1. Introduction
During last few years considerable activities on developing city transportation system have been initiated in Belgrade. These activities are related to reconstruction and revitalization of the existing elements of traffic infrastructure, as well as to preparation of the study, planning and design documentation for investments into further development of the transport system.

For the purpose of establishing optimal development of the transport system in Belgrade, it was necessary, using existing resources, to create a modern transport model, which enables determination of various development strategies in relation to changes in transport demands.

Considering this issue respective city authorities, the City Council – Traffic Department, and Directorate for City Development and Land Use, in public tender procedure awarded the Faculty of Transport and Traffic Engineering and CEP – Center for Town Development Planning, to develop the Belgrade Transport Model (BeTraMod).

The primary requirement of the Transport Model was that it be used as a functional tool in the process of effecting balance between benefits and the costs invested into transportation infrastructure of the city.

Another task of the Transport Model was to provide basis for transportation planning in terms of medium-term and long-term investments into transport system.

The last, although not least important, objective was training of certain number of people to acquire relevant knowledge and skills in the field of planning and management of transport system development (including learning and application of the up-to-date software tools).

Activities on creating the Belgrade Transport Model (BeTraMod) initiated in the end of 2002, and it was finished in 2003. The main work was done by research team from University of Belgrade, Transport and Traffic Engineering Faculty.

2. Definition of Transport Model
At the beginning of work on the Transport Model one of the main issues was to define a Transport Model, in modern sense and according to investors’ requirements. On the basis of the survey carried out by experts in traffic and transport problems, use of available literature and the insight into experiences of some cities with already formed transport models, adequate harmonization and definition of this concept was reached. Transport Model implies a set of relevant data (numeric, graphic and other), indicators, parameters and simulation models, expressed in space and time, in such way that:

- characteristics and behavior of transport system in the past can be reconstructed;
- certain regularities in transport demands and transport supply, on one hand, and socio-economic and land use parameters, on the other hand, can be established;
- present state of transport system can be presented and evaluated;
- future functioning of transport system, or its parts, can be evaluated, forecasted or designed;
- specific, existing states or states defined by development scenarios can be evaluated using Transport Model elements.

Once established, a Transport Model is open for additions and upgrading that may comprise all elements or parts of integral elements, with innovated or altered data, indicators, parameters and simulation models. Therefore, it can be said that Transport Model is developing concurrently with transport system, i.e., more broadly speaking, and parallel with the city planning system.

General application purpose of the Transport Model is to serve as:

- official basis for calculations to respective authorities or
local self-government organizations, whose activities are directly connected to planning, programming, management and building of transport system;
• basis of various research and scientific research projects;
• basis for the appraisal process;
• basis for search of the optimal solutions of traffic regime;
• basis of intelligent transport systems in the portion of dynamic traffic control
Transport model is defined for a local self-government administrative area, i.e., for its inner parts. Some parameters of transport model may be defined also for a group of administrative zones of a number of territorial self-governments, or for a smaller area that represents subject of special research and analysis.
Transport model is used as official planning-design basis for elaboration of:
• study/analyses/expertise of transport system of specific inner zone in relation to the purpose of this transport model formation, that are aimed at development planning and programming, selection of strategies and/or tactics, etc., of the zones they are prepared for;
• studies/analyses/expertise being prepared for specific components of transport system (modes and/or infrastructure), aimed at planning and research of development, selection of strategies and/or tactics etc., of the selected component;
• studies/plans of locations allotted for construction of apartments, commercial, service, industrial, storage, transportation and similar facilities, traffic structures and areas, or facilities in which said usage is partially represented;
• general and draft design of infrastructure and transport structures; and
• pre-feasibility and feasibility studies of infrastructure and traffic structures.
Users of Transport Model are authorities, organizations and entrepreneurs dealing with development of a specific zone, investing into this zone and performing other activities or a specific undertaking, in which transport represents a vital component.
Potential users have to request adequate Transport Model data from respective authorities, and on the basis of the data obtained in such manner, they will carry on their intended investment activities.
Elaborated and adopted studies/analyses/expertise/plans and designs have to be submitted to respective authority in charge of Transport Model, to enable verification of findings and issuance of adequate approvals for further investment steps. The organ authorized to issue approvals is obliged to make entry of adequate data into Transport Model from studies/analyses/expertise/plans and designs. Thus, continuous updating of investment intents and their impacts on Transport Model is ensured.
In view of general application value of the Transport Model, it is obvious that concept of the user of Transport Model has broader meaning. In this case, having in mind the basic purpose of creating Transport Model, application value is oriented to users mainly in the scope of planning, programming, management and development of transport system.
Data, indicators, parameters and formulations of simulation models derive from/are made on the basis of official government data sources (land registry office/cadastre, government land surveying, statistics, internal revenue service, etc), from other sources (plans, analyses, studies, expertise), and from sources from continuous and/or occasional research carried out by institutions, organizations, organs and other entities.
All data have to be on the level of traffic zones, or some other zones. Usually, three basic data groups are formed, and they comprise information base for the needs of planning and management of transport system development. These three groups are:
• Independent indicators consisting of data on spatial, industrial, demographic and economic characteristics of the zone. Typical data for each traffic zone are: number of inhabitants, number of households, number of workers, motorization level, income per household, land use and intensity of land utilization, working space, income per employee, scope of trial work.
• Data on transportation and traffic infrastructure – consisting of data on technical and functional characteristics of all subsystems, such as: street and road network, network of public worker transportation, terminals, parking, freight transport network, etc.
• Data on movement characteristics, such as: total scope of movement in the area (mobility), movement distribution per purpose, movement distribution in space, movement distribution per time, movement distribution per mode, etc.

