Modern Tools in Transportation Planning: Transport Model of Belgrade

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This paper presents the procedure for building Belgrade transport model as a tool for the optimization of Belgrade transport system development. City Council of Belgrade financed the Belgrade Transport Model (BeTraMod). It was a first experience of city government of Belgrade in developing huge data basis about transport system using software. This way defined model can be used by different users 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. Since BeTraMod is created it was already used for project documentation of three projects: pre-feasibility study and general project of Inner-city Ring Road, pre-feasibility study and general project of Light Rail Transport and feasibility study of Bypass road of Belgrade.

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 develope 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, trans-shipment and similar facilities, traffic structures and areas, or facilities in which said use is partially represented;
- general and draft designs 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 sub-systems, 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 sub-categories. 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.

Highway			
Cate-gory	Speed	Number of lanes	Additional characteristics
00	120	2X2	
01	100	2X2	
02	80	2X2	
03	120	2X2	By-pass
Arterial route			
10	80	2X2	
11	Cca 80	2X1	
12	Cca 60	2X2 (2X3)	
13	Cca 60	2X1	
14	Cca 60	2X2 (2X3)	Tram
15	Cca 60	2X1	Tram
I category			
20	60	2X2	
21	60	2X1	
22	50	2X2	
23	50	2X1	
24	50 / 60	2X2	Tram
25	50 / 60	2X1	Tram
II cat-egory			
30	50 / 60	2X2	
31	50 / 60	2X1	
32	40	2X2	
33	40	2X1	
34	40 / 60	2X2	Tram
35	40 / 60	2X1	Tram
Other			
40	Walking		
50	Tram lane		
60	Railway		

