

# How can a transport model be integrated to the strategic transport planning approach

A case study from Budapest

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**Abstract—** The aim of this paper is to present the state-of-practice in transport modelling in Budapest. BKK and its subcontractors created an integrated multimodal transport model (MTM) as a result of a three year process. This model is based on large-scale data gathering process and it will provide support for decision making processes. More solid, evidence based decisions can be made with the help of this new tool, which at the end can improve the quality of life in Budapest.

**Keywords—** transport model, macroscopic, transport planning

## I. INTRODUCTION

BKK Centre for Budapest Transport is the fully integrated urban transport managing authority of the Hungarian Capital. BKK is an entity between the local government (municipality) and transport providers and operators. Up to now, feasibility studies with transport models in Budapest were made only by private companies, therefore, to build up this competence at BKK, an integrated multimodal transport model (MTM) has been developed for future transport related feasibility studies.

The aim of this paper is to present the state-of-practice in macroscopic transport modelling at the Hungarian Capital. This paper introduces the unified transport model and its components. Additionally, it shows the possible applications of this complex decision support tool related to strategic transport planning. Finally, it points out some challenges, barriers and draws some conclusions.

This paper is adopted a pragmatic perspective, since the describe processes and tools can be mainstream in some countries, but it is innovative in Hungary. The paper will highlight those parts of the development process, which are unique from the Hungarian point of view. With this approach, the authors would like to provide information for other Central-Eastern European cities about an internally used transport model. The idea of this paper is twofold: show the main technical details of the model as well as provide some insight the policies behind it.

## II. DEVELOPMENT OF THE TRANSPORT MODEL

The aims of the MTM, in line with the requirements of the European Commission and other funding organizations, are the following:

- provide a unified and solid basis for the transport development plans in Budapest and it's agglomeration
- be platform independent
- provide open access, which means that anybody, who is qualified and experienced enough to use it (from city officials through transport planners to university students), can have access to the data
- be capable to exchange data with different registers, databases
- match to the transport model of the Hungarian National Transport Strategy
- be in line with the Budapest 2030 Long Term Urban Development Strategy and the Balázs Mór-plan, the new development strategy of urban transport
- use the state-of-practice analytical modelling as the basic approach

The MTM is the first macroscopic transport model which is owned by the Municipality of Budapest, also the first model which will be continuously updated and maintained. As it was introduced earlier this MTM is new in Budapest, although the methods and processes are traditionally used in macroscopic transport modelling.

The development of a large scale and long-term transport model such as the MTM, required special expertise, therefore BKK issued a public tender in early 2013. Due to the complex selection process, the Consortium (consist of the three largest consultancy and modelling firm in Hungary) finally could start their work in late 2013. The length of the contract is more than two years, which can give an idea about the scale of the work.

MTM will be the new baseline model for Budapest, so BKK can compare all results from different project developed by different consultants, which was not the case before. Additionally it is expected to be observed price reduction in the market of transport modelling, since a base model is available. Opposed to the model development, which is a highly specialized task, BKK will have the necessary human resources to use this new model internally.

An international benchmark was carried out at the beginning of the work, which showed that cities around Europe are tends to have transport models for internal use. However, these models are rarely public ones. Several scientific publication have been carried out with different innovative modelling approaches (e.g. [1]–[4]), but the traditional methods only presented in general books [5] and guidelines. Limited information available from practice based examples from European cities. One of these examples is the Capital of United Kingdom. London has a logical, easy-to-understand framework of models which can be used as an example for the model development tasks. In London, there are different models in close cooperation to provide a solid ground for transport and other decisions, these models are the following:

- Railplan (Public Transport Assignment Model): A public transport model that allocates the predicted demand to public transport modes (eg. rail, underground, bus) and using the extensive set of walking links, it predicts the routes people choose to get to their destinations, as well as the associated crowding impacts. It was developed in the Emme modelling software in late 1980's, but transformed to a Cube model. [6]
- The Highway Assignment Models (HAMs): Five strategic models covering the entire London area (5600 zones) which predicts the routes that drivers choose and the associated congestion and delay impacts on London's roads. The development of these models started in 2008 to provide a consistent basis for highway modelling. The model development included detailed surveying, travel time observation and road counts. [7]
- The London Transportation Studies Model (LTS): A strategic model which uses population and employment forecasts and other inputs to predict the number of trips to be made in London in the future (trip generation), where people travel to and from (trip distribution) and which transport mode they use (mode choice). Additionally, the model predicts the travellers' routes within London and its surroundings (trip assignment). The mode choice model only uses the following modes: car, public transport, non-motorized. The development of LTS started in 1961 in a Unix based software, but it was transformed to a Cube model. [8]
- The London Land-Use and Transport Interaction Model (LonLUTI): A model which predicts the land

