PERIODIC TIMETABLE OPTIMIZATION IN THE PUBLIC ROAD TRANSPORT SERVICES

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Abstract: A prospering transport system is an important precondition for a modern society, for economic growth, employment and welfare. Concerning the development in rural areas an easy access to the infrastructures is essential. Making regional accessibility better is not only investing in the rolling fleets of public transport but also optimizing public transport networks. Changes in the elements and connections of transport networks have an influence on the quality and price of public services offered as well as on passenger satisfaction. In the following an analysis and optimization of public transport networks by object oriented logistical approach will be presented.

Keywords: transport systems, optimization, transport networks

1. Introduction

Considering the success of periodic timetable on certain railway lines of the Hungarian State Railways (MÁV) and in order to prepare the regional integration and interoperability of the public transport services in the North Hungarian region the Borsod Volán Public Transport Company (BV Zrt.) in cooperation with the Bay Zoltán Foundation for Applied Research and also with the Department of Materials Handling and Logistics of the University of Miskolc have conducted researches for the implementation of periodic timetables in specific relations of the region. The examinations which have already been carried out refer to transformations of the recent traffic structure in the chosen agglomeration areas of the North Hungarian region.
Both the passenger demand and the economical effectiveness have to be taken into account in the course of establishing a computerized, mathematical simulation model for transforming the existing traffic infrastructure. Using the elaborate simulation model it is possible to harmonize the timetables of the regional railway and bus companies in the near future. To reach this goal and establish this modern, effective traffic system according to the passengers' demand some further practical questions have to be answered.

2. Problem Definition

In the course of the simulation attempts the relationship of an existing intercity bus line operated on quasi periodic timetable and the connecting bus lines from the region agglomeration was analyzed.

The reason for choosing this subject was that the large number of the external factors does not allow the implementation of a periodic timetable in the whole public transport network at once. Therefore after the transformation of the network structure the periodic timetable will be applied for only certain segments of the network whereas for other segments the "traditional" timetable will remain.
For this reason it is really important to create good interfaces between the connected network segments, which indulge the claims of network operators as well as the demands of the customers. One of the most important factors of this interface from the travelers' point of view is how much time is needed to change buses.
The analysis for obtaining solutions for reaching the goals described above was done in the frame of the following logical structure:

- determination of the general mathematical model of the logistical network of public transport from object oriented viewpoints,
- characterizing the network objects by general logistical parameters,
- revealing the connection system between the network objects,
- characterizing the network connections by logistical parameters,
- revealing the information technology background of the network operation,
- revealing optimization methods and restriction parameters by using information about the operational system,
- describing the optimal handling method of the expectations of procurer on the network operation and the operator's economic claim,
- harmonization opportunities of the examined road transport network with other transport networks.

3. Mathematical basics

Mathematical model of the public road transport network is derived from the graph theory. The objects in the examined transport system are the followings:

1. characteristic points, relation system and distances of the road network,
2. route parameters in relation with the road network,
3. vehicle parameters,
4. passenger-based parameters in relation with vehicle stops.

3.1. A possible set of the road network

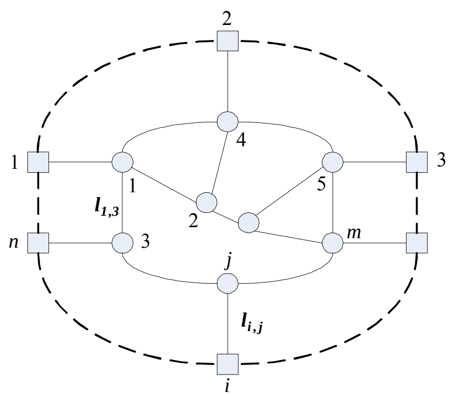

Figure 1. A possible set of the road network

Figure marks:

□ input-output points of the network (interface),
○ network nodes,
- - network boundary,
l_{ij} distances between nodes and/or input-output points.

