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TECHNICAL-ECONOMIC ANALYSIS OF VARIANTS OF A MICRO LOCATION FOR THE DTO CRUSHING PLANT OF THE DTO SYSTEM AND CONNECTING CONVEYOR T1 AT THE OPEN PIT POTRLICA, PLJEVLJA[**]

Abstract

The Additional Mining Design for coal exploitation at the open pit "Potrlica" - Pljevlja for the period 2020 - 2025, has defined the exploitation system important parameters and development of the open pit. Among others, for the first half of 2022, it is planned to move the crushing plant to a new position, in a direction of the excavation front. Generally, the new position of the crushing plant has been verified within several project and study documents. Nevertheless, there is a need for precise definition of the crushing plant positions and conveyors within the DTO system in order to the create favorable and safe working conditions for mechanization on the loading plateau of the crusher, to provide a more favorable position of the crusher with the aim of easier plateau drainage and a more convenient approach to the crusher for easier maintenance, and to minimize the costs of relocation to a new position while respecting the projected dynamics of relocation works. In order to ensure the fulfillment of the set goals, a techno-economic analysis of the variants of a micro location of the crushing plant at this open pit was performed with an overview given in this paper.

Keywords: *conveyor, costs, techno-economic evaluation*

1 INTRODUCTION

The Additional Mining Design of coal exploitation at the open pit "Potrlica" - Pljevlja for the period 2020 - 2025, defines the dynamics of development of the open pit, vertical division of the mine and landfill, excavation and disposal capacities, safety factor (Fs) of slopes and other important exploitation system parameters. The relocation of the crushing plant to a new position is designed for the first half of 2022, in line with the excavation front development. The new position of the crushing plant was determined in the previous studies and project documentation, respecting the basic evaluation criteria such as reducing the length of discontinuous transport, vertical position in relation to the center of gravity and duration of the new crushing plant position.[1] Unlike the previously conducted analyzes on the basis of which the macro location of the crushing plant was determined, and that included the analysis of work on the entire area and throughout the life of mining, the analysis of micro location of the crushing plant and position of the conveyor T1 was

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done in goal of the costs minimization and minimization the preparatory works in narrower area of the new location of the crusher and analysis the specific structural-geological and geomechanical characteristics.

In order to build the cutting trench for the conveyor and crushing plant, the specific geological and geomechanical explorations and tests were performed.

In addition to the natural conditions that condition the micro location of the conveyor route and the crushing plant cutting trench, scope, technology, dynamics, and costs of preparatory works, in the immediate vicinity of the planned facilities there is a dam, tunnel and riverbed of Ćehotina and transmitssion line what complicate the works.

Analysis of the micro-location of the cutting trench of the conveyor and crushing plant includes:

- Analysis of the route of the T1 conveyor, and definition a macro location of the cut of the crushing plant in accordance with the previously, project documentation defined position, and
- Analysis of the relocation of buildings with a position partially shifted towards the excavated surface of the open pit providing a reduction in the volume of preparatory work.

Analysis and determination of techno-economically improved position of the connecting conveyor T1 towards the open zone of the mine in a function of identified influencing factors, position of paleorelief and other lithological members for which conditions are provided after changing the position of crusher in relation to the connecting conveyor T1.

2 SPECIFICS OF ECONOMIC ANALYSIS

When it comes to the economic analysis of the considered variants, here, which is generally present in mining, it appears through the specifics in relation to the economic-investment analyzes in other areas.

1. The first specificity is that the planned works are within the contour of the projected open pit, and excavation of masses during the cutting can be seen as a part of regular production at the open pit, although they require a special manufacturing technology or are performed dynamically earlier, provided for in the regular production plan.

2. Secondly, the performance of such works is a necessary condition for further mining operations in a safe and economical manner with a stable production, and in economic terms can be considered as the investment activities for certain phases of open pit mining. This character of the funds for realization the necessary works is important to emphasize mostly because of the possibility for their provision, whether they are financed from the current profit or from loans.

3. Such activities do not bring direct profit to the open pit, and the volume of costs-investments can be high and significantly affect the indicators of economic efficiency of the open pit in a long run.

