APPLICATION OF TRANSPORT DEMAND MODELING IN POLLUTION ESTIMATION OF A STREET NETWORK

by

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The importance of transportation modeling, especially personal car flow modeling, is well recognized in transportation planning. Modern software tools give the possibility of generating many development scenarios of transport system, which can be tested quickly. Transportation models represent a good (and necessary) basis in the procedure of environmental traffic impacts and energy emission estimation. Research in this paper deals with the possibility of using transportation modeling as a tool for estimation of some air pollution and global warming indicators on street network, produced by personal cars with internal combustion engines. These indicators could be the basis for defining planning and management solutions for transport system with respect to their environmental impacts. All the analyses are based on several years of research experience in Belgrade. According to the emissions of gases from the model, the values of other green house gases can be estimated using the known relations between the pollutants. There is a possibility that all these data can be used to calculate the transportation systems impact on temperature increase in urban areas.

Key words: *environmental impacts of transport, demand modeling on street network, pollution estimation, energy emission estimation*

Introduction

Urban transport system development and exploitation could present unique challenge and opportunity to contribute to achieving green house gases (GHG) emission reductions. Passenger cars, often with only a single occupant, dominate personal travel. For example, average occupancy of passenger cars in Belgrade is less than 2 (1.4–1.7 persons per car) [1] and average occupancy of public transportation vehicles (buses) is about 90 passengers. This means that about 50 passenger cars would be needed to transport the number of passengers transported by one bus. The emission of CO for the same passenger kilometers using passenger car is 700 times greater than for the bus. Not to mention the problem of spatial occupancy [2-4].

Road transport percentage share of CO_2 emission from combustion in OECD countries in 2003 was 23% [5].

Sustainable transport principles set numerous requirements in the proces of modern traffic planning, including an analyses of all positive and adverse impacts of the planned measures with respect to spatial development, economy, society, ecology, *etc*. The conventional planning methods for solving specific problems in the traffic system tend to be less used. Instead, solutions with optimal impacts in various aspects are pursued. This, on the other hand, means that economic criteria do not necessarily have to be the only, or the most important ones, in evaluating and selecting the solutions. Transportation planning is not an objective in itself, but it is rather shaping the transport system so as to become compliant with the principles of sustainability [6, 7].

According to the European Union Council of Ministers of Transport, sustainable transportation system is one that [8, 9]:

- allows the basic access and development needs of individuals, companies, and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations,
- is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development, and
- limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise.

However, regardless of the applied approach to traffic planning, quantity of transport demands has to be determined first. Transport demands, on the other hand, depend on spatial development of urban area and land use, as well as on accessibility of some transport modes, costs and management policy (pollution management, parking, transport infrastructure charge, *etc*. [10, 11]).

Energy efficiency has an important influence on transportation planning at the time of energy shortage. Different technical solutions and new infrastructure elements enable numerous options in development of the system which should accommodate growing transport demands. On the other hand, different transport modes have various emission and energy characteristics [12-14].

Selection of different solutions, their analyses, prediction and quantification of the effects of applied measures usually involve application of modeling procedures together with the use of modern simulation tools. If it is not possible to quantify the effects in absolute values, it is always possible to rank the variants in relative sense according to the adopted criteria. Previous analyses and quantification of envisaged measures may provide considerable savings related to "blind" implementation of measures [15].

Environmental analyses relate to the effects of new transport system considering noise quantity, air pollution, warming on street network in the future, *i. e*. what will be the impact of the envisaged actions on transport demands, as the basic parameter which determines the adverse effects of traffic.

Development of infrastructure to improve accessibility induces construction of other types of structures which will result in an increase in transport demands in the future period. For example, upgrading of urban street network or improvement of technical characteristics on some sections may increase capacity and attract more cars [16].

In addition to their indisputable advantages, increased capacity may bring about some adverse effects as well. First of all, construction of new structures is performed in an urban environment or it serves urban environment using its fringe areas. In this way the land area is occupied and its use is thus changed, irrespective of the fact whether the existing traffic route, residential or agricultural land is in question. As a result the system changes its performance relating to spatial distribution of capacities. In this way, from the aspect of accessibility, position of some inhabitants and system becomes improved or aggravated.

This paper addresses the possibility of using transportation modeling as a tool to estimate indicators of air pollution and global warming on the street network. These indicators could be the basis for defining planning and management solutions in the transport system from the aspect of their environmental influence. The point of this environment analysis is to be based on traffic speed on street network, as a transport system feature, but not on vehicle and fuel characteristics.

In the last few years, several capital projects in transport infrastructure have been initiated in Belgrade. The most interesting among them are: the City bypass (about 50% of the project completed), the New Sava bridge (final phase, it will be completed in 36 months), the Inner semi-ring road (preparatory phase), *etc*. All these projects started with transport demand analyses, based on demand modeling [17].

