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ROUTE OF SOUTH SECTION OF BUDVA BYPASS - REVIEW OF PRELIMINARY DESIGN OF ORGANIZATION AND TECHNOLOGY CONSTRUCTION

Abstract

The Budva bypass, spanning approximately 30 kilometers, is divided into three distinct sections: North, Middle, and South. The Terms of reference required the preparation of a Preliminary design for the construction elements of all structures along the section and route. The Southern section, which is the subject of this article, begins at the end of the Middle section in Vrijesno. The route of the Southern Section goes through the hilly hinterland above the Budva coast, from Kamenovo to Petrovac. In Petrovac, it is connected to the main road M-2 Petrovac-Sotonići-Virpazar via the intersection "Petrovac". The total length of the Southern section is 8.56km. There are five bridges and one tunnel in this route. There are, also, retaining structures and slope protection, conection routes and deviations, one interchange, and noise protection walls on this section of bypass. In this article, parts of Preliminary Design of organization and technology construction are showned. Network plan structure, approximate estimation of the duration of the works, approximate cost estimation, and approximate cash flow estimation during construction are presented.

Keywords: organization, technology, construction, route, bypass

ТРАСА ЈУЖНЕ ДИОНИЦЕ ОБИЛАЗНИЦЕ БУДВА – ПРЕГЛЕД ИДЕЈНОГ ПРОЈЕКТА ОРГАНИЗАЦИЈЕ И ТЕХНОЛОГИЈЕ ГРАЂЕЊА

Сажетак

Обилазница око Будве, дужине приближно око 30км, подијељена је на три дионице: Сјеверну, Средњу и Јужну. Пројектним задатком је предвиђена израда Идејног пројекта изградње свих објеката на дионици и трасе. Јужна дионица обилазнице, која је предмет овог рада, почиње на крају Средње дионице у Вријесну. Траса Јужне обилазнице пружа се кроз брдовито залеђе Будванске обале, од Каменова до Петровца. У Петровцу се спаја са главном трасом регионалног пута М-2 Петровац – Сотонићи - Вирпазар преко раскрснице „Петровац“. Укупна дужина Јужне дионице обилазнице Будва је 8.56 km. На траси ове дионице се налази пет мостова и један тунел. Такође, на овој дионици се налазе потпорни зидови, заштите косина, приступни путеви и девијације, једна петља и зидови за зажтиту од буке. У овом раду су приказани дијелови Идејног пројекта организације и технологије грађења. Структура мрежног плана, приближна процјена трајања радова, приближна процјена коштања и приближан ток новца током грађења су презентовани.

Кључне ријечи: организација, технологија, грађење, траса, обилазница

1. INTRODUCTION

Throughout the project documentation development, current regulations, guidelines, methodologies, strategic plans, and reports were employed as reference materials. [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17]

The route of the Southern section begins at the end of the Middle section in the zone of the settlement Vrijesno. The route is then placed through the hinterland of the coast through Čelobrdo, Marovići. In the Tudorovići zone, the route enters a tunnel about 3 km long. After exiting the tunnel, the route over a series of bridges leads to the main road M-2. The connection of the Bypass with the main road is designed through the connecting road on which a toll ramp is organized. The connecting road is connected by a highway with a roundabout. The connecting road and the bypass intersect with a interchange, with four direct ramps.

Due to the cutting of the existing road network, one deviation was designed.

2. ROUTE

2.1. TYPICAL CROSS SECTION

The typical cross section of a road is designed based on specified velocities, and the widths of various elements are determined accordingly. For the main alignment (Figure 1.) with a design velocity of 100 km/h, the elements and their respective widths are as follows:

- traffic lanes 4x3.50m
- edge strips 4x0.35m
- dividing belt min 3.00m
- shoulder 2.00m
- berm 1.25m
- grid 0.9m
- inflow-outflow strip 3.50m.

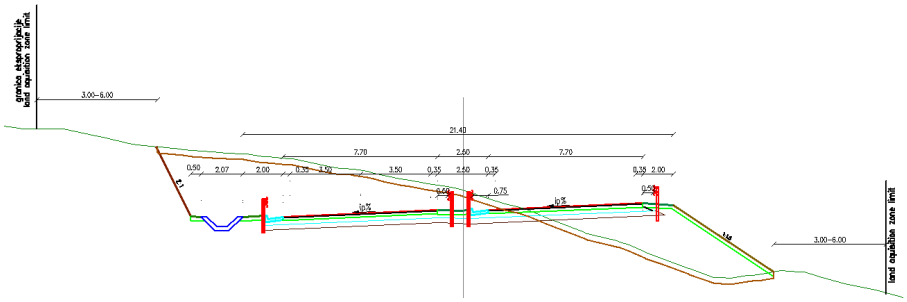

Figure 1. Typical cross section of main alignment

The Terms of References require the dividing strip to be at least 3.00 meters wide, and according to TEM standards (Trans-European standards and recommended practice), this width includes edge strips. Therefore, the width of the dividing strip according to TEM is calculated as 2.5 + 2x0.35 = 3.2 meters, which meets the required minimum width.

