rail and road service integration objective of BKSZ is to harmonise schedules of parallel local and regional bus services on radial routes in Budapest.

Regional bus lines cross the capital border in 24 places, and go on 20 radial routes towards a terminus (see Figure 2). On most routes there are also parallel local lines. On some of these routes the regional services have the same or bigger frequencies in peak hours than the local ones. On these routes the offered parallel capacities and schedules need to be harmonised to reach more efficiency and to save public money.

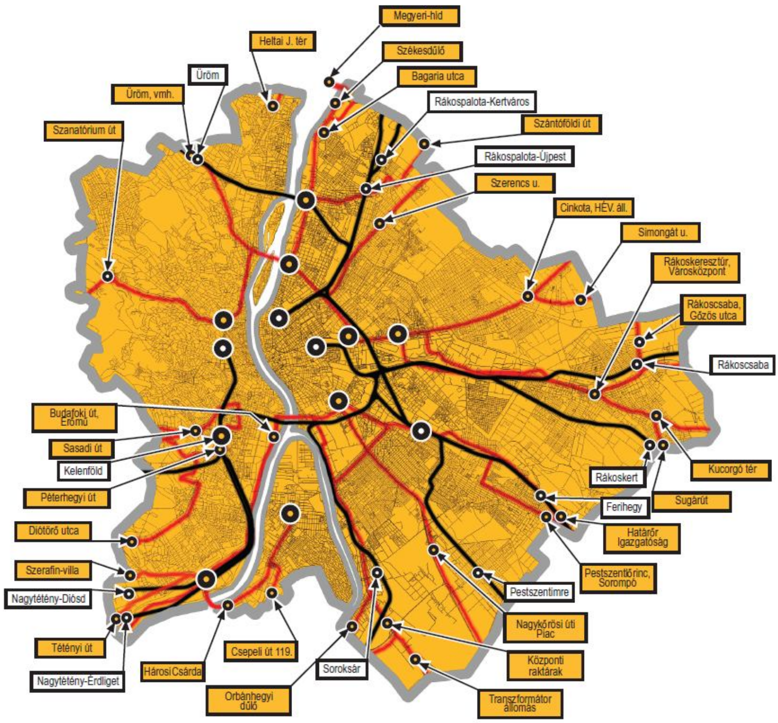


Figure 2. Regional bus and railway lines in Budapest

4. Tariff integration

Before existing and proposed integrated tariff system of BKSZ will be described, let us know the classification of public passenger transport tariff systems. After studying different tariff systems in Europe seven main categories are identified which are summarised in the following list [1]

- Grouping of service access points (stops, stations transfer points),
- Algorithm of tariff calculation,
- Spatial limit of ticket validity,
- Time limit of ticket validity,
- Personal validity of ticket,
- Volume discounts,

- Travel discounts,
- Technical solutions.

Existing local and regional (interurban) tariff systems in Hungary are different from each other according to above mentioned categories. The BKSZ tariff integration introduced in 2005 and extended in 2009 consist of local season passes only.

Budapest local tariff is a one zone flat fee tariff which is extended on some suburban bus lines operated by BKV on two additional zones around Budapest. Single tickets and season tickets without photo pass are valid only on local services. Since 2009 all season tickets with photo pass are valid also on suburban services of national railway and on regional bus services within Budapest.

Existing regional tariff in Hungary is a so called "changing km-based calculated tariff" calculated from starting stop to end stop until 50 km in 5 km steps until 100 km in 10 km steps. Since 2007 tariff level per km is same on rail and road services. There are transfer tickets only on services of national railway lines and season transfer tickets on regional bus services. There are no single transfer tickets between rail and bus services and on different regional bus lines. If traveller has a Budapest Pass, he or she needs to buy a cheaper regional ticket valid only outside Budapest on a shorter length.

Travel discounts (concessionary fares) are different on local and regional services regulated by mainly governmental partly municipal degrees.

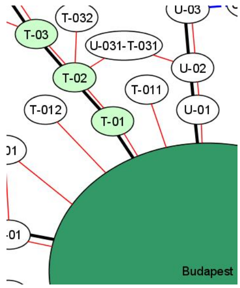
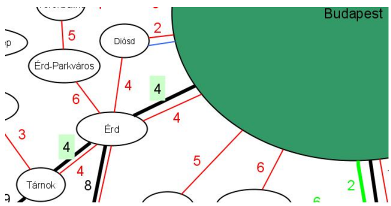
Proposed BKSZ integrated tariff need to

- be transparent, easy to understand,
- attract more passengers to public transport,
- be valid on both local and regional services with same discounts,
- help rail and road service integration,
- be proportional with usage,
- be extendable,
- ensure adequate incomes,
- giving adequate usage statistics.

BKSZ integrated regional tariff fulfils above mentioned conditions with difficulties. In the proposal of integrated regional tariff elaborated by an expert group of BKSZ [4], there are three versions of further extension of tariff integration (see Table 1).

Competent authorities did still not decide on the proposal.

Table 1. Proposals of integrated regional tariff system

• existing "changing km-based calculated tariff" extending between rail and road modes in case of season tickets	
• introduction of 5 km broad tariff zones	
• introduction of tariff zones by settlements and km based calculated tariff between zones like VVNB tariff zone system.	

5. Developing an integrated passenger information system

The development of an integrated public passenger transport system in frame of a transport association also needs to elaborate an integrated passenger information system. This means unified information thorough the whole route from door to door.

In BKSZ area following steps need to be realised for an integrated passenger information system [5]:

1. Harmonisation of station and stop names
   1.1. Harmonising bus stop names at transfer points with railway station names
   1.2. Harmonising regional bus stop names with local bus stop names in Budapest
2. Better regional bus stop information
3. Introduction of numbering of regional services
4. Better information of connecting services
   4.1. Onboard information on local services

4.1.1. Route maps with connecting services (also regional)
4.1.2. Audio information on connecting services (also regional)
4.2. Online intermodal travel planner

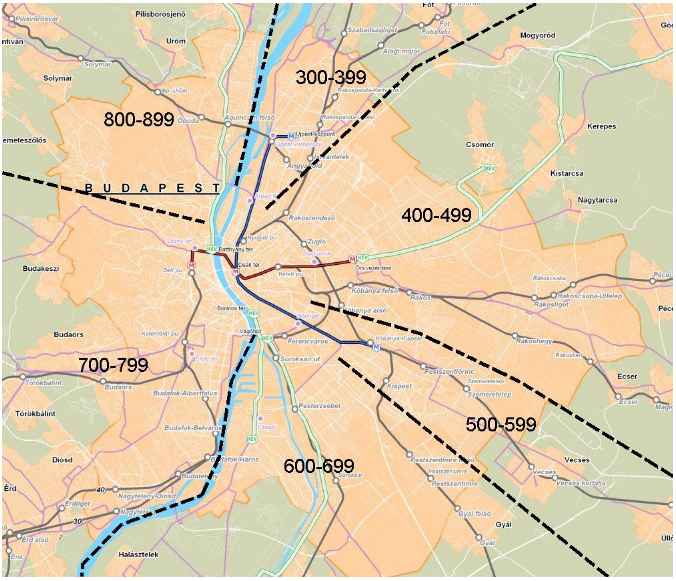


Figure 3. The regional bus numbering sectors

Regional bus numbering from sector to sector around Budapest started in August 2007 as well as harmonisation of local and regional bus stop names in Budapest and development of regional bus stop information. Until 2009 on almost all incoming routes in Budapest numbered regional busses are in operation (see Figure 3). Parallel to bus line numbering stop names were unified and bus stop schedule information was developed. The suburban railway lines will be numbered soon.

Figure 4. Local service map showing regional connections [2]

In 2008 Budapest local schedules were significantly changed. Since introduction of new schedules connecting services are signed on onboard route maps and indicated by voice (see Figure 4). Also local service (bus or tram) stop names changed near railway stations to harmonise each other.

Railway operator regional bus services and local operator have own travel planner offering own transport services. Development of a prepared online local and regional intermodal travel planner in the BKSZ area is still not in operation because different reasons.

References

[1] Denke, Zs.: *Viteldíjrendszerek elmélete és a jelenlegi hazai viteldíjrendszerek kritikája*, Városi Közlekedés, Vol. L. No. 5. (2010), pp: 280-286

[2] Denke, Zs., Németh Z.: *Az utastájékoztatás BKSZ szempontú továbbfejlesztésének eredményei*, Városi Közlekedés, Vol. L. No. 3 (2010), pp: 156-161

[3] Author collective (editor: Denke Zs.): *A BKSZ díjszabási közösség bevezetésének előkészítése*, Budapest (2009)

[4] Denke, Zs.: *Implementing of Budapest Transport Association,* presentation on UITP Seminar for CEEC organizing authorities, Budapest (2009)

Usage of Complex Counting and Survey System in the Planning of Urban Public Transport System

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Abstract: One of the main problems of planning urban public transport systems is the calculation of demand. The simplest way to solve this problem is to perform a detailed passenger counting and questioner. Through the project "Új Magyarország" TIOP 1.3.1 the Department of Transport at the Széchenyi István University has got a new complex system to support passenger counting and passenger surveys. This article summaries the need for such a system, the operation and the first experiences with it.

Keywords: transport planning, public transport, counting, survey

1. The importance of the calculation of passenger demand for planning public transport

Nowadays because of congestion and pollution caused by the rising share of private transport the need for an alternative form of mobility is higher than before. Such an alternative form of mobility is public transport. Public transport can only be a real alternative, competing against private transport if it is well organized as well as servers demand on an appropriate level and has long-term sustainable operation.

Public transport has nowadays dual roles. The primary task is to ensure the basic mobility for those who have no other transport option (captive riders). However, in addition to this public transport has to offer a competitive alternative to private transport for those who have possibility to choose between modes (voters). [3]

To fulfil the first task (basic mobility) there is a need for a minimal level of service on a reasonable price level but to serve task two (competitive alternative) it has to perform an optimal level of service.

Difficulty of public transport system's planning lies on the problem that to plan both level of service there is a need for knowledge on both demand segments (captive riders, voters) travel demand in time and space. It can be said that the cornerstone of planning a public transport system is the knowledge of travel demand. Without this knowledge even the smallest measure on a public transport system is only the result of a guessing and the effect caused by this measure cannot be forecasted. [4] The methods for discovering travel demand are naturally long time known [5] but their use is only limited possible.

There are several well known methods to explore travel demand. Such a method is passenger survey or the application of a “check in - check out” e-ticketing system.

The application of an e-ticketing system for this purpose provides very accurate and detailed day after day time-varying data. Contrary to this the establishment of such an e-ticketing system is very costly especially for smaller bus operators.

In contrast to this to organise a passenger survey is possible only temporally while it's human resource and financial requirements are high. In addition to this the reported results are not always detailed and reliable enough since sufficiently large and representative sample is very difficult to produce even if it is needed in several time period of the day. [1], [4]

A possible method to at least partially eliminate these problems is the application of an IT system based complex counting and survey system.

2. Difficulties with traditional surveying and counting methods

The most obvious way to determine travel demand is to equip questioners with pre-printed formulas. For many years this method has been the most common way to discover travel demand. If the aim of a study not only quantitative (cross-section counting) or qualitative (origin-destination survey) but both then we have to face more difficulties.