An idea to check possibilities of transportation modeling to estimate indicators of pollution on the street network will be applied to a Case study.

Case study of Belgrade

Belgrade is the capital of Serbia and the biggest city in the Southeast Europe. It lies on the banks of two rivers, the Danube and Sava. Population of Belgrade has increased over 2.5 times in last 50 years of the 20th century. Now, about 1.4 million people live in the urban area of Belgrade [1] .

With a rise in level of motorization, and even only in the case of rise in the level of passenger car use, the existing street network capacity will not be able to accommodate increasingly passenger cars per higher demands. About 67% of the primary street network in the City is with one lane per direction. In addition, traffic management system is obsolete and it is not adequate for traffic demands. Average car speed in the central zone of the City ranges between 12 and 18 km/h, what results in delays which on some sections amount even to 45% of the total travel time [1]. Average level of motorization is about 300 passenger cars per 1000 inhabitants.

Based on traffic survey, the inhabitants of Belgrade perform approximately three million trips per day. In modal split passenger cars participates with 22% of all daily person trips. In peak hour this percentage is about 23%. Total number of passenger cars on the Belgrade street network during day is about 480 000, and in peak hour it is approximately 60 000 [18, 19]. The Master plan of Belgrade 2021 envisages an increase in mobility and a slight increase in number of inhabitants. Hence, it is expected that the total number of trips will be about 3.5 million trips per day. The predicted share of passenger car in the modal split is 25 to 30%. That means that during peak hour there will be about 80 000 passenger cars on the street network [1].

Future Belgrade transport system is defined in the Master plan of Belgrade 2021. One of the main problems in the transport system is lack of bridges and shortage of capacity on the street network. The Plan proposes the building a new street corridor (bridge over the Sava river with the Topcider tunnel), which should be the alternative path to the old Gazela bridge (fig. 2). The old Gazela bridge is the part of the highway Corridor ten (X) and one of the bottlenecks on the Corridor.

New road sections result in new traffic assignment on street network. The main objective of newly built capacities is to balance passenger car volume on network. However, new assignment produces a new quantity of pollution on the same urban area [20]. The question is, does it mean that the benefits in traffic volumes imply the benefit in ecological sense. The answer could be reached trough the modeling process.

Traffic volume analysis in the Case study of the subnetwork (fig. 3) represents the basis for all impact estimations. The street network of interest consists of two alternative paths across the Sava river. First, the road across the old Gazela bridge which is a part of a European Corridor X; and second, across the new bridge and a tunnel. The two paths are connected with the orthogonal high capacity trunk network.

Figures 1 and 2. City area and a detail of network of interest

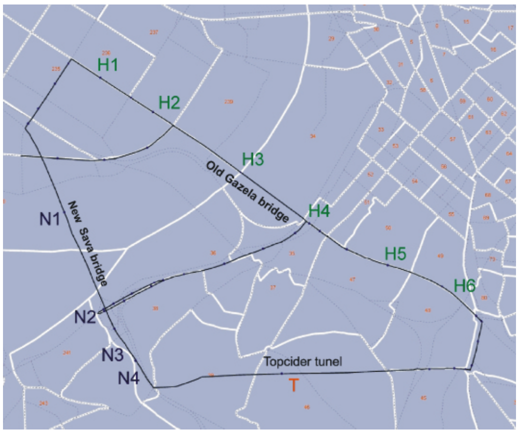

Figure 3. Street network sections in the area of interest

Street and road network was classified according to the street capacity and speed, traffic regime, management system, number of lanes per direction, *etc*. The origin-destination (OD) matrices for specific type of vehicles were taken from the Transport model of Belgrade [18, 19]. They represent the transport demand identified in the traffic survey conducted in the Belgrade urban area. The scenarios were all analyzed during the morning peak hour (7-8 a. m.), when transport demands are extreme and represent the basis for dimensioning the transport system. They were assigned with the passenger car and heavy vehicles OD matrices.

The main consideration when formulating the scenarios were the operating conditions (speeds) on the highway section and Topcider tunnel.

Different vehicle speeds are related to the engine working regime, via the transmission. During the movement, vehicles produce noise and pollution gases. Therefore, the environmental impacts of vehicles could be estimated through the speeds of traffic flow.

Modeling of traffic assignment and pollutant emission levels were done in transportation planning software – Visum. Calculation of pollution emission level is in accordance with emission factors of the Federal Office for the Environment of Switzerland (BUS). Regression curve is defined for every pollutant through:

$$Emiss = a + bv + cv^2 + dv^3 + ev^4 + fv^5$$

The parameters (a, b, c ...) of the polynomials were determined empirically for different pollutants of cars and trucks where v, represents the speed of traffic flow [21].

