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Review Paper

IMPORTANCE OF TRANSPORT ANALYSIS IN LARGE URBAN PROJECTS

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Abstract. *In a series of urban analyses used in the development of urban plans, there is also a traffic analysis. It is aimed at assessing the impact of the capacity of planned contents on the transport network of the narrower and wider area. In this paper, a large city project for the Belgrade waterfront area was selected as a case study and the analysis done as a transport study for the planning process for this location. Traffic analysis deals with the assessment of how much load planned purposes (housing, business, commercial, public facilities, etc.) will generate and how this will affect the existing and planned road network, standing out approach with six basic phases used in the research and description of the differences between three conceptualized network designs. For these purposes, the appropriate software is used, which for the set network load parameters at different times of the day creates scenarios of the number of vehicles and dominant directions of movement and indicates the shortcomings of the network that needs to be adapted to the requirements of users (0 –with modest attractiveness based on previous plans for the area, 1-3 for different network designs in the peak hours). This type of analysis with its results provides an input or planning the spatial organization of content and connections within the area and with a wider environment.*

Key words: *urban planning, large project, transport analysis, traffic network, Belgrade waterfront.*

1. INTRODUCTION

Urban and spatial planning is one of the basic instruments for examining and directing the spatial dimension of sustainable development (Awasthi, et.al., 2018). The role of the planner is particularly evident when planning densely populated urban areas, for which investors, political supporters, and the planner must first and foremost consider and resolve the problem of traffic limitations. This requires specific methodological procedures

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that go beyond the development of a specific plan, requiring analysis and planning at the level of the whole city.

A traffic model is an essential tool primarily for planning but also for operating road traffic infrastructure. It is a mathematical model for simulation of traffic situations in reality, relying on theoretical foundations like network theory and kinematic wave model. The quantity being modeled and measured is the traffic flow: the throughput of vehicles per time and capacity of streets. The creation of the model aims to indicate a possibility of the traffic jams and to ensure an optimal flow in the network. By modeling it is easier to understand complexity of interactions and predict the behavior of the traffic system. The models usually include a description and a design of the urban streets network (their capacity, number of lines, intersections, directions, signalization, etc.) and assumptions on the users' behavior (choice of using personal cars or public transportation, or alternatives like bicycles, peak hours, etc.). Simulation, as a tool, provides visual demonstrations of the present scenario and for different future scenarios. The results can be useful for traffic engineering analysis, evaluation of new infrastructure designs a priori, as input to social-economical models, energy use, emission and air quality estimation models, or for developing and testing traffic control.

For this paper the most significant aspect is the research for needs and terms of development, calibration, and application of long-term traffic forecasts models based on attraction and production for large and new urban area, interpolated in the existing surrounding. It explores how and why it is necessary to include a transport model simulation in urbanization processes in a sustainable way, processing local characteristics, and promoting integrated, inclusive, comprehensive, and multidisciplinary ways in the process of planning, designing, and decision-making. The purpose is to present an approach and review all the steps of the conducted transport analysis, required input data, studied scenarios and the significance of the obtained results on the selected case study, and give recommendations for the future use of similar studies for planning purposes. The goal is to test an initial hypothesis about the possibility of an indication of the practical application of the theoretical model and a prescription of the necessary steps to achieve improvements in sustainable urban planning and design. The novelty is in the multilevel analysis of the customary processes with the added value of a specific and demanding context in the case study. The necessity for such a scientific investigation lies in the need for summarizing important methodological steps, drawing parallels between requirements and achieved results, and indicating possible applications in other conditions that require a special attention when interpolating new content.

The paper starts with a literature review, referring to relevant researches that are thematically close to the topic, and this is compared with findings from the case studies later in the Discussion. The chapter Initial position gives an overview and a contextual base for a better and easier understanding of the location, explains the concept and chronology of the planning process including the available and used initial data and documents. In Materials and methods the research goes deeply in the case study and transport analyses. The context is followed by Results with an interpretation of analyses for various scenarios of attraction and production and influence on traffic load. The chapter Discussion and Conclusions, besides referring and comparing to international experiences, includes the main conclusion. Despite the transport analysis being quite a common instrument for modeling, screening and exploration, the contribution of the paper is its focus on describing phenomena within the context of large-scale development in question, with the possibility of using this experience and comparing it with other similar situations, demands, and locations.

Authors proceed from the thesis that, when planning large projects in a city, it is essential to conduct a transport analysis of the attraction and production (traffic load) of the planned content on the wider transport network of the city, as a key method and one of the first steps in planning. The decision to introduce such a method is crucial, as urban transformation at this scale implies a greater impact on the overall city system. Expected outputs and outcomes should be considered in terms of the spatial distribution and organization, capacity limitations of the area, and efficient connectivity with the surrounding urban tissue. In order to carry out such an analysis, it is necessary to have an adequate information base, containing data from both existing plans and the newly planned project. In addition, it is necessary to have access to GIS software and a transport model of the city. The informational base used for the calculations and simulations of the scenarios in this paper was “The transport model of Belgrade”, used previously in practice, but here for the first time with respect to such a large and central location, with great urban regeneration change. For transport analyses that rely on the use of a model, it is essential to determine the input data for that model; that is, how to examine the possible volume and distribution of trips, depending on the volume and structure of the newly planned content. In this paper, we present a new methodological approach, used for conducting a transport analysis for the planning and implementation of one of the largest projects in recent years in Southeast Europe. In accordance with the above, this paper belongs to the fields of water-front urban development and urban transport planning. It is a case study, showing how transport analyses influence the creative process of urban planning and the associated final decisions. Our purpose is to emphasize the importance of this approach in this kind of large city project, with a special goal to appoint the key role of transport analyses for redefinition of the proposed plan’s solutions and finalization of the implementation. The paper describes the process, with an overview of the experience and the final outputs. In the literature review and discussion, the research is connected with a theoretical basis and results provide data that will be useful for future urban regeneration plans.

2. Literature Review

Some authors in the literature have expressed similar attitudes, which we build upon in this paper, starting with pointing out the significance of transport as one of the three most important aspects of urban development, together with land-use and environmental protection (Waddell, 2002); namely, the need to consider the sustainability of transport (Goldman & Gorham, 2006) and connecting land-use with transport accessibility (Geurs & Wee, 2014) and transportation planning (Guerra et.al., 2018). Particularly significant are the views that, in recent years, transport plans have been necessary for new investments, as well as in the development of plans and the consideration of land-use (mainly in the United Kingdom, the United States, Continental Europe, and Australia) (Gruyter et. al, 2018).