use for different human activities depending on Government policies and transport investment. It assesses the land-use impact of transport schemes and provides a rigorous analysis of the demographic, economic and transport impacts of land-use proposals. The LonLUTI model developed in MS-DOS based software in 2008. [9]

- The London Regional Demand Model (LoRDM): this model is still under development. It is a demand balancing model which is similar to LTS but uses the HAMs and Railplan for modelling the choice of route. [8]

All the above mentioned models have been developed with careful adherence to industry guidelines, and are led or reviewed by experts in the field of transport modelling. In particular, the Department for Transport's Transport Analysis Guidance (WebTAG) was followed to ensure the model is robust and reliable. [8] BKK not used these models inside MTM, but the structure and logical framework was used as a best practice example in Budapest, given the aim of public availability.

BKK will not only use MTM as a tool for the transport development planning tasks, but will integrate it to the strategic planning processes. Our model – together with the joint impact models and assessment procedures – can be efficiently used for the strategic planning processes, the preparation and ranking of different transport development projects, as well as the ex-post evaluations of different projects and the strategy itself.

### III. INTRODUCTION OF THE TRANSPORT MODEL

MTM was not built as a separate transport model; it was designed in a way to connect the already existing systems and created some additional ones. MTM includes some new approaches and techniques which were never used in Hungarian transport modelling before (e.g. a real four-step approach). As it was recognized from the day-to-day practice and the international review, a good model needs reliable, up-to-date and useful data, therefore a traffic measurement system and data storage system was designed, which directly connects to the model. This chapter introduces details of MTM, highlights some innovative elements of it and finally it describes the additional systems.

The model framework consists of several subsystems (sub-models) from which some are in-line with the usual modelling practices, for example:

- hierarchical zone system for different purposes
- transport network (supply) model
- transport demand model

This model represents a whole workday in October. This is true for demand model and for network model too. Nowadays, just like in any other cities, in Budapest there are some on-going reconstructions, but in the model there is an ideal status of them.

Some other parts of the model are unique, such as:

- cycle demand and assignment
- using of GTFS data

#### A. Zone system

MTM is unique in its zone system too, since it contains not only Budapest, but also the entire Municipal Region which is relevant from commuter transport modelling purposes. The commuter traffic (~500 000 commuters per day) has significant impacts for Budapest's everyday life, therefore this part of the model is very important. [10]

Within Budapest, the number of zones is also increased and – thanks to the hierarchical structure – each level of aggregation contains different information according to the data availability and disaggregation. The following structure is used:

- 23 districts
- 164 sub-districts
- 520 city development units
- 922 transport modelling zones

The previous models for Budapest usually used the 520 city development units. These zones divided to smaller ones to reach an optimal level of disaggregation (in each zones contains less than 4200 inhabitants) which finally resulted 922 transport modelling zones.

For the agglomeration, the model contains 199 settlements which were divided into 255 smaller transport modelling zones (in each zone less than 12 000 people lives). The 199 settlements were categorized according to the public transport services level (e.g.: basic timetable), and only those settlements were involved that have direct access or directly combined timetable by public transport.

Some special zones were determined e.g. supermarkets, malls, logistics centres, industrial areas and the Liszt Ferenc Budapest International airport.

Additionally, the model has 24 cordon zones, to provide the match with the transport model of the Hungarian National Transport Development Strategy.

In each level of disaggregation, the model stores a large dataset of socio-economic background information, which is used for building the demand model (e.g.: number of residents, number of employees, number of households, number of kindergarten, schools and healthcare facilities).

#### B. Transport network

This is a multimodal transport model, therefore it contains private and public transport network. There are approximately 11 000 nodes, 30 000 links, 6 700 connectors, 8000 stop points and 1000 line routes in this model.

The nodes – representing junctions – are sorted to five categories, according to their control type, and each type used

different impedance calculation methods. The links are categorized to forty-five types. For private transport link types, additionally for the usual differentiating factors (speed, capacity and impedance attributes) the distinction was made also by road type, within or outside city limits.