Assignment analysis

The analysis focused on free flow speeds on two alternative routes (first, across old Gazela bridge and second, New Sava bridge with Topcider tunnel). Different combinations of speeds represent application of different elements of infrastructure that would allow these free flow speeds. It means, also, different traffic volume and different basic environmental consequences in scenarios.

Transportation modeling process is based on Transport model of Belgrade [18], which is a tool that enables determination of various development strategies in relation to changes in transport demands. The Transport model of Belgrade implies a set of relevant data (numeric, graphic, and other), indicators, parameters and simulation models, expressed in space and time.

Two alternatives were compared: scenario S1 (fig. 4) where free flow speeds are equal on both alternative paths, 80 km/h, and scenario S2 (fig. 5) in which free flow speed on the new corridor is higher compared to the old bridge, 80 km/h and 60 km/h.

In the scenario S1, the old Gazela bridge has strong attraction, and hence it is the dominant path with much greater flow of cars than the alternative path. Volume-capacity ratio (Q/C) is in the range of congested conditions. Trucks do not have any options in path choice, since there is a city act regulating the paths reserved for such vehicles. In this way flow of trucks is

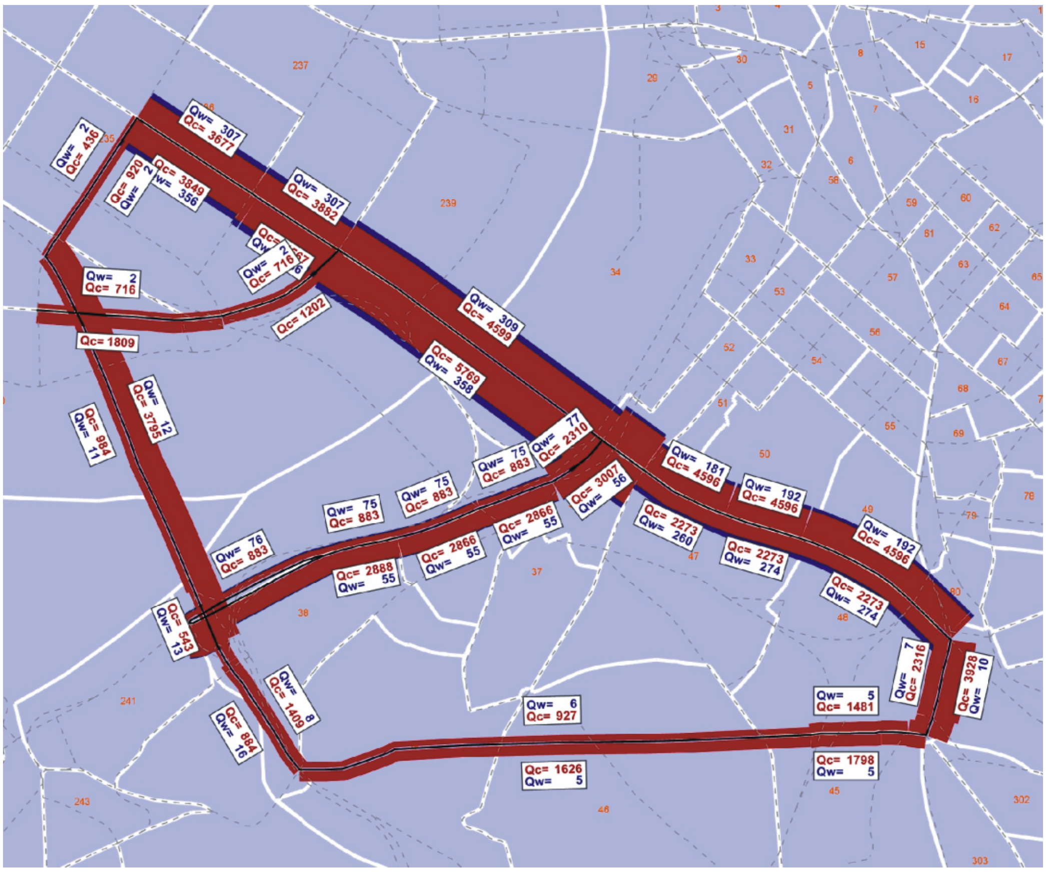

Figure 4. Peak hour traffic volumes – scenario S1 (Qc - Personal car, Qw – Heavy vehicle)