However, literature reviews of the theories of urban development and transport planning, as well as the experiences in planning and transformation of urban waterfronts, so far, are of the greatest importance for such a research (Wang & Lu, 2001; Timur, 2013; Norcliffe et. al., 1996; Colquhoun, 1995). Wrenn, Casazza, & Smart (1983) pointed out the importance of transportation changes during urban transformations of waterfronts, including the relocation of ports, industrial activities, and new land-uses. Experiences based on case studies have been present-ed in the literature by Dovey (2005) for the Melbourne urban waterfront, Lehrer & Laidley (2008) for the Toronto waterfront, and Chang & Huang (2010) for the Singapore waterfront. Any successful waterfront redevelopment, according to the research of Hoyle (2000) reflects varied forces and trends, involves community attitudes and environmental sensitivities, and in-fluences transport evolution and urban change. The revitalization phenomenon has been examined using community attitudes in Canada and urban regeneration in East Africa, in order to illustrate retrospective and prospective dimensions.

Changes in the urban development of waterfronts for megaproject construction in Central and Eastern Europe is not a new topic, as it has been seen before, for example, in the town of Orsova after the Iron Gates hydroelectric power station was constructed (Varan & Cretan, 2017; Cretan & Vesalon, 2017), or for the largest private property development project in Tallinn (Feldman, 2010). In the literature, the authors have mostly pointed out that mega-project construction could lead to environmental and social risks in certain countries (Vesalon & Cretan, 2013). In this way, the political ecologies of mega-projects could be welcome as proper development projects, but could also be contested by the local people. Keeping in mind that the case study location used in the present paper is next to passenger docks used for river cruising boats, it is possible to draw correlations with tourism development and creating the image of the city at this particular nodal point (Light, et. al., 2020; Danilović Hristić, et. al., 2020). Due to burgeoning research in the field, new measures, new evaluation methods, and new theories and approaches for incorporating flexibility into large-scale infrastructure design have appeared (Taneja, el. al., 2011; Jakovljević, et.al., 2015; Stokić & Radovanović, 2015).

For the subject of this paper, the most interesting comments have been presented by Grubbauer & Camprag (2018), who stated that, during the development of the Belgrade Water-front Project, public interest was declared for the needs of the private investor and opportunities for local people to influence solutions were reduced. Many authors have argued about procedure and process of Plan development and adoption (Petrović Balubdžić, 2017; Petrović Balubdžić, 2020; Kadijević & Kovačević, 2016), public engagement (Cvetinović, 2016; Koelemaij, 2019; Lalović, et.al., 2015; Fagan & Ejdus, 2020, Perić, 2020), urbanism for the investor (Krsmanović, 2020; Koelemaij, 2020, Aranđelović, et.al., 2017; Aranđelović, 2020; Backović, 2019; Djukić, et.al., 2020), and public domain (Zeković, 2018; Zeković & Maričić, 2020; Machala & Koelemaij, 2019; Pope, 2020; Matković & Ivković, 2018), thus leading to the conclusion regarding how significant and unique this area is.

In addition, the emphasis in the literature has generally been placed on models. The im-portance of transport models and their connection with planning practice has been indicated by Brömmelstroet & Bertolini (2011), as well as Algers, Eliasson, & Mattsson (2005). It is also interesting that the models belong to "knowledge technology" applied in the field of transport, but which are often little (or not at all) used, resulting in poorly designed plans; the responsibility for this has been placed on irrational decision-making and politics (Gudmundsson, 2011). Individual authors have further pointed out the significance of models and simulation of service levels on city streets (Bhuyan & Nayak, 2013) and emphasized the goal of identifying missing traffic connections (Krivda, et. al., 2021).

In some literature (Zeybek & Kaynak, 2008; Fainstein, 2009; Dostál, et. al., 2021), this kind of large project's influence and the transport system dimension of planning has been high-lighted. The novelty of this paper and the advancement with respect the current literature is in explanation of the criteria for model development and testing the impact of the project proposal on macro location scale.

3. Initial Position

The area covered by the Belgrade Waterfront project (Regulation on the Establishment of the Spatial Plan for the Special Purpose Area of the Riverside Region of the City of Belgrade - the area of the Sava River Basin for the project "Belgrade on the Water", 2015) is 177 ha on the right bank of the Sava River, in the central area of Belgrade. The Plan was prepared for this area and declared as a national interest, adopted by the Government of the Republic of Serbia (Figure 1). The authors were responsible planners and team leaders in the process of making the plan and, in this context, they delivered analyses during the planning process, as described in this paper. This involves a complete change of land-use, as most of that space was used by Belgrade Railway Station and rail infrastructure, with a significant part of the area being dilapidated and serving no real purpose. The Belgrade Waterfront project envisages the construction of almost 2,000,000 m^2 of buildings with different purposes, the majority of which are for housing, business, and commercial purposes (Figure 2, Table 1). The project is characterized by planned high density construction (63% land occupancy) and multiple-story (i.e., high-rise) buildings (up to 110 m, with the emphasis on a business and residential tower 180 m in height). The project is being implemented by the public/private partnership Belgrade Water-front, established by the Government of the Republic of Serbia. Work on this plan has been marked by its regional aspect, which is related to the planning of transport and infrastructure systems, requiring modeling, projections, and planning far beyond the scope of the project (i.e., at the level of the entire city of Belgrade).

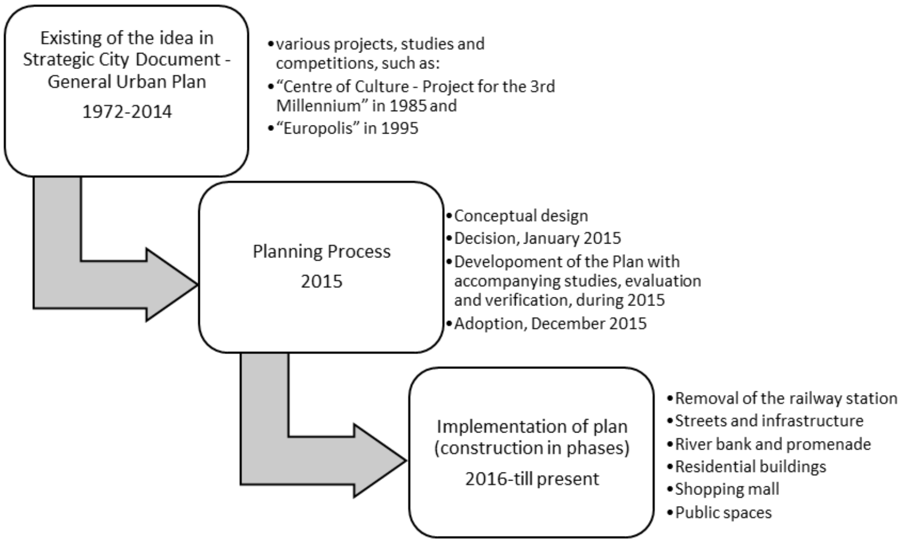


Fig. 1 The general timeframe of the realization of the BWF project
(*Source*: Authors)