The model uses four different type of connector according to their travel time. These values are unified for every demand segments, depend on the zone attributes: in a very good network service level and downtown zone has 4 minutes, an average network service level has 6 minutes, a low network service level has 10 minutes, in agglomeration with only rail connection, this value is 15 minutes, which represents the worse access time of railway stations. Connectors are differentiated by transport system usage too. There are connectors for multimodal, private transport, walk and freight transport type.

In Budapest's model, a three level public transport stop modelling has been used. The biggest unit is the Stop, the second is a Stop which contains same placed stop points, and the third level is a Stop point which means the physical stop locations. These three level thinking, which originates from the software provider PTV, is useful to get calculated information on three levels, from whole stop attributes (sum of transit passengers or transit waiting time on an intermodal hub). From the model building perspective, this structure needs many place-specific details, for example transfer walking time.[11]

The public transport networks in Budapest are from three different services: BKK is responsible for local public transport, National Railway Company MÁV for rail transport in the agglomeration and National Coach Company VOLÁN for coach transport in the agglomeration. The public transport network used in this model is also unique, due to two significant developments:

- It contains lines and scheduling data for public transport and this data can be updated directly from the public GTFS database, provided by BKK on its website (unfortunately, since the national coach companies and the Hungarian State Railways cannot yet provide such open data, these schedules have to be updated manually).
- On the BKK network, every stop points have unique identification which is similar to BKK's ForTe system for lines and passengers data. Therefore the model can connect to the data in this system.

The transport network contains parameters for the cyclist assignment; also the road network was refined in order to provide a good basis for this state-of-the-practice approach. In order to further enhance this transport mode, BKK joined to the FLOW project consortium. This project implements a new state-of-the-art through the application of new transport simulation models in the FLOW Partner Cities (Budapest, Dublin, Gdynia, Lisbon, Munich and Sofia) for the integrated analysis of pedestrian and cyclist movements and their impact

on urban congestion; these analyses and models are expected to become lighthouse examples for other cities.

### C. Demand model

The transport demand model used in Budapest is also the first of its kind in Hungary, from several points of view:

- The demand matrices are generated in two different ways: a direct matrix approach derived from a household survey conducted in 2014, other surveys and data, for example: statistics of ticket and season ticket sales. The second way is a synthetic matrix approach developed solely for this purpose. This second four-step synthetic demand model can be run in Excel in order to be platform independent. The final matrixes are made by direct matrixes which are modified by synthetic matrixes with pivoting methods. Prognosis matrixes are calculated similar than present matrixes with population and motorization prognosis.
- The demand segments used in this model is also very detailed, since it contains four categories for freight transport as well as car, taxi, public transport and cycling.
- Additionally, to fulfil the requirements of transport planning, it contains an average daily matrix and 5 different matrixes for the different periods of the day.

### D. Assignment procedures

The assignment model also has some specific features for public and private transport.

For every demand segments in private transport use equilibrium assignment, this distributes the traffic according to Wardrop's first principle: "Every road user selects his route in such a way that the travel time on all alternative routes is the same, and that switching to a different route would increase personal travel time." [5] The initial assignment works in seven steps (20%-20%-20%-10%-10%-10%-10%) with different cost function for every vehicle categories. The cost function is described in the (1) equation. The assignment use four different VDF functions for link impedance as well as node and turn VDF functions, which are BPR type.

$$C_c = C_t + C_o + C_f + C_r \quad (1)$$

where:

- $C_c$  is the total generalized travel cost
- $C_t$  is the travel time cost
- $C_o$  is the travel operating cost
- $C_f$  is the road toll cost
- $C_r$  is used to represent the access restriction

The public transport assignment was designed in a way that it is capable to use headway based assignment for the strategic planning purposes. In this model passengers have elapsed

waiting time information. It means passengers know how long they have been waiting already at the stop and decide according to this information between different public transport routes.