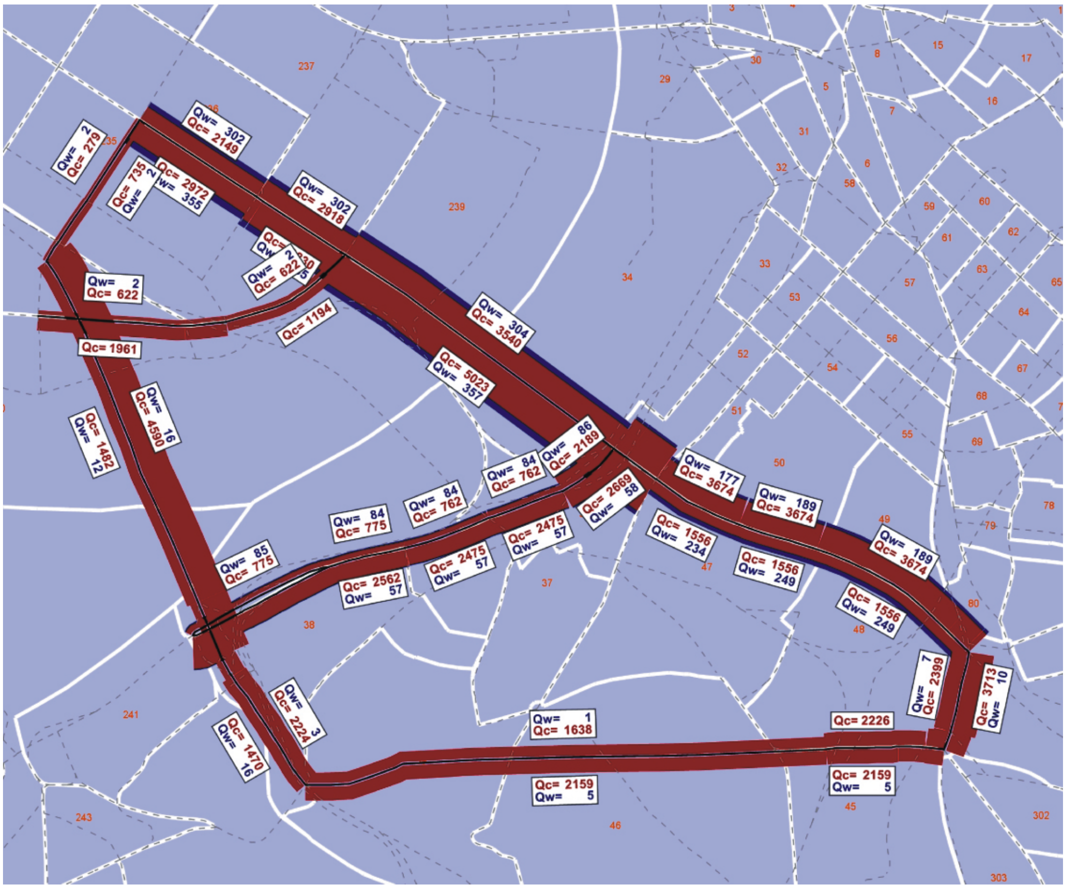

Figure 5. Peak hour traffic volumes – scenario S2 (Qc – Personal car, Qw – Heavy vehicle)

treated as a constant in different scenarios. Lower free flow speeds on the old bridge section give the advantage to the alternative path, thus providing the balance to the scenario. Scenario S2 keeps the old bridge at the limit of capacity and encourages drivers to use the alternative path (because it is faster).

Environmental analysis

Various alternatives of street network produce differences in traffic flow and in environmental indicators. Environmental impact of scenarios S1 and S2 was compared to the results of scenario S2. This scenario displays better traffic conditions (higher speed) on the new Sava bridge than on the Old Gazela bridge, while scenario S1 has the same speeds on both bridges. New network elements should provide better service quality than the existing ones.

Scenario S2 has higher levels of noise on almost all links of the old Gazela bridge. The difference is up to 2.4 dB, with maximal level of 75.3 dB. This increase is significant, considering how hard it is to achieve the reduction of noise. On the other hand, noise on the new Sava bridge is between 0.95 and 2.27 dB higher, with maximal level of 69.91 dB (tab. 1, figs. 6 and 7).

Table 1. Noise levels

	Link	Noise [dB] S1	Noise [dB] S2	S2-S1 [dB]	(S2 – S1)/S2 [%]
Corridor X	H1	73.7	74.7	1.0	1.4
	H2	73.7	75.1	1.4	1.8
	H3	74.7	75.3	0.6	0.9
	H4	72.6	75.0	2.4	3.2
	H5	74.9	73.4	–1.5	–2.2
	H6	74.4	73.4	–1.0	–1.4
New Sava bridge	N1	69.0	69.9	0.9	1.4
	N2	67.4	68.4	1.0	1.5
	N3	64.5	65.7	1.2	1.8
	N4	64.5	66.8	2.3	3.4
Tunnel	T	68.4	70.6	2.2	3.1