2.1. Cross-section passenger counting

To study a local public transport system the questioners has to travel on the busses; it means 2-3 people per vehicles. It resulted in 80-100 persons for a shift in a small city with 30-50.000 inhabitants. It means that such a study requires about 200 employees for a one day counting. Their task is to determine the number of passengers boarding and alighting in every stop through the whole day. To perform this task all of them get a set of sheets related to the number of runs they have to count. They have to count averagely 20 runs it resulted in 800-1000 sheets for the whole crew for one day. If the preparation was sufficient they got their set of sheets in the right order. However given the fact that they have to work with these sheets on a moving vehicle they are not able to do other tasks, therefore they are spending a significant proportion of their working time idle travelling between stops.

After completing the counting the fulfilled sheets has to be collected than ordered and finally type in into a database in a computer.

2.2. Origin-destination survey

Discovering travel demand's structure in time and/or space passengers has to be questioned. Classical method for this task is the use of pre-printed questionnaires by questioners, where questioners reading the questions and writing the answers manually. The method is very simple but to organize and carry out is not. To have sufficiently large and representative sample lot of passengers has to be questioned. [2], [6] It means for a small city up to 2-3 thousand passengers to be questioned (due to need for some reserve up to 3-4 thousand questionnaires may be required). To work on a simple questionnaire (passenger sex, age, ticket type, motivation, origin and destination) does not need more than one minute. Assuming that the interviewers spending 50% of their working time with active questioning they need 4-6 thousand minutes to complete the sufficient number of questionnaires. Calculating with 10 hours working time per day 10 interviewers could perform this task. Provided that:

- One interviewer can found 200-300 passengers to be questioned
- One interviewer carrying whole day about 200-300 sheet of questionnaires

It is clear that such intensity of questioning is hard to imagine, moreover, the result of such a survey would provide very limited spatial coverage. To avoid these problems even in a small city the employment of 40-50 people is needed. The weather (wind, rain) could be another difficulty because under such circumstances their work is doubtful and the consistence of their sheets is unstable.

After the fieldwork of the counting and questioning the data on the sheets should be recorded on computer for further processing. The time demand of this recording can be as high as the counting's one was, because of the quality of the sheets caused by the weather and other circumstances.

After all it can be decided that to discover travel demand (cross-section and origin-destination) even in a small city it is necessary to have several weeks of preparation, up to five thousand sheets to copy and about 250 people to work on the field. After the field work sheets should be collected, ordered and process them by computer.

3. IT system based complex counting and survey system

Nowadays it is possible to perform the tasks mentioned above with the help of IT solutions thanks to the fast development communication and mobile computing technologies.

3.1. Cross-section passenger counting

The task to be performed is identical to the passenger counting done with traditional methods. The difference is that there is no need to print out about thousand sheets and the post processing is also faster. Till the recording of counting sheets for 4000 runs needs about 30 till 60 hours, the data exchange between 80 to 100 mobile data collector equipments needs about 6-10 hours. Another advantage of hand-held equipments is the automated communication without any operation done by humans therefore this communication is absolutely error free but the traditional data recording from sheets can have errors done by the operator itself.

A cross-section counting is not limited to counting of passengers but also can include other tasks like monitoring the service (eq.: accuracy to timetable...). At an IT-based data collection system it is possible to collect data about all departure and dwell time in each stop. In this way it is possible to have very detailed picture on the movements of the vehicles on the whole public transport network. Parallel to this all of the hand-held data collectors includes GPS receiver to post monitoring the job of the counter. This feature helps to check the archivated data on time and place of the counting.

3.2. Origin-destination survey

The task to be performed is also the same as the survey done with traditional methods. There is a big difference related to the traditional method because there is no need for printing hundreds of questionnaires which dependent on the length of the questionnaire could be as much as 3-8 thousands pages. Since questioners do not have to carry lot of paper under various weather conditions, their job will be much easier than before.

The questionnaires are pre-edited with dedicated software. It can include into the questionnaires conditional jumps or branches which will appears automatically the questioner do not have to think it over. Therefore number of errors could be decrease (or eliminate) and speed of the questioning could be increase. Speed is an important feature but not only at this stage but at the data reading into the computer's database. Since at such a complex system data reading is automated but at traditional methods data reading needs up to 15-30 hours.

In contrast to traditional counting and questioning methods there is revolutionary new feature that since counting and questioning are done with the same equipment counters are able to fulfil questionnaires between two stops. With this new opportunity the number of questioners could be decrease (since they are substituted by counters) or the size of the sample could be increase. Taking the sample shown before: 200 counters counting each 20 runs with averagely 11 stops, the possibility to ask a passenger is 200 times 20 multiplied by 10, which resulted in 40.000 sections (link between two stops). If a counter can ask averagely in every second section a passenger, it takes a sample with 20.000 passengers (!). If we calculate with a success factor of 1 to 4 (1 passenger on 4 sections) it takes 10.000 passengers. This last number is also much higher than the sample size of the traditional method (2-3 thousand passengers) without extra employees. Very important to remark that this is only a theoretical assumption because length of the sections does not allow in all cases to ask a passenger and the appearance of the passengers is also not uniform.

After all it can be determined that a new IT system based complex counting and survey system has several advantage compared with traditional methods. It can work faster and more accuracy without (or with small) demand on printed sheets. Additional to this it can collect more and detailed data than a traditional method. Because of increase of tasks done by one labour the demand for human resource can be lowered but the staff have to be more motivated and qualified than before.

4. Structure of an IT system based complex counting and survey system

The structure and operation of an IT system based complex counting and survey system can be divided into five steps:

- collection of base data in digitalised form
- preparation of data, building the base model
- collecting traffic (travel) data
- working up and cleaning of the collected data
- data export (if needed)

These five steps follow each other linearly and produce a complex structure. This structure can be seen on figure 1.

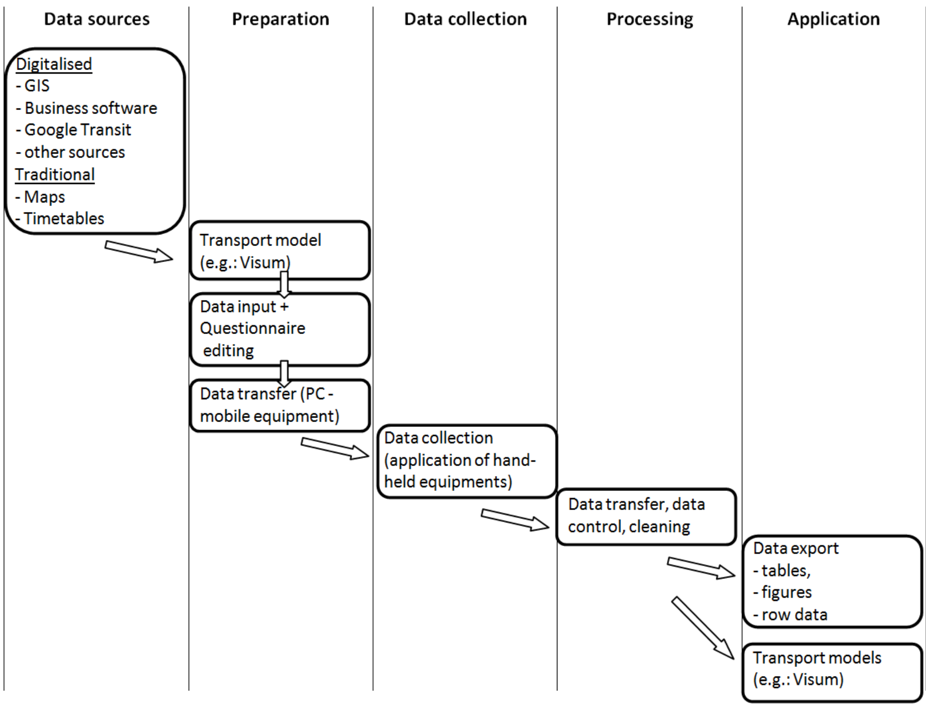


Figure 1. Operation of an IT system based complex counting and survey system

The key of the operation of an IT system based complex counting and survey system is the traffic model. This is the centre of the system therefore the first step is to collect the data needed to build up the traffic model (network - routes, stops, lines, timetable, vehicles...). These base data can be accessible either as digital data or only as data “existing on paper”. If the data is in digital form the job is to import it. In the case there is no digital data it has to be digitalized. After collecting all the needed data the traffic model can be built in a transport planning software like PTV's Visum in our case but it can be also other products like Cube, TransCAD etc. This traffic model is the base for the counting system; it is the data source for the counting system's database. The questionnaires are completing this database for a whole. If the whole database structure and content is ready it can be exported to the mobile equipments.

The most critical point of the whole process is the counting and interviewing. If it is well prepaid and organised without any disturbance the data is collected into the hand-held equipments. After these the data should be read from these equipments into the database. As next all the data has to be checked as a logical but also as a mathematical structure.

The last step has two stations. Firstly the data can be visualised as lists but also as figures, secondly they can be exported back to the transport planning software. In the planning software it is possible to build up e.g. a demand model based on the questionnaires to help evaluate new plans.

4.1. Hardware requirements of the system

The hardware requirements of the system can be divided into four parts parallel to the process shown before:

- data input
- data processing
- data collection
- visualisation

It is possible to divide all four topics into sub-topics. First element of the hardware system is the data input because of the timeline of the process. The aim of the data input equipment is to digitalize map information existing only as traditional map.

Figure 2. Handheld, rugged computer

The centre of the hardware system is a desktop PC or even a server computer. It could be completed with mobile computers (laptop) to make post-processing and field work more efficient. For communication between the elements either wired or wireless communication can be used. The most comfortable way to have wireless communication is to establish a Wi-Fi network between the desktop PC, the laptops and handheld computers.

One of the most important elements is the handheld computer itself. There are two major questions: what kind of handheld computer do I need? How much handheld equipment do I need?

There are lot of handheld computers; the spectrum is varying from the simplest customer equipment till the most expensive industrial standard computer. Based on field experiences an average industrial standard equipment is good enough because its ability to resist against water, dust and drop. The other interesting question is the number of the equipments. Based on the size of the public transport system in small or medium cities in Hungary 80 to 90 equipments could be enough for most of the cities apart the 6-8 biggest ones. In these biggest cities (other than Budapest) this fleet is enough although the counting would last up to 3 days.

Last element of the system is for visualise results, mostly graphical results like figures. For this purpose a plotter is the most common solution although some graphical printer in bigger size (up to ISO A1) could be enough.

4.2. Software requirements of the system

The operation of the above specialized hardware elements is completed by a well prepaid software background. The coordination of these elements is done by central software. The operation of this central software requires the processed data of the traffic model done by the transport planning software. This central software fills the main database of the whole system by processing the traffic model. Other feature of this central software is the questionnaire module which allows creating or editing questionnaires.