Having in mind the mentioned techno-economic analysis, it must contain in the specific case at least:

- a description of the project which explains the problems to be solved by the project and the objectives to be achieved,
- technical-structural analysis descrybing the physical input data, technical options as well as investment costs,
- financial analysis that assesses the financial flow from a perspective of the project holder,
- economic analysis which represents an upgrade of the financial analysis and takes into account the wider effects of performed works, and
- the project description should, first of all, on the basis of definition the problem, define the goal or series of goals, necessary to be achieved in order to

solve the problem. The goal(s) must be defined on a measurable way and the project is defined on that basis.[2]

Within the technical-structural analysis, the experts on technical issues present the technical aspects of the project.[3]. This usually involves a preliminary design and cost estimate, or as in this case a detailed project at the construction level with the exact amount of materials, equipment and staff required, parts of the technical analysis may include:

- available technologies,
- production plan (including use of infrastructure),
- personal staff,
- project location,
- implementation plan,
- project phases,
- safety at work,
- environmental protection.

The main purpose of financial analysis is to use the project cash flow forecasts to calculate the appropriate net return indicators, mainly through two basic indicators: financial net present values and financial rate of return, which are used to calculate the income from investment expenditures. Financial analysis is the basic tool for decision makers to decide whether a project should be implemented or not, or from the investor point of view whether the project should be financed or not.

While the financial analysis considers only the impact of the project on the owner, economic analysis looks at the project more broadly, as a whole, and seeks to measure the benefits and benefits that result from the project implementation. Economic analysis is also necessary in cases of the environmental or social impacts, which have no market value although they significantly contribute to achieving the project objectives, which is the case here given that the implementation of this project has a key impact on coal production as a whole.[4]

The economic analysis starts from the discounted cash flow, which is used in the financial analysis, to calculate the financial profitability of the project regardless of the sources of financing and is adjusted to all disturbances. These adjustments are made on the basis of an assessment the monetary value of benefits and costs, for which there is no established market by introduction a theoretical representation of the effects and financial consequences of the project implementation.[5] Economic analysis is therefore suitable for assessment the feasibility of projects that are not financially viable (discounted project value less than 0, profitability rate less than a discount rate), but for which there are strong reasons to provide them with the financial support, due to their indirect benefits.

3 PRESENTATION AND CALCULATIONS OF THE DESIGNED SOLUTION OF A ROUTE FOR THE CONVEYOR T1 AND POSITION OF THE CRUSHING PLANT

With relocation of the overburden crushing plant, the truck transport route to the top of the landfill will be shortened by an average of 1,600 m (compared to the variant when the transport would be purely discontinuous) or by about 900 m (compared to the old position of the crusher). In addition to this significant shortening, the old position of the crusher is unsustainable from an aspect of the planned development of the front at the landfill, i.e. further use of the CCS system is possible only with the relocation of the crusher. The new position of the crusher is determined through multiple analyzes or constructed variants and represents the optimal compromise of several influential factors.

The time required for relocation the crushing plant will largely depend on the organizational capabilities of the Investor and execution of preparatory works, and it is estimated that it will be between 4-6 months. It should also be borne in mind that the certain technological operations (primarily mechanical and construction) will be performed much easier and better during the months with more favorable weather conditions. Having in mind the stated available capacities of the DTO system during 2022, to be half smaller (projected operation of the CCS system with a capacity of 3 million tons), which was taken into account in calculation. After relocation, loading into the crusher will be done from the floor E-745. The E-745 floor itself will be ramps connected to the higher floors (E-760 and E-775) as well as to the lower floor (E-730) from which the associated overburden masses will be treated by the CCS system.

In technical terms, when solving the problem of choosing the micro-location of crushing plant and conveyors of the CCS (crusher-conveyors-spreader system), as well as the techno-economic indicators, three key factors were identified to compare the efficiency of the solution:

- quantity and type of excavated material by variants,
- parameters of drilling and blasting works in the conditions of the vicinity of the facilities (arranged riverbed, tunnel and dam of the relocated river Ćehotina and transmission line), and
- stability of the loading plateau in the conditions of loading with equipment that will move on the plateau.