The cyclist assignment uses a newly developed function. It works similar than private road transport with a multistep equilibrium assignment and a generalized cost function. This function consists of travel time cost and a specific impedance variable. This link impedance variable is based on the link length and a unique multiplication factor depends on the link category. The model consist seven different link categories according to the motorized transport volume and the quality of cycling infrastructure:

- dedicated cycle lane
- common dedicated cycle and bus lane
- cycle path
- roads recommended for cyclist (low traffic roads)
- roads open for contraflow cycling
- roads where cycling is prohibited

### E. Traffic counting, surveys and database system

Good, reliable and up-to-date data are absolutely necessary for a traffic model development, especially calibration and validation. Our project made a traffic measurement and data storage system for these purposes. The traffic measurement system has many periodical counting and surveys. The counting is made in every spring, autumn, and summer annually. The other part of the measurements is the surveying, which contains household survey, stated preference survey and on-site OD survey. These large-scale data collections are made every four year.

The main features of the road traffic counting can be summarized in the followings. The system suggests recording everything in spring and autumn, but only independent cyclist counting made in summer:

- Two types of counting exist, according to the length: five hours (7:00-9:00 and 16:00-19:00) and sixteen hours (6:00 – 22:00). From the 100 locations of road traffic cross-section counting: at 13 locations counting lasted for sixteen hours, at 87 locations for five hours.
- Within these manual counting, there were differentiation between cars, cycles, motorcycles, buses and four freight vehicle categories, which numbers are recorded in 15 minutes intervals.
- Additionally, at 58 independent cycling counting locations counting lasted for five hours, and at 8 locations for sixteen hours. In these locations the staff recorded the infrastructure usage preferences: road, dedicated cycling infrastructure pedestrian areas.

Public transport counting can be summarized in the followings:

- Two types of counting exist, according to the length: five hours (7:00-9:00 and 16:00-19:00) and sixteen hours (6:00 – 22:00)
- Visual usage observation has been made in total of 104 locations: 41 bus lines, 38 tram lines, 20 trolleybus lines and 5 coach stations were involved.
- Board and alight passenger counting was made on some significant Metro, Suburban railways, Cogwheels stations, 20 rail stations.
- A large-scale full length board and align counting was made on one metro line in annually, in a rotating method.

Household surveys and other surveys in detail [12]:

- In Budapest there were 10 000 households surveyed
- In agglomeration there were 4 000 households surveyed
- 1 000 households did stated preference surveys
- Cycle questioning happened in 25 locations about their OD, purpose and frequency.

There were other data sources, which have been used in the model development and update:

- FCD data from freight logistic companies,
- traffic flow characteristics from induction loop traffic sensors and licence plate recognition cameras,
- territorial statistical data from the Hungarian Statistical Office (KSH) and the Budapest Capital City Planning office (BFVT),
- information from the km-based electronic toll collection system (HU-GO) from NÚSZ,
- ticket sales data from MÁV.

Large datasets have been collected, analysed and transformed in order to feed the model and the data collection will continue in the upcoming years.

Data have to be organized in a database system in order to be a transparent and easy to handle. The original results of traffic counting are stored in Excel sheets, which are calculated by a transfer table for the final database (MS Access or Mysql). (See Fig. 1). Data from other source are transformed to the appropriate structure of the database model, for example calculated traffic flow multiplication factor from loop detector data.

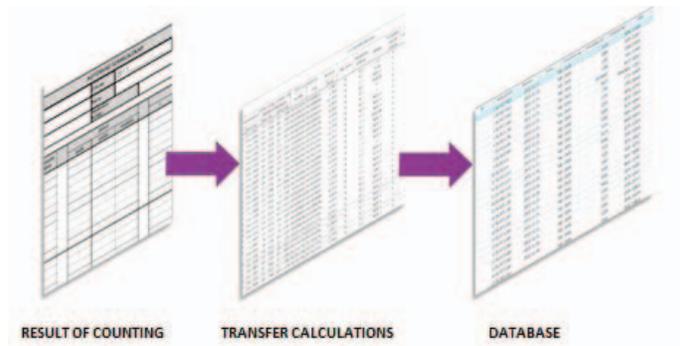


Fig. 1. Traffic counting data transformation

All of these data go to a geo-database system, which can be used for other tasks. If it is required, providing these data for other use (feasibility studies, road reconstruction design, road operating, etc.) is very easy to do. As this database is connected to our model via link identification system, it can be used directly to calibrate and validate our model.