The minimum transverse slope of the road is 2.5%, and the maximum in the curve is 7,0%.

2.2. BOUNDARY ELEMENTS OF PLAN AND PROFILE

The plan and profile elements have been determined by considering the designated design speed, adhering to the standards of neighboring countries, and aligning with TEM.

Table 1. Elements of plan and profile

		label	regulation	design
Layout plan	Minimum radius of horizontal curvature	min R	450m	500m
	Minimum radius of the horizontal curvature in the counter-slope	min R	3000m	-
	Minimum transition curve parameter	min A	180	250
	Maximum direction length	max L	2000m	710m
Longitudinal profile	Maximum longitudinal slope	max in	5%	3.15%
	Minimum longitudinal slope	min in	0.5 %	1%
	Minimum radius of convex roundness (in = 0%)	min Rv konv	9000m	15000m
	Minimum radius of concave curvature	min Rv konk	4000m	8000m

The geometric layout of the bypass route has been intricately designed in accordance with the established boundary elements of the plan and profile. Apart from facing highly complex terrain conditions, the design was significantly shaped by the necessity for numerous structures, including tunnels and bridges. Due to this complexity, especially with the goal of separating the axes within tunnels, the axis and elevation of the right and left lanes of the bypass were independently defined on two subsections. Simultaneously, a shared axis and elevation were maintained on two other subsections.

Furthermore, compliance with professional requirements, such as ensuring a maximum height distance between the right and left lanes in tunnels (in the range of 2.5-3 meters as per transverse evacuation connection conditions), as well as considerations outlined in the Layout plan of tunnels and bridges, played a role in limiting the ability to have a more autonomous guidance of the axis and elevation for the right and left lanes.

2.3. LAYOUT

The elements of the horizontal geometry of this variant are designed for Vr = 100km/h. The minimum applied radius on the open route is 500m, and in the tunnel 1000m.

There are two deviations and one interchange named “Petrovac” in the main route. The "Petrovac" interchange is an uneven rhombus-type intersection with a roundabout.

The intersection of the connecting road and the M-2 highway is designed as a roundabout. A toll ramp has been designed on the connecting road.

2.4. LONGITUDINAL PROFILE

The grade of the main direction was designed with a maximum longitudinal slope of 3.15% on a length of 1545m.

2.5. BRIDGES AND TUNNELS

The locations where the bridges commence and terminate are strategically selected to establish an optimal connection between the bridge structures and the surrounding terrain while ensuring a rational placement of supports. The choice of modern bridge construction technologies is deliberate, focusing on those readily available and proven in the domestic market and neighboring countries. This approach aims to facilitate the involvement of local construction companies in the Project's implementation.

The main route incorporates five designed bridges, each assigned specific chainages and lengths, as outlined in the following table (Table 2.):

Table 2. Bridges lenght

Bridge	Start L/R	End L/R	Length L/R
1	-/3077	-/3734	-/657
Krastavac	6626/6627.75	6654/6789.75	28/162
Vukovici	6977/6994	7364/7471	387/477
Zukovica	7849/7848	7949/7976	100/128
Petrovac	8242/8242	8314/8314	72/72
Total			587/1496

The total length of the bridges of main route is 2083m.

Given the current stage of Project development, where precise data on geological and geotechnical soil conditions are not yet available, the commencement and conclusion points of the tunnel have been strategically chosen. This selection aims to ensure an ample height for the superstructure in the portal zones, allowing for flexibility in adapting to potential variations in soil conditions.

In the case of the bypass route, one tunnel has been designed (Table 3.).

Table 3. Tunnel lenght

Tunnel	Start L/R	End L/R	Length L/R
Tudorovici	3665/3742	6607/6620	2942/2878

The total length of the tunnel is 5820m.

3. TECHNICAL AND TECHNOLOGICAL SOLUTIONS FOR MAIN ROUTE CONSTRUCTION

The analysis gave technical and technological solutions for the construction of the main alignment. A significant emphasis was placed on recommending a high level of mechanization for carrying out earthworks, with manual labor being suggested only in specific situations where necessary.