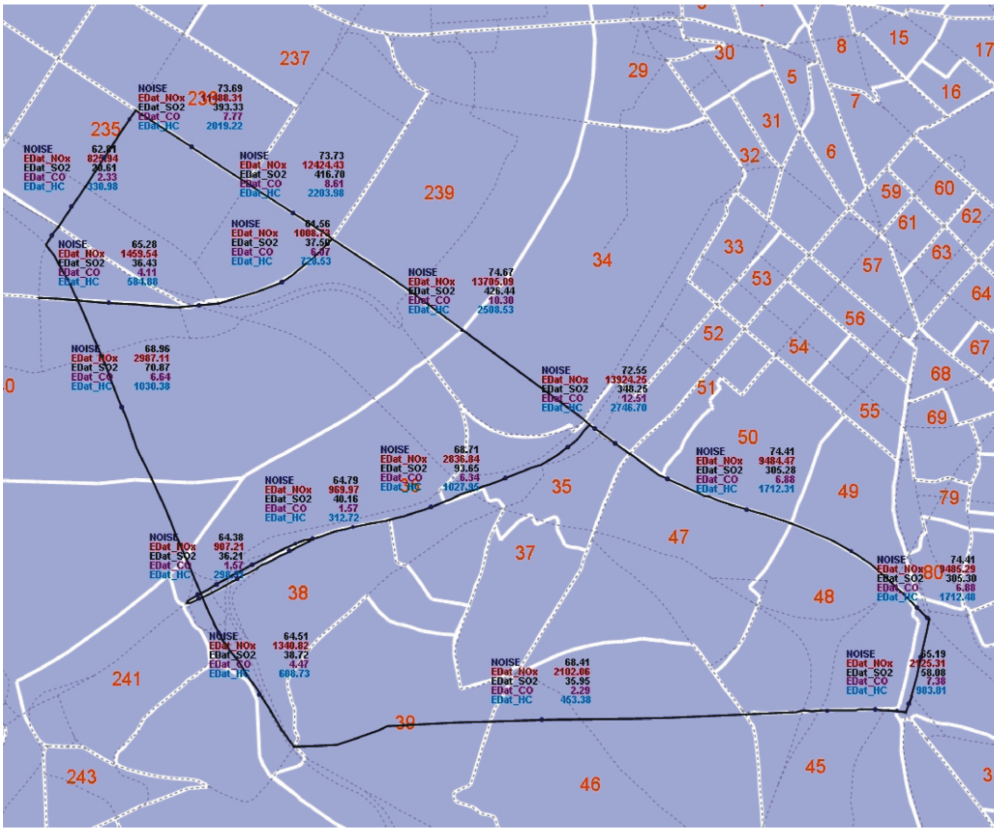

Figure 6. Noise and air pollution indicators – scenario S1

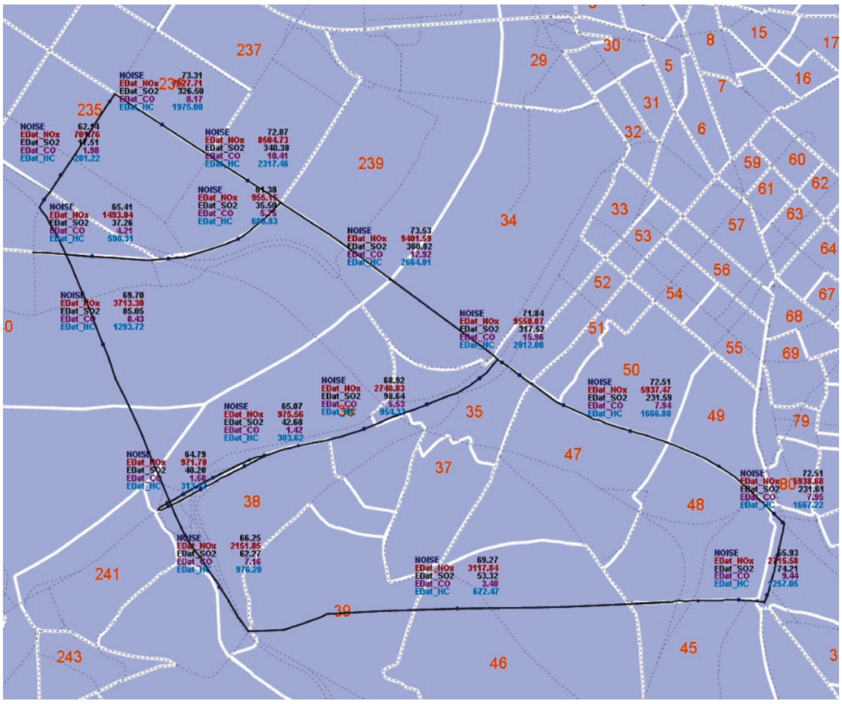

Figure 7. Noise and air pollution indicators – scenario S2

Nitrogen oxides (NO_x) are the product of incomplete combustion. The values on the old Gazela bridge are between 3.2 and 4.4 kg/km lower, while the new Sava bridge has an increase between 0.5 and 1.0 kg/km. The values of reductions in peak hour are much greater than the increase on the alternative path, showing the quantity of benefits (tab. 2, figs. 8 and 9).