Table 1: Transport route categories defined by Belgrade Transport Model

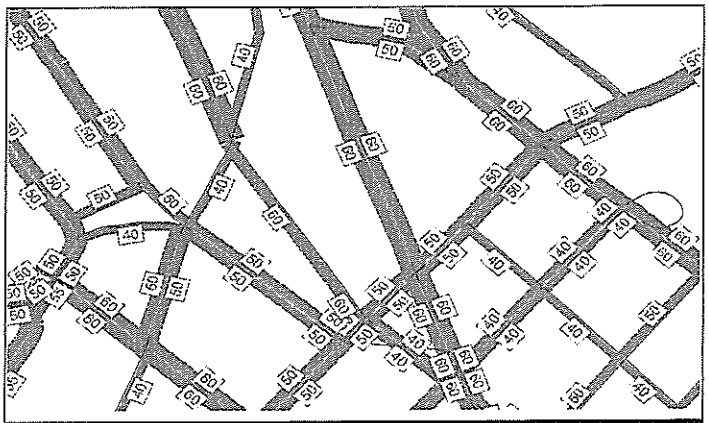

Figure 1: Speed chart on street network – a detail

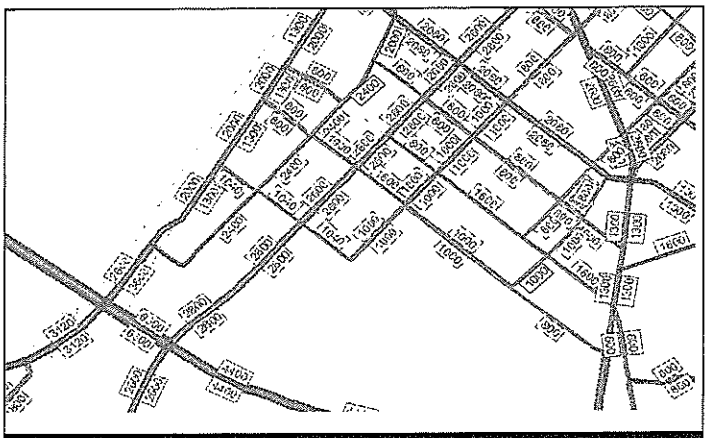

Figure 2: Street network capacity – a detail

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

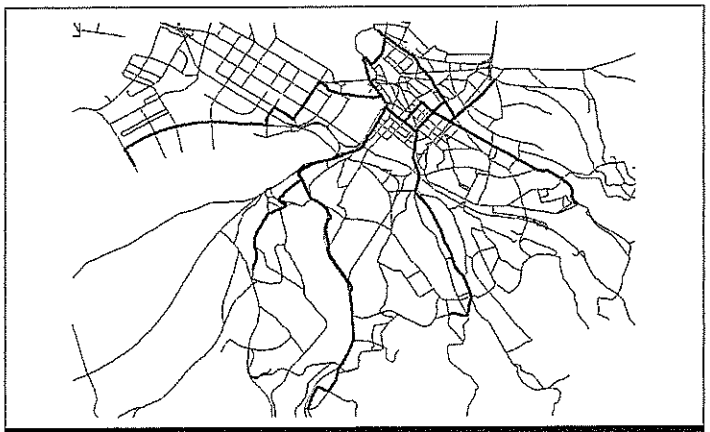

Figure 3: Public transportation line network - tram

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

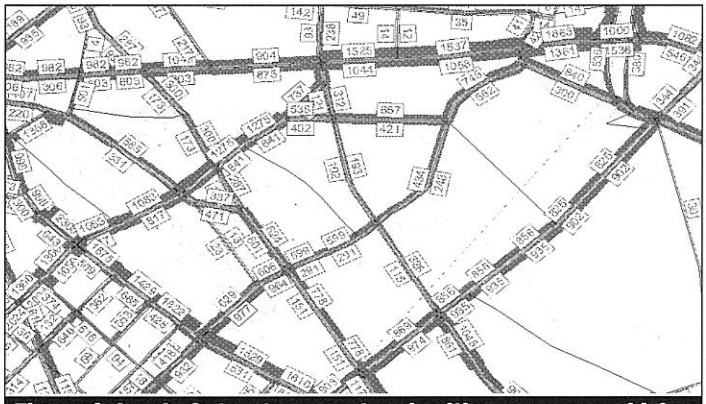

Figure 4: Load of street core network with passenger vehicles in peak hour – a detail

6. Sofware

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.

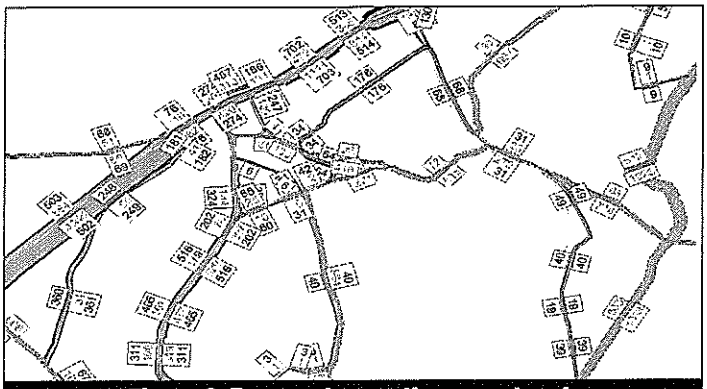

Figure 6: Transport operation on network

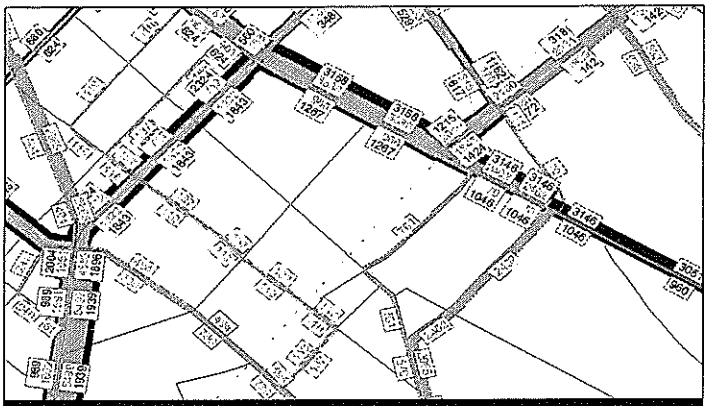

Figure 7 Capacity and flow rate on network – a detail

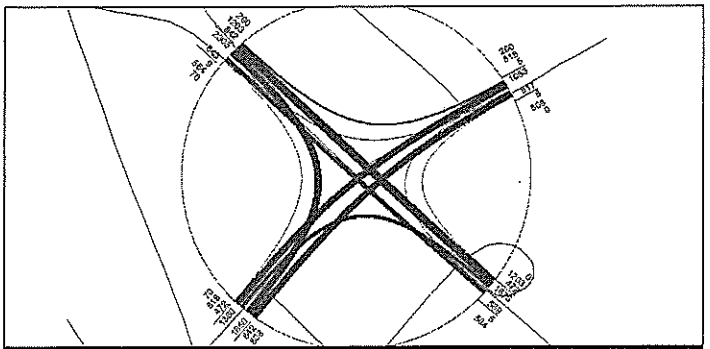

Figure 8: Node load (Main Post Office Intersection)

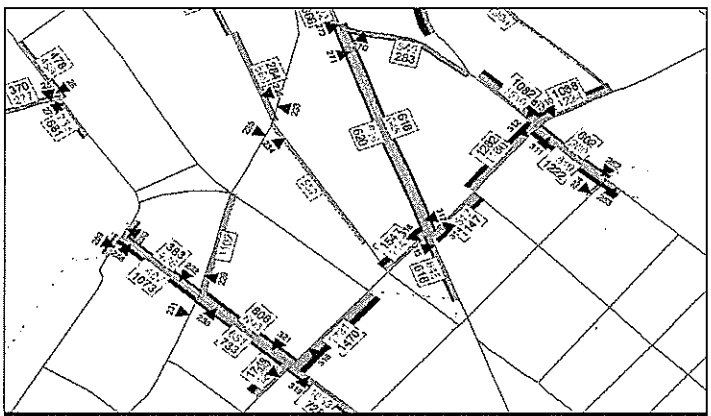

Figure 5: Locations of traffic count stations with values of entrance-exit flows from intersections