For reinforced concrete works, the proposal is to utilize pre-machined reinforcement produced off-site and transported as completed elements to the installation location. Concrete production is planned at a concrete batching plant and is then transported using machinery for both external and internal transport. The casting process involves the use of traditional formwork, crafted from high-quality chipboard or steel. It's important to note that the specific choice of mechanization is not within the scope of this analysis. This decision will be influenced by adopted work methods and construction technology, as well as factors such as the existing state of mechanization, the financial standing of the contractor, market conditions for machinery, the condition of personnel, and the ability to maintain the machines.

3.1. DETERMINATION OF THE ANNUAL ALLOCATION OF HOURS FOR WORK EXECUTION

The calculation of the annual working days for work execution considers variations in weather conditions, specific work methodologies during different seasons, and takes into account public holidays.

3.2. MATERIALS PROCUREMENT

The materials required for the execution of works on the open route will predominantly be sourced from Montenegro or neighboring countries, and the procurement plan is outlined as follows:

- Cement will be delivered from Serbia and Albania to the site by trucks.
- Aggregate will be delivered from Montenegro to the site by trucks.
- Additives for concrete will be delivered from Serbia to the site by trucks.
- Steel will be delivered from the Federation of Bosnia and Hercegovina, Serbia, or Turkey to the site by
- trucks.
- Fuel will be delivered from Montenegro or the surrounding countries to the site by trucks.

- Equipment arriving from the port Bar will be transported by vehicles to the site. The remaining equipment arriving from surrounding countries will be transported by trucks to the site.
- Asphalt will be delivered from the asphalt base (in Montenegro) to the site by trucks.

3.3. CONCEPT OF WATER AND ELECTRICITY SUPPLY

Water required for construction will be supplied through a mobile water tank, supplemented by the use of local water sources. Initially, electricity for the construction site will be generated through generators. Following the completion of power lines, the site will then receive electricity through the substation.

3.4. CONSTRUCTION SITE PLAN

The construction site necessitates strategic planning for the arrangement of temporary structures such as offices, dining rooms, worker cloakrooms, toilets, water tanks, and machinery parking. Additionally, there is a requirement to organize transportation for workers commuting to and from the construction site from their respective locations.

3.5. WORKS ON THE OPEN ROUTE

The plan for the open route involves the segmentation of main activities into two categories: earthworks and road construction works.

4. NETWORK DIAGRAM STRUCTURE

Using the predetermined work positions essential for project completion, an initial list of activities was created (Figure 2.). This list was formulated using the MS Project 2013 software package. Activities in the list are interlinked with links representing the sequential order of operations during work execution. The interconnected activities collectively form the structure of a network diagram. This planning approach is based on the network planning technique. The overall number of activities in the network diagram structure is 22, with 4 activities identified on the critical path.

ID		Outline Number	Task Name	Duration
1		1	**CONSTRUCTION OF THE ROUTE/IZGRADNJA TRASE**	**960 days**
2		1.1	**Construction of the main route/Izgradnja glavne trasa**	**760 days**
3		1.1.1	Trasa/Route	760 days
4		1.1.2	Potporni zidovi/Retaining walls	360 days
5		1.1.3	MSE i kosine/MSE and slopes	450 days
6		1.2	Vezni put/Link road	150 days
7		1.3	**Denivelisana raskrsnica Petrovac/Interchange**	**220 days**
8		1.3.1	Trasa/Route	220 days
9		1.3.2	Naplatna rampa/Toll station	150 days
10		1.4	**Devijacija 1/Deviation 1**	**90 days**
11		1.4.1	Trasa/Route	90 days
12		1.4.2	Potporni zid/Retaining wall	70 days
13		1.5	Saobracajna signalizacija i oprema/TSE	150 days
14		1.6	Zastita od pozara/Fire protection	60 days
15		1.7	Pejzazno uredjenje/Landscape	75 days
16		1.8	**Instalacije/Installations**	**920 days**
17		1.8.1	Hidrotehnicke instalacije/Hydrotechnics	660 days
18		1.8.2	Elektroinstalacije jake struje/High voltage	670 days
19		1.8.3	Elektroinstalacije slabe struje/Low voltage	440 days
20		1.8.4	Sistem nadzora i upravljanja saobracajem/TCMS	210 days
21		1.9	**CONSTRUCTION OF PAVEMENT/IZRADA KOLOVOZNE KONSTRUKCIJE**	**210 days**
22		1.9.1	Construction of pavement/Izrada kolovozne konstrukcije	210 days

Figure 2. List of activities

In the Figure 3 the network plan is shown.