The connection between the crushing plant and landfill will be realized with a system of three conveyor belts (T1 220 m long, T2 350 m long, as well as T3 315 m long). The T1 conveyor is placed at an angle of 4.5° (connecting elevations 735 and 750 m above sea level). The other two connecting conveyors (T2 and T3), as well as including the landfill conveyor T0, are placed horizontally at the elevation of 750 m above sea level. In the technological sense, it is very important that the conveyors T2 and T3 are horizontal, because with the advance of the landfill front, a connection with the landfill conveyor is established through them (all set at the elevation of 750 m above sea level). Longitudinal profiles of connecting conveyor routes are given in Figure 1.

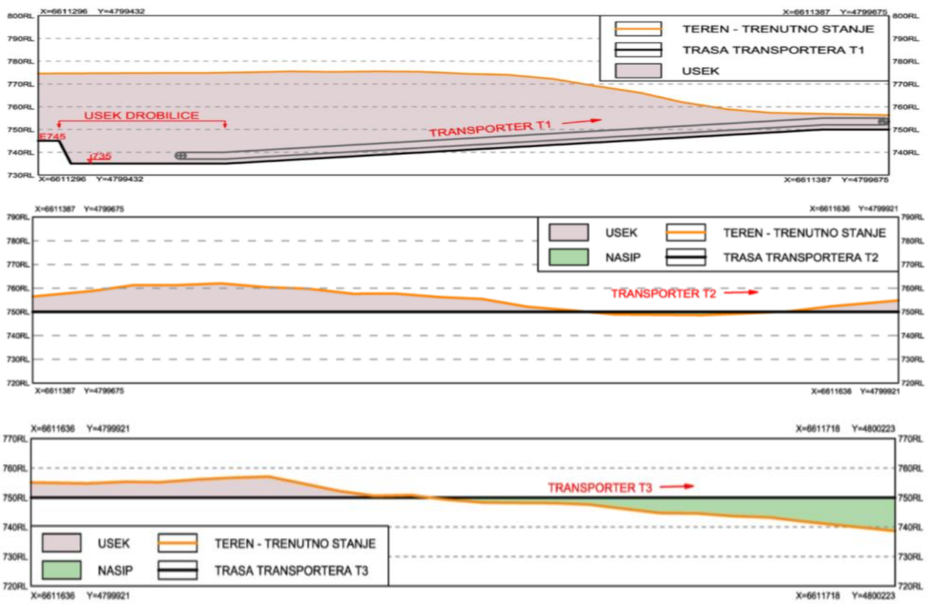

Figure 1 *Longitudinal profiles of connecting conveyor routes according to the valid DRP 2020-2025*

The conveyor route was constructed with a width of 16 m, in order to enable an unhindered movement of auxiliary machinery and occasional transport of overburden to the top of the landfill in case of capacitive deficit of the CCS system. The constructed route of the conveyor is mostly in the cut, which does not exceed a depth of more than 16 m, and to a lesser extent in the embankment (maximum height 8 m). During the formation of the crushing position and route of the conveyor, the CCS system, it is necessary to excavate significant quantities due to the formation of cuts (about 400,000 bcm) and to fill significantly smaller quantities (about 24,500 lcm). These quantities are included in the total projected capacity at the overburden for 2022 (part of the planned 8,000,000 bcm) and shown in Table 1. It is also important to emphasize that a significant part of the mass in the cut would be excavated even if there is no displacement of the crusher, only in later period, during regular production at the surface mine.

3.1 Calculations of the Stability of the General and Partial Slopes

The slope of the open pit "Potrlica" at this cross-section consists of limestone, floor clay, coal clay, coal, interlayer clay, gray clay and marl. Apart from the fact that the working environment of the subject area is characterized by the exceptional anisotropy, it is also characterized by the structural complexity. In accordance with that, there are large deviations in terms of physical and mechanical indicators of the represented rock masses. Checking the slope stability of the notch of conveyor and crusher and plateau of the slipway was determined for the geomechanical section GM-1 whose position, together with the designed condition of the crusher position, is given in Figure 2.