A special attention was paid to the protection of public interest, as production of the plan was followed by the constant criticism from the section of the public that was against the realization of the project, which is often the case in the planning of "mega" projects (Dogan, 2015). In accordance with the analysis of the existing state, the overall goal of the plan was to transform and completely reconstruct the dilapidated area into a new, modern city center - socially acceptable, economically viable and spatially integrated into the Belgrade's existing cultural and historical spirit. Based on the stated general goal, several operational goals were stated, of which the most important are: harmoniously fitting into the natural environment, with a special emphasis on flood protection; the formation of a new public transport system, with a focus on railways; complete regeneration of infrastructure; the protection of cultural property of particular importance; forming new gathering places; creating a new tourism brand. In addition to the problem of transport, the complexity of the project is compounded by the fact that the space is situated on the bank of the Sava River, in the vicinity of its confluence with the Danube River, which is the main symbol of the city. This raises many questions concerned with riverside planning, as has been pointed out by numerous authors; in particular, (Jones, 1998; Millspaugh, 2001; Bruttomesso, 2001, 2004; Butuner, 2006; Wegener, 1998).

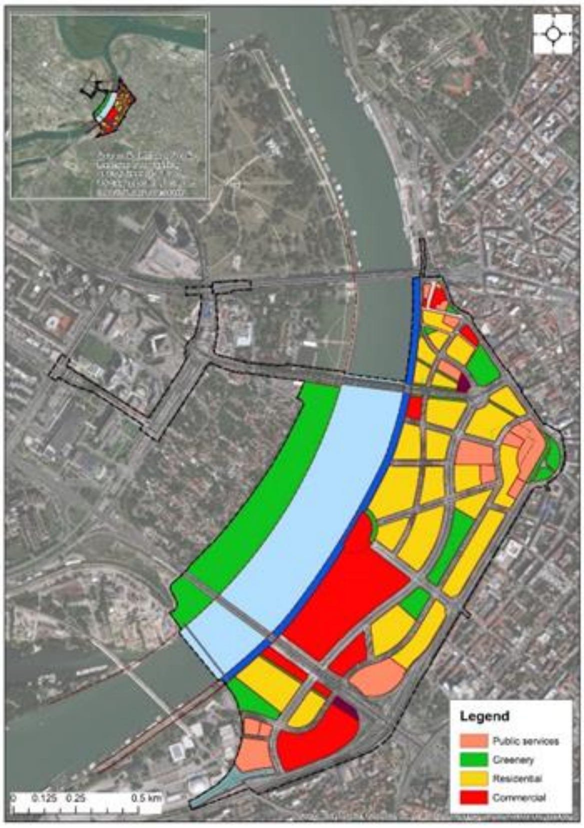


Fig. 2 The position and layout plan with the planned land-use purposes for the area and roadways of the Belgrade Waterfront Project

(*Source*: Authors, on the base of the Spatial Plan for the Special Purpose Area of the Riverside Region of the City of Belgrade - the area of the Sava River Basin for the project "Belgrade on the Water")

The following information and data were used in the preparation of the Transport analysis:

- The master plan proposed by the investor (draft delivered by Ministry of Spatial planning was a part of the initial idea, developed by the private foreign investor—Eagle Hills Company—involved in the realization of the project). A textual explanation of the Belgrade Water-front Project, with basic planning solutions as a part of initial project proposal, including land-use dispersion, expected gross building area, volumes of the structures, and basic plot of the internal traffic matrix;
- Proposed initial elements of the Spatial-urban plan: The situational solution for the location of the Belgrade Waterfront Project, with the planned purposes for the area, the transport solution, and regulating and leveling elements prepared by the licensed urban and traffic planners on the basis of the Master plan (with partial adjustments);
- The General Urban Plan of Belgrade (General Urban plan of Belgrade 2021, "Official Gazette of Belgrade" No. 11/2016);
- The Transport Master plan of Belgrade SMART PLAN (The Transport Master plan of Belgrade SMART PLAN), developed especially for monitoring the transport system functioning and collecting all necessary data continuously, in order to analyze the current state and its changes, or to predict scenarios regarding the urban transport in the Belgrade city area; and
- GIS Transport Model of Belgrade, containing analyses of the traffic flow for the entire city with the designed load of the existing and planned uses and capacities.

The General urban plan of Belgrade is a strategic development plan with general elements regarding the spatial development of the city. It contains general urban solutions with the main purposes of the area, general routes and corridors, transport and other infrastructure, and other elements. In the analysis, the projections for transport parameters were used from this plan, on the basis of which the trends of transport supply and demand for a long-term planning period were determined.

The transport model for Belgrade, developed by Urban Planning Institute of Belgrade for the purpose of producing plans in the City of Belgrade, served as the basis for the analysis and evaluation of the model. In it, on the basis of the general urban plan as the base scenario for the development of Belgrade, prognoses were defined for the transport parameters and transport infrastructure, as well as the demand for the movement of passenger cars and public transport for several time periods until 2021. This kind of transport model leads to a direct connection between the land-use and volume of construction and the transport parameters, pointed out particularly in the research (Wegener, 2004; Webster, et. al., 1988, Crame, 2000, Kasraian, et. al., 2018; Wardman, et. al., 2016). The transport model was developed using the PTV Visum software package, and it contained 550 zones (77,000 ha) and a length of the primary street network of around 2000 km with 7000 sections. It contains an origin–destination matrix of car trips and public transport passengers for two rush-hour periods: The morning (7–8 AM) and afternoon (4–5 PM) peak hours.

4. Materials and Methods

The aim of the presented transport analysis was to establish the following for the final phase of the Belgrade Waterfront Project, depending on the volume and structure of its contents: The possible trip generation in peak time periods (Stathopoulos & Tsekeris, 2003); their distribution, according to the type of transport; a method of connecting a location with the primary street network and public city transport system; and any necessary interventions in the improvement of the transport system. Our goal was to design the most efficient transport service, both for the locations concerned and the city as a whole.