3.2. Route parameters in relation with the road network

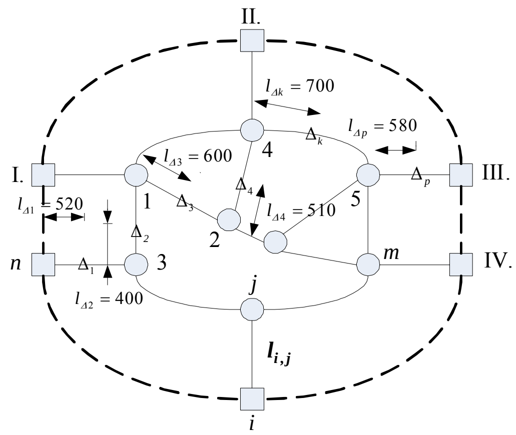

Figure 2. Route parameters in relation with the road network

Figure marks:

□ input-output points of the network (interface),
○ network nodes,
△ vehicle stops,
- - network boundary.

The number of the input-output points (interfaces): $i=1,2,\ldots,n$,
the number of the nodes: $j=1,2,\ldots,m$,
the number of the vehicle stops: $k=1,2,\ldots,p$ in the examined network.

3.3. Vehicle parameter matrix

$$
B(i,j) = \begin{array}{c} \\ 1 \\ 2 \\ \vdots \\ x \\ \vdots \\ a \end{array}
\begin{array}{c} 1 \quad 2 \quad \ldots \quad y \quad \ldots \quad b \\ \left[\begin{array}{c} \\ \\ \\ b(i,j) \\ \\ \\ \end{array} \right] \end{array}
$$

Figure marks:

x – vehicle type index,
a – number of the vehicle types,

y – vehicle type parameter index,
b – number of the parameters of a vehicle type.

Ordinary vehicle type parameters:

1. vehicle capacity (passenger/vehicle),
2. standard running cost (Euro/km), including:
   - fuel cost,
   - repair cost,
   - wage cost,
3. vehicle geometry (m):
   - length,
   - width,
   - height,
4. number of doors to go up,
5. number of doors to get down.

3.4. Passenger-based parameters in relation with vehicle stops

The number of the passengers in a vehicle stop along an interval is stochastic in the course of a (demand driven) periodic timetable public transport system. The distribution function of the parametric variants is supposed to be equal.

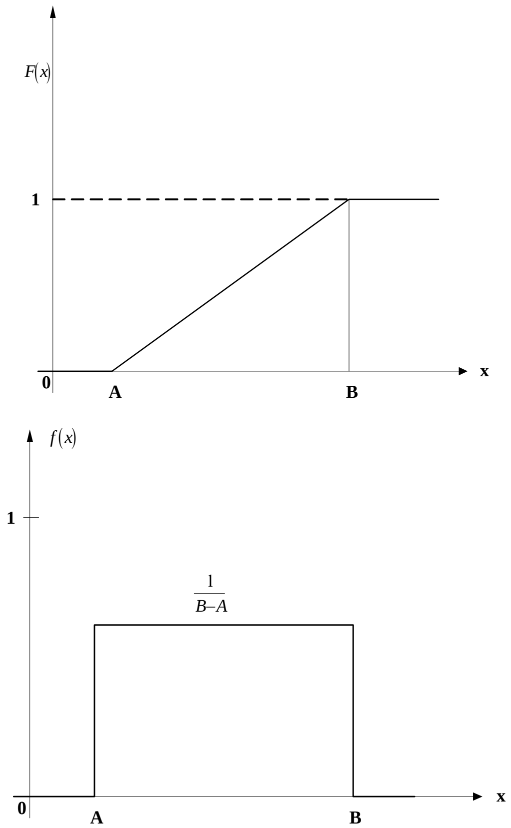

Figure 3. The distribution function of the parametric variants

The density function *f(x)* in this case:

$$f(x) = \begin{cases} \dfrac{1}{B - A} & \text{if } A < x < B \\ 0 & \text{else } x \neq A,\ x \neq B \end{cases}$$

These functions determine the minimal A_i and maximal B_i numbers of the passengers.

4. Characterization of the simulation model

Simulation attempts mean such kind of examination methods which are applicable for modeling real environment processes. Interrupts and disturbances of the real (public transport) system are avoided by using simulation techniques. Functionality is examinable and state change evaluation can be carried out by the help of PC aided simulation tools. One of the main advances of the application of simulation tools is the comparison of the different functional alternatives.