#### IV. COMBINATION OF STRATEGIC PLANNING AND TRANSPORT MODELING

Transport is one of the key areas of urban policy, the quality of transport significantly influences the competitiveness, liveability, operability of the city – development of transport must be treated only having a unified approach with regional perspective. Transport is an integrated system from public transport through road transport to cycling, from road maintenance to major investments. In the international practice, the organizational framework of transport has been gradually transformed in the last decades, a new intermediate level appeared between municipalities and operators, this transport authority, as a professional organizer, is responsible for the integrated management of transport, ensuring clear tasks and responsibilities for the owner, the authority and the operators. In Budapest, system integration and more efficient operation wouldn't have been possible without the complete overhaul of the institutional structure – clear division of tasks and responsibilities, professional competences and establishment of accountability was needed. By foundation of BKK Centre for Budapest Transport in 2010, integrated management of transport related tasks has been put upon professional basis.

During the recent review of the Development Plan of Budapest Transport System a situational analysis has been carried out that identified the following key problems affecting the capital's transport system: randomly selected developments that are not integrated into the urban context, dominance of sectoral and sub-sectoral thinking, fragmented control at local and inter-local level that blocks integrated solutions, and decisions that give wrong answers to the changing urban lifestyle and habits. Almost all identified key problems feature fragmentation and lack of integrated approach: to establish the optimal use of resources and to provide predictable funding, integrated overview of maintenance, operation and development is necessary. Sectoral and regional integration,

and integrated policies are critical for defining the proper direction of transport development, also for solving the identified problems. In the spirit of Sustainable Urban Mobility Planning, Balázs Mór-plan has been created in 2014, based on the former planning experience, international good examples and best practices, also using the results of the above mentioned situational analysis; it creates the framework of the most urgent tasks in strategic planning. The plan represents an integrated manner, identifying goals to be reached in Budapest transport development in a network context, and defining the most important traffic development measures based on a comprehensive urban development vision.

A new transport management approach requires also new methodologies in preparation of developments, in which is key to identify problems at a strategic level, an accurate knowledge of transport demands and conceptual plans that are based on these data, while strategic background of these plans are becoming an increasingly important factor, as available financial resources are shrinking. To help the decision making process prior to transport planning adequate quantity and quality of data must be available, this can be ensured by increasing of automated data collection in the near future, also by using modern information technology and tools.

Requirements of the increasingly spreading passenger and goods-based dynamic transport modelling, along with the need for these processes to become more accurate and reliable, encourage the use of innovative data collecting technologies [13]. It is completely unimaginable today not to model the expected effects of general transport management measures, before their introduction: for example before a new public transport ticketing (E-ticketing) system, access regulation of certain areas (congestion charging scheme) or parking management issues (parking fee policy). Better understanding of travel behaviour is, and improved focus on secondary effects, of which the traditional surveys not in all cases provide adequate options. Therefore, not only statistical data is to be updated regularly, but constant monitoring of traffic is needed, to be able to feedback traffic effects, from which subsequent evaluations can be derived, to be a hard basis for several studies.

However, in theory, general steps of strategic planning are well known for professionals (see Fig. 2.), in practice, currently, Budapest does not have a holistic programming methodology that would create a framework for all projects with different complexity and timing from all different areas of transport development, nor would generate a realistic, feasible, midterm (4-5 year) program by ranking of projects. The realization of the transport development strategy requires this programming methodology that is able to evaluate and rank projects already prepared or new project ideas, based on city policies and professional know-how. Impact assessment and evaluation system for monitoring the transport development strategy evaluating of its effectiveness and observing the fulfilment of goals that would ground midterm review of strategic targets is also missing. No SMART\* indicators and their base values are available that could be used to evaluate

effects of implemented projects from the point of view of reaching strategic goals (current project-level monitoring practice cannot alone be used at strategic level). To fill these gaps, working out a new methodology for impact assessment and evaluation has just been started recently: from strategic goals and measures of Balázs Mór-plan [14] it deduces sets of SMART indicators to be measured and tested, including data acquisition and processing methods and an evaluation and reporting system. From Spring 2015, the Unified Traffic Model for Budapest will also be available (with a regularly updated database), which is a working tool for strategic planning and programming, but may become suitable for supporting impact analysis and evaluation work.

The Integrated Transport Model can provide various types of indicators for strategic planning, programming and impact analysis and evaluation processes, for each transport development alternatives. These are, at first, traffic related indicators of transport users and the transport network (e.g. travel times, passenger and vehicle performances, environmental pollutants etc.), secondly, connectivity indicators for the network (such as accessibility or changes of location potentials). Since the Integrated Transport Model can provide these indicators for the present and for the future years (2020, 2030 or 2050), therefore it will take its place in transport strategy planning, as a well-used tool.