Table 2. Nitrogen oxides levels

	Link	NO_x S1 [gkm^{-1}]	NO_x S2 [gkm^{-1}]	S2-S1 [gkm^{-1}]	(S2-S1)/S2 [%]
Corridor X	H1	11488	7528	–3960	–52.6
	H2	12424	8505	–3919	–46.1
	H3	13705	9402	–4303	–45.8
	H4	13924	9550	–4374	–45.8
	H5	9069	5909	–3160	–53.5
	H6	9484	5937	–3547	–59.7
New Sava bridge	N1	2987	3713	726	19.6
	N2	2490	3185	695	21.8
	N3	1176	1684	508	30.2
	N4	1341	2152	811	37.7
Tunnel	T	2102	3118	1016	32.6

Figure 8. Air pollution indicators NO_x – scenario S1

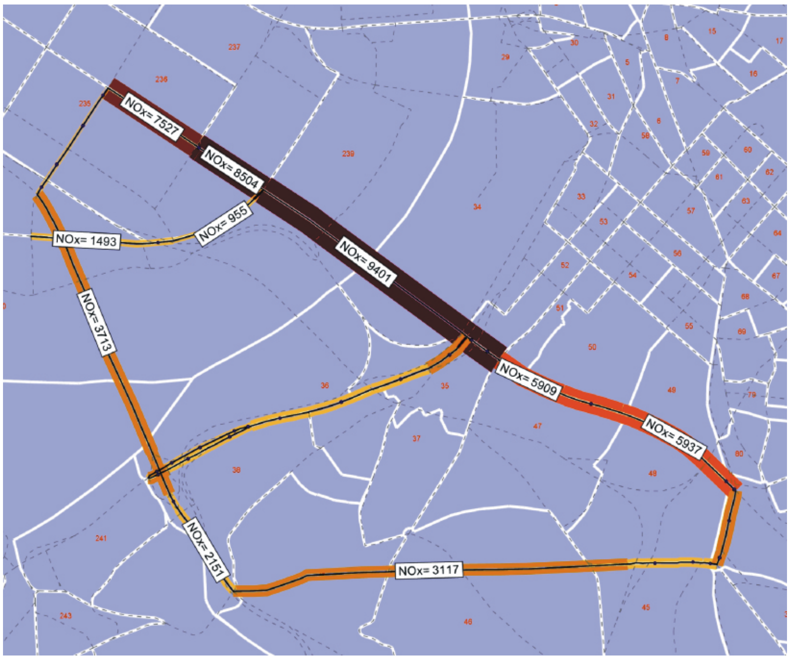

Figure 9. Air pollution indicators NO_x – scenario S2

The sulfur dioxide levels are shown in tab. 3.

Table 3. Sulfur dioxide levels

	Link	SO_2 S1 [gkm^{-1}]	SO_2 S2 [gkm^{-1}]	S2-S1 [gkm^{-1}]	(S2-S1)/S2 [%]
Corridor X	H1	393.3	326.5	–66.8	–20.5
	H2	416.7	348.4	–68.3	–19.6
	H3	426.4	360.8	–65.6	–18.2
	H4	348.3	317.5	–30.8	–9.7
	H5	281.9	230.5	–51.4	–22.3
	H6	305.3	231.6	–73.7	–31.8
New Sava bridge	N1	70.9	85	14.1	16.6
	N2	70.6	89.4	18.8	21.0
	N3	38.1	47.9	9.8	20.5
	N4	38.7	62.3	23.6	37.9
Tunnel	T	36	53.3	17.3	32.5

During the peak hour, the system operates at the limit of its capacity. Consequently, there are higher levels of carbon monoxide on the entire network. The main reason is lower speed of traffic flow and incomplete combustion. The levels of CO on both corridors in scenario S1 are environmentally better than in scenario S2 (tab. 4, figs. 10 and 11). Similar situation is with hydro carbons (tab. 5).

Table 4. Carbon monoxide levels

	Link	CO [kgkm^{-1}] S1	CO [kgkm^{-1}] S2	(S2-S1)/S2 [kgkm^{-1}]	(S2-S1)/S2 [%]
Corridor X	H1	7.8	8.2	0.4	4.9
	H2	8.6	10.4	1.8	17.3
	H3	10.3	12.9	2.6	20.3
	H4	12.5	16.0	3.5	21.6
	H5	6.8	7.9	1.1	13.8
	H6	6.9	7.9	1.0	13.4
New Sava bridge	N1	6.6	8.4	1.8	21.2
	N2	8.4	10.9	2.5	22.5
	N3	3.5	5.7	2.2	37.7
	N4	4.5	7.2	2.7	37.6
Tunnel	T	2.3	3.4	1.1	32.7

