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ANALYSIS OF THE LOCATION FOR THE ACCOMMODATION OF THE NEW TRAM AND BUS DEPOT OF GSP BEOGRAD

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Abstract

To convert the industrial zone into a zone of residential and commercial content in New Belgrade, it is necessary to relocate the garage of the Belgrade City Transport Company (GSP) from Block 66 in New Belgrade to a new location at the end of the Dr Ivan Ribar settlement, i.e. in the extension of Yuri Gagarin Street, south of the state road New Belgrade - Surcin. In accordance with the set requirements, the layout of the largest number of facilities was made for the purpose of defining the space for the accommodation of the CTC(GSP) Belgrade tram and bus depot at the proposed location. The paper presents an analysis of the site in question, with the definition of three Variant solutions with the distribution of facilities related to the areas occupied by tram tracks and pavement for bus traffic, as well as accompanying contents related to architectural facilities, plants and devices. Also, presented is the process of selecting the optimal Variant solution using the method of multi-criteria compromise ranking.

Keywords: tram, track, vibrations, urban areas, analysis

1 Introduction

To transform the existing industrial zone into the future residential and business area in New Belgrade, it is necessary to relocate the garages of the Beograd City Transport Company from Block 66 in Novi Beograd to a new location where the relocation of the tram and bus depot is planned.
The end of Dr. Ivan Ribar settlement, i.e. the extension of Yuri Gagarin Street, south of the state road Novi Beograd- Surcin, and west of the Petrac amelioration canal were proposed for the new location (Figure 1). In accordance with the set requirements it was necessary to analyze the suitability of the proposed location and select the most acceptable variant solution for tram and bus depot.
The analysed location at New Belgrade embankment covers an area of about 92.40 ha. The location consists of two parts. The first part is located north of the planned state road Novi Beograd- Surcin and south of the planned Yuri Gagarin Street.
This area covers the surface of 35.22 ha. The second part of the site is the area south of the state road section Novi Beograd- Surcin, and west of the planned Yuri Gagarin Street. The second part of the site covers an area of 57.17 ha. Morphologically speaking, the area belongs to the alluvial plain of the Sava River, the so-called Novi Beograd alluvial plateau with elevations from ~69.7 to ~73.8 above sea level.

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The site has the following limitations (Figure 1):

- Connecting overhead line 110 kV for TS 110/35 kV Surcin- Beograd, which partly passes through the planned depot location and has a protective zone of 30m on both sides of the lines from the final phase conductor, below which the construction of buildings is prohibited, except for infrastructural and traffic facilities.
- The Detailed Regulation Plan for the construction of a gas pipeline. The Plan incorporates MMCS and the existing gas distribution pipeline, with a protection zone of 60m.
- The proposed boundary in the plan encompasses existing melioration canals: Dudovski canal and Canal 19, which flow into the Petrac II Canal located in the contact zone.
- Likewise, the area of the planned bus-tram depot is in the zone of sanitary protection of the Beogradsko Izvoriste.

Figure 1 New location for tram and bus depot with Indicators of location boundaries

The entrance to the planned location is defined by the Detailed Regulation Plan of the area along Vinogradska Street, with a traffic connection to the highway bypass, the city municipality of Novi Beogad and Surcin – Phase III (Figure 2).

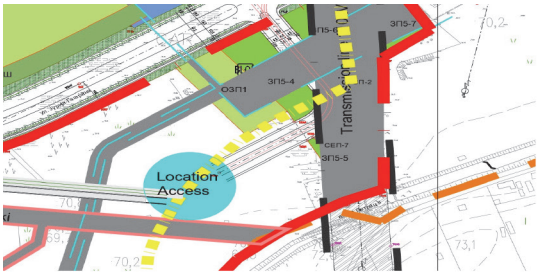

Figure 2 Access to the location according to the Detailed Regulation Plan for the area along Vinogradska Street

1.1 Official vehicles

For the relevant length of the tram, when planning the capacity for tram traffic, a tram length of 35 m was adopted. For “solo” buses, the length is 12 m, and for articulated buses, the length is 18 m. A length of 8 m is adopted for vans and minibuses. The width of the vehicle is 2.5 m.