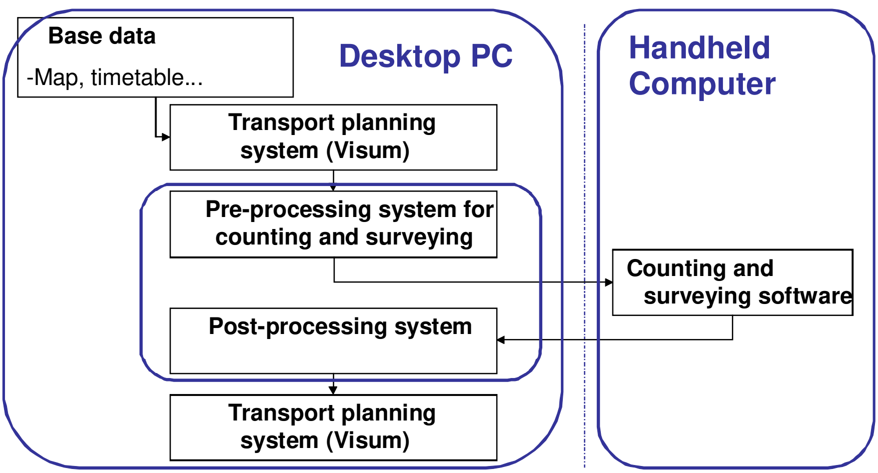


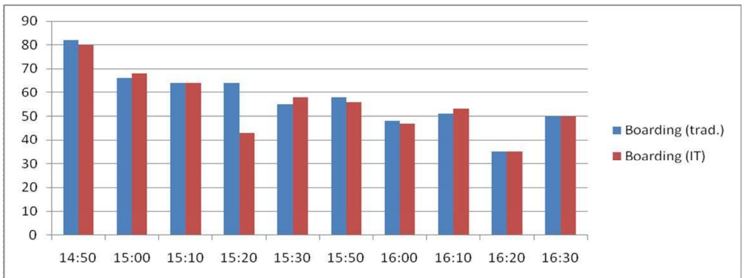
Figure 3. Logical structure of the system's elements

The whole data structure or better the relevant part of the database can be than exported to the handheld computer. On the handheld equipment runs another software product especially for counting and interviews. The aim of this software is to help the counting and the surveying to be quick and precise or rather the structured data storage.

After data collection all the data will go back to the main database for a logical check. After this check it is possible to have a quick, first look evaluation of the collected data. Afterwards data can be exported to the transport planning software for further analysis.

5. First results

First test counting and surveying was done in Győr in spring 2011. Through the afternoon rush hour runs of a line from the most used lines was counted and the passengers were interviewed. The test included 20 runs from the line "11" where parallel two groups of counters worked. Figure 4 shows the differences between traditional and IT based counting.



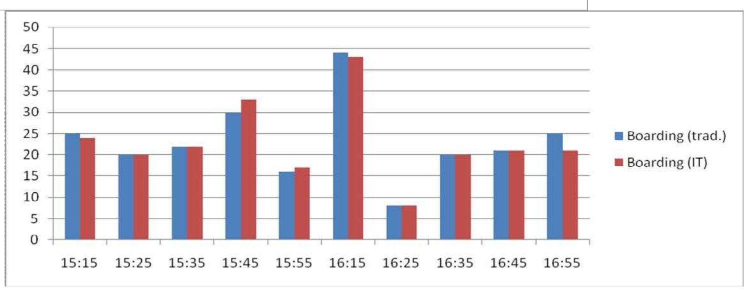


Figure 4. Counted numbers of passengers there and back on the line "11"

In the picture one can see that there is no or minor differences between traditional method and IT based method.

Another interesting evaluation is the running times between stops. (Figure 5. and Figure 6.) It can be seen the timetable (dotted line) and the running times of each vehicles worked in that time period.

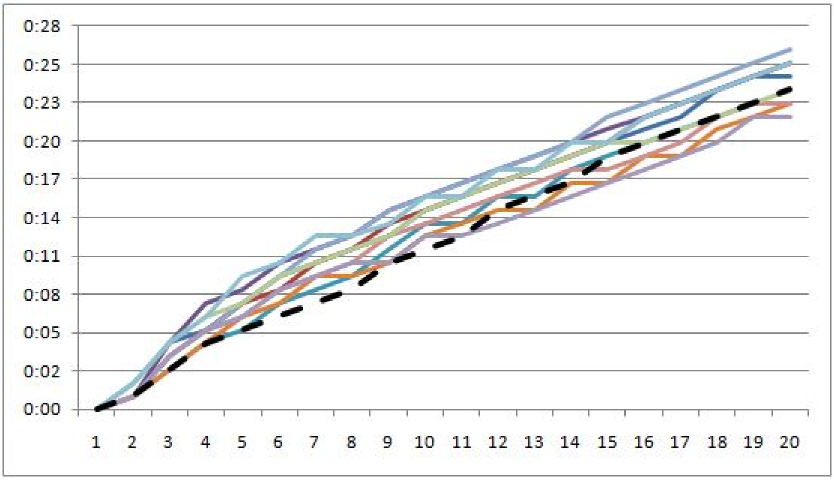


Figure 5. Running times of vehicles on the route line 11 compared to timetable (dotted line) direction: from the city

There is another figure in the opposite direction. It is nice to see that vehicles running forward but stacking in the jam close to the downtown.

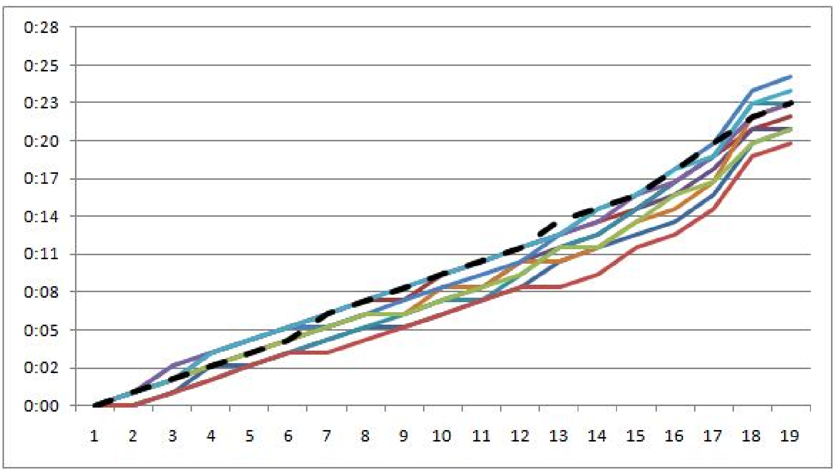


Figure 6. Running times of vehicles on the route line 11 compared to timetable (dotted line) direction: to the city

It is now possible to check the whole line route network to find the bottlenecks.

6. Conclusions

The above shown IT based complex counting and survey system's first test which ended in spring 2011 has shown that this system can fulfil the expectations but has some risks.

One of the risks is the coherence of the used database and the authenticity of the base data because they must be syntactically and logically correct. Another risk is the staff. The staff has to be more motivated and well trained compared to traditional methods.

References

[1] Berki, Zs.: *Közlekedési háztartásfelvételek számítógépekkel*, Városi közlekedés, Vol. 5, (2005), pp. 304-307.

[2] Fülöp, G., Hirkó, B., Mátyus, J., Prileszky, I., Szabó, L.: *Közlekedési üzemtan I.*, SzIF-Universitas Kft, (1999).

[3] Horváth, B.: *Optimális szolgáltatási színvonal a közforgalmú közlekedésben*, Városi Közlekedés, Vol. 4, (2010), pp. 239-242.

[4] Horváth, B.: *Schlüssel der Verkehrsplanung – Methode zur Bildung zeitabhängiger Quell-Ziel-Matrizen*, Der Nahverkehr, Vol 3. (2010), pp. 54-57.

[5] Horváth B., Horváth, G.: *Methodolgy of Public Transport Planning, in Young researcher's conference*, Paris, (1998).

[6] Nagy, E., Szabó, D.: *Városi közlekedés kézikönyve*, Műszaki Könyvkiadó, Budapest, (1984).

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State of the Art Transportation Modeling and Environment Calculation

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Abstract Why do we need models?
The main objective of transport modeling is to support transportation planning processes. The quality of impact studies is increased with the help of models during the planning process. One aspect of modeling objectives focuses on the reduction of operating and maintenance costs for transport service providers. Both, revenues as well as service quality can be improved with the help of modeling.
The introduction of cost-benefit analysis systems results in increased efficiency. This kind of analysis should be based on calculations with actual models based on current data. In case of EU finance investments, it is absolutely mandatory to provide the evidence for an infrastructure project's usefulness before its implementation. This is of particular importance if independent administrative organizations participate in joint tenders. Furthermore, impact studies based on generally accepted models are recognized in legally contentious cases.
The results of studies can be presented by professionals to politicians, decision-makers and the public in a clearly visualized format.

1. What kind of tools exist?

Current modeling methodologies require modern computer-aided modeling with the help of generally accepted specialized modeling software. Regardless of what software the administration is using, it must be based on regularly updated database records. The databases should be maintained with GIS software and advanced transportation planning software. Socioeconomic data (e.g. population, employment, travel demand indicators, etc.) should be recorded for modeling purposes in addition to network data. This data should be available as best as possible corresponding to the desired level of zone detail. Modeling is based on network elements. Modern modeling tools manage private and public transportation elements in one integrated system. Theses network elements include inter alia the railways, roads, junctions, crossings, public transportation lines, timetables, stops, etc.

Transport modeling software can be divided into three categories:

- Macroscopic
  Administration of network elements, building of strategic forecast models, static system
- Mesoscopic
  medium-size projects, dynamic system
- Microscopic modeling system
  Junctions and small-size project simulation, 3D-vizualization, dynamic system

2. What kind of methodology will be used?

The construction of a network model is the most important part of the model development process. If the administrative does not maintain its own digital network the model can be constructed with digital navigation networks (e.g., TeleAtlas, NAVTEQ). Timetables, public transport lines can be imported from open sources or from digital databases (e.g., Microbus from IVU or Google Transit) provided by public transport authorities.

2.1. Modeling on macroscopic level

The most widely used method to build transport models in the world is called 4-step-modeling and consists of:

- Trip generation
- Trip distribution
- Modal split
- Assignment

The next stage of the modeling process should be the calibration of modeled traffic volume results with measured traffic count data, where available.

In the past, calculations were made on paper. Today, because of the complexity and the amount of statistical data, calculations are being done solely with the help of specialized modeling software such as VISUM by PTV AG.

Model results include important details for private transport such as link and turning movement volume, delay, travel time and level of service (LOS).

Modeling results for public transport contain operational indicators such as performance, travel time management, vehicle use as well as passenger flow indicators such as number of passenger boarding and alighting, seat occupancy, stop accessibility as well as service cost-benefit analysis.

