The Road Traffic Modelling and Design of the Traffic Database of Győr in Project Smarter Transport

S. Fazekas, T. Péter

Budapest University of Technology and Economics, Department of Control for Transportation and Vehicle System
H-1111, Budapest, Műegyetem rkp. 1-3.
Phone: +36 1 463 1013, fax: +36 1 463 3087
e-mail: alexanderfazekas@gmail.com, peter.tamas@mail.bme.hu

Abstract: In this paper we review our tasks in project Smarter Transport, and overview the network modelization process of city Győr. We also review the main concepts of the traffic road network databank, which will store the measured and assessed quantities and the road network model. We discuss the goals and the main requirements of the database system, which aims to support the modelling process. We briefly overview the architecture.

Keywords: traffic modelling, macroscopic model, traffic database, Smarter Transport

1. Introduction

The Smarter Transport project aims to aid public road transportation via the application of infocommunication technologies. The following steps will be executed within the confines of this project:

- the current state and traffic load of Győr's road traffic network will be assessed, the collected data will be structured
- the macroscopic model of the road traffic network will be set with PannonTraffic, our proprietary modelling software
- the macroscopic mathematical model will be applied on the network model and the simulated traffic load will be calculated
- the simulated traffic levels will be compared with measured data.

Setting up the road network model with correct parameters could be very time consuming process because of the large amount of data. Therefore a customized databank system should be planned and implemented to subsidize the above described process and to improve the speed of the modelization. The further advantages of the databank system are the following:

- all input data - which is required by the simulation process - can be stored in one place, despite input data can derive from different sources (different measurements, various authorities)
- paper documentations and plans can be processed before the application of data
- input data can be preprocessed and filtered, noise can be reduced

If the modelling software and the databank system are connected, there is no need to adjust every single model parameter manually. The databank system could aid these tasks based on the location of the current element.

Considering these advantages, a databank system could improve the pace and the quality of the network modelization. To achieve this, the databank software should be able to

- store and display all data related to a district's or a city's road network
- aid PannonTraffic in the process of parameter assignment to model elements
- store and display the model of the road network.

2. Software development for traffic modelling

In scientific researches there is no possibility to use simulation software without knowing exactly the mathematical model working in the background. The PannonTraffic Engineer developed by our team [11, 14] is a complex software for creating the road network, simulating the traffic and analyzing the simulation results. This software works with the published macroscopic traffic model of T. Péter in [7, 9, 12, 17, 18, 19, 20, 21] and Péter and Bokor in [6, 15, 16]. The advantage of the PannonTraffic software to similar, commercial software products is that the computation algorithm is not a black-box, but a well-known process. This model is developed for high-speed modeling of large-scaled traffic networks, to be able to apply for control optimization and prediction. The elements of the transportation infrastructure (lanes, traffic lights, pedestrian crossings, bicycle roads, etc.) are mapped through an interactive surface input while they are parameterized by several feature. We succeeded to implement the simulation with a high-performance algorithm. With the PannonTraffic Engineer we are able to achieve complex analysis to examine the effect of changes in the traffic orders, the road network geometry or the predictable traffic.