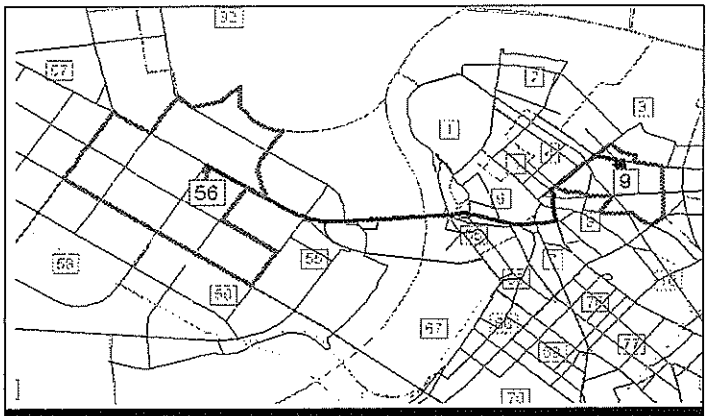

Figure 9: Minimal paths (for PV and PT) between zone pairs per distance criteria

Active nodes only Node 1

Basic display only stop

No.	Name	Stop	NumLegs	Type	Vol-PrT	NumSLines	NumLines
1	AP - obilaznica	0	3	00	554	0	0
2	AP - aerodrom	1	4	40	979	2	1
3	Novi novosadski put - Autoput	0	4	20	2411	0	0
4	AP - Bezaniska kosa	0	4	20	4603	0	0
5	AP - Tosin bunar (Studentski dom)	1	4	20	4846	11	7
6	AP - Omladinskih brigada	1	4	20	7029	10	5
7	Milentija Popovica - AP	0	4	20	7294	0	0
8	Jurija Gagarina - Autoput	0	4	00	9147	0	0
9	Mostar kod Bigza	0	4	20	13717	1	1
10	456 Mostar AP	1	5	20	10912	7	4
11	AP - Bul. JA	0	4	20	8864	0	0
12		0	4	00	3807	0	0
13		0	4	00	3952	0	0
14	AP - kruzni put	0	3	20	1495	0	0
15	15	1	2	40	432	2	1
16	Zrenjaninski - Bratstva i jedinstva	1	3	00	1531	5	3
17	Zrenjaninski put - Ivana Milutinovica	1	4	10	1877	12	6
18	Zrenjaninski put - Koteski put	0	3	10	2364	0	0
19	Zrenjaninski - Milesevska	0	3	00	2364	0	0
20	Zrenjaninski petlja	1	4	00	2364	14	7
21	Pancevacki novi - Pancevacki stari	0	4	00	0	0	0
22	Zrenjaninski petlja	1	3	00	680	2	1
23	Zrenjaninski petlja	0	3	00	130	0	0
24	Pancevacki most (ulaz Zrenjanin i Pancevo)	0	3	00	1574	0	0
25	Pancevacki most (izlaz Zrenjanin i Pancevo	0	3	00	1452	0	0
26	26 Bul. Kralja Aleksandra - Ritopek	1	4	00	1335	12	6
27	27 Bul. Kralja Aleksandra - Kruzni put	1	4	00	1287	16	8
29	17 Avalski put - Pinosava	1	3	00	1145	8	4
30	Avalski put - Vase Carapica	1	3	00	1128	2	1
31	Avalski put - Z Gavrilovica	1	3	00	1122	8	4
32	Bul. JA - - Zemljoradnicka	1	5	00	1945	6	3
33	5604 S-Filipovica - Ibarska	1	3	00	40	4	2
34	Ibarska - Lipovica	0	3	00	991	0	0
36	Ibarska magistrala - Kruzni put	1	4	10	1555	6	3
37	8604 Savska magistrala - Umka	1	3	00	1415	6	3