The methodological approach can be seen in six basic phases: 1) analysis of the land use and capacities of project; 2) selecting, processing and defining traffic and urban data which will be used to estimate the trip production; 3) estimated trip production and the expected number of cars on the street network generated by the Project; 4) defining three basic scenarios of street network in Project area; 5) evaluation phase in GIS traffic model of the City; 6) application of analysis results - selection of the scenario, correction and promotion of project elements, definition of new planning solutions of importance for the whole city. This methodological approach was applied for the first time in the city of Belgrade, with a special novelty in defining traffic and urban data and estimation of the trip production.

The statement that one of the most important steps is to create a model concept, and the correct methodology for model creation is selected, and the appropriate (or required) degree of abstraction of the analyzed locality is determined (Krivda, et.al., 2021), is absolutely applicable to this research.

The specificity of the methodological approach can be seen in the quantification of the project area for the Belgrade Waterfront Project and estimation of the number of trips generated by the planned content. Unlike earlier, mainly using statistical methods based on the traffic counting data and their relation with the construction and planning capacities, using average values of the parameters at the level of the city, we set up a methodological approach which starts from the specifics of the space and the planned project. In addition, this methodological approach takes into account new urban strategies in the area of sustainable transport and mobility, considering the trip distribution using different types of transport and the greater role of public transport, as well as the real framework of budgeting for their implementation.

The basic data for the planned Belgrade Waterfront Project, which was the starting point for the authors, consists of the balance of the area for the planned purposes, on the basis of which the number of units and the expected number of inhabitants and employees were calculated.

Table 1 General information about the area and capacity of the Belgrade Waterfront Project
Source: Spatial Plan for the Special Purpose Area of the Riverside Region of the City of Belgrade - the area of the Sava River Basin for the project "Belgrade on the Water"

Land-use	Gross building area (m^2)	Number of units (apartments, offices, rooms)	Capacity (residents, employees)
Residential buildings	1,065,747	5,684	16,484
Schools, kindergartens	41,080		
Hotel	153,910	2,199	
Commercial space	95,632	480	
Shopping mall	148,444		
Business offices	386,450	3,864	12,634
Culture, leisure, entertainment	26,987		
Total	1,918,250		

In addition to these data, we used the following parameters to estimate the trip production:

- Employment rate of 40%;
- percentage of movements in the morning peak hour of 70%;
- area per employee of 60 m^2;
- number of trips per area unit (100 m^2), depending on the type of content;
- the distribution of types of transport - on foot 20%, by car 30%, and public transport 50%;
- car occupancy of 1.4 passengers per vehicle; and
- origin to destination ratio of 20:80% in the morning peak hour and 53:47% in the after-noon peak hour.

Based on the above data, the trip production and distribution generated by this area after the final implementation of the planned content was estimated for two relevant time sections: Morning and afternoon. For this assessment, in the morning peak hours, the primary trips were departure and arrival at work; while, in the afternoon peak hour, trips to commercial facilities were also included. The total number of car trips was distributed according to origin/destination trips: In the morning peak hour, the percentage ratio of origin to destination trips was 20:80; while, in the afternoon, this figure was 53:47 (calculation is based on yearly statistics and outputs of GIS Transport model of Belgrade).

Table 2 Estimated trip production in the afternoon peak hour and the expected number of cars on the street network generated by the Belgrade Waterfront Project

Land use	Number of passengers	Number of passengers on foot	Number of passengers by car	Number of passengers in public transport system	Number of trips by car
Residential buildings	4,616	923	1,615	2,077	1,154
Hotel	1,297	259	454	584	324
Commercial space	4,780	956	1,673	2,151	1,195
Shopping mall	11,876	2,375	4,156	5,344	2,969
Business offices	13,897	2,779	4,864	6,254	3,474
Culture, leisure, entertainment	2,159	432	756	972	540
Total	38,624	7,725	13,519	17,381	9,656

Source: GIS Transport model of Belgrade, Urban Planning Institute of Belgrade, PE

The data obtained were used to determine the load for the city transport model; that is, a correction was made to the origin–destination matrix of car travel for 2021 for roadway zone 34, which fully occupies the space intended for the implementation of the Belgrade Waterfront Project, as well as for the wider surroundings. At this stage, an analysis of the impact of the attraction and production of the project was conducted for the morning and afternoon peak periods; however, as the load on Belgrade's road network is the heaviest in the afternoon peak hour and origin–destination trips are relatively balanced, we continue by presenting the effects of the attraction and production on the afternoon peak hour, both on the internal traffic solution and the wider surrounding network.

In the literature, researchers have often considered the problem of such assessments and parameters of transport flows, as well as the problem of defining the origin–destination matrix of trips in city transport networks, while pointing out the need for examining and improving the reliability of such methods (Anand, et. al., 2015; Chikaraishi, et. al., 2015, Lyons, 2016). A transport analysis of the attraction and production of the planned contents was carried out by entering situational solutions for the project, in the form of three basic scenarios, into the scenario for the street network of the city for 2021 (Scenario 0), which contains the existing and planned street network.

In Scenario 1 (Figure 4), a central high-capacity road is planned, which extends through the central part of the area, with the role of introducing traffic flows into this zone and servicing specific content in the immediate surroundings. This road is linked by two junctions with a full program of connections through peripheral roads. In this scenario, the functioning of the existing tram bridge is planned in the system of road and rail transport, integrated with one lane in each direction and an inflow–outflow-type connection to the central, high-capacity road. The tram traffic from the bridge is the same as its current state to the peripheral streets (B). In addition to this access to the subject area, four more positions were planned, by means of an inflow–outflow junction and roundabouts. At the same time, the penetration of three radial roads towards the Sava River is planned, which increases the availability of the contents planned inside this space.

In Scenario 2 (Figure 4), the central roadway (A) is in a new position, in the direction of the bridge via an intersection with a full program of connections linked with the peripheral road (B); meanwhile, at the opposite end, the connection is planned by means of an inflow–outflow-type junction (C). The old bridge remains in operation for the road–rail traffic system, with the same number of traffic lanes as there are currently. The difference, in relation to Scenario 1, is that the old bridge (1) connects with the central roadway in the area (A) by means of a circular intersection, which is joined by two more new roadways. The central roadway is connected with the peripheral street, by means of a section from the large circular intersection, through a four-way intersection with a full program of connections. Tram traffic is also planned, along the centrally divided island on that part of the central street, to the connection with the existing tram network.