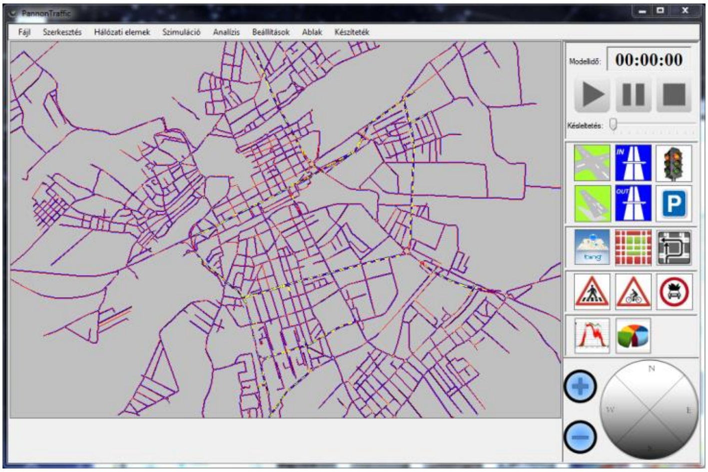

Figure 1. Main screen of PannonTraffic Engineer with the network of Győr

2.1. Creating the network

The road network graph's vertexes represent crosses in the traffic network, they are connected with directed edges representing the lanes. If there are parallel lanes in the real road network, then they are connected with more edges. The edges (lanes) are joined with connections. The transmitting of vehicles between lanes is described by α(t) and β(t). These functions are assigned to connections. α(t) describes the macroscopic vehichle distribution in the end of the lanes, β(t) represents the priority relationships of the connection. These functions are assigned to every connection between lanes.

The network graph can be set up based on the public social map data of OpenStreetMap service. The aim of the development was to reduce significantly the human-processing time of the network development.

In practice this means, that the region of a city about ~460 km^2 can be downloaded and reconstructed in 2 minutes by our software. In this road network we have crossings and road sections (with one lane each direction – except of one-way streets of course). Running simulation is not possible in this phase, few more add-ins, fixes and settings are needed. It's necessary to create lanes with the competent item number, and assign pedestrian crossings, parking places to them. Although the length of the lanes is correct thanks to the proportional mapping, but there is no information for example about the capacity of parking places, so we have to set it up manually, like the settings of the cooperation functions (for example α(t), α(t) and γ(t) functions) which we are able determine only after doing some measurements on the network.

2.2. Setting the model parameters

After creating the examined road network there are following the user made intervention operations. This large network was divided into 19 segments. These segments are basically bounded by major streets, and their size depends on the complexity of the actual territory. Three working phases were defined properly which are easy to divide into further parts.

I. Recover of the missing crossings

II. Split up the long streets to approx. equivalent distances

III. Adding parking places to the inside lanes

By parceling the network to 19 segments, the working process and the time requirements turned into well-planned, furthermore not a single street fails when doing the improvements.

The definition of the capacity of the parking places and the lanes can be automatized partially. Estimating the capacity of lanes or parking places could be managed by image processing, but there are two main difficulties. Firstly the quality of the satellite- and aerial images are not adequate. Secondly the time interval of our project does not allow such a long-term task.

In the case of lanes there is an easy solution. Using the GPS coordinates of the end point of the road sections the lane distances can be calculated unambiguously by reconverting the GPS coordinates to model coordinates.

The same process for the parking places is available only partially. In case of parallel or angled parking the capacity can be estimated knowing the length of the owner lane and the angle of the parking place arrangement. In the national standards it is fairly equally defined at which angle arrangement what sizes must be insured for each places. In this case the process is automatizable as we can see. On the other hand if there are parking lots (typically at residential area or warehouses) we cannot count the capacity like we did above. There is only the possibility to make personal counting on the spot or rely on the satellite images of the territory and count the parking places. There is the same case with the underground or multi-storey car parks, except of the fact that no satellite images can give information about them. Of course nowadays it is not hard to find information about this hidden park lots on the internet. Surveying the parking place capacities with the help of aerial images we can get some extra information about hidden parking places in a city. Namely there are lots of buildings having inner court, where the owners have sometimes more dozens of parking places, which would not be discovered in all cases.

During the verification process of the road network using the OpenStreetMaps integration it was noticed that the number of the parallel lanes is not defined at all in the internet database. This problem led on the same solution like described above related to the parking lots. For being able to do this process as fast as possible we improved the user interface of PannonTraffic Engineer. The panel dealing with parking places now contains some extra functions for determination of capacity (e.g. arrangements types, manual counting results). The parallel lanes have to be set manually.

3. Designing the traffic database

There are two main group of requirements defined about the databank system [4,5]. Firstly there should be an intuitive user interface where users can browse, search, compare and upload the measured and simulated traffic data easily. Secondly we have to design a proper interface for the PannonTraffic application. The PannonTraffic modelling software is based on a public, macroscopic model [8, 9, 10]. It is developed by our team; we can easily extend its functionality and integrate with the database system. PannonTraffic software should be able to connect to the databank system via this interface and query the quantitative (measured and estimated) parameters of the traffic network, adjust them to the proper model element, and upload the simulation results into the database after applying the mathematical model.