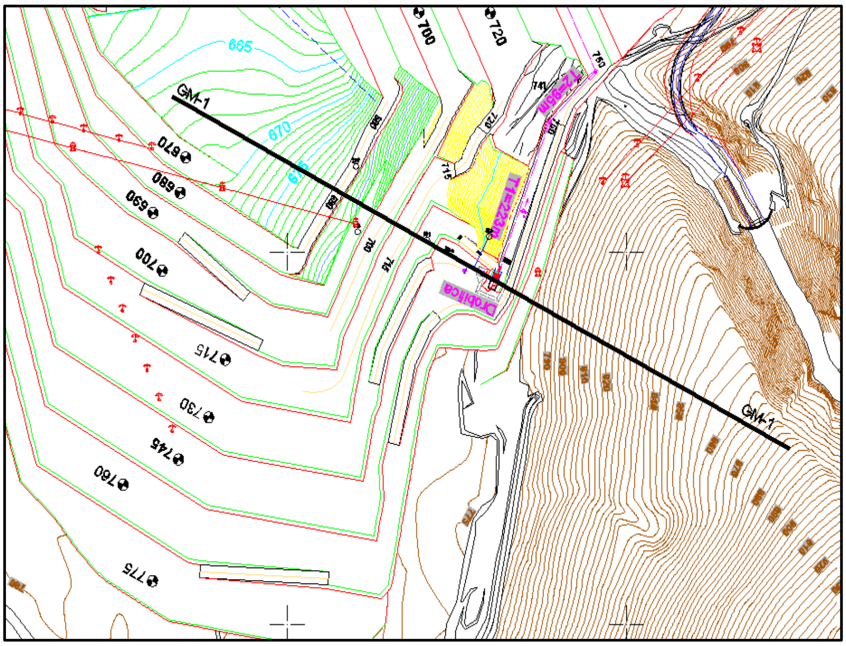

Figure 2 *Position of the analyzed GM-1 profile at the open pit "Potrlica" - condition of works at the end of 2025 according to the valid DRP 2020-2025*

The appearance of the analyzed slope on the GM-1 profile corresponds to the condition of works at the end of 2025.

An example of stability analysis of the slope of notch formed in the limestone, and Variant 2 notch of the crusher and conveyor is given in Figure 3.

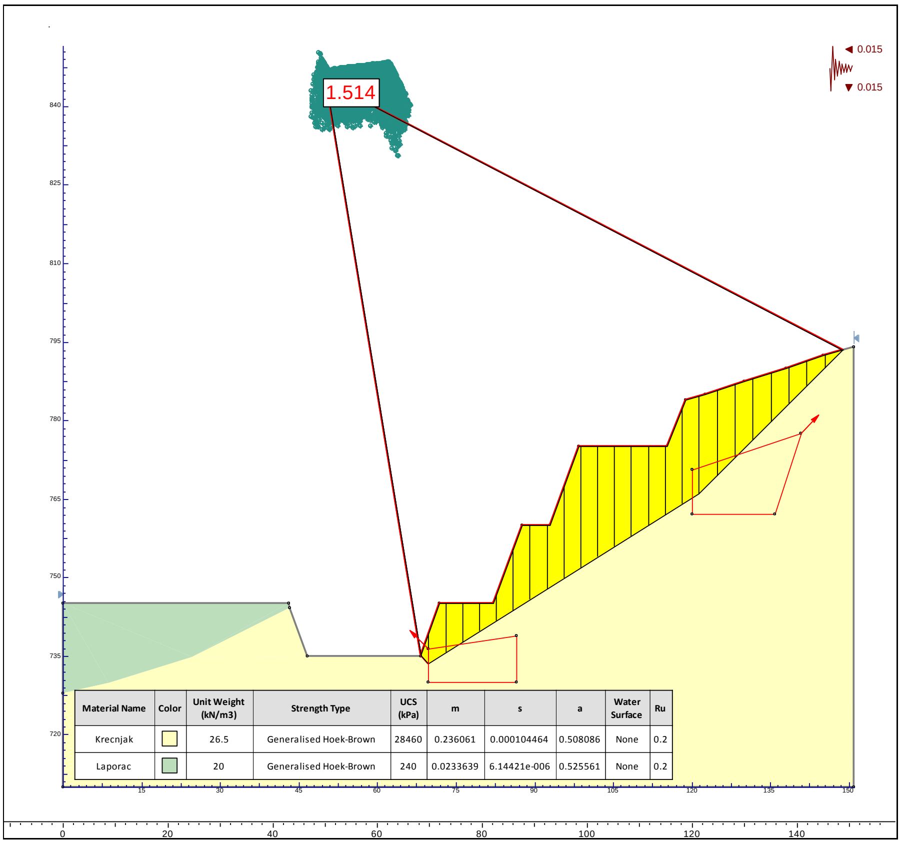

Figure 3 *Example of calculation of the safety factor of the cut slope formed in limestone*

When it comes to the calculation of the stability of truck overpass plateau, the calculation was done for the conditions of slope load by the machinery moving along it for Variant 2 (Figure 4) and Variant 1 (Figure 5) of the cutting trench construction.