In Scenario 3 (Figure 4), a new road and rail bridge are formed in the position of the old bridge (1) which, in the profile, has two lanes in each direction and a separate lane for a capacity rail system, such as a metro; that is, new lanes in each direction and separation of the road and rail transport are introduced, which form a large circular intersection with the central roadway in this space (A). In addition to the traffic route that leads to the bridge and the central roadway, two one-way routes flow into the large circular intersection. For the central roadway, which stretches from the circular intersection to the peripheral street (B), a rail system is planned for the central lane. The connection between the central roadway and the peripheral streets is achieved by means of an intersection with a full program of connections.

5. RESULTS

In the evaluation phase, all scenarios contained a complete street network planned for implementation by 2021, by means of the General Urban Plan, including capital traffic projects (e.g., bridges, bypasses around the city, and so on).

In Scenario 0 (Figure 3), development of the area for the Belgrade Waterfront Project is planned with far more modest attractiveness. The preference of long-term development, considering the decades-long neglect of transport, was given to the transport infrastructure, including the road and primary city street network, as well as the capacity rail system. In addition, model analyses showed that some primary traffic routes are working at the limit of their capacity. The newly built bridge over the downstream tip of the river island on the Sava River with three lanes in each direction as well as the planned new bridge carry a significant volume of the traffic, thereby easing the existing two bridges with three lanes in each direction. This was expected considering that the analyses showed that every third motorized trip crossed one of Belgrade's rivers (the highest volume being for the Sava River). Other parts of the street network that were of significance for serving the area of Belgrade Waterfront, and which directly surround it, had a satisfactory level of service in this scenario, the value of which did not exceed 100 (except in primary intersection zones).

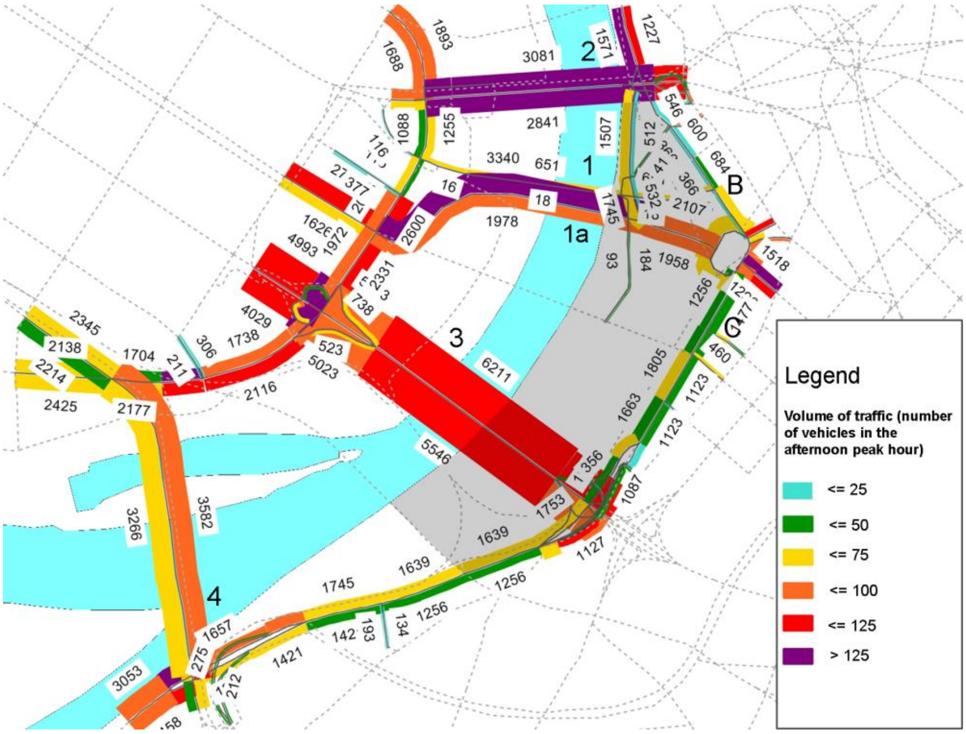


Fig. 3 Traffic load of the street network for Scenario 0 (source: GIS Transport Model of Belgrade, Urban Planning Institute of Belgrade, PE)

In the afternoon peak hour, the total number of trips generated by the contents of the Belgrade Waterfront was 30% higher than in the morning peak hour, where the number of car trips burdening the network was higher by 26%. Analysis of the afternoon peak hour showed that, on a selected street network (with a length of 43 km), the most burdened bridges were those crossing the Sava River. On these bridges in this time period, 37% of the transport was generated, expressed in vehicles/hour (or 40%, when expressed in vehicles/kilometer). In the street network, the loss of time due to the low level of service amounted to 735 vehicles/hour, of which 299 vehicles/hour were on the bridges; that is, 41%. Compared with the morning peak hour, the loss of time in the afternoon peak hour for the total selected street network was about 7% higher, and about 5% higher for the bridges.

The basic parameters by means of which the results of the analysis were further quantified (i.e., the parameters that measured the attraction and production of the planned Belgrade Waterfront Project) were as follows: Volume of transport (V), capacity of the roads (C), and level of service (percentage load capacity V/Cx100).

Scenario 1. (Figure 4) By raising the attractiveness of the area of the Belgrade Waterfront Project, the transport conditions in individual primary urban sections of the street network changed significantly. About 49% of the selected length of the street network in Scenario 1 had a level of service greater than 75, while as much as 33% had a level of service greater than 100. The loss of time on the selected primary street network amounted to 1,400 vehicles/hour, of which 692 vehicles/hour came onto the bridges (i.e., 49%).

Of the total 9,656 vehicles generated by the subject area in the afternoon peak hour, 5,320 (about 55%) used one of the bridges for either their departure or arrival. In relation to the total transport load on the bridges in the afternoon peak hour, the greatest load of traffic (with 71%) was on the old tram bridge (1), with 18% on the existing bridge (3). In this scenario, there was a relatively low share of traffic on the existing bridge (2; about 2%), with about 8% on the new bridge (4). High participation of origin–destination transport on the bridge (1) was expected, considering that the bridge on the right bank of the Sava River connects with the internal roadway, based on the principle of inflow–outflow and, in this conception of the solution, it represents the internal roadway in this area.

The analysis of the internal street network indicated that it carried a large share of the traffic, not only for the internal network, since (as well as having local significance) it played the role of being a transit connection through the area (17–29%). At the same time, it can be seen that the primary access to this area came from the direction of peripheral street (C), from which 52% of the total number of vehicles was generated in the afternoon peak hour.