2 Variant solutions

In the process of analyzing the site in question, three variant solutions were defined that refer to the area occupied by the tram tracks and the bus pavement, as well as the accompanying contents related to architectural objects, plants and devices. All Variant solutions are in the area south of the State Road section Novi Beograd - Surcin, and west of the planned Yuri Gagarin Street. Variant solutions were formed with the assumption that the planned route of

the gas pipeline and the route of the 110 KV transmission line will not be moved, but that the proposed solutions of the tram and bus depot will be adapted to the situation on the ground, and that it is possible to displace and redirect the Dudovski canal into the pipe.

2.1 Variant solution 1

2.1.1 Depot for trams

The proposed Variant solution was formed based on the assumption that the depot should accommodate up to 150 trams max. 35 m long. Immediately after the entry of the tram line to the location in question, two groups of 13 tracks with a total length of approx. 3700 m were formed. Track lengths range from approx. 130 to approx. 160 m. As the left and right tram tracks are connected by cross switches during the formation of the parking tracks, the entry of trams is enabled on all 26 tracks. Access to the second entrance (exit) to the tram depot at the intersection of Jurija Gagarina Street and the state road in the Novi Beograd - Surcin section is provided from the group of tracks for tram parking in the open space. If there is no need for the trams to go to the vehicle maintenance hall, they can go to both exits/entrances from the depot area across the designed turning point. On the tracks located in the maintenance hall measuring 100 m x 85 m, a maximum of 50 trams with a length of 35 m can be accommodated. Behind the vehicle maintenance hall, there is a turning point for trams that leave or enter the maintenance hall, as well as trams that leave the hall from the right group of tracks and return to the main transit tracks in the central part of the tram depot [1].The total area occupied by the tram tracks with the tram maintenance hall is approximately 4.79 ha.

2.1.2 Depot for buses

The decision of the bus depot was made under the assumption that approximately 250 vehicles should be accommodated. Emphasis is placed on the accommodation of articulated buses, which are represented in the fleet of GSP Belgrade to a greater extent than other road vehicles. The parking scheme foresees 219 places for articulated buses, 30 places for “solo” buses and 24 places for vans, a total of 273 vehicles. For the parking of articulated buses, so-called one-way parking spaces at an angle of 45° are used [2]. For the parking of “solo” buses, minibuses and mid-size buses, a combined parking scheme with alternating one-way passage is proposed. Within the bus depot complex, places for filling fuel and electric chargers, two vehicle washing lines, a hall for emergency repairs and workshops with warehouses for spare parts are provided. The movement along the vehicle repair lines through the halls is one-way.

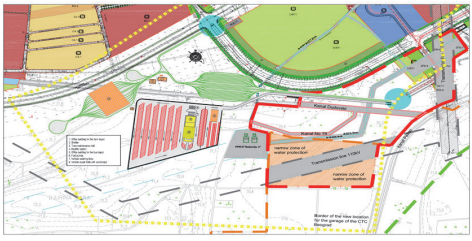

Figure 3 Variant solution 1 of the tram and bus depot

In front of the bus depot, the construction of an administrative office building with dimensions of 45 m x 21 m is planned. In front of the building, there is a parking lot for parking up to 140 passenger vehicles for the needs of employees and official visits. In this Variant solution, it is planned to redirect the Dudovski canal into the pipe. The ilustrate of variant solution 1 is given in Figure 3.

2.2 Variant solution 2

2.2.1 Depot for trams

Variant solution 2 for the tram depot was given in relation to the request of GSP "Belgrade" that parking space should be provided for min. 200 trams approx. 35 m long, with respect to the existing operating technology in the Sava tram depot in Novi Beograd (Block 66). The track length in the open-air parking lot according to this solution is approx. 7100 m (track length approx. 230 m), which enables the parking of approx. 200 trams. The length of the tracks located in the vehicle storage hall is approx. 830 m, on which it is possible to accommodate approx. 30 more trams. The entrance/exit from/to the area of the tram depot is in the same positions as in Variant solution No. 1.

2.2.2 Depot for buses

According to the current situation, the organizational units of Beograd City Transport Company have 176 articulated buses, 73 "solo" buses and 110 vans, and mid-size buses. The parking scheme and project elements of the bus depot were formed according to the requirement that the number of vehicles be min. 500, in proportion to the existing fleet.
In addition to the administrative building, the bus depot complex should comprise, according to the user's request, a hall for service and night inspection, two vehicle washing lines, service hall II and an emergency repairs hall with accompanying workshops, cloakrooms, and wet knot for maintenance workers, fuel stations and electric chargers. The total area of the halls is 20% larger than halls of the existing depot in Block 66 in Novi Beograd. The location of the halls in relation to the traffic lanes is oriented in such a way that vehicles can move through the halls in one direction.