By comparison the calculated values of safety factors, the general conclusion can be made that the plateau in Variant 2 is constructed with a higher safety factor, which is also a variant in which the amount of excavation is higher.

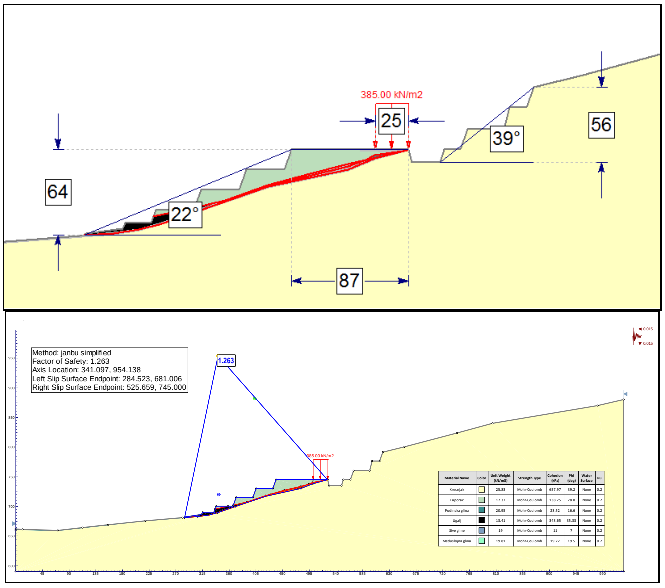

Figure 4 *Geomechanical model of the designed slope in the zone of crushing plant and plateau of truck on a map of the condition of works designed for 2025 with a detail of profile for Variant 2*

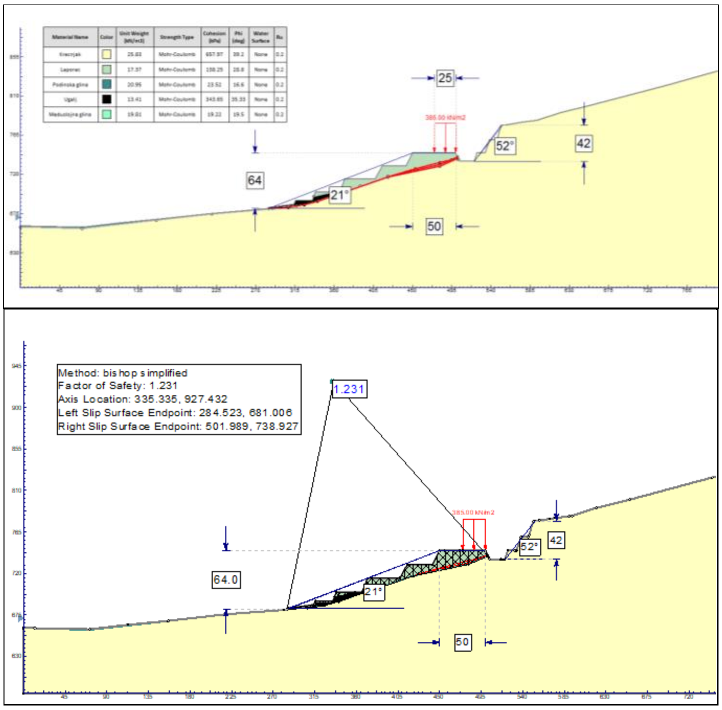

Figure 5 *Geomechanical model of the slope of cutting trench position for Variant 1 with an example of the calculated safety factor*

3.2 Description of Variant of the T1 Conveyor Route and Access Roads

Variant solution 2 involves making a cut in accordance with the existing design documentation, which means that the cut of conveyor conveyor and crusher is placed in an extreme eastern position, and as a whole in the limestone material. The amount of masses to be excavated or filled (cuts and embankments) is shown in Table 1.