Scenario 2. (Figure 4), In this scenario, there were no significant differences in the load on the section of the selected network, such that the characteristics of the utilized capacity and other effects that were analyzed were very similar to that of Scenario 1. Compared with the total traffic load on the bridges in the afternoon peak hour, the greatest volume of traffic (at 64%) was still on the old tram bridge (1), with 19% on the existing bridge (3), which was very similar to the previous scenario. In addition to its local importance, in this scenario, the internal network also played the role of a transit connection through the area, whereby the share of the traffic that did not have Belgrade Waterfront Project as its destination was somewhat higher than in Scenario 1 (around 37%). Given the capacity characteristics of the internal roadway, the level of service it achieved was completely acceptable. The primary access to this area was still from the direction of peripheral road (C), where 55% of the origin–destination traffic is generated; which was 3% more than in Scenario 1.

Scenario 3. (Figure 4), In this scenario, there were small changes in the traffic picture of the selected street network. It was concluded that the transport routes presented were key sections of the Belgrade transport network. This was due to the fact that, from the total transport engagement that was realized on the complete street network of the city (28,490 vehicles/hour, 1,189,765 vehicles/km), 10% of vehicles/hour and 8% of vehicles/km were on the selected volume of the street network.

Time losses on the selected street network in this scenario amounted to 1,043 vehicles/hour, which was about 20% less than in Scenarios 1 and 2. Time losses on bridges amounted to 393 vehicles/hour, which made up about 38% of the total; namely, about 21% less than in Scenarios 1 and 2. This confirms that the new bridge (1), with its higher capacity, caused a reduction in the time loss, despite the very modest solution regarding its connection with the primary traffic network.

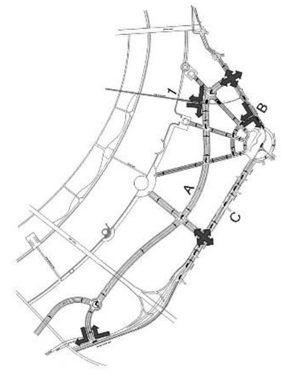
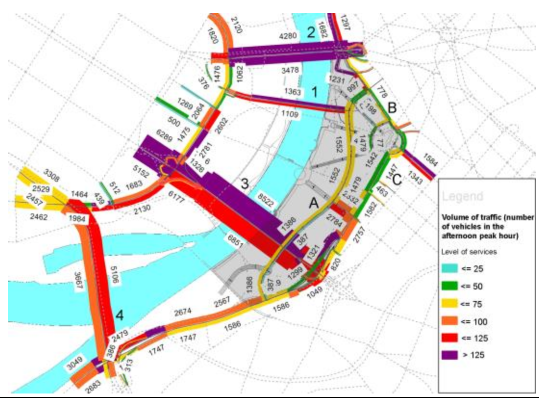
The new bridge that would be built in the place of the old tram bridge (1), with two times greater capacity, was still the route with the highest volume of traffic. The share of origin–destination traffic in the total number of vehicles on the bridge was 49%. Due to the in-creased capacity and good connection with the street network, this bridge takes a significant volume of the origin–destination traffic from the other bridges, such that, in this scenario, the share of traffic on the bridge (3) was about 8%, that on the bridge (4) was about 6%, and that on the bridge (2) was less than 1%. With the descent from the newly planned bridge (1) to the ground and its connection via a circular intersection with three primary planned traffic branches, this “northern” node was one of the two main approaches to the Belgrade Water-front Project and served as a connection with the part of the city on the left bank of the Sava River. The southern approach to the area, also formed as a circular intersection, primarily pro-vided access from the southern and eastern parts of the city.

Analysis of the internal street network also showed that, in this scenario, in addition to its local significance, the internal transport network had the role of a transport link. Depending on the section, the share of transit traffic in the total number of vehicles that was not going to the area under observation was about 17% on the main internal roadway (A). The primary access to this area was still from the direction of the peripheral street (C), where 41% of the total traffic was generated.

Generally speaking, similar traffic load relationships can be seen at the access to the area analyzed in both Scenarios 1 and 2. A large volume of traffic at the access to the intersections indicated that they are critical points in this solution and that consideration should be given to opening at least one more intersection on the length of the peripheral roadway (C). This scenario, compared to the previous one, showed slightly better results for the traffic effects; however, the large concentration of attractive content in this area generated a large volume of motorized trips in the peak hour, with very limited possibilities of access to the planned con-tents.

The most important city routes intersect in the subject area. As seen from the analysis and prior to testing the model for the impact of the new content, the highest percentage of the network’s operation had a very low level of service. Each increase in the number of vehicles in the network can lead to even more unfavorable traffic conditions on certain routes outside of the peak periods. The analysis of the wider city area indicated the necessity for having a new bridge in the subject area. However, the extent of its range in the area of the Belgrade Water-front Project should not be stopped but, rather, the traffic connection underneath the bridge must be planned in the northeast direction, towards the Danube slope of the city with the possibility that the route of the peripheral street (B) can be connected with this stretch.

Traffic flow problems on the bridges over the Sava River in Belgrade also exist in less attractive riverside areas. Raising the attractiveness of the area planned for implementation of the Belgrade Waterfront Project changed the traffic conditions in some of the primary sections of the city street network significantly, such that time losses rose while the level of service decreased. Out of the estimated total of 9,656 vehicles generated by this area in the afternoon peak hour, over 50% used one of the bridges, either for their departure or return, which indicates that the bridges in this area are very important for connecting the city, in a wider sense, but also for connecting the areas on the riverside belt.