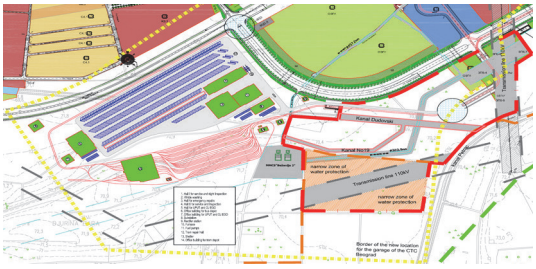

Figure 4 Variant solution 2 of the tram and bus depot

In addition to the mentioned halls, to the west of the parking area, there is a maintenance hall for vehicles of the Traffic Unit Contracted transport and internal transport, as well as the vehicles of the Organizational Unit Electrical - Construction Operatives, with accompanying workshops, wardrobes and wet knot and an administrative building The access road to the facilities is planned with two traffic lanes with a minimum width of 2x3 m. In this Variant solution, canal Dudovski will be redirect into the pipe. The ilustrate of variant solution 2 is given in Figure 4.

2.3 Variant solution 3

2.3.1 Depot for trams

According to Variant solution 3, the tram depot completely matches the tram depot proposal in Variant solution 2.

2.3.2 Depot for buses

According to Variant solution 3, it is assumed that the bed of the Dudovska canal will be displaced along the perimeter of Yuri Gagarin Street and the State Road of the Novi Beograd - Surcin section. The parking scheme and project elements were formed according to the same requirement as in Variant solution 2. The ilustrate of variant solution 3 is given in Figure 5.

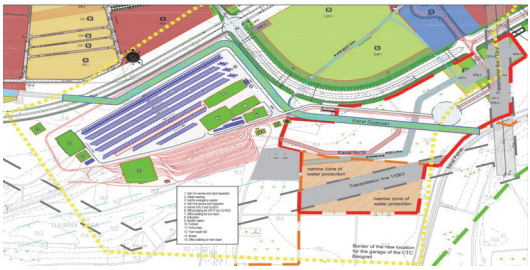

Figure 5 Variant solution 3 of the tram and bus depot

3 Multi-criteria evaluation of Variant solutions

The term evaluation refers to the estimation and decision-making procedure, including the procedures for defining goals and criteria (functional, ecological, economic) relevant for evaluation and decision-making. The modern development of science, technique and technology has made it possible to introduce an approach based on multi-criteria evaluation and ranking methods in the theory of decision-making. At the end of the multi-criteria evaluation process, explicit output data related to the selected Variant solution is obtained. The VIKOR method was developed based on the compromise ranking elements. Based on the method, a program package (VIKOR) that solves optimization tasks with multiple heterogeneous and conflicting criteria was developed [3].

3.1 Evaluation of the offered Variant solutions using the VIKOR method

Three Variant solutions were generated, and they were presented in the previous chapter 2. When choosing the optimal Variant of the offered solutions, the evaluation criteria and their relative weights were defined, and they are a numerical reflection of the importance of the criteria. To determine the relative weights, a simplified Delphi method was applied to a sample of 30 respondents (civil and traffic engineering). The following criteria were defined: K_1 - The number of trams approx. 35 m long in the open parking lot, K_2 - The number of spaces for trams in the maintenance hall, K_3 - The length of the tracks on which the trams are parked (km), K_4 - The area under the tram tracks including the tram maintenance building (ha), K_5 - The number of articulated buses in the depot, K_6 - The number of solo buses in the depot, K_7 - The number of vans, mini and midi vehicles in the depot, K_8 - The area occupied by the bus depot together with the maintenance halls and vehicle repair workshops, K_9 -

The area occupied by administrative buildings, parking lots, access roads and other facilities in the function of the depot (ha), K_{10} - The area occupied by the Dudovski canal (ha) and K_{11} - Free areas with the possibility of greening (ha). The numerical values of the criteria of the offered Variant solutions and the indices of extremism (max = 1; min = 0) are shown in Table 1. The decision maker envisaged four scenarios:

S_1 - The decision maker gives the greatest priority to the functional effect - the maximum number of parking spaces in the tram and bus depot: the first, third, fifth, sixth and seventh criteria, while the other criteria are less significant ($\omega_1 = \omega_3 = \omega_5 = \omega_6 = \omega_7 = 0.15$; $\omega_2 = \omega_4 = \omega_8 = \omega_9 = \omega_{10} = \omega_{11} = 0.041667$).