Table 1 *Quantities of excavated and filled material when moving the crusher in variant 2*

	Cutting trench		Embankment	
Floor	Quantity (čm^3)	Quantity (t)	Quantity (rm^3)	Quantity (t)
775-790	24,378	47,537	/	/
760-775	101,236	197,412		
745-760	111,020	216,493	11,486	17,229
730-745	15,370	29,972	4,782	7,173
In total	252,004	491,413	16,268	24,402

The second analyzed variant assumes that the route of the T1 conveyor is shifted by 7° at the elevation of drive station in relation to the existing one. The length of route of the T1 conveyor is 200 m, the level of drive station is at 750 m above sea level, and the level of return station is 735 m above sea level. By movement the route of conveyor T1, the scope of auxiliary and preparatory works in the limestone was reduced (Table 2). The width of conveyor route is 16 m, what enables an unhindered movement of machinery. In parallel with the route of conveyor, i.e. above the plateau of the crusher, a transport road has been designed, which will be the connection between the 745m floor and external landfill Kutlovača. The new position of the crushing plant is shown in Figure 6 (Variant 1).

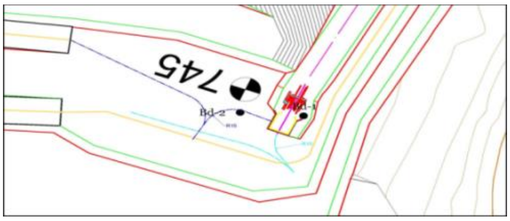

Figure 6 *New positions of the crushing plant*

The foundations of crushing plant are located at the level of 735 m above sea level in the limestone massif. The overhaul of crushing plant, the place of unloading, is located at the level of 745 m above sea level. The crushing plant is rotated 90° and placed perpendicular to the T1 conveyor. This position of the crushing plant significantly reduced the scope of auxiliary work. The calculation of cubic masses for material types was done by the method of parallel sections. The calculation results are given in Table 2.

Table 2 *Calculation of cubic masses by the method of parallel sections for different types of materials*

Profile tag	Surface area	Medium surface	Distance	Volume of Marl	Volume of Limestone	Volume
1	487.00	500.00	25.00		12,500.00	12,500.00
2	513.00	595.00	25.00		14,875.00	14,875.00
3	677.00	746.00	25.00	8,112.50	10,537.50	18,650.00
4	815.00	863.50	25.00	8,687.50	12,900.00	21,587.50
5	912.00	874.00	25.00	4,686.42	17,163.58	21,850.00
6	836.00	845.50	25.00	5,225.00	15,912.50	21,137.50
7	855.00	750.50	25.00	4,901.90	13,860.60	18,762.50
8	646.00	545.59	25.00	4,762.50	8,877.21	13,639.71
9	451.00	529.00	10.00	3,125.00	2,165.00	5,290.00
10	607.00					
				39,500.82	108,791.39	148,292.21

3.3 Drilling and Blasting

The Sandvik DI 310 drill owned by the Investor, is planned for drilling the blasting boreholes of 89 mm diameter. The drilling angle is 70^o, which is how much the slope of the floor was adopted. Drilling of the blasting boreholes should be done in a triangular arrangement in two or three rows. The convergence coefficient should be m = 1-1.25; m = a/W., adopted m = 1. Drilling and blasting are done in two shifts. During the design of drilling and mining works, a strict attention was paid to the choice of explosives, geometry of the blasting boreholes, construction of the blasting filling and method of initiation in order to minimize the negative impact of seismic waves on the surrounding structure.

3.4 Other Works

Preparatory works on the construction of cut for the conveyor and crusher consist of terrain preparation for drilling and blas-ting works. On the terrain surface, a bulldozer will perform a partial leveling by removal the surface cover to create a plateau for drill.

For the execution of works on the construction of cut of the T1 conveyor and crushing plant according to the variant solution, it is planned to engage:

1. Hydraulic excavator type Hyundai LC 800 bucket volume 4.5m^3,
2. 3 Terex 30 trucks with a capacity of 30 t,
3. One Komatsu 375 bulldozer,
4. Sandvik DI 310 drills.

Since there is a real need for limestone at the open pit Potrlica, it is envisaged that the excavated limestone will be deposited near the surface mine. The limestone landfill is positioned west of the displaced course of the river Ćehotina and south of the excavation front. The area where the limestone landfill is located is covered by the exploitation for the period of validity of the DRP 2020-2025. The limestone landfill is temporary.