Figure 10. Air pollution indicators CO – scenario S1

Figure 11. Air pollution indicators CO – scenario S2

Table 5. Hydro carbon levels

	Link	HC [gkm^{-1}] S1	HC [gkm^{-1}] S2	S2-S1 [gkm^{-1}]	(S2-S1)/S2 [%]
Corridor X	H1	2019	1975	–44	–2.2
	H2	2204	2317	113	4.9
	H3	2509	2664	155	5.8
	H4	2747	2912	165	5.7
	H5	1661	1659	–2	–0.1
	H6	1712	1667	–46	–2.7
New Sava bridge	N1	1030	1294	263	20.4
	N2	1138	1461	323	22.1
	N3	510	769	259	33.7
	N4	609	976	367	37.6
Tunnel	T	453	672	219	32.6

Transportation system performance

Measures of transportation system performance may include vehicle-kilometers traveled, level of congestion, speed, travel times, or other parameters. System performance measures, such as travel time savings and vehicle-kilometers traveled, are commonly used in transportation planning. Various aspects of system performance can also be used as the key inputs for forecasting other impacts. For example, vehicle-trips, vehicle kilometers traveled, and vehicular speeds are used to forecast emissions of criteria pollutants. Transportation performance also affects accessibility, which in turn affects land use patterns as well as economic development [22, 24].

Important outputs of the Case study analysis are vehicle hours and vehicle kilometers: vehicle hours for economic analysis and vehicle kilometers for environmental analysis. Scenarios comparison gives relative values of measures applied and enables quantification of effects.

Through the modeling process in the Case study, vehicle kilometers and vehicle hours were computed for subnetwork of interest.

Comparison of specific scenarios of traffic parameters indicates that scenario S2 has certain advantages with respect to traffic assignment throughout the street network (tab. 6). The same transportation demand produces less vehicle kilometers with a slight increase of vehicle hours.

However, comparison of environmental scenarios shows a different picture. The analyzed network and its orthogonal cros-sections loaded with peak hour traffic volumes produces different pollution emissions for scenarios S1 and S2. Compared to S2, pollution levels of NO_x and SO_2 decrease while the levels of CO and HC increase.

The effects of various pollutants on environment and heating are different [25]. Measuring those effects, as an overall impact on the environment, would require use of weighting factors for different impact elements.

Table 6. Global traffic and pollution indicators

Indicators	Scenario 1	Scenario 2
Vehicle kilometers	71182	68746
Vehicle hours	1630.5	1654.3
Nitrogen oxides [kg]	70,6	58.3
Sulfur dioxide [kg]	2.1	1.9
Carbon monoxide [kg]	86.2	99.9
Hydro carbons [kg]	16.6	17.9

The modeling output given in the Case study could provide the basic elements of congestion, for example, the emission of CO and NO_x. According to those values, using the relations between pollutants, other pollutants emissions could be calculated (CO_2, H_2O, and CH_4). In this way all of the GHG produced by traffic could be estimated. This estimate of the overall impact of traffic could be valuable as input data for performing calculations of traffic influence on global warming.

The use of transport modeling for computations of air pollution components of street network traffic shown in this paper can be the first step in estimation of all GHG emissions. The relations between emissions of different GHG by vehicle kilometer traveled can be used, as suggested by U.S. Department of Energy* [26, 27]. The data represent gasoline exhaust products per vehicle kilometer traveled. The relations among the pollutants should be selected to fit the characteristics of fuel and vehicle fleet, or obtained by a specific survey.

Summary and conclusions

Transport demand modeling as a pollution assessment tool was initiated to provide an aid in the decision making process related to street network planning.

Conventional evaluation of alternative street networks is based on operational and economic criteria. However, the principles of sustainable planning imply that, besides economic, other aspects should also be included, particularly those within the scope of traffic related environmental conditions.

Belgrade Case study, based on the existing Transport model of Belgrade, shows that it is possible to use traffic assignment models to predict and quantify pollution on urban street networks.

Traffic modeling on a street network gives a possibility to simulate environmental indicators of noise and air pollution by network sections, generated by the use of passenger cars. In this specific case it relates to quantification of noise, CO, NO_x, HC, and SO_2, that are generated on two bridges across the Sava river and in the newly built tunnel – depending on the speed on the network, which in turn depend on street design and management measures.

Sometimes a solution that is the best from traffic point of view may not be optimal from ecological point of view.

The major disadvantage of this pollution indicators assessment procedure may be lack of adequate databases on characteristics of vehicle flow in cities, as well as databases on exploi-

* Alternatiaves to Traditional Transportation Fuels, 1994, The Energy Information Administration – Office of Coal, Nuclear, Electric and Alternative Fuels – U. S. Department of Energy

tation characteristics of the street network and traffic infrastructure. Also, characteristics of vehicle fleet and fuel have to be estimated.

Future research activities in the area of transport demand modeling in pollution assessment should be oriented towards development of the tools for transport demand modeling in global warming assessment.

Objective dimensioning of adverse environmental effects of car use represents significant aid for those who make decisions about traffic infrastructure development. This implies formalization of the proposed procedures within decision making process.