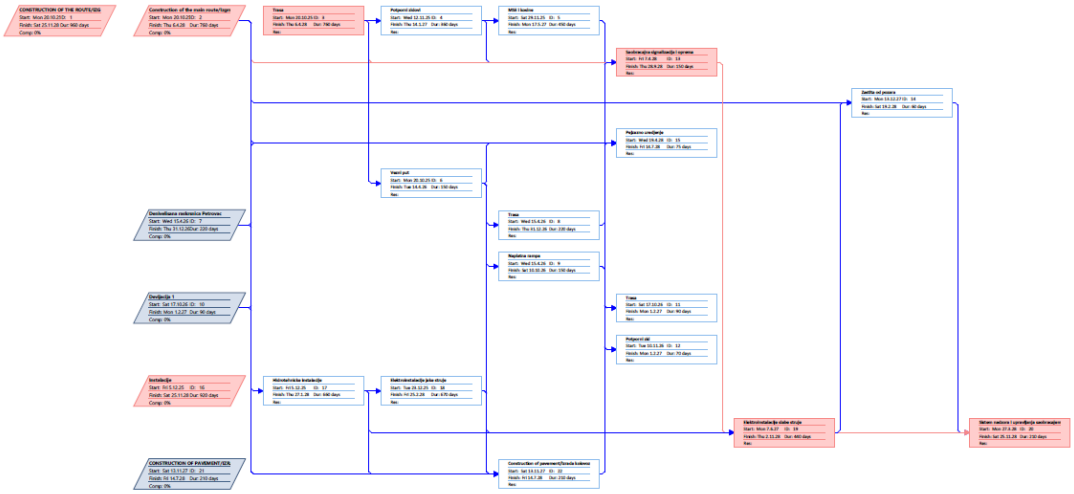

Figure 3. Network plan

5. APPROXIMATE ESTIMATION OF THE DURATION

The work schedule entails operating six days a week, with a nine-hour daily shift, including a one-hour break. Public holidays are designated as non-working days. The duration of activities was estimated considering the work volume outlined in the Preliminary Designs Bill of Quantities (BoQ). The deadline for completing all activities was calculated based on the constructed network diagram. Construction commencement is slated for October 20, 2025. The construction duration spans 960 working days, culminating in the project's completion on November 25, 2028. The project timeline is visually presented in the Gantt Chart (Figure 4).

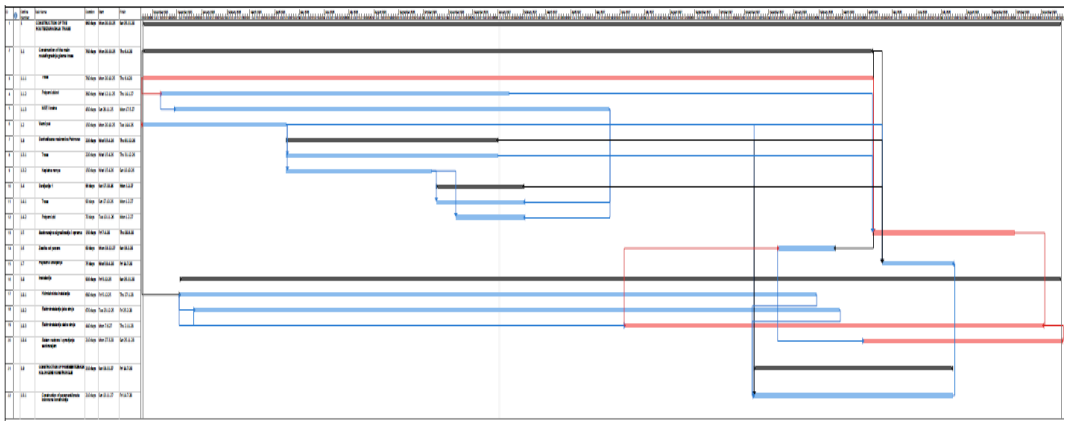

Figure 4. Gantt Chart

6. APPROXIMATE COST ESTIMATION

An approximate cost estimate was derived from the unit prices provided in the Preliminary Design of the main route. The total construction costs, excluding unforeseen works and VAT, sum up to €77,596,023.77.