3. Belgrade Transport Model - BeTraMod
Belgrade did not have, so called, transport model till now. Certain elements of transport model in the form of isolated numerical and graphical data, studies, analyses, expertise and development scenarios could be found at various institutions, but, in most cases, they were not compatible. In some cases, however, they were systematized into an applicable form, but some data were in the form of draft materials with limited application possibilities.
The basic data sources for formation of BeTraMod were:
• Belgrade Master Plan 2021.
• BETRAS Study
• Traffic count on Belgrade primary street network
• Travel time survey on Belgrade primary street network
• Freight traffic regime
• Inventory of Belgrade street network
• Distance table of GSB lines
• Documentation of Beogradput Company on regimes at main intersections in the city
• SYSTRA – public transportation study
• 2001 Passenger count and survey
• Results of traffic survey of some characteristics of street network in Belgrade, carried out for the needs of elaboration of Belgrade Traffic Model
Basic data used:
• Geo-reference basic data on the street network from 2003 Master Plan
• Zoning system from the BETRAS Study
• Map with positions of public transport stops
• Bases are drawn in Auto-Cad, and then converted into extension *.hgr, i.e. format that can be read by selected software

4. Networks
Street network is based on the Master Plan of Belgrade. Besides that, a portion of lower-category street network used on the route ends by various sub-systems of Public City transportation was added to it. Total length of the primary street network in the Transport Model is 801 km.
Street and road network classification system was designed specially for this Transport Model on the basis of route capacity and speed, traffic management system, composition of traffic flow, number of lanes per direction, etc.
Road network categories in the Transport Model are defined by 4 basic categories, each category comprising adequate subcategories. Total number of sub-categories is 22.
Portions of network used exclusively by pedestrians (transfer links), as well as right-of-ways used exclusively by trams and railway corridors are classified into a special category.

<table>
<thead>
<tr>
<th>Highway</th>
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<td>40 / 60</td>
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<td>Tram</td>
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<td>Walking</td>
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<td>60</td>
<td>Railway</td>
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</table>

Public transportation line network has been formed according to data obtained from the GSB Planning and Research Development Institute; Lasta Belgrade based company and Bevoz. This network consists of 141 lines - 106 bus lines, 10 tram lines, 7 trolley lines, 13 Lasta lines and 5 Bevoz lines.

5. OD Matrix
Basic matrix in Belgrade Transport Model is based on the work trip matrix prepared by the City Bureau of Statistics. This matrix relates to spatial distribution 160 x 160 traffic zones. Volume of work trips is 536,706 trips per day.
This matrix is calibrated by factors related to trip purpose distribution, transportation means distribution, peak-hour rate, percentage of internal-internal trips, vehicle occupancy, etc. Two peak-hour matrixes have been obtained, as follows:
- passenger vehicle matrix, and
- public transport trip matrix
Passenger vehicle matrix consists 59,590 passenger vehicles in the peak-hour. Public transport trip matrix comprises 101,865 trips in the peak-hour and it was calibrated according to the result of count and survey in the public city transportation carried out in the end of 2001.

6. Software
The basis for creation of Belgrade Transport Model is VISUM 8.0 software package.
VISUM is a computer-based traffic-planning program, representing basic tool in analysis and forecast of transport system elements. The essence of transport system in VISUM comprises street and road network, public transportation network, and possibly freight transport network as an independent unit or a part of street network.
Basic qualities of this package are:
- Insignificant demand of hardware support
- Compatibility with GIS and Auto CAD
- Relatively simple operation in design application
- Good visual view of output data
- Quick operation during calculation of network parameters and network load
- Public transportation elaborated in great detail
- Impact of traffic on environment is treated through various types of pollution (air pollution, noise, etc)
- Possible use of filters for each element of transportation system defined in the Model (zones, nodes, links, public transportation sub-systems) and per each input characteristic for given elements (capacity, speed, street name etc.).