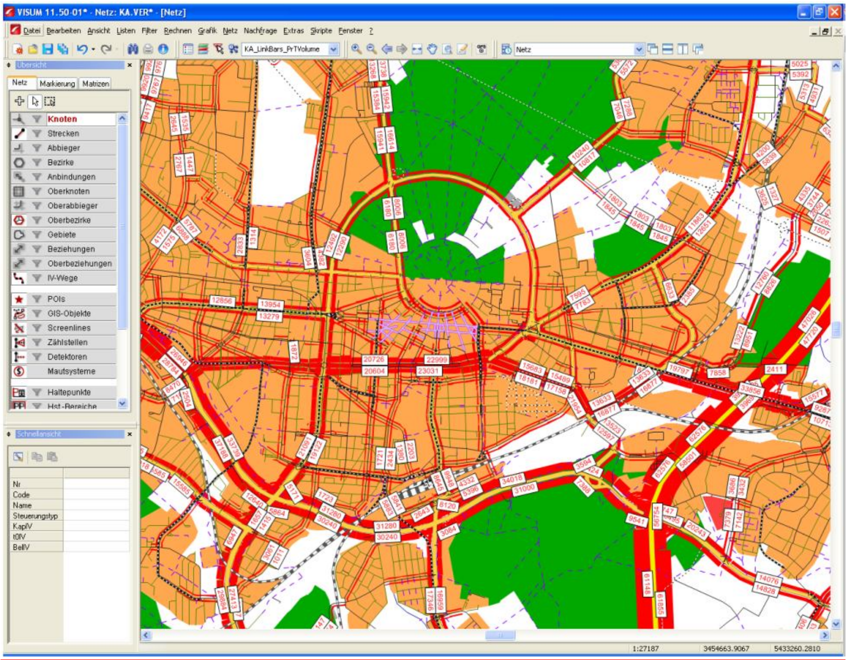

Figure 7. Screenshot of network model in VISUM macroscopic strategic planning tool

2.2. Modeling on mesoscopic and microscopic level

It is difficult to draw a clear dividing line between microscopic and mesoscopic systems. A microscopic simulation of medium-sized networks is extremely time consuming. In some cases, it can take up to several days (or weeks) to run the simulation. However, detailed systems evaluation requires dynamic traffic flow modeling. Therefore, mesoscopic models (e.g. Mezzo from KTH) are recommended for such cases.

In most cases, traffic flow will be simulated with microscopic simulation software such as VISSIM from PTV AG. This system can be used to simulate individual vehicles as they interact with the roadway infrastructure, traffic control and other vehicles. Modern transport modeling systems integrate public transport and private transport in one model which allows the creation of partial networks. Each modeled entity exhibits different kind of properties such as speed, acceleration, size, etc.

Micro simulation systems are an essential tool for transportation planning today. Foremost, it is absolutely necessary to use microscopic simulation systems for impact or capacity analysis of networks for which no standard analytical methods exist. This includes multi junction traffic signal systems, networks with combined roundabouts and traffic signals or highway ramps with high levels of volume fluctuation. Further use cases are traffic signals with actuated signal control or public transport priority.

Figure 2. Screenshot of network model in VISSIM microscopic simulation tool

Pedestrian simulation is a separate, specialized field of microscopic traffic simulation.

Microscopic simulation results typically include density, duration of congestion, delay and travel time between pre-defined cross-sections, as well as raw data for individual vehicles as desired.

3. Evaluation of environmental impacts

Today, the responsibilities of transport engineering include the calculation of environmental impacts from traffic. In this field we need to distinguish between the calculation of source emissions and environmental impacts at the receptor level. Vehicle emissions depend on the particular traffic situation and the vehicle's engine. The measurement results are used in a matrix commonly referred to as "engine map". The calculation of environmental impacts is dependent on the characteristics and architectural landscape of the area.

The emission calculation can be performed at two different levels. The calculation on both levels will be dominated by traffic volume and fleet composition.

- The most widely used network-level computational method in Europe is the internationally recognized HBEFA.
- The highest quality of regional and local impact calculation is available by the TNO EnViVer software program.

For computing the environmental impacts it is necessary to mate the emission calculation results with a particle dispersion model.

References

[1] EnViVer manual (2010), TNO, Netherlands

[2] HBEFA *The Handbook Emission Factors for Road Transport,* HBEFA (2010).

[3] Helbing, D., Farkas, I., Vicsek, T.: *Simulating Dynamical Features of Escape Panic*. In Nature, (2000), 407, p. 487–490.

[4] Helbing, D., Farkas, I.J., Molnar, P., Vicsek T.: *Simulation of Pedestrian Crowds in Normal and Evacuation Situations*. In Schreckenberg and Sharma (2002), p. 21–58.

[5] Helbing, D., Molnár, P.: *Social Force Model for Pedestrian Dynamics*. In Physical Review E 51(5), (1995), p. 4282-4286.

[6] Johansson, A., Helbing, D., Shukla, P.K.: *Specification of the Social Force Pedestrian Model by Evolutionary Adjustment to Video Tracking Data*. In Advances in Complex Systems 10(4), (2007) p. 271–288.

[7] Schnabel,W., Lohse, D.: *Grundlagen der Straßenverkehrstechnik und der Verkehrsplanung*, Verlag für Bauwesen, Berlin (1997).

[8] VISSIM manual, PTV AG, Germany (2010).

[9] VISUM manual, PTV AG, Germany (2010).

[10] Werner, T., Helbing, D.: *The Social Force Pedestrian Model Applied to Real Life Scenarios*. In Galea (2003), p. 17–26.

New Ways in Vehicle and Crew Scheduling

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Abstract: Vehicle and crew scheduling are two major planning problems arising in public bus transport companies. Briefly stated, these problems aim at assigning vehicle itineraries to scheduled trips and crews itineraries to tasks resulting from the vehicle schedule. The main objective of a vehicle and crew schedule is to offer a given service that allows passengers to travel easily at a low fare while minimizing asset and operating costs. Traditionally, both planning steps have been approached sequentially where vehicle schedules are determined before crew schedules. These processes have two main problems first they are not able to take into consideration of crew scheduling during vehicles scheduling, generally there is no loop back to the previous step, second they planning horizon is generally one day, although the crew scheduling of one day has effect on the next day due to labour rules.

Key words: public transport, vehicle scheduling, crew scheduling

1. Introduction

Operational plan in public transport operation means the “production plan” of the service. It includes:

- vehicle schedules
- staff (crew) schedules
- rosters

Vehicle schedule is a group of runs which belong to one and only one vehicle, practically the daily task of one vehicle. The needed number of vehicles on a given day is equal with the number of vehicle schedules.

Crew schedule is the work plan of one driver, which consists of blocks from vehicle schedules. Crew and vehicle schedule can be the same but it not necessary. Number of drivers is equal with the number of crew schedules.

The roster is framework valid for a time period last for several days and inherits the crew schedules to be performed by a given driver. To make the service possible there is a need for drivers for each roster; so the needed number of drivers is equal with the number of rosters. Final task of the planning is to find drivers for each roster.

The goal of operational planning is to prepare operational plans with the lowest cost which secure the service with the observance of several rules and laws

Operational plans are interrelated. Minimizing the number (and cost) of vehicle schedules may resulted in a higher staff cost. Looking further, the minimizing of staff schedules for a given day may result in a higher roster costs.

To solve this interrelation there are several methods: sequential and integrated.

2. Methods of vehicle and crew scheduling in general

The two main methods for vehicle and crew scheduling are: sequential and integrated. These two main methods are basically different, as the sequential works step by step till the integrated combine several steps.

The sequential method's three main features are:

- Vehicles scheduling with an optimum criteria only for vehicle usage and vehicle cost minimizing
- In the next step crew scheduling with minimize crew cost regarding rules and external employment conditions
- Last step is the creation of rosters using external employment conditions and taking crew schedules day by day. Aim of this step is to minimize the total crew cost

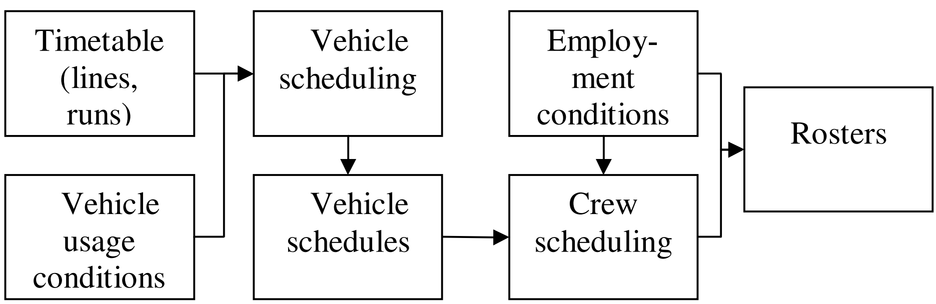

Figure 1. Sequential method for vehicle and crew scheduling

The result of a sequential method is not optimal for the whole vehicle-crew-operator (as whole) system. Therefore there are integrated methods to give better solutions.

The partly integrated methods have a sequential first part but in step one the needs of step two is taken into account. The order of these steps can be as follows:

- at vehicles scheduling the employment conditions of drivers are taken into account

- the runs of lines are collected through the crew scheduling considering vehicles usage conditions

Another partly integrated method is where through the crew scheduling roster building requirements are considered.

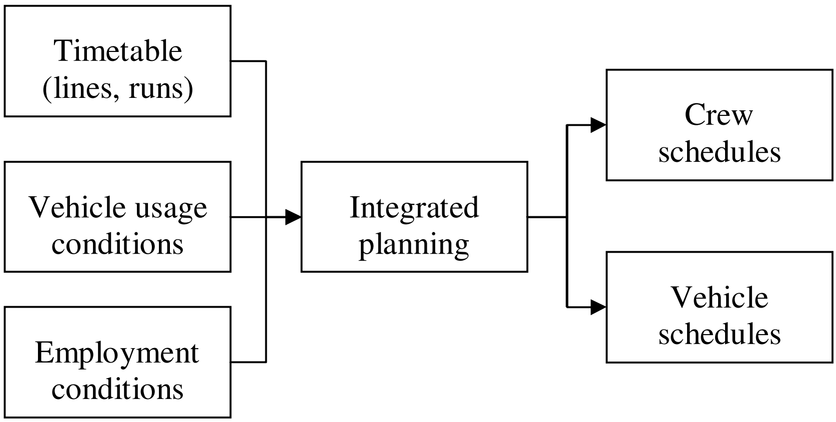

Figure 2. Integrated method for vehicle and crew scheduling

At fully integrated methods the optimum criteria of the method is to minimize the costs for the whole system (vehicles-crew). These methods produce vehicle and crew schedules at once in one step. Lately there are models to include also roster planning into this single step. Therefore all three steps of operational planning of public transport are collected into one single step.

3. Sequential methods for vehicle and crew scheduling

The sequential method has two main steps: vehicle scheduling, crew scheduling which ended in rosters.

3.1. Vehicle scheduling

First models for vehicle scheduling (Vehicle Scheduling Problem – VSP) are dated back to the 60's. The heart of the matter is to connect runs of lines to each other. For each of the departure runs have to search an arriving run which vehicle able to perform it. It is possible to connect vehicles on different terminate stops; in this case there is a need for an empty run between the two terminate stops. If there is no appropriate arriving run a new vehicle has to be used. Till the vehicles are parking at the depot there is a need for an empty run before the first and after the last run. Aim of the task is to find the least cost solution for this "run connection".