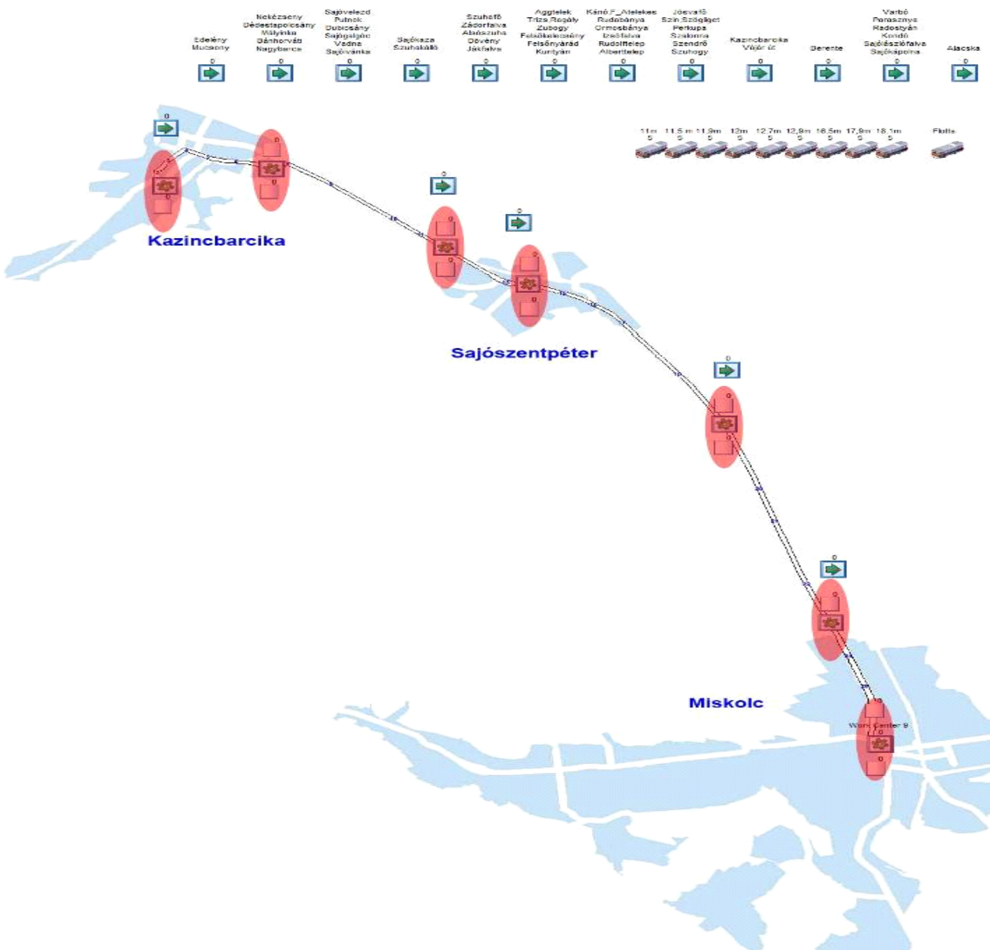

Figure 4. The simulation model

The applied simulation tool is the SIMUL8 Professional, which is Windows based software. This software enables modeling mostly discrete processes and such systems (networks) which are built by discrete elements. The SIMUL8 Professional has object oriented programming language in this way the elements and connections of the examined system reproducible with ones of the in built object types. The SIMUL8 Professional software aids modeling stochastic processes accordingly any object parameter can be characterized with distribution or density functions.

The simulation model of the public transport network was established by SIMUL8 Professional in the course of the problem solving. The network objects and network parameters (e.g. the timetable of the agglomeration routes) which are defined in the mathematical section was strictly implemented. The practical periodical time can be calculated with the help of the simulation model for minimizing the time consumption of bus changing or the running costs of the transport system operation. The parameter evaluation and collection during the examinations enables observing the effectiveness and utilization of the network objects.

5. Optimization

The most typical features of the connection between network segments which are operated by different kind of scheduling principles are the followings:

- time consumption of bus changing from the travelers' point of view (time parameter),
- periodical time related operational cost along the determined operation interval considering economic viewpoints (cost parameter).