7. What is it that Belgrade Transport Model makes possible
Belgrade Transport Model is in fact a tool for determination of optimal development of the Belgrade Transport System based on the existing state and on future demands forecast. This model enables generation and analysis of various development strategies related to changes in transport demands or interventions in the transport system.
Traffic flows are described on macro level using software and adequate data and information.
Result of passenger flow simulation represents a set of data that can be calibrated to results of adequate counts and other research.
Of course, primary objective of state simulation (existing or planned) is to determine state in design working day hour (peak-hour), when transport demands are extreme and represent basis for dimensioning of the transport system.
In the street network segment it is possible to analyze:
- On level of entire network:
  - Total network length per categories
  - Total number of nodes
  - Number of links
  - Number of directions not allowed on the network
  - Number of intersections with specific number of intersection legs
  - Locations of traffic count stations with values of entrance-exit flows from intersections
  - Isochrones related to selected zone or node, etc.
- On level of links:
  - Flow rate, capacity and speed of link
  - Distance of link
  - Transport operation on link (veh/hour and veh/km)
  - Ratio of capacity and flow on link, etc.
- On level of nodes:
  - Node load.
  - Number of entrance-exit legs.
  - Traffic regime in the node, etc.
- On level of zones:
  - Number of origin and destination trips
  - Travel time between zones.
  - Number of connected nodes in a zone, etc.
- Minimal paths (for passenger cars and public transportation) between zone pairs per impedance, distance and time travel criteria.
In the public transportation segment it is possible to analyze:
- On level of entire system:
  - Number of trips in the system (this parameter is direct and determined by travel matrix)
  - Number of tours in the system and per sub-systems (sub-system share in realization of travel volume represents the basis for analysis of potential systems utilization and for correction on line network)
  - Number of transfers in the system presented by number of trips realized by through-trips, with 1, 2 or more than 2 transfers.
  - Average trip distance in the system and per sub-systems
  - Average time of travel, trip and waiting for vehicle arrival (in the system and per sub-systems)
  - Transport operation realized in the system and per sub-systems
Parameters of offered and utilized transport operation, as well as their mutual relationship provide possibility to evaluate transport quality and rationality in the system and its parts.
- On level of corridors:
  - passenger flow,
  - coefficient of capacity utilization,
  - unbalance of capacity utilization between core corridors (they
represent basis for the analysis of transport capacity utilization of the existing or planned sub-system on the corridor.

- On level of lines:
  - passengers' getting in vehicles at all stops in the simulation period
  - passengers' getting off vehicles at all stops
  - passenger flow at stops
  - travel time between stops, with dwell time at stops (this should be checked)
  - utilized transport operation
  - average trip distance
  - average travel time
  - passenger exchange coefficient

Locations of intensive passenger transfers on the network and transfer flows between lines represent significant indicator of deficiency of lines on the network. Simulation model enables analysis of:

- transfer volume realized among lines
- total transfer time
- walking time, if transfer is realized between two different stops

All presented data for corridors, lines and stops, as well as a number of other characteristics can be listed from the model. Besides simulations of flows in public transportation on real network there is also a possibility of network loading with "equal offers on lines". Such load provides possibility to analyze line potentials according to their positions on the network. Results of line network loads with assumed change of dynamic traffic state are valuable as well. This model provides possibility to correct planned dynamic parameters of street network to public transportation sub-system.

Belgrade Transport Model basically contains:
- classified and described street and road network,
- network of passenger public city transportation
- freight transport network,
- basic matrix of passenger vehicle work trips
- basic matrix of passenger public transportation work trips
- load of street network with adequate basic matrix
- load of public transportation network by adequate basic matrix, and
- already mentioned documentation basis

8. Further activities on Belgrade Transport Model

Forming a Transport Model, generally, requires continuity resources are needed in the initial phase. When certain elements are completed, intensity of activities on Transport Model decreases. However, due to constant need to update data and changing circumstances, this Model is continuously upgraded.
This applies to the Belgrade Transport Model, as well. Further activities on Belgrade Transport Model upgrading could be:

- Perform comprehensive traffic research in Belgrade area.
- This implies a survey in households on characteristics of citizens’ local movements and passenger surveys on terminals and outer cordon lines on origin-destination and transit movements. Such research would enable formation of real movement matrices and determination of regularities between independent parameters and movement characteristics.
- Enlarge Model street network adding lower category transport routes to it, in compliance with the new zonal system.
- Form foreseeable development scenarios of street network and public transportation network for future state, and add and test them in the Transport Model.
- Make adequate database on ecological parameters being consequence of traffic. These elements are particularly important in the procedure of appraisal of alternative solutions.
- Check current study and project documentation related to traffic and transport infrastructure through Belgrade Transport Model, and include adopted documentation into this Model. For managing and development BeTraMod it will be useful to form a task group that will continuously work on Belgrade Transport Model.

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