S_2 - The decision-maker gives preference to the criterion of the total maximum area of the tram and bus depot - criteria four and eight, while all other criteria are less significant ($\omega_4 = \omega_8 = 0.25$; $\omega_1 = \omega_2 = \omega_3 = \omega_5 = \omega_6 = \omega_7 = \omega_9 = \omega_{10} = \omega_{11} = 0.0556$).

S_3 - When deciding, the decision maker gives priority to the criterion related to environmental protection - maximum free area for greening - criterion eleven, while all other criteria are less significant ($\omega_{11} = 0.30$; $\omega_1 = \omega_2 = \omega_3 = \omega_4 = \omega_5 = \omega_6 = \omega_7 = \omega_8 = \omega_9 = \omega_{10} = 0.07$).

S_4 - For the decision maker, all criteria have equal importance, so their weights are equal ($\omega_1 = \omega_2 = \omega_3 = \ldots = \omega_{11} = 0.09091$)

Table 1 Numerical values of the criteria of the offered Variant solutions and extreme indices

V.S.	Defined criteria										
	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}
V1	106	48	5.4	4.78	219	30	24	4.76	0.92	0	46.71
V2	202	28	8.06	6.29	249	144	178	9.64	1.21	0	40.03
V3	202	28	8.06	6.29	249	130	178	9.01	1.14	2.37	38.36
Extr	1	1	1	1	1	1	1	1	1	0	1

3.2 Ranking results - selection of the optimal Variant solution

Table 2 shows the results of the evaluation of Variant solutions using the VIKOR method.

Table 2 Ranking results

Scenarios	Weight	Ranking list	A compromise solution for the finsl decision	
			Set of alternatives	An advantage
S_1	0.545	1. 0.000 VARIANT 2 2. 0.057 VARIANT 3 3. 1.000 VARIANT 1	VARIANT 2 VARIANT 3	5,7% 94.3 %
S_2	0.554	1. 0.000 VARIANT 2 2. 0.089 VARIANT 3 3. 1.000 VARIANT1	VARIANT 2 VARIANT 3	8.9 % 91.1 %
S_3	0.545	1. 0.336 VARIANT 2 2. 0.545 VARIANT 1 3. 0.814 VARIANT 3	VARIANT 2 VARIANT 1	20.9 % 26.8 %
S_4	0.545	1. 0.000 VARIANT 2 2. 0.149 VARIANT 3 3. 0.545 VARIANT 1	VARIANT 2 VARIANT 3	14.9 % 39.6 %

According to scenario S_1, based on the evaluation results, it can be concluded that Variant solution 2 represents the most favorable solution (ideal), which in relation to the set of Variant solutions has an advantage of 5.5% in relation to the first and next offered Variant solution 3.
According to scenario S_2, based on the evaluation results, it can be concluded that Variant solution 2 represents the most favorable solution (ideal), which in relation to the set of Variant solutions has an advantage of 8.9% in relation to the first and next offered Variant solution 3.
According to scenario S_3, because of the evaluation results, it can be concluded that Variant solution 2 is the most favorable solution (far from the ideal by 33.6%), which in relation to the set of Variant solutions has an advantage of 20.9% compared to the first Variant solution offered - Variant 1, and 47.7% in relation to Variant solution 3.
According to scenario S_4, based on the evaluation results, it can be concluded that Variant solution 2 represents the most favorable solution (ideal), which in relation to the set of Variant solutions has an advantage of 14.9% compared to the first and next offered Variant solution No. 3, and 54.5 % in relation to Variant solution 1.

4 Conclusion

The paper presents an analysis of the area of the Novi Beograd embankment with an area of approx. 92.40 ha for the construction of the tram and bus depot of the Belgrade City Transport Company. In the process of the subject analysis, three Variant solutions of the tram and bus depot were defined with the areas occupied by the tram tracks and the roadway for bus traffic with associated facilities, plants, and devices. For the purposes of determining the most favorable alternative solution, the multi-criteria evaluation method (VIKOR method) was used. The evaluation of the proposed Variant solutions for the four proposed scenarios was carried out. The obtained results showed that in all four scenarios Variant solution 2 is the most favorable solution.

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