During the design process we aimed to create a general solution.

The databank system should be a way where measurement and simulation results can be published, namely it should be available remotely, thus we will implement it as a web application.

3.1. About storing data

The database system is designed to store every type of data which could be required as input or output for the simulation process, or describe the current state of the network. The stored data can be classified based on how are they produced and on what are they relating.

Some kind of data is linked to model objects. For example traffic density of time functions are linked to lane objects. Other quantitative parameters are assigned to GPS positions. In PannonTraffic simulation software, parameters can be assigned to the objects and not to the positions. For example a parameter can be assigned to a lane or a cross object, hence the database system should support to determine the owner objects which are initially assigned to locations, but not to objects.

The database should store density of time functions for each lane. These functions can be generated based on the measurement results, but simulated density of time functions should be also stored in the databank.

Users should be able to:

- Estimate and set the quality of the road surfaces for each lane and the width of each lane with the user interface of the application
- Set the maximum (and optionally minimum) allowed speed for each lanes
- Assign the traffic-distribution and priority describing ratios or functions for every crosses, for every connection. (These functions are defined in the macroscopic model as α and β functions. In the current phase, these ratios and functions will be estimated, because there will be no measurements of traffic-distribution in the interchanges.)
- Estimate the transparency of each cross and assign these estimations to the crosses. (To support and help this task, the sampling cars may record their run with camera, and the application should store and display these photographs taken from the sampling cars.)
- Assign the list of traffic signs to the given sampling point based on the photographs. (These datasets should be queryable and searchable. Place of pedestrian stops can be set manually also.)

There are exact, measured and estimated parameters in the traffic network. The nature of data determines the way how data should be handled and stored. Exact data can be set and stored once, they are valid in every circumstances in the given traffic network. Programming of traffic lamps belongs to this category. The time intervals of green and red signs can be set and check on the user interface of the application.

There will be measurement data collected via GPS samplings. Some sampling cars having GPS equipments will run in the traffic on predefined routes. These chronological data of car positions and speeds will be the base of calculated vehicle density of each lane of the traffic network [13]. These data may be distorted by noise, so filtering processes should be elaborated. The exact way of filtering will be determined later, in the development phase.

In some cases (especially in sudden, non-traffic depending impacts and events) manual exclusion may be required. For this purpose we design the system to store the photographs bound to sampling points. Using these photographs, users can roam the sampling routes again. During these steps, the user interface will support the necessary manual processing steps, for example the recognition and administration of the road quality or the traffic signs.

During the manual data processing special properties of the network can be recorded also. Custom tags (similar to labels) can be assigned to every single measurement location or recognized object, and this list of tags could be modified freely during the whole term of the modelling and data recording process. The meaning of tags can be administrative only (for example to mark those areas of the network, where the modeller would like to perform more detailed reviews, or to tag the areas where some uncertainty is or further review is required), but in a later stage of the modelling process these labels can get extra meaning in the model.

After exclusion of distorted samples, the system estimates the density of time functions of every lane in the network from the GPS data of the sampling cars. The estimation is based on the „relevant speed" of the advance on the lane. „Relevant speed" means the velocity determined by the traffic on the lane. Estimation is done by using these speeds with the fundamental correspondence between vehicle density and average speed.

This calculation of traffic density of time functions should be repeatable with different parameter sets, hence the database system should store unprocessed, raw datasets of GPS measurements and the calculated density of lane functions separate.

Not only density functions are based on estimation, but α and β coefficients, but till the vehicle densities are calculated automatically from GPS coordinates, α and β coefficients are judged manually.

3.2. Supported processes by the database

Measurements and collecting the required data should be done in the first phase. GPS sampling measurements and the traffic lamp programmes of interchanges are necessary.