In order to establish daily or annual values of emissions it is necessary to apply average annual daily traffic (AADT) for modeling.

Future analysis would refer to identifying the typical vehicle in the passenger car fleet of survey area, measuring the fuel economy and fuel characteristics.

References

[1] ***, Master plan of Belgrade 2021 (in Serbian), Urban Planing Institute of Belgrade, Belgrade, 2003
[2] Vuchic, V., Urban Transit System and Technology, John Wiley & Sons, Hoboken, N. J., USA, 2007
[3] Vuchic, V., Urban Transportation: Operation, Planning and Economics, John Wiley & Sons, Hoboken, N. J., USA, 2005
[4] Yang, M., Climate Change and GHGs from Urban Transport, Asian Development Bank, Metro Manila, Philippines, 2002
[5] International Energy Agency (IEA) http://www.iea.org
[6] Dalkmann, H., Transport and Climate Change, Modul 5e – Sustainable Transport: A Sourcebook for Policy-Makers in Developing Cities, GTZ Divission, Federal Ministry for Economic Cooperation and Develoment, Eschborn, Germany, 2007
[7] Vukanovic, S., *et al*., Data Base for Economic Evaluations of Transport Infrastructure Projects in Belgrade Area (in Serbian), Traffic and Transprot Engineering Faculty Institute, University of Belgrade, Belgrade, 2006
[8] ***, Victoria Transport Policy Institute, Online TDM Encyclopedia (TDM Transportation Demand Management Mobility Management), http://www.vtpi.org/tdm
[9] ***, The Global Development Research Center: Urban Environmental Management Guiding Principles for Sustainable Transportation, http://www.gdrc.org/uem/sustran.html
[10] ***, Bureau of Equity and Environmental Services, Transportation and Global Warming: Defining the Connection and the Solution, WisDOT Research & Library Unit, 2007
[11] Wada, K., Sectoral Approaches in Global Warming Measures – Expectations, Expected Roles and Its Challenges, Energy Conservation Group, Global Environment and Sustainable Development Unit, IEEJ, Japan, 2008
[12] Saunders, M. J., *et al.*, Incorporating Transport Energy into Urban Planning, *Transportation Research, Part A. 42* (2008), 6, pp. 874-882
[13] Tomboy, W., Environmental Affairs Group, Toyota Motor Europe, Making Energy Efficiency Work in Transport, International Cooperation on Energy Efficiency, Geneva, 2008
[14] ***, Cordis – Information & Conumication Technology: Mobility, Environmental Sustainability and Energy Efficiency, http://cordis.europa.eu/fp7/ict/programme
[15] Djoric, V., Transportation Demand Modelling: Sustainable Transport and Energy Eficiency Aspect (in Serbian), *Tehnika – Saobraćaj, 17* (2008), 6, pp. 17-24
[16] Vuchic, V., Transportation for Livable Cities – CUPR – Rutgers University, N. J., USA, 1999
[17] Jovic, J., *et al.*, Traffic Assignment Analysis on Belgrade Half Ring Using Transportation Model of Belgrade (in Serbian), Traffic and Transport Engineering Faculty Institute, University of Belgrade, Belgrade, 2006
[18] Jovic, J., Modern Tool in Transportation Planning – Transport Model of Belgrade, *Transporti Europei, 9* (2003), 24, pp. 31-38
[19] Jovic, J. *et al*., Transport Model of Belgrade (in Serbian), Transport and Traffic Engineering Faculty Institute, University of Belgrade, Belgrade, 2007

[20] Djoric, V., Ecological Parameters Modelling Using VISUM Program Pack on Basis of Transportation Model of Belgrade (in Serbian), *Tehnika – Saobraćaj, 16* (2007), 5, pp. 11-18
[21] ***, VISUM 10.0 User Manual – PTV Planung Transport Verkehr AG, Karlsruhe, Germany, 2007
[22] ***, Inter Academy Council: Energy Demand and Efficiency and Transportation Energy Efficiency, http://www.interacademycouncil.net/CMS/Reports
[23] ***, UIC: Energy Efficiency, http://www.uic.asso.fr/uic
[24] ***, US Department of Transportation, Federal Highway Administration, Transportation System Performance, http://www.fhwa.dot.gov/Planing/toolbox/transperf_overview.htm
[25] Rhode, H., A Comparison of the Contribution of Various Gases to the Greenhouse Effect, *Science, 248* (1990), 4960, pp. 1217-1219
[26] Wang, M. Q., Measurement of Emissions: Greenhouse Gas Estimates for Alternative Transportation Fuels (unpublished), Final report prepared for Energy Information Administration, Vienna, VA, 1995
[27] ***, EIA (Energy Information Administration), Alternatives to Traditional Transportation Fuels 1994, Vol. 2, Greenhouse Gas Emissions", http://www.eia.doe.gov

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