Most easy task if there is only one depot and one type of vehicle (Single Depot Vehicle Scheduling Problem – SDVSP). The task is more difficult if there is several depots (Multi Depot Vehicle Scheduling Problem – MDVSP). If there are different types of vehicles it is possible to use two kind of usage: strict (hard), permissive (soft). At hard restriction a given run is allowed to perform only by one type of vehicles. In this case the problem can be divided into parts based on vehicle types. Using soft restriction (which is more realistic) a given run can be carried out by several types of vehicles, the only limitation is the capacity, there is a lower limit for capacity all of the vehicles which are bigger than the limit are allowed to perform this given run. The vehicle usage is more efficient at this case but it is much harder to find a solution.

The run connections can be figured out by using of graphs (connection network); there are two kinds of graphs:

- connection based
- time-space network

In the connection based network the runs (included the empty runs before the first and after the last runs) are the nodes and the possible connections are the links. All of the links are directed. A link starting from a node is a departing run and other way round.

In the time-space network all of the terminate stops and depot have a time axle. On these axles there are nodes for departing and arriving runs. The links between axles are the connections between runs. There are two kinds of links:

- link on an axle means waiting in a terminal stop for the next run
- link between different axles means an empty run between terminal stops and waiting for the next run

All links have their own cost (time and distance related). The empty run before the first run includes the cost of a new vehicle because this empty run means the need for a new vehicle.

One possible solution of the VSP is a subset of links for which the followings are right: all nodes have one and only one arriving link and one and only one departing link. The task is to find the least cost subset of links with this limitation.

If there is several depot the problem is more difficult because all vehicle have to finish in the same depot where it started in the morning. The need of calculation capacity is linear to the size of the problem but exponential in the case of multi depot problem. It is proven [1] that SDVSP is polynomial but MDVSP is non-polynomial (NP-hard).

There are other special limitations like maximal or minimal length of running km on a day; or one technical break for each vehicle on each day.

3.2. Crew scheduling

The crew scheduling problem (CSP) is similar to the vehicle scheduling problem but more difficult because of the external employment conditions and limitations. Based on these limitations Fischetti had proven [2] that CSP is also an NP-hard problem.

The first thing to solve CSP is to find interchange points through the runs. Interchange points are in time and space fixed points where the change of crew is possible. Between to interchange points there is a duty therefore all duties have two interchange points one at the start and one at the end.

Between two interchange points the “distance” should be as long as possible, but as short as one driver can perform it without any break.

Shift is the task for one driver for one day it inherits one or several duties (practically several). Aim is to find duties for shifts fulfilling employment conditions and have least cost.

Similar to VSP in this case also possible to build up a connection network; where nodes are the interchange points. Links means the connection between two duties. A link is possible if it does not harm employment regulations. The real problem is to decide if a link is possible or not.

4. Partly integrated methods for vehicle and crew scheduling

In the 90's computer capacities was not enough for integrated models therefore partly integrated models were developed. Structure of these is simple: integrated model with sequential calculation methods.

One of these models was developed for Rom [3]. In this model the requirements of crew scheduling were taken into account through vehicles scheduling but rosters are planed only afterwards.

Another example is developed by Gintner [4] [5]. In this case the vehicle schedule is changed to be better for crew scheduling. This is possible till there are several similar solutions for vehicle scheduling.

5. Integrated methods for vehicle and crew scheduling

Integrated models have two main types:

- Integrated Single Depot Vehicle Crew Scheduling Problem – ISDVCSP or simple SD-VCSP
- Integrated Multi Depot Vehicle Crew Scheduling Problem – IMDVCSP or simple MD-VCSP

The MD-VCSP is a more complex task it can be handle only through multi step models. The main criterion is to find vehicle and crew (for each and every run) which are located in the same depot. Integrated models are able to produce the least cost solution vehicle and crew scheduling.

The first integrated model was published by Freling [6]. It has three components:

- quasi-assignment model for vehicle scheduling
- a set-partitioning model for crew scheduling
- requirements for secure the compatibility between vehicle and crew schedules

Because of the complexity of the problem even the newest models are multi step ones. This structure enlarges the time demand of the calculation parallel to the size of the problem.

6. A proposed interactive method for vehicle and crew scheduling

Literature also cites the statement that professionals could be used an interactive tool much better than a very sophisticated model with optimal solution even when the interactive one cannot present the real optimal solution. It cannot give one "perfect" solution but can help the professional planer to work more easily. The models for optimization have several problems in the everyday work:

- At real scale problem the preparation work and running time is too long. With about 1000 runs and 2-4 depots the running time of a model is about 10 hours. Running time has strict correlation to number of depots. In real life in rural service number of depot can be up to 200-250 which makes running time unrealistic
- Vehicle requirements are normally soft it means there is no possibility to divide the task into parts. It makes the problem more complicated
- In the reality lines – runs – vehicle schedules and crew schedules have strong connections. It means there are runs only to make vehicles scheduling more easily. Therefore optimizing an existing timetable (set of runs) gives no win (or not too big one). It would need a higher integration of steps from timetable planning till roster planning.
- There too much limitation due to drivers employment conditions

A simpler interactive planning tool could eliminate these problems but makes manual planning process more effective. It could have the following steps:

- Analyzing vehicles fleet
- Analyzing vehicle demand (requirements of types...)
- Checking of runs which indicates new vehicles – modifying these runs
- "Pre-vehicle scheduling"
- Evaluation of vehicle schedules from the side of crew scheduling
- Dividing "Pre-vehicle schedules" into blocks
- Regrouping of blocks with checking of employment requirements

This method seems to be sequential but it can be integrated because of the several feed back in the process.

The effectiveness of such a process can be evaluated by comparing costs in the planned and the existing situation. In the practice there are a maximal and a minimal level of costs. Maximal level costs (maxima) for a planned system is the cost of the existing one. The minimal level can be calculated as follows:

- Vehicle scheduling with a simpler method (comparing departure and arrival times). It gives a theoretical minimum but it is not realistic. It is the lower limit for vehicle cost

- Simpler crew scheduling without any consideration on vehicles scheduling. This will be the lower limit for crew cost
- The minimal level of costs (minima) for the system is the sum of this to lower limit.

The effectiveness of a solution can be measured be comparing it with the maxima and minima. In the interactive method the cost should be tend to the minima.

7. Conclusions

The research project about vehicle and crew scheduling started just few months ago therefore definite results are not jet present. We discovered in this short period of time the previous models and methods and pointed out the weak points of these solutions. Our project is focused to produce practically usable results and models.

The first results of this project show that the present models are more theoretical and can be used only under special circumstances. In the real life the complexity of the boundary conditions are so high that one single model is not able to give a usable solution. This recognition of our research is resulted in the first statement that says: for professionals an interactive tool is more usable than an automatic integrated model.

References

[1] Bertossi, A.A.,- Carraresi P., Gallo G.: *On some matching problems arising in vehicle scheduling models*, Networks 1987 Vol.17, Issue 3, pp.271–281

[2] Fischetti M., Martello S., Toth P.: *The fixed job schedule problem with spread-time constraints*, Operations Research 1987 Vol.35, No.6, pp.849-858

[3] Darby-Dowman K., Lewis R. L.: *An Integrated Decision Support System for Public Transport Operations*, Computer Aided Transport Scheduling 1988. Springer Verlag

[4] Gintner V., Steinzen I., Suhl L.: *A Time-Space Network Based Approach for Integrated Vehicle and Crew Scheduling in Public Transport*, 11th Meeting of the EURO Working Group on Transportation, 2006.

[5] Gintner V., Steinzen I., Suhl L., Kliever N.: *A Time-Space Network Approach for the Integrated Vehicle-and Crew-Scheduling Problem with Multiple Depots*, Journal of Transportation Science, 2010 Vol.44, Issue 3, pp.367-382

[6] Freling R.: *Models and Techniques for Integrating Vehicle and Crew Scheduling*, Ph.D. thesis, Tinbergen Institute, Erasmus University Rotterdam, 1997.

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Availability Based Markov Type Process Model of Vehicle Operational System Study

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Keywords: maintenance, availability, operational strategy

1. Introduction

In the course of the operation (use and maintenance), the condition of technical devices – realized {PA} during their production – undergo changes (deterioration and reconstruction process). The characteristics of these typical changes are usually shown as a means of a *so-called see-saw diagram* [1].

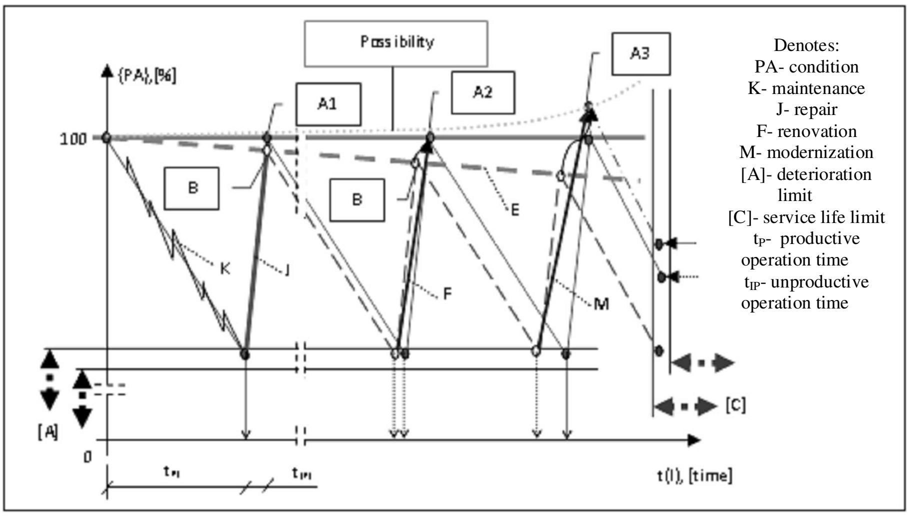

Figure 1. Typical change in the condition of a technical device, as a function of operation time/performance

Some important strategic questions can be composed – connected to the operation of technical systems (rolling stock), having long service life and high use value – that demands theoretical considerations and consequences to answer to.

Such question may be for instance:

- what should be the structure of the specified operational system,
- what factor variables are dependent on the availability factor in a specified operational structure and how can it be calculated,
- how can the structure of maintenance system be chosen – according to desirable target functions – and be changed in the most effective way.

In the case of a specified device park (stock of vehicles) and operational environment, the composing of possible answers to these proposed questions can be performed with the help of the study of the general mathematical model of the operational process, as a stochastic course of events.

The paper tries to present such a general model and algorithm that enables the study of quantitative and qualitative of the operational structure – even in the case of (operating) time distribution that is different from the exponential.

2. General mathematical description of the operational process

Starting from the characteristic of the operational process of the rolling stock (technical devices in general), the description – apart from a few exceptions – of a stochastic based model can be applied. The stochastic process – also known as random event process or possibility process – can be explained as a sum of stochastic variables, as explained in the field of probability. According to this the stochastic process can be considered a binary function $\xi(\omega,t)$ defined by a $T \times \Omega$ set, where $T \subseteq (-\infty, +\infty)$ is a set of parameters that have a countable infinite, or continuum cardinality [in our case: $T \subseteq (0, +\infty)$ operation time variable], and $\Omega\{0,1\}$ is the set of probabilities that can be assigned. The $\xi(\omega,t)$ surface (the set of points) can be derived from the ($\omega_0 \in \Omega$, $t_0 \in T$) plane sections of the realization and marginal-probability functions of the process (figure 2).