In the second phase further position assigned parameters can be set manually on the interface of the application. By iterating through the photographs of the traffic network created during the GPS sampling runs [1, 2, 3] every traffic affecting factors can be registered and estimated including quality of road surface and traffic signs. These parameters will be linked to the positions. It is important that the classifications are not quantitative, but subjective. Users can group the objects and impacts into several classes. For example if the question is about the transparency of a cross, the user can assign adjectives like „good", „moderate", „dangerous" „very dangerous"; and „good", „potholed" can be used in case of quality of the road. The quantitative meaning of these adjectives can be modified later by the modeller, so the parameters of the simulation can be refined after setting up the model. The classifications can be customized; the list of the available properties and the quantitative meaning of these items can be modified every time.

In the third phase a PannonTraffic Engineer model is created by users. This model can be based on the public database of OpenStreetMaps, but it can be a high-level model containing only the priority roads.

In the fourth phase the PannonTraffic model will be uploaded to the database application, which resolves the owner model object for each position-assigned parameter. Assume that there are more position assigned parameter for the same lane. The system should determine the root parameter, which should be assigned to the macroscopic model element. Before these steps the engineers should select the way of calculation of the root parameter for each parameter type. All required data are stored before this step; hence the calculation of the root parameter is repeatable, if a better way of root calculation is identified.

In the fifth step the macroscopic model is applied to the traffic network

In the sixth step the output of the macroscopic simulation – including the simulated density of time functions of the inner sections – are uploaded to the database system.

In the seventh step the differences between the measured and the simulated density functions can be compared. If it is required the process can be restarted to refine the parameters from the second or third phase.

3.3. Integration objectives

The PannonTraffic modelling software and the planned databank website has some common functions and use cases, as users should be able to display the simulation results, to navigate on the network graph, and to adjust the traffic network parameters with both software.

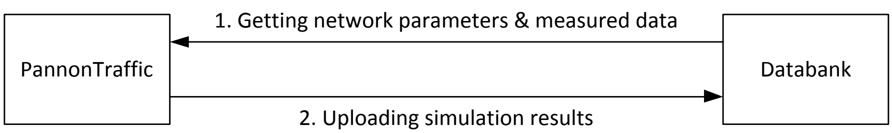

Figure 4. The modelling software gets the parameters from the databank and uploads the simulation results after the simulation process

The weaknesses of the software could be eliminated if PannonTraffic was a web application. In this case it would be reasonable to make this implementation in the databank, so the two systems could be integrated: the process of registering measurement results, storing model dependent an independent network parameters, traffic network modelling, simulation and analysis could be executed at one place. This solution suits to the Software as a Service (SaaS) paradigm, so customers, engineers, students should not deal with the installation and the operation of PannonTraffic software. It could be easy to give a trial to the would-be users. In case of this solution the users would get not an instance of the modelling software, but some user accounts to the databank and the modelling software with modelling and processor time. The business logic will contain the data processing and filtering implementation, furthermore the user authentication and administration. The data access layer will suit the database engine to the business logic. The simplified figure of the architecture is shown below.

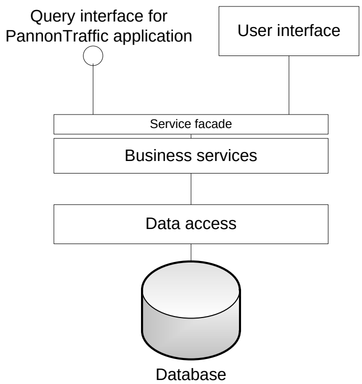

Figure 5. The simplified architecture of the database system

4. Summary

We introduced our first tasks in the Smarter Transport project [22, 23, 24, 25, 26, 27, 28, 29]. We defined these tasks accurately and made suggestions to schedule the processes according to the detailed segmentation of city Győr. By the 19 segments it is possible to distribute the tasks to more persons and execute the work processes parallel. We detailed some solutions for defining capacity of the road sections and car parking lots and presented a software development related to the problem. We have overviewed the main requirements related to the databank system. We have discussed the main types of stored data and the process which will be supported by the software. We have reviewed the main items of the planned architecture. Finally we have investigated the advantages of considering the further development of the databank system and the PannonTraffic application as one integrated web application despite of two different stand-alone software.

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