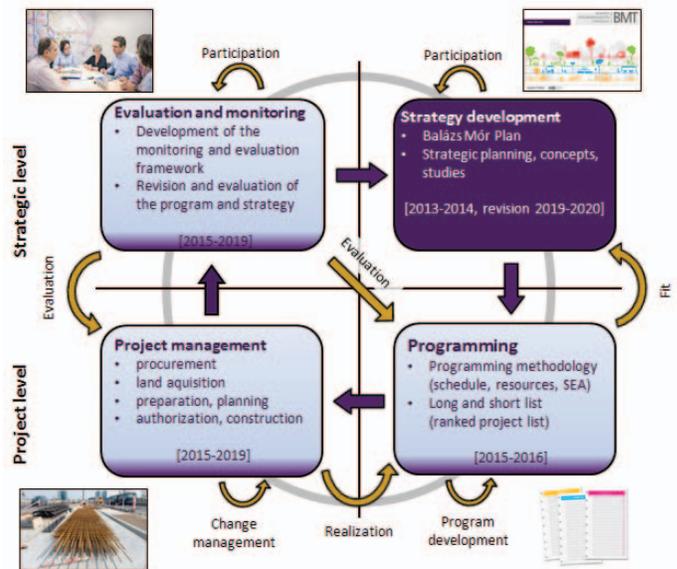


Fig. 2. General steps of strategic planning [15]

## V. LESSONS LEARNT

During a long and large-scale project like the development of the macroscopic transport model for Budapest agglomeration is inevitable that there are challenges on which the managers have to overcome. In this last chapter some of the main challenges and lessons learnt are summarized.

First, the problem with the procurement process has to be mentioned. Usually, in Hungary the decision factor on the procurement procedures is mainly the best price, but in this project, it was not possible to formulate an absolutely closed Terms of Reference. The Client wished to give some room for the Contractor to provide the most adequate solution for model development, without tying its hands. Therefore an open tender was launched, where the tenderers were required to submit their technical offer along with their price offer. We still believe that this was the appropriate process; however, due to the lack of practice, this lengthened the procurement procedure heavily. This lengthy procurement procedure required some restructuring of the internal deadlines of the project.

It was important to involve the cyclist layer to our model. Since this solution is of state-of-practice and Budapest has limited cyclist data, the results have to be used carefully, and it requires further research and development. In order to enhance this part of the model, BKK has joined an international consortium that kicked-off the FLOW project, which is funded under the Horizon2020 programme. BKK, with the help of BME, will work on cyclist modelling in the upcoming three years. This R&D project will help BKK not only to enhance the cyclist part of the model, but also to share knowledge with other partners, as well as to keep at the frontier of the state-of-the-art modelling practices. Using an enhanced transport model which properly integrates cycling can give the Client the necessary evidence that is needed to convince decision-makers to introduce more cycling and walking measures in urban environment. Providing hard evidence can strengthen the acceptance of adopted measures. Additionally, it is a requirement of the framework of an impact assessment on e.g.: cyclist projects [16] and traffic calming measures [17], [18].

As the model is based on a large dataset collected during the project development phase, it will be obsolete as soon these data become outdated. In the other words, the model is capable to function as long as its background data is updated continuously. As it was described in Chapter III, BKK staff, together with the Consortium experts proposed a continuous updating and data collection procedure for the model. This update program contains data collection (traffic counting, surveying), data purchase (statistical information), data integration to the model (calibration, validation) and finally publication of the results. [19]

The complexity of the model is itself a challenge in more than one ways. Due to the high number of zones in the model, this cannot be run in the smaller scale VISUM software packages, which can be a problem for SMEs in the Hungarian transport planner market. As it is one of the first working four step model in Hungary, especially which includes so many

different transport layers, the procedure sequence (especially the parameters) is highly complex and complicated, although the demand model was not even incorporated in it. The demand model itself is now working separately as a spread sheet model. Due to its complexity, it has to be mentioned, using the model is requiring high level of knowledge in transport modelling. Although BKK will provide the model structure to the future Contractors, it won't be a ready to use model. In each tasks, the experts should redesign the model for the purpose of a specific project, which usually include the increased detailing of the model in a specific area and calibration for the model on this area.