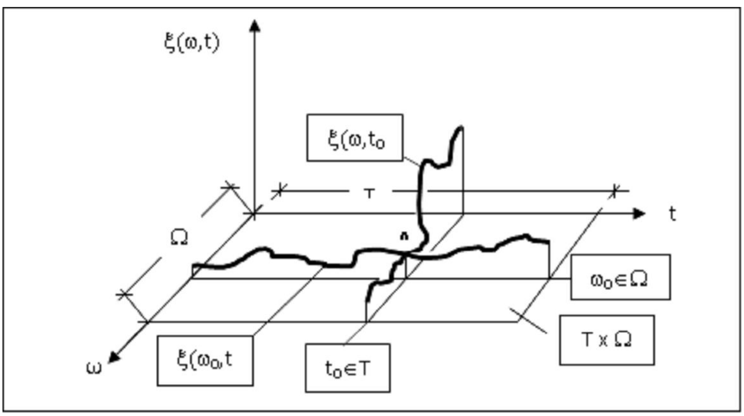

Figure 2. The characteristic functions of the stochastic process
$\xi(\omega,t_0)$ – boundary probability function, $\xi(\omega_0,t)$ – realization (time) function

According to the above, the stochastic process can be understood as the assembly of the $\xi(\omega_i,t)$ realization functions, where certain realization functions are differentiated consecutively by the $\omega_i \in \Omega$ index.

It is known from system theory studies that processes can be explained, as sequences of change of conditions. So, if we know the operational conditions, furthermore the sequence and time of these, presumably we possess a tool that can help describe the structure, behaviour and general characteristics of the operational system, in accordance with aspects of quality and quantity [2].

The random sequence of operational conditions can be demonstrated as a means of a mathematical formalism, the so-called *operational chain*. The operational chain is a directed graph in which angle points can be assigned to operational conditions, and edges can be assigned to contacts between these conditions.

In the case of the system-approach study of a multi-unit technical device stock (stock of vehicles) several random operational chain realizations have to be calculated, which is a unique consideration that makes the demonstration and performance of analyses hard. For this reason, in our study such formalism is applied that meets the criterion of the weighted *operational (condition-transitional) graph.*

The operational graph is a directed graph in which angle points demonstrate discrete operational conditions and edges demonstrate the possible change of conditions existing between them. If the probability – being characteristic to the possible change of conditions – and/or other operational parameters are assigned to the edges then we are talking about a weighted directed condition-transitional operational graph [1].

If we, based on our present knowledge, sum up the main (discrete) conditions – that can be suitably separated from each other – determining the availability then it can be established that these are not cardinal (which is good news from the aspect of performability of analytical processes). Such *operational condition* can be for instance:

- the intended use,
- the maintenance,
- the reparation and
- waiting for any of the above (including the condition of storage and transport).

In order to simplify our additional studies, we should accept the following restrictive conditions in advance, regarding to the operation of stock of vehicles, as a technical system:

1. The studied system should have a timely *stationary* feature, namely *the behaviour of the system should not depend on the choice of the "t" starting point of our study, but only on its "Δt" interval.* Keeping our former denotes:

$$P\{\xi_{t+\Delta t}(\omega) - \xi_t(\omega) < X\} = P\{\xi_{v+\Delta t}(\omega) - \xi_v(\omega) < X\} \quad (1)$$

every t, $(t + \Delta t)$, v, $(v + \Delta t) \in T$, $\omega \in \Omega$ *and in the case of* $v \neq t$.

(In other words: the probability of $P\{\xi_{t+\Delta t}(\omega) - \xi_t(\omega) < X\}$event – where X is a positive real number – should be *invariant* contrary to the choice of a "t" moment.)

2. The behaviour of the system has to meet the *arboricity condition*, namely the *probability* of the fact – that in the case of $\Delta t \rightarrow 0$ *more, than one change in the condition will be realized - should be zero, if* $\xi_i(\omega) = i_t$.

$$\lim_{\Delta t \to 0} \frac{P\{\xi_{t+\Delta t}(\omega) - \xi_t(\omega) > 1 / \xi_t(\omega) = i_t\}}{\Delta t} = 0 \tag{2}$$

(Note: in the case of a failure i_t is functional in the formula and generally it denotes a "t" moment condition.)

3. The system should have the feature of "*memoryless*," *namely its next possible condition should be only determined by its actual condition and it should be uninterested in how the system got into the actual condition.*

$$P\{\xi(\omega, t_{n+1}) = i_{n+1} / \xi(\omega, t_1) = i_1, \xi(\omega, t_2) = i_2, \dots \xi(\omega, t_n) = i_n\} =$$
$$= P\{\xi(\omega, t_{n+1}) = i_{n+1} / \xi(\omega, t_n) = i_n\} \tag{3}$$

(Note: in the formula "t" represents the moment, "i" represents the condition, which is assigned to it.)

It is known that in the case of the synchronous and simultaneous fulfilment of the 1. - 3. conditions, the behaviour of the system can be described, as a success of *a homogeneous Poisson process (Markov chain) that is continuous in its time space and discrete in its status space.* The **P**(t) condition probability (row)vector is used for the probability characterization of the specified stochastic process. The vector can be determined by the following formula:

$$\frac{d\overline{P(t)}}{dt} = \overline{P(t)}\,\overline{\overline{Q}} \tag{4}$$

(Chapman-type) matrix differential equation, where **Q** – is a quadratic *generator matrix* (in N×N size) in which elements (besides our determined restrictive conditions) are constant – and have consecutively $1/T_0$ value – λ *event densities* (T_o – denotes the expected value of the interval between two adjacent possible discrete conditions) and N is the same as the number of discrete conditions of the multi-stage system.

In the general case λ event density quantifies the probability that in the system, during Δt time, in the case of $\Delta t \rightarrow 0$ exactly one change in the condition (e.g., failure) is produced, if – according to our former explanation $\xi_i(\omega) = i_t$.

$$\lambda(t) = \lim_{\Delta t \to 0} \frac{P\{\xi_{t+\Delta t}(\omega) - \xi_t(\omega) = 1 / \xi_t(\omega) = i_t\}}{\Delta t} \tag{5}$$

3. Markov-type operational process realization

Besides the introduced marginal conditions, sum up the operational scheme of a stock of vehicles – having optional elements – as a technical system that contains N=6 discrete conditions (figure 3).

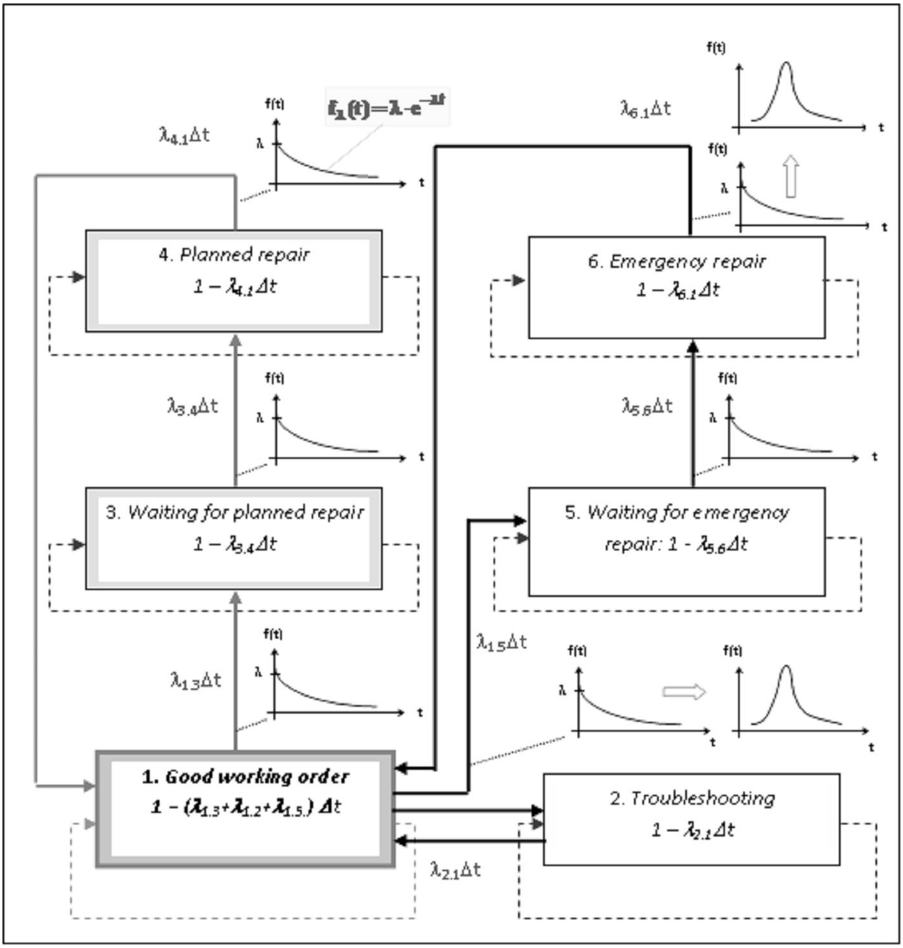

Figure 3. Multistage vehicle operational system (weighted) condition-transitional graph realization

At this point it is important to remember that the studied operational structure forms a complete event system, so the system has no other conditions beyond the specified, and thus, the probability of being in a running order can be identified as the availability factor (applicability) of the system. (Of course – in the practice – the choice of the discrete conditions and the assignable condition-transitional graph can be performed, according to the current aim of study.) In our case, the relations necessary for the description of the operational process can be produced in the following form:

The generator matrix:

$$\overline{\overline{Q}} = \begin{vmatrix} -(\lambda_{1.2}+\lambda_{1.3}+\lambda_{1.5}) & \lambda_{1.2} & \lambda_{1.3} & 0 & \lambda_{1.5} & 0 \\ \lambda_{2.1} & -\lambda_{2.1} & 0 & 0 & 0 & 0 \\ 0 & 0 & -\lambda_{3.4} & \lambda_{3.4} & 0 & 0 \\ \lambda_{4.1} & 0 & 0 & -\lambda_{4.1} & 0 & 0 \\ 0 & 0 & 0 & 0 & -\lambda_{5.6} & \lambda_{5.6} \\ \lambda_{6.1} & 0 & 0 & 0 & 0 & -\lambda_{6.1} \end{vmatrix} \tag{6}$$

The system-equation (differential equation system):

$$\left.\begin{aligned} \dot{P}_1(t) &= -(\lambda_{1.2}+\lambda_{1.3}+\lambda_{1.5})P_1(t)+\lambda_{2.1}P_2(t)+\lambda_{4.1}P_4(t)+\lambda_{6.1}P_6(t) \\ \dot{P}_2(t) &= -\lambda_{2.1}P_2(t)+\lambda_{1.2}P_1(t) \\ \dot{P}_3(t) &= -\lambda_{3.4}P_3(t)+\lambda_{1.3}P_1(t) \\ \dot{P}_4(t) &= -\lambda_{4.1}P_4(t)+\lambda_{3.4}P_3(t) \\ \dot{P}_5(t) &= -\lambda_{5.6}P_5(t)+\lambda_{1.5}P_1(t) \\ \dot{P}_6(t) &= -\lambda_{6.1}P_6(t)+\lambda_{5.6}P_5(t) \end{aligned}\right\} \tag{7}$$