Figure 10.VISUM listing with node characteristics

No.	StrName	FromNode	ToNode	Type	Length	Cap-PrT	Cap-PuT-Total	VolVeh-PrT	NumLines	v0-PrT
1	Autoput	1	100	00	1277	8800	0	554	1	120
2	Autoput	2	2784	00	2035	8800	0	979	1	120
3	Autoput	2559	2560	02	1044	8800	0	2558	2	80
4	Autoput	4	5	02	524	8800	0	3660	2	80
5	Autoput	5	6	02	1015	8800	0	3736	3	80
6	Autoput	6	400	02	996	8800	0	5912	4	80
7	Autoput	7	3127	02	33	8800	0	6598	4	80
8	Autoput	8	9	02	1397	12000	0	8371	4	80
9	Autoput	10	2103	02	159	13000	0	9561	16	80
10	Autoput	10	600	02	397	8800	0	5389	7	80
11	Autoput	12	3063	02	111	8800	0	2045	1	80
12	Autoput	12	700	02	308	8800	0	2045	1	80
13	Autoput	13	1100	02	194	8800	0	1403	1	80
14	Autoput	14	15	01	378	8800	0	432	2	100
15	Zrenjaninski	16	2531	11	450	4000	0	1299	4	80
16	Zrenjaninski	18	2526	12	292	5200	0	2364	7	60
17	Zrenjaninski	18	2357	12	102	5200	0	2364	8	60
18	Zrenjaninski	19	2356	12	307	5200	0	2364	8	60
19	Pancevacki	22	2483	12	740	7200	0	680	1	60
20	PA-most	22	23	13	317	3600	0	130	1	40
21	PA-most	23	24	13	447	1800	0	121	1	40
22	PA-most	25	22	13	736	3600	0	550	1	40
23	PA-most	25	20	13	498	1800	0	902	8	40
24	Bul-KA	27	2883	13	626	2600	0	1278	6	60
26	Avalski-put	30	2707	13	695	2600	0	1128	6	60
27	Avalski-put	30	31	13	318	2600	0	1122	7	60
28	Avalski-put	31	3208	13	723	2600	0	1122	7	60
29	Ibarska	33	34	10	1044	7200	0	40	2	80
30	Ibarska	2824	3195	10	802	7200	0	951	4	80
31	Ibarska	2574	2836	10	916	7200	0	1165	5	80
32	Savska-mag	37	38	13	760	2600	0	1767	3	60
33	Savska-mag	39	3213	13	1301	2600	0	1665	2	60
34	Savska-mag	39	40	13	1081	2600	0	1764	2	60
35	Savska-mag	40	41	13	100	2600	0	1876	2	60
36	Obilaznica1	41	42	90	340	0	0	0	0	120
37	Obilaznica1	42	3089	90	437	0	0	0	0	120

Figure 11.VISUM listing with link characteristics

SLinID	OpName	TSysCode	NumStop	Length	RunTime	PassKm[D]	PassKm[Y]
10 H	GSP	T	26	10072	42min40s	1956	586800
10 R	GSP	T	24	10072	42min41s	2505	751500
101 H	GSP	A	24	17304	41min11s	8694	2608200
101 R	GSP	A	24	17256	41min4s	7036	2110800
102 H	GSP	A	4	1384	2min36s	0	0
102 R	GSP	A	4	1384	2min36s	0	0
104 H	GSP	A	18	12632	29min42s	10	3000
104 R	GSP	A	18	12584	29min35s	711	213300
105 H	GSP	A	22	15605	42min1s	119	35700
105 R	GSP	A	22	15557	41min54s	845	253500
106 H	GSP	A	27	25454	52min48s	23	6900
106 R	GSP	A	27	25406	52min42s	538	161400
107 H	GSP	A	2	3193	5min40s	0	0
107 R	GSP	A	5	3193	5min38s	195	58500
108 H	GSP	A	13	10741	28min1s	7588	2276400
108 R	GSP	A	13	10866	28min21s	2205	661500
109 H	GSP	A	3	3193	5min35s	0	0
109 R	GSP	A	5	3193	5min34s	0	0
11 H	GSP	T	22	11098	37min25s	129	38700
11 R	GSP	T	22	11098	37min26s	417	125100
12 H	GSP	T	20	10380	44min40s	2118	635400
12 R	GSP	T	20	10380	44min40s	1440	432000
13 H	GSP	T	19	10541	42min1s	694	208200
13 R	GSP	T	19	10540	42min1s	151	45300
14 H	GSP	T	28	11247	44min15s	3558	1067400
14 R	GSP	T	26	11247	44min15s	2954	886200
15 H	GSP	A	18	8529	28min7s	2318	695400
15 R	GSP	A	18	9455	28min31s	5123	1536900
16 H	GSP	A	22	10487	37min43s	6016	1804800
16 R	GSP	A	23	10187	36min38s	3098	929400
162 H	Lasta	L	8	17074	1h8min15s	0	0
162 R	Lasta	L	8	17074	1h8min15s	0	0
17 H	GSP	A	26	12109	39min53s	21976	6592800
17 R	GSP	A	29	12723	37min39s	14534	4360200

Figure 12.VISUM listing with sub lines characteristics

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 cordons on origin-destination and transit movements. Such research would enable formation of real movement matrixes 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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