These parameters have to be evaluated in the following cases:

- in the case of the isolated operation of the intercity bus line,
- in the case of the attached agglomeration routes to the intercity bus line.

The differences between the parameter values in the above cases refer to the quality of the network segment connection.

The aim of the examinations was to minimize the above mentioned differences therefore the determination of periodical time can be economically efficient and it will also guarantee competitive travel times with private transport in the examined relation.

New optimization procedure was worked out during the examinations with the elaborate computer simulation model which is applicable to make connection between the network sections operated on different kinds of timetables in a proper way from the view of operator as well as the customers.

Using the optimal periodical time the average waiting time increases by approximately 20%, while the number of customers rises by 40% and the cost increases proportionately with the number of customers on the bus connection points in the examined area. Examining further problems related to the periodic timetable elaborate procedures will be applicable in the future; e.g. the efficiency of the road and railway public transport systems can be comparable.

The following practical questions have to be considered in the course of future plans:

- How correlate the periodical time of the bus departures to the utilization of the vehicle capacity? How influenced this correlation by the transport market supply?
- How can be determined the basic periodic time of the periodic timetable? How could the periodic time reflect on the travel demand changes during a day?

- Is it possible to apply a common (shared) periodic timetable on different populated areas?
- How can be reconciled the claims connected to public services with the periodical timetable?
- What kind of effect has the development of the market demand driven periodic timetable on the costs of operation?

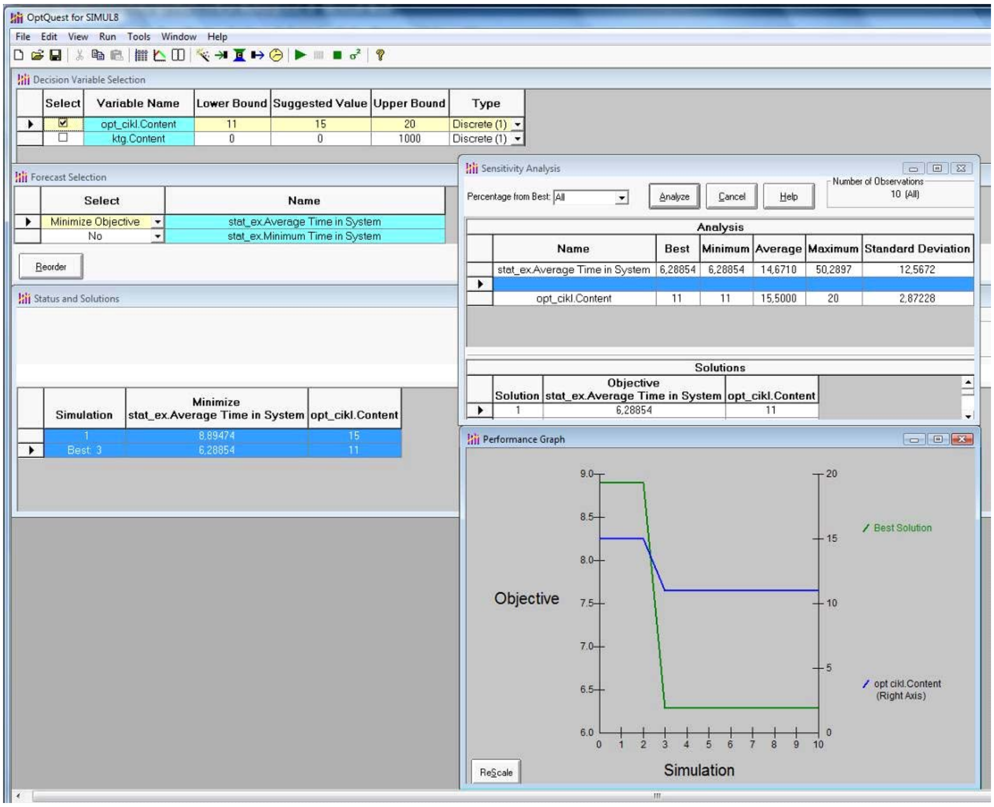

Figure 5. Optimization module of the simulation software

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