The algebraic (Kolmogorov) equation-system, the characteristic for the t→∞ balance condition:

$$\left.\begin{aligned} 0 &= -(\lambda_{1.2}+\lambda_{1.3}+\lambda_{1.5})P_1+\lambda_{2.1}P_2+\lambda_{4.1}P_4+\lambda_{6.1}P_6 \\ 0 &= -\lambda_{2.1}P_2+\lambda_{1.2}P_1 \\ 0 &= -\lambda_{3.4}P_3+\lambda_{1.3}P_1 \\ 0 &= -\lambda_{4.1}P_4+\lambda_{3.4}P_3 \\ 0 &= -\lambda_{5.6}P_5+\lambda_{1.5}P_1 \\ 0 &= -\lambda_{6.1}P_6+\lambda_{5.6}P_5 \\ 1 &= P_1+P_2+P_3+P_4+P_5+P_6 \end{aligned}\right\} \tag{8}$$

(8) as a solution of an equation-system, we can elaborate the formula, suitable for the determination of the availability factor

$$P_1 = \frac{1}{1+\frac{\lambda_{1.2}}{\lambda_{2.1}}+\frac{\lambda_{1.3}}{\lambda_{3.4}}+\frac{\lambda_{1.3}}{\lambda_{4.1}}+\frac{\lambda_{1.5}}{\lambda_{5.6}}+\frac{\lambda_{1.5}}{\lambda_{6.1}}} = \frac{1}{1+\frac{T_{2.1}}{T_{1.2}}+\frac{T_{3.4}}{T_{1.3}}+\frac{T_{4.1}}{T_{1.3}}+\frac{T_{5.6}}{T_{1.5}}+\frac{T_{6.1}}{T_{1.5}}} \quad (9)$$

in a form where,

- $\lambda_{i.j}$ event densities can be considered as ($\lambda_{i.j}$= $1/T_{i.j}$) factor variables,
- The sensitivity of certain factor variables of P_1 probability – as a result variable – can be established through the determination of $\varepsilon_{i.j}$ *partial elasticity*, according to the following:

$$\varepsilon_{i.j} = \frac{\partial P_1 / P_1}{\partial \lambda_{i.j} / \lambda_{i.j}} \quad (10)$$

Within the framework of an experiment it can be inferred that within the studied operational structure

- the average interval between two unexpected degraded operations is $T_{1.2}$=2880 hours,
- the average time requirement of the troubleshooting of an unexpected degraded operation (error) is $T_{2.1}$ = 0.5 hours,
- the average interval between two unexpected failures is $T_{1.5}$= 4320 hours,
- the average interval of waiting for an emergency repair after an unexpected failure is $T_{5.6}$ = 120 hours,
- the average lead time of the emergency repair is $T_{6.1}$ = 340 hours,
- the average scale of the interval between two adjacent planned repairs is $T_{1.3}$ = 8760 hours,
- the average interval of waiting for the planned repair is $T_{3.4}$ = 6 hours,
- the average lead time of the planned repair is $T_{4.1}$ = 150 hours.

Besides the presumed realizations of the factor variables, on the basis of (9), the $\mathbf{P_1}$ applicability will have a 0.8893 numeric value, namely 88.93 %.

In analyzing the relation it can be established that the $\mathbf{P_1}$ result variable is finally determined numerically by eight factor variables ($T_{1.2}$, $T_{1.3}$ … $T_{6.1}$). The strength of the effect between certain factor variables and the result variable is shown in table 1.

The $\mathbf{\Delta P_1}$ alterations, listed in the second line of the table, were produced by consecutively increasing the certain $T_{i.j}$ intervals by 10 % and the P_1 values, calculated in this way they were compared to the original 0.8893 numerical value. (The 3rd line of the table shows the differences under discussion in a percentage.)

Table 1. The rank of partial elasticities

Elasticity	$\varepsilon_{1.2}$	$\varepsilon_{1.3}$	$\varepsilon_{1.5}$	$\varepsilon_{2.1}$	$\varepsilon_{3.4}$	$\varepsilon_{4.1}$	$\varepsilon_{5.6}$	$\varepsilon_{6.1}$
ΔP_1	0.000013	0.001262	0.007722	-0.000014	-0.000054	-0.001352	-0.002101	-0.00616
ΔP_1 %	0,0013%	0,1262%	0,7722%	-0,0014%	-0,0054%	-0,1352%	-0,2101%	-0,616%
Rank	8	5	1	7	6	4	3	2

On the basis of (10) it is clear that the $\mathbf{\Delta P_1}$ numerical values also mean a rank between the certain (denoted in the inferior number of $\boldsymbol{\varepsilon}$) $\mathbf{P_1}$ factor variables simultaneously in regards to the strength of their effect with reference to the applicability index.

The data of table 1 show that – besides the success of the taken average interval numerical values – the most effective way to control the applicability index in the studied operational structure is to modify the $T_{1.5}$ variable so that it is the average value of the occurring interval of the unexpected failures, following the functional conditions.

The second and third most effective way is to change the values of $T_{6.1}$ (the average lead time of the emergency repair) and $T_{5.6}$ (the average interval of waiting for an emergency repair after the unexpected failure) factor variables.

It is clear that the numerical values of $\mathbf{\Delta P_1}$ have to be interpreted by considering them on the basis of their sign. This means that in the case of a "+" sign, the increasing of intervals that represent certain factor variables, results in the increasing of the applicability of P_1, in the case of a "–" sign, it results in the decreasing of the applicability of it.

4. Semi-Markov operational process realization

The experience shows that all three simplifying conditions (mainly those stationary) – formerly conceived by us – will generally not be realized simultaneously in practice in the case of vehicles

In the formal language of mathematics it means that the time distribution between the certain adjacent "i.j" possible discrete conditions and the time distribution of staying in certain conditions is not always exponential-like, with a $1/\lambda_{i.j}$ constant expected value.

It follows that the elements of the elements of the **Q** generator matrix, so the coefficients of the equations of the Chapman-type general differential equation system will not be constant, but the actual – mainly those that have two parameters – $\lambda_{i.j}(t)$ functions, are determined by time distributions. The same statement applies to the coefficients of the equations of the Kolmogorov-type equation-systems.

In the case of the presumed conditions, the determination of the expected value of the limit distribution of P_1 ($t \to \infty$) of $\mathbf{P_1(t)}$ applicability function can be performed according to the following steps (figure 4):

1. Drawing the operational condition-transitional graph.

2. Production of the empiric values of event intervals, explained in the condition-transitional graph, recording the theoretical type and parameters of their distribution (performing statistical tests, if needed). From the aspect of the procedure – applicable here – there are two possible events:

   A.) The time distribution of every event is exponential (see Markov process realization)

   B.) The time distribution of not every event is exponential-like.

The solution, according to version B) can be performed in the following way:

1. a control variable with k = 1 initial value has to be initiated,
2. a random realization will be generated for the value of $T_{i.j}^{(k)}$ event intervals – weighted on the basis of their known distribution function – in the case of *every interval distribution, different from exponential* (in the case of exponential distribution, there is no need to do so, as $\lambda_{i.j} = 1/T_{i.j}$ = constant),
3. the values of $\lambda_{i.j}^{(k)} = 1/T_{i.j}^{(k)}$ event density will be calculated,
4. the numerical value of $P_1^{(k)}$ applicability factor in the "k" cycle will be calculated,
5. the numerical value of the control variable will be increased by one and the operations of version B) – detailed above – will be performed according to the meaning as far, as at least >30 db P_1 numerical value will be available – suitable for a small sample element number,
6. on the basis of $P_1^{(k)}$ an interval estimation will be given for the P_1 expected value (through a previous choice of suitable significance level),
7. in order to prove the internal mechanisms of action a sensitivity (simulation) study will be performed, in regards to the P_1 expected value,
8. the results will be evaluated and proposals will be made in order to improve the efficiency of the operation of the system.

Within the framework of the previous example, it is presumed that in the course of the operation of the technical system – having performed H =100 observation – the $t_{1.5}$ (occurring interval of emergency repairs, following the good working order) and the $t_{6.1}$ (performing interval of emergency repairs, following the good working order) intervals, realizations – showing clearly different distribution from the exponential – were produced for (table 2 and 3 and figure 5 and 6).

For the sake of simplicity presume that our observations verified our previous assumption, regarding the exponential distribution in the case of the other studied $t_{1.2}$, $t_{2.1}$, … $t_{4.1}$ with the $T_{1.2}$, $T_{2.1}$, … $T_{4.1}$ expected values.

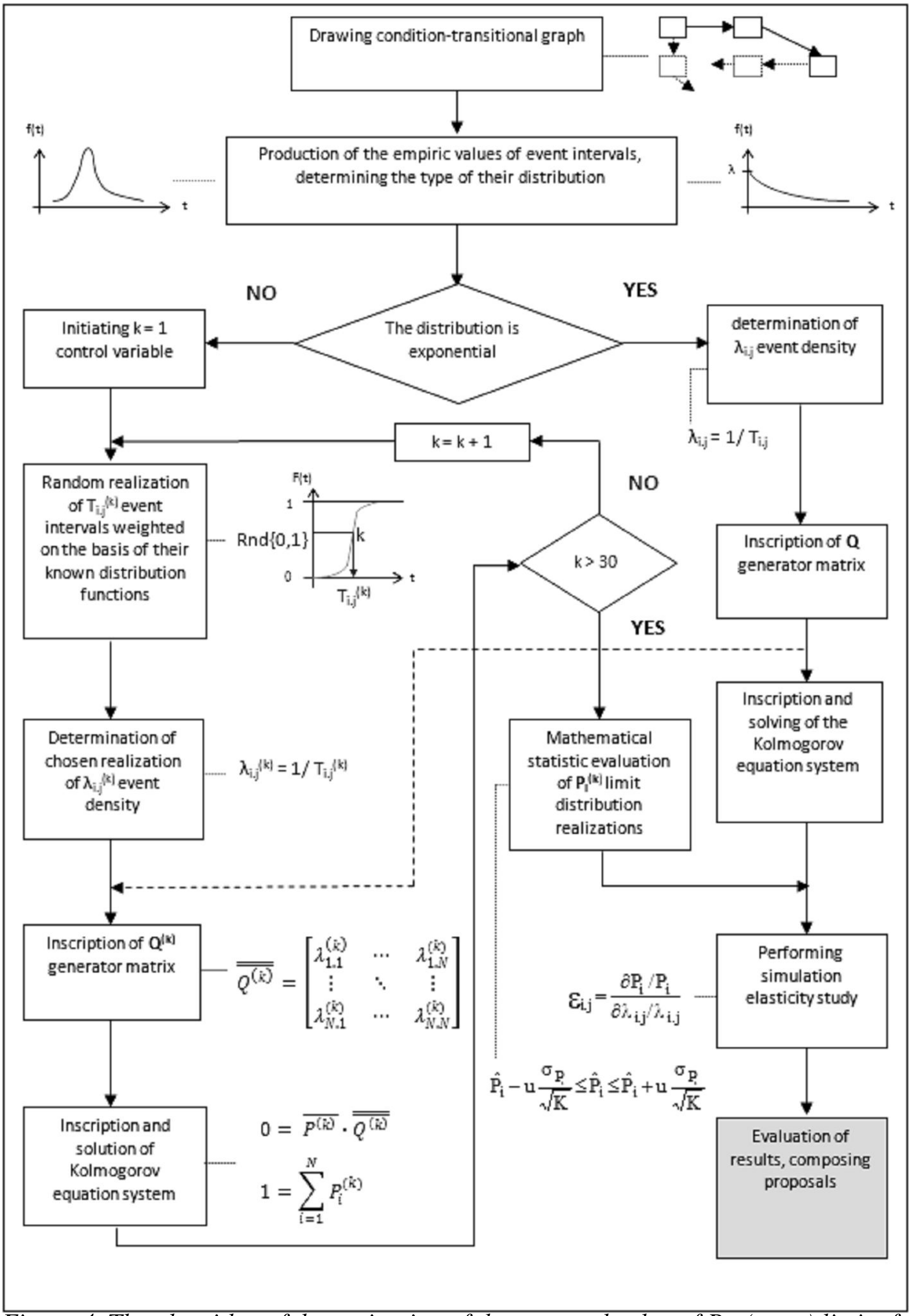

Figure 4. The algorithm of determination of the expected value of P_1 $(t \rightarrow \infty)$ limit of $P_1(t)$ applicability function