4 OPERATING EXPENDITURE BUDGET

The basis for an economic analysis was the calculation of costs of the normative material and energy by the individual technological operations for Variant 1, and an example of calculation is given in Table. Table 3 shows the quantities of normative material. Table 4 shows the prices of normative material, and Table 5 shows the total costs of normative material. Table 6 shows labor costs.

Figure 7 shows the swot analysis.

Table 3 *Quantities of normative material*

	Fuel (l)	**Grease**	**Spare parts (kg)**	**Tire (pcs.)**	**Caterpillar (pcs.)**	**Explosive (kg)**	**Nonel detonators (pcs.)**	**Fuse (m)**	**Detonating cord (m)**	**Deto-nators (pcs.)**	**Drilling (m)**
Auxiliary works	2,558	259.51	74								
Drilling and blasting						51,902	1,097	1,097	1,928	7	15,274
Excavation	52,177	2,609	741		0.31						
Transport	127,057	6,353	741	3.59							
Total	**181,792**	**9,221**	**1,557**	**3.59**	**0.31**	**51,902**	**1,097**	**1,097**	**1,928**	**7**	**15,274**

Table 4 *Prices of normative material*

Type of material	**Price (€)**
Fuels	1
Grease	1.35
Spare parts	10
Tire	3500
Caterpillar consumption	10
Explosive Beranit 2	1
Nonel detonators	0.198
Slow-burning stick	0.39
Detonating cord	0.4
Mining capsules	0.27
Drilling	4

Table 5 *Total costs of normative material*

	Fuel (l)	**Grease**	**Spare parts (kg)**	**Tire (pcs.)**	**Caterpillar (pcs.)**	**Explosive (kg)**	**Nonel detonators (pcs.)**	**Fuse (m)**	**Detonating cord (m)**	**Deto-nators (pcs.)**	**Drilling (m)**
Auxiliary works	2,558	350	741								
Drilling and blasting		0				51.902	217	428	771	2	61.096
Excavation	52,177	3,522	7,415		30.5						
Transport	127,057	8,576	7,415	12,582							
TOTAL	**181,792**	**12,449**	**15,571**	**12,582**	**3**	**51,902**	**217**	**428**	**771**	**2**	**61,096**
TOTAL	**336,813**										

Table 6 *Labor costs*

Type of operation	Number of operatives in change	Number of operatives	Position	Net salary (€)	Gross (€)	In total/ month (€)	In total (€)
Manager	1	1	Engineer	1200	1764	1764	3529
Prepara-tion	1	2	Bulldozer operator	800	1176	2352	4705
Drilling	2	4	Drilling opera-tor and assistant	700	1029	4117	8235
Blasting	2	2	Igniter and assistant	700	1029	2058	4117
Loading	1	2	Excavator operator	800	1176	2352	4705
Transport	3	6	Truck drivers	800	1176	7058	14,117
Total	**10**					**19,705**	**39,411**

Table 7 shows the operating costs as well as labor costs

Table 7 *Costs per working operations*

Work type	Price (€)
Auxiliary works	3,650
Drilling	114,417
Loading	63,116
Transport	155,630
Manpower	39,411
Total (€)	**376,224**

Figure 7 *Swot analysis*

5 TECHNO-ECONOMIC COMPARISON OF CONSIDERED VARIANTS AND CONCLUSION

Table 8 shows the costs, i.e. the techno-economic comparison of variant solutions.

Variant 1 - comprises the route of conveyor and cut of the crushing plant rotated at the point of the drive station of the conveyor T1 by about 7^o in relation to the designed condition.

Variant 2 - comprises the route of conveyor and cut of the crushing plant remained in the position as in the valid Additional Mining Design, but the calculation was given by the method of parallel sections in relation to the initial state and which is common with Variant 1, i.e. the condition of works at the end of 2022.

Table 8 *Techno-economic comparison of variant solutions*

	Variant 1	**Variant 2**
Quantities to be excavated	148,292.21	252,005.0
Costs (€ /m^3)	2.54	2.49
In total (€)	376,224	627,492

Content of the Analysis enables a definition of the basic natural, techno-economic and organizational factors of making the cut of the T1 conveyor and crushing plant with the aim of easier determination their precise location.

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