The total sum represents the sum of the costs of the execution of the mentioned work:

- Construction of the main route with associated retaining walls, MSE and slopes
- Interchange Petrovac with toll station
- Deviation 1 with associated retaining walls
- Traffic signalization and equipment
- Fire protection
- Landscape

- Instalation (hydrotechnichs, high and low voltage, Central and distance traffic control and management system)
- Construction of pavement

7. APPROXIMATE CASH FLOW ESTIMATION

The peak construction costs are anticipated in December 2026, reaching €4,013,280.03, while the lowest costs are expected in November 2028, totaling €71,494.49.
Determining the center of gravity of the investment involves analyzing the diagram and cumulative cost curve, revealing that the center of gravity falls in November 2026.
In addition to cash flow estimates, cost diagrams were crafted based on the type of work, illustrating the percentage participation of each work category in the overall costs. The highest cost is attributed to the Construction of the main alignment, amounting to €46,501,201.90, constituting 59.93% of the total costs. Conversely, the lowest cost is related to Fire protection, totaling €1,869.99, with a minimal percentage participation of 0.002%.

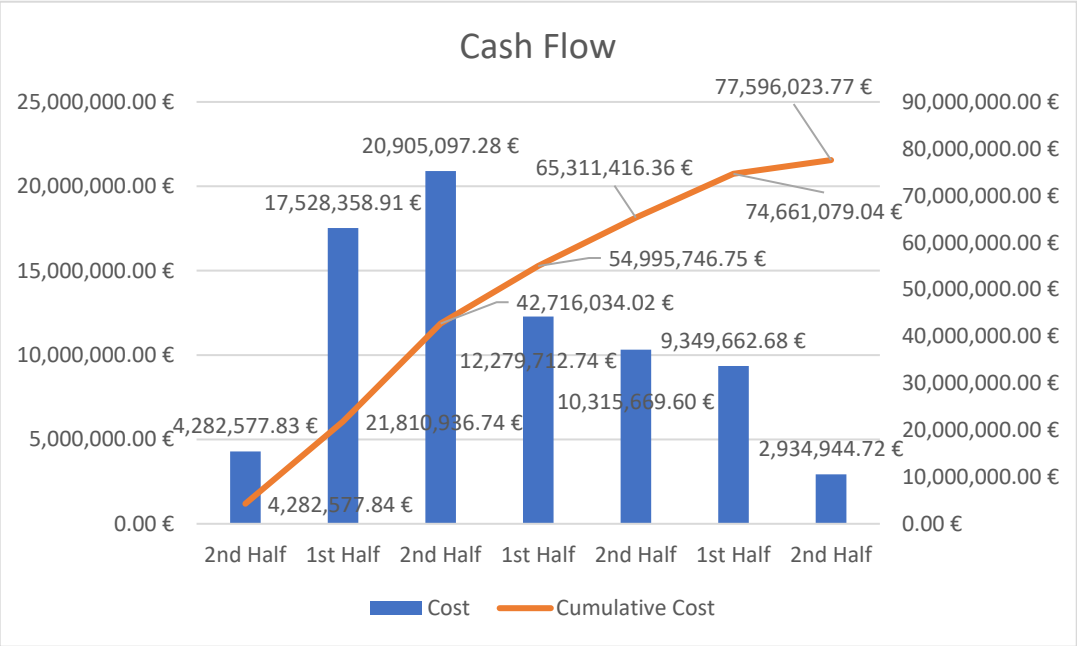

Figure 5. Cash Flow

8. CONCLUSION

The Budva Bypass is about 30 km long and consists of three sections: North (about 8 km long), Middle (about 13 km long) and South (about 9 km long).
The Southern section, which is the subject of this article, begins at the end of the Middle section in Vrijesno. The route of the Southern Section goes through the hilly hinterland above the Budva coast, from Kamenovo to Petrovac. In Petrovac, it is connected to the main road M-2 Petrovac-Sotonići-Virpazar via the intersection "Petrovac". The total length of the Southern section is 8.56km.
Following a comprehensive analysis, proposed were technical and technological solutions for the construction of the main route..The initiation of the project involved creating an initial list of activities based on predetermined work positions deemed crucial for project completion. This list was generated using the MS Project 2013 software package, with activities linked together to represent the sequential order of operations during work execution. The interconnected activities collectively constitute the structure of a network diagram, employing the network planning technique. The entire network diagram structure comprises 22 activities, with 4 activities identified on the critical path.
The completion timeline for all activities was determined using the constructed network diagram. Construction is scheduled to commence on October 20, 2025. The project's duration encompasses 960 working days, concluding with its completion on November 25, 2028.

A rough cost estimate was generated based on the unit prices outlined in the Preliminary Design of the main route. The total construction costs, excluding unforeseen works and VAT, amount to €77,596,023.77.

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