Table 2. Realizations of emergency repair occurring interval

$t_{1.5}$	serial number	1	2	3	4	5	6	7	8	9
h *[hour]*	duration interval	3500-3600	3601-3700	3701-3800	3801-3900	3901-4000	4001-4100	4101-4200	4201-4300	4301-4400
f *[piece]*	occurrence frequency	5	15	20	30	10	5	10	5	0
f_R	relative occurrence frequency	0,05	0,15	0,2	0,3	0,1	0,05	0,1	0,05	0,00

Table 3. Realizations of emergency repair interval

$t_{6.1}$	serial number	1	2	3	4	5	6	7	8	9
h *[hour]*	duration interval	200-220	221-240	241-260	261-280	281-300	301-320	321-340	341-360	361-380
f *[piece]*	occurrence frequency	2	8	5	35	35	5	7	3	0
f_R	relative occurrence frequency	0,02	0,08	0,05	0,35	0,35	0,05	0,07	0,03	0,00

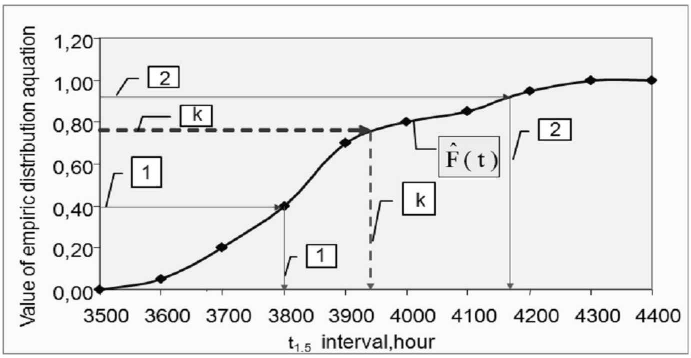

Figure 5. Empiric distribution function of $\boldsymbol{t_{1.5}}$ *interval*

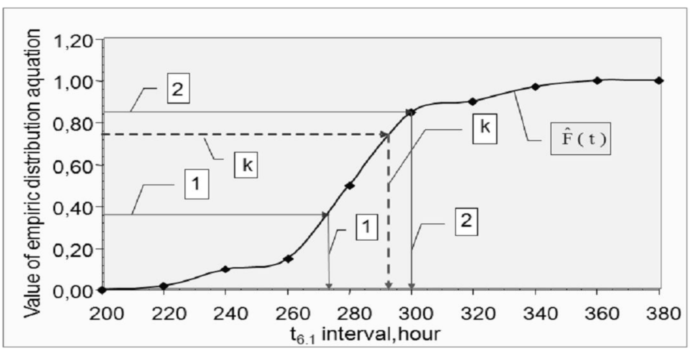

Figure 6. Empiric distribution function of $\boldsymbol{t_{6.1}}$ *interval*

$T_{1.5}^{(k)}$ generation of expected value realization:

k	1	2	3	4	5	6	7	8	9	10
rnd(0,1)	0,41	0,92	0,75	0,48	0,22	0,77	0,43	0,25	0,74	0,05
$T_{1.5}^{(k)}$	3800	4175	3930	3825	3720	3950	3820	3725	3950	3600
k	11	12	13	14	15	16	17	18	19	20
rnd(0,1)	0,86	0,97	0,98	0,17	0,96	0,09	0,36	0,18	0,36	0,21
$T_{1.5}^{(k)}$	4075	4225	4230	3675	4220	3625	3775	3675	3775	3700
k	21	22	23	24	25	26	27	28	29	30
rnd(0,1)	0,44	0,01	0,29	0,50	0,26	0,65	0,72	0,81	0,43	0,69
$T_{1.5}^{(k)}$	3825	3525	3750	3845	3725	3875	3925	4000	3825	3900

$T_{6.1}^{(k)}$ generation of expected value realization:

k	1	2	3	4	5	6	7	8	9	10
rnd(0,1)	0,38	0,85	0,93	0,51	0,93	0,69	0,78	0,96	0,43	0,31
$T_{6.1}^{(k)}$	273	300	330	278	330	290	295	335	275	270
k	11	12	13	14	15	16	17	18	19	20
rnd(0,1)	0,27	0,61	0,97	0,41	0,34	0,69	0,67	0,59	0,05	0,16
$T_{6.1}^{(k)}$	265	285	340	275	270	290	285	280	230	260
k	21	22	23	24	25	26	27	28	29	30
rnd(0,1)	0,70	0,07	0,07	0,88	0,97	0,54	0,91	0,09	0,77	0,20
$T_{6.1}^{(k)}$	290	205	235	305	335	280	320	235	295	285

$P_1^{(k)}$generation of **availability index** realizations:

k	1	2	3	4	5	6	7	8	9	10
$P_1^{(k)}$	0,8917	0,8934	0,883	0,8913	0,878	0,8914	0,8876	0,8771	0,8897	0,8878
K	11	12	13	14	15	16	17	18	19	20
$P_1^{(k)}$	0,8989	0,8978	0,8875	0,8885	0.9005	0,8841	0,8887	0,8874	0,9003	0,8939
K	21	22	23	24	25	26	27	28	29	30
$P_1^{(k)}$	0,8887	0,9007	0,8987	0,8861	0,8771	0,8919	0,8849	0,9036	0,8877	0,8914

In addition to the accepted conditions, on the basis of the calculations, according to the algorithm, shown in figure 4,

- Besides 95% significance level (α=0.05), the symmetric bilateral confidence interval (u=1.96; K=30) of $\hat{P}_1$ applicability factor is estimated as follows:

$$\hat{P}_1 - u\frac{\sigma_{P1}}{\sqrt{K}} \le \hat{P}_1 \le \hat{P}_1 + u\frac{\sigma_{P1}}{\sqrt{K}} \tag{11}$$

$$88.75\ \% \le \hat{P}_1 \le 89.23\ \%$$

so we can state with 95 % reliability that – besides the studied operational system structure – the applicability (availability) index of the specified technical devices will be positioned within the interval, designated by 88,75 and 89, 23 %.

- on the basis of the results of parameter sensitivity studies – performed according to the same methodology as the earlier – it can be established (see table 4) that there was no change in the rank between the factor variables.

Table 4. Rank of parameter sensitivity

Elasticity	$\varepsilon_{1.2}$	$\varepsilon_{1.3}$	$\varepsilon_{1.5}$	$\varepsilon_{2.1}$	$\varepsilon_{3.4}$	$\varepsilon_{4.1}$	$\varepsilon_{5.6}$	$\varepsilon_{6.1}$
ΔP_1	0,000013	0,001282	0,008	-0,000014	-0,000054	-0,001352	-0,002191	-0,005
ΔP_1 %	0,0013%	0,1282%	0,89%	-0,0014%	-0,0054%	-0,1352%	-0,2191%	-0,56%
Rank	8	5	**1**	7	6	4	**3**	**2**

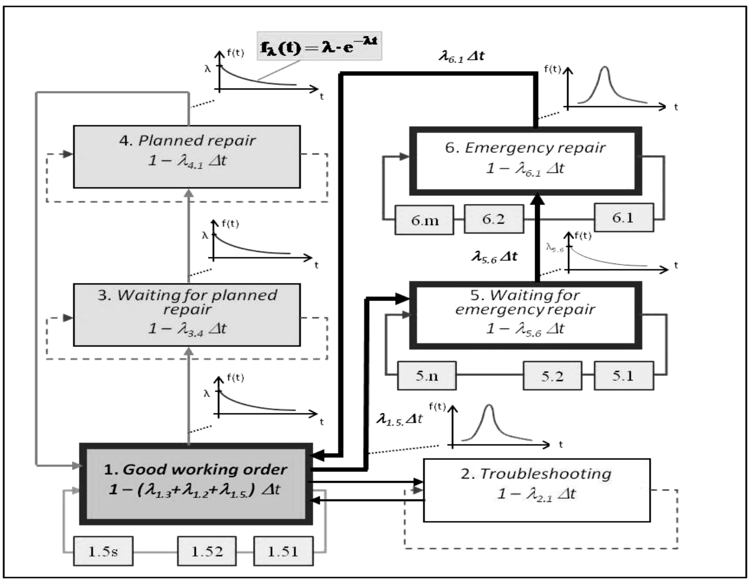

Figure 7. The most effective possibilities of the increase of the availability index

The performed studies make it possible to draw the conclusion that – within the specified operational structure and besides these operational parameters – the most effective way to increase the availability index means the expedient alteration of the operational chains of conditions, creating the 1-5-6-1 loop of the connecting condition-transitional graph (see figure 7).

Summary

Nowadays a real demand appears on behalf of transport organizations for the implementation of an "availability based" operational strategy, and treating maintenance as an integrated part of vehicle purchasing in the case of very valuable stock of vehicles. That is how it happened in the case of putting into operation the Stadler-FLIRT electric self-propelled train fleet, where – within the framework of a public procurement procedure – the entity submitting the tender had to guarantee 94 % effectiveness of the availability index (within the framework of a 30 year long maintenance contract) regarding the entire interval of the contract.

In this document we have tried to describe the multi-stage operational process of vehicles (as technical systems) using a stochastic-based model with the aim of the operational structure to be analyzable and to be able to optimize with adequate depth and soundness. For the description of the operational structure – in resolving the marginal conditions of the known homogeneous Poisson process model – we proposed such a general algorithm that is suitable for determination of numerical value and dependence ratio of the availability factor (also in the case of parameter distributions that are different from the exponential) and through that, it is also suitable for the practical establishment of an availability-based vehicle-operational strategy.

References

[1] Zvikli S: *Operation, maintenance I.* , Universitas-Győr Ltd., (2008).
[2] Zvikli S: *System analysis* Széchenyi István University - Electronic lecture notes, http://rs1.sze.hu/~zvikli/ (2009).