<table>
<tr><th>Scenario</th><th>Layout plan</th><th>Traffic load of the street network in the afternoon peak hour</th></tr>
<tr><td>1</td><td></td><td>
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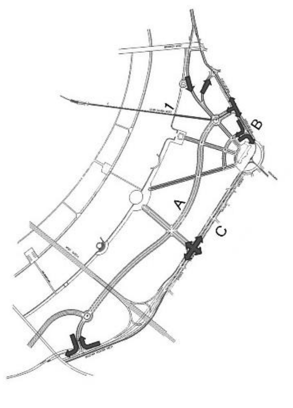
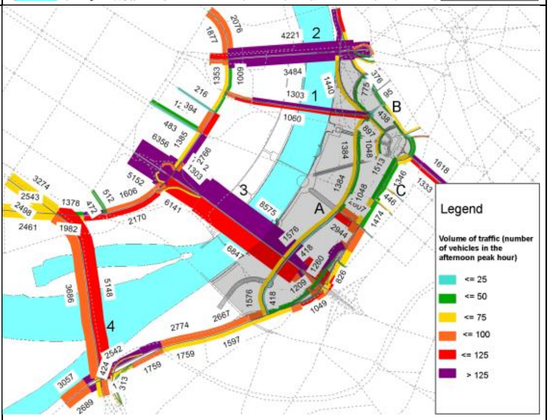
<tr><td>2</td><td></td><td>
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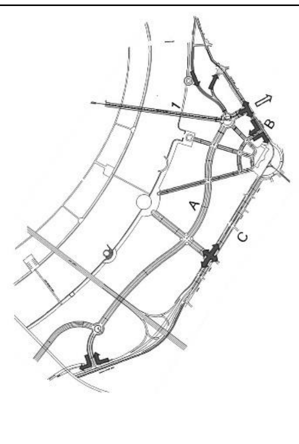
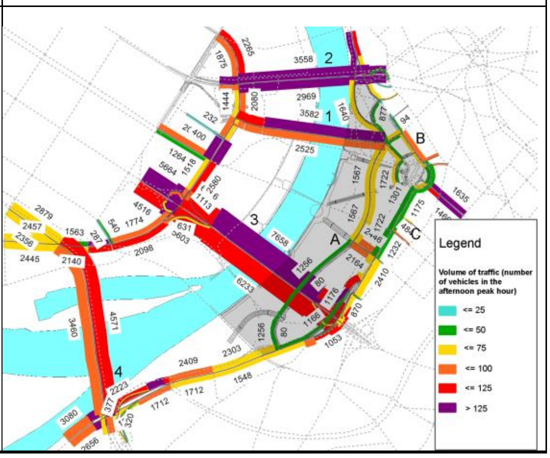
<tr><td>3</td><td></td><td>
</td></tr>
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Fig. 4 Layout plan (left) and traffic load of the street network in the afternoon peak hour (right) in Scenarios 1-3
(*Source*: GIS Transport Model of Belgrade, Urban Planning Institute of Belgrade, PE)

Based on the Transport analysis of the attraction and production of the planned content on the transport network, it can be concluded that Scenario 3 offers somewhat more favorable conditions than Scenarios 1 and 2 for the traffic flow conditions on the primary city street network and the street network that directly serves the project area.

One of the shortcomings is that this area can be approached only from one side; that is, from the direction of peripheral streets B and C. The profile of the street C was defined, in the plan, to have three tram lanes in each direction, while the rank of the street B was reduced after the planned shift of freight traffic; further, preference was given to public city transport (trams). At the same time, the large volume of traffic at intersections indicates that they are the critical points of this solution.

Analysis of the traffic effect for a number of scenarios of the street network showed that the best results could be achieved by the construction of at least two new bridges over the Sava River, one of which would have to be located in the area planned for the implementation of the project. The scope of the new bridge (1) must not be limited to the riverside belt of the project area but, rather, it is necessary to further plan a new traffic route (i.e., a tunnel section, in a northeast direction towards Belgrade’s Danubian slope). In its profile, new bridge (1) must contain separate space for the functioning of a capacity rail system. At the same time, it is necessary to consider the possibility of opening another intersection (or more) along the length of peripheral roadway C.

In its current state, public city passenger transport in the subject area runs on peripheral roads (B, C), as well as the access road to bridge (1), by means of the bus or tram sub-systems of the public transport system. The maximum capacity of existing public transport lines for passengers travelling in this area is approximately 20,500 places/h.

Taking into account the planned distribution of different forms of transportation, in the period ahead, it is necessary to have a transport capacity available for almost 30,000 passengers; almost double the number of transport units. This points to the need—parallel with the implementation of the purposes and contents of this space—to also secure other modes of transport, through the realization of capacity rail systems, possibly going through the area planned for the development of the project.

As this area relies largely on the Sava River, it is necessary to take advantage of its potential and to define the locations of harbors, in order to secure the potential for connecting this area with the river traffic.

In line with the results of this analysis, when producing the plan for the area of Belgrade Waterfront, corrections and amendments were made to the initial planning solution. Another approach to the area was planned with a full program of connections and another on the principle of inflow–outflow from the peripheral roads (B, C). These solutions significantly eased the planned approaches to the subject area and improved the distribution of the traffic volume. The level of service of the branch, by means of which traffic enters and leaves the area of the Belgrade Waterfront Project from the planned circular intersection on peripheral road-way C (in both directions), operates at a regime of less than or equal to 75, which is acceptable for urban traffic conditions.

Bearing in mind the insufficient capacity of conventional transport modes (tram, bus), the planning solutions provide the possibility of introducing a capacity rail system (metro line) in the direction of bridge (1). This plan envisages the construction of a new road and rail bridge in this position (the section for the rail system is planned for the central part of the bridge construction); that is, the route that connects the street network on the left and right banks of the Sava River by two circular intersections.

It is especially important to note that a bus terminus is planned within the subject area, directly next to the zone of the greatest attraction (commercial), which opens the possibility of better access to these facilities.

The extent of traffic routes from the newly planned bridge (1) does not terminate within the limits of the project area; a tunnel has already been planned that connects this route with the Sava and Danube slopes of the city, thus creating an alternative to the traffic routes that, at present, play this role but feature an unsatisfactory level of service.

6. Discussion and Conclusions

The extensive scientific literature in the field of transport has indicated that the use of transport analysis and modeling is not a novelty in planning. We point to this fact in our paper, where the starting points relating to the significance of transport analysis as a planning method and the need to use models were linked to numerous references presented in recent years. However, the problem of transport and planning in cities is so complex that, with the dynamic development of software and geographic information systems, it is necessary to continuously develop transport models and improve traffic analysis methods. Bearing in mind the scope of the planned construction for the Belgrade Waterfront Project, with its position in the city center on the bank of the river, and with traffic being the biggest problem in the spatial development of Belgrade, we recognized the specificity of the situation and defined a new methodological approach for Transport analysis of the impact of the attraction and production of this project on the city traffic network.

In our opinion, the contributions of the proposed methodology and the procedure used to carry out the analysis can be seen in several key segments: First, the process of quantifying the planned area and estimating the number of trips that the planned content will generate, based on specially derived parameters and data on the structure, size, and attractiveness of the planned content. Second, our analysis was conducted in such a way that the layout solution for the proposed Belgrade Waterfront project was considered in terms of three basic scenarios of the street network of the city for 2021, which contained both the existing and planned street networks. Finally, in the testing of the model; that is, in testing the load of the expected traffic, which was carried out for the highest volume of traffic up to that time (previously carried out for incomparably smaller projects). It is interesting to note that some authors have emphasized the need to define and examine multiple scenarios in their analyses, in order to avoid errors and limitations in the application of the results (Anand, et. al., 2015; Chikaraishi, et.al., 2017; Lyons, 2016).