There were several problem related to the use of GTFS dataset. As it is designed to provide very detailed information to route panning services, it contains significantly more information as required by a strategic model. In fact it contains too much information, since it also has all the service runs and specificities for a given day. The model developer had to come up with a solution to simplify the GTFS dataset and create and adequate one for strategic planning purposes. At the end this resulted in two separate models one for operational purposes and one for strategic planning.

However, once the model will be available for application, basic data for measurement and project evaluation is going to be independent from user specific circumstances, which will contribute to more accurate assessment procedures and comparison of results. After mapping out necessary data linkage, the model can also be prepared to provide indicators for the yet to be elaborated programing, monitoring and evaluation systems, making it a powerful instrument in the toolbox of strategic transport planning, on a unified basis.

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## REFERENCES

- [1] M. E. Ben-Akiva, S. Gao, Z. Wei, and Y. Wen, "A dynamic traffic assignment model for highly congested urban networks," *Transp. Res. Part C Emerg. Technol.*, vol. 24, pp. 62–82, Oct. 2012.
- [2] A. Balázs and R. Markovits-somogyi, "Implications of Behavioural Economics for the Transport Sector," *Period. Polytech. Transp. Eng.*, vol. 1, no. 41, pp. 65–69, 2013.
- [3] M. Ben-akiva, J. Bottom, S. Gao, H. N. Koutsopoulos, Y. Wen, B. Jon, G. Song, I. N. Koutsopoulos, and W. Yang, "Towards disaggregate dynamic travel forecasting models," *Tsinghua Sci. Technol.*, vol. 12, no. 2, pp. 115–130, Apr. 2007.

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3-5. June 2015. Budapest, Hungary

- [4] H. Liu and D. Z. W. Wang, "Global optimization method for network design problem with stochastic user equilibrium," *Transp. Res. Part B Methodol.*, vol. 72, pp. 20–39, Feb. 2015.
- [5] J. de D. Ortúzar and L. G. Willumsen, *Modelling transport*, 4th Editio. Chichester: John Wiley & Sons Ltd, 2011.
- [6] TfL, "London's Public Transport Assignment Model ( Railplan )," London, 2014.
- [7] TfL, "London's Highway Assignment Models," 2014.
- [8] TfL, "The London Transportation Studies Model (LTS)," London, 2014.
- [9] TfL, "The London Land-Use and Transport Interaction Model ( LonLUTI )," London, 2014.
- [10] M. Juhász, T. Mátrai, and L. S. Kerényi, "Changes in Travel Demand in Budapest During the Last 10 Years," *Transp. Res. PROEDIA*, vol. 1, no. 1, pp. 154–164, 2014.
- [11] PTV AG, *PTV Visum 14 Manual*. Karlsruhe, 2014.
- [12] I. Cre, T. Mátrai, and M. Wolek, "Public transport innovation□: changing structures to achieve ambitious targets," *Eurotransport*, vol. 11, no. 6, pp. 36–38, 2013.
- [13] A. Medvig and M. Juhász, "Innovatív közlekedéstervezési eszközök és forgalomfélévételi módok," *Közlekedéstudományi Szle.*, vol. 63, no. 5, pp. 28–35, 2013.
- [14] BKK, *Balázs Mór-terv: Budapest közlekedésfejlesztési stratégiája 2014-2030*. Budapest: BKK Budapesti Közlekedési Központ Zrt., 2014.
- [15] L. S. Kerényi, "Budapest új közlekedésfejlesztési stratégiája, a Balázs Mór-terv," in *Nemzeti Közlekedési Napok*, 2014.
- [16] J. Tóth and T. Mátrai, "Újszerű , nem motorizált közlekedési megoldások," in *Közlekedéstudományi Konferencia*, 2015.
- [17] M. Juhász, "Közúti forgalomcsillapítási intézkedések feltételrendszerének vizsgálata," in *Közlekedéstudományi hallgatói és PhD konferencia*, 2013, p. 1.
- [18] M. Juhász, "Travel Demand Management – Possibilities of influencing travel behaviour," *Period. Polytech. Transp. Eng.*, vol. 41, no. 1, pp. 45–50, 2013.
- [19] Modell Konzorcium, "Budapest és agglomerációjának teljes területére egységes forgalmi modell, 4. Mérőföldkő," Budapest.