In addition, using the analysis results to define new planning solutions gives full significance to the analysis and confirms the views that it is a key method in the urban planning of large projects. Based on the influence of the attraction and production of the project and the perception of the level of service on the peripheral street network, a traffic solution was selected for the project area (one of the scenarios), which was supplemented with new solutions (two new approaches to the location).

The implementation of the method and study results led to a spatial change of the initial design, proving that the traffic matrix needs some adaptations and additions, in order to provide efficient functioning. The important changes to the initial design proposal given by the Master plan were those connected to the traffic analyses developed in parallel with the urban planning stage. This is one reason why we evaluated this method as a key method; proving, in this case study, how it is important to cross-check all evidences of the planned consequences, based on the expressed creativity and visionary attitude. More importantly, based on an examination of the level of service in the wider street network of the city, the proposed transport solutions have importance for the sustainability of the whole city, involving such measures as the construction of a new bridge, a tunnel connection linking the two slopes of the city, and guidelines for further development of the city's public transport, among others. The main goal was to avoid and reduce traffic congestion and overload in the traffic network of the city. These solutions have not only been accepted, but special plans and designs have been made for them and they are currently already being implemented.

The authors have found support for these views, regarding the importance of models and simulations of service levels for city streets (Bhuyan & Nayak, 2013), especially in research that emphasizes the goal of identifying missing traffic links (Krivda, et. al., 2021). At the same time, we found similar observations in the literature about urban development and transport planning, as well as in the experiences of planning and transforming urban water-fronts, especially in one work which pointed out the importance of transportation changes during urban transformations of waterfronts, which include industrial activities and new land-uses (Wrenn, et.al., 1983). Changes in urban development of waterfronts for megaproject construction in Central and Eastern Europe are similar; for example, in the town of Orsova after the Iron Gates hydroelectric power station was constructed (Varan & Cretan, 2017; Cretan & Vesalon, 2017). It is of special importance that some authors have pointed out that mega-project construction could lead to environmental and social risks (Vesalon, Cretan, 2013). Considering the subject of this paper, the most interesting comments are that, during the development of the Belgrade Waterfront Project, public interest was declared for the needs of the private investor, while opportunities for local people to influence solutions were reduced (Grubbaner, Čamprag, 2018). The authors of this paper agree with such statements and, at the same time, point out the importance of the role that urban planners must play in the process of defining capital planning solutions.

An analysis of such proportions was carried out, for the first time, in the case of Belgrade (previous analyses were carried out for incomparably smaller projects). Using the existing model tailor-made for local circumstances and analysis results to define new planning solutions gives full significance to the analysis and confirms our opinion that it is the key method in the urban planning of large projects. The main conclusion that can be drawn from the paper is about the importance of the mutual influence of land use and the street network and how important it is to provide adequate transport analyses for the development of a new plan. The authors underline that the implementation of the results from the case study led to a spatial change of the initial design and provided some adaptations and additions for an efficient functioning of the traffic matrix. They assert that the participation of and cooperation between professionals of different specializations during the planning and design process is essential and very welcome in the phase of evaluating the plan proposals. The findings can be used as an input for decision-making and upgrading the existing methodology and followed by further research based on other case study models. The conclusions are about lessons learned and the impact of the process.

It is not the only method; especially as urban planning has a multidisciplinary character and many different aspects may influence the final proposal. The purpose of the paper was to present it as an important part of creative process, with very exact conclusions, that lead to the final solutions. The presented results may be practically important for water-front urban development, as well as for urban transport planning. In case of Belgrade, it was done for the first time at such a scale, keeping in mind the total reconstruction and land-use change influencing the wider city area. Based on the influence of the attraction and production of the project and the perception of the level of service on the peripheral street network, a traffic solution was selected for the project area (one of the scenarios), which was supplemented with new solutions (two new approaches to the location). Most importantly, based on an examination of the level of service in the wider street network of the city, new transport solutions, which are of importance for the whole city, were pro-posed, such as the construction of a new bridge, a tunnel connection linking the two slopes of the city, and guidelines for further development of the city's public transport system, among others. Beside the main focus of this paper, the car transport flow, an entire plan was developed with mobility standards and requests in mind, including public transport network solutions, routes for bicycles and pedestrian paths, and the possibility to introduce some alternative types of transport in the future (river taxi, cable car, and so on). These solutions have not only been accepted, but special plans and projects have been made for them and they are currently already being implemented. Overall, we consider that the problem of transport and planning in cities is so complex that, with the dynamic development of software and geographic information systems, it is necessary to continuously develop transport models and improve traffic analysis methods.

Finally, it is fair to mention that, despite the good will and skill of the planners, transport analyses and the use of models carry with them possible shortcomings; for example, how current the transport model used in the analysis is and whether the data it contains remain valid. Other possible shortcomings are the question of whether the methodology used to estimate the number of new trips is effective, whether the parameters are good, whether the quantification of the planned area has been carried out adequately, and so on. Therefore, the authors agree with the claims that, for future research, more critical attention should be focused on the assumptions of modeling, which is the foundation of their research, as well as methodological approaches to the development of transport analysis.

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ZNAČAJ SAOBRAĆAJNE ANALIZE ZA VELIKE GRADSKE PROJEKTE

U nizu urbanističkih analiza koje se koriste prilikom izrade urbanističkih planova nalazi se i saobraćajna analiza. Radi se sa ciljem sagledavanja uticaja kapaciteta planiranih sadržaja na saobraćajnu mrežu užeg i šireg područja. U ovom radu kao studija slučaja izabran je veliki gradski projekat za područje Beograda na void i urađena analiza kao saobraćajnastudija za potrebe procesa planiranja ovog prostora. Saobraćajna analiza se bavi procenom koliko će optećećenje genererisati planirane namene (stanovanje, poslovanje, komercijala, javni objekti i sl.) i na koji način će se to odraziti na postojeću i planiranu mrežu saobraćajnica. Za ove potrebe koristi se odgovarajući softver koji za zadate parametre opterećenja mreže u različito doba dana stvara scenarija broja vozila i dominatnih pravaca kretanja i ukazuje na nedostatke mreže koju treba prilagoditi zahtevima korisnika. Ovaj vid analize svojim rezultatima daje imput za planiranje prostorne organizacije sadržaja i veza unutar područja i sa širim okruženjem.

Ključne reči: *urbanističko planiranje, veliki projekat, saobraćajna analiza, saobraćajna mreža, beogradska obala.*