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FILTER RULES FOR SOIL AND GEOSYNTHETICS

Abstract

Harmful effects caused by the water flow through various constructions (dams, embankments, etc.) are successfully solved by installing the various filter layers. The basic functions of filter layers are fast water evacuation with preventing the internal erosion and removal of small soil particles. These filter layers are usually made of coarse-grained materials (sand, gravel, stone aggregates), but in addition to the natural materials, the artificial geosynthetic materials are increasingly used. This paper presents the basic filter rules that need to be followed in order to perform a successful design of various filtration and drainage systems.

Keywords: *filter, base, grain-size distribution, water permeability, stability, clogging, durability*

1 INTRODUCTION

The outlet area of water filtration is often a crucial factor for the stability of individual structures weather those are embankments, dams, retaining walls, underground structures, etc. Therefore, in most cases, the basic goal is to prevent the infiltration of too much water into construction/soil, or to remove water that already exists there. Particularly sensitive places are at the contact of fine-grained and coarse-grained soil, when the water flows quickly in parallel with that contact. For these reasons, the filter layers are built that should meet certain rules-criteria. The term "filter rules" is used in defining a method for rapid evacuation of water while preventing the migration of small particles of the basic defended soil (base B) into or through the filter (F), under the action of forces caused by water flow. This means that the success of filtration process is based on interconnection between the defended soil and filter layers. As filtration of water through the soil is a complex function that depends on the size, shape and arrangement of voids, so the filter rules are based on interaction the individual particles and void phase, i.e. they depend on a grain-size distribution of the base and filter layers, i.e. relations of their characteristic diameters.

The first research related to the filter rules-criteria was published more than 100 years ago (1910), and they refer to the earth dams [8]. However, the rules that are still in use are attributed to the works of K. Terzaghi and A. Casagrande, which were published somewhat later, in the 1920s [1, 8]. These rules were developed during the construction of an overflow dam in the Austrian Alps in 1920 (patented in 1922), that is, on abasis of the study conducted by K. Terzaghi while working on filter layers for

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several dams in South Africa. In these works, it is stated for the first time that the filter must perform a dual role:

- that its grain-size distribution guarantees the stability against removal-leaching of small fractions from the protected zone - base (B), and
- to ensure a sufficient water permeability for rapid evacuation of water, so as not to increase the pore pressure in the body of construction (dam, embankment, etc.).

Very often, and especially in the last twenty years, the lack of adequate natural conditions is overcome by installing the drainage and filtration systems made of artificial - geosynthetic materials. These systems can be designed from individual layers of geosynthetic materials or are combined with the other components with which they form the complex drainage systems. Geosynthetic materials are also successfully used for the surface acceptance of precipitation, acceptance and diversion of groundwater and their discharge into a drainage system. Their successful application is associated with the good filtration characteristics such as the retention of fine soil particles while providing a rapid fluid circulation through the filter [12].

2 FILTER RULES FOR SOIL

In the case of natural soil, the rules are based on the grain-size distribution of a filter, whose task is to reduce the hydraulic gradient at the contact between the soil (base B) and coarse-grained deposit (drainage - filter F) by the transitional grain size. In this way, the leaching of small soil particles with groundwater is prevented. As a rule, a material with grain-size distribution is chosen for filters, which prevents the removal of small fractions, while reducing the filtration gradient to a minimum. A number of filter rules can be found in the literature; the most famous are: Terzaghi (1922), USBR (1947 - 1974), Sherard and Dunnigan (1985), Honjo and Veneziano (1989) [7, 18, 15, 16].

The Terzaghi filter rule is based on two basic criteria:

- the first that ensures sufficient water permeability of filter (F) and rapid evacuation of water, and can be defined as follows: "the smallest diameter of the finest fractions of filter, out of which there are 15% finer, should be at least four times larger than the coarsest fractions of the base, out of which there are 15% finer", i.e. [13].

$$\frac{F_{d15}}{B_{d15}} \geq 4; \qquad \min F_{d15} \geq 4B_{d15} \tag{1}$$

- the second, which guarantees the stability of filter against leaching of fine fractions, i.e. defines the void sizes of filter (F) in order to prevent the removal of fine fractions from the base (protected zone - B): "the largest diameter of the most coarse fractions of filter, out of which there are 15% finer, should be at most four times larger than diameters of the finest fractions of the base, out of which there are 85% finer" [13].

$$\frac{F_{d15}}{B_{d85}} \leq 4; \qquad \max F_{d15} \leq 4B_{d85} \tag{2}$$

where:

B_{d15} – grain diameter of the base out of which there are 15% of finer

B_{d85} – grain diameter of the base out of which there are 85% of finer

F_{d15} – grain diameter of the filter out of which there are 15% of finer

In addition to the above criteria, it is proposed that the lines of grain-size distribution of filter (F) should be approximately parallel to the lines of grain-size distribution of the base (B). In practice, it often happens that the proposed criteria cannot be achieved by installing only one filter, so that the multi-layer filters are installed that allow a gradual transition from the fine-grained (base) soil to the coarse-grained soil, which are filters.

The method of application of the Terzaghi filter rule is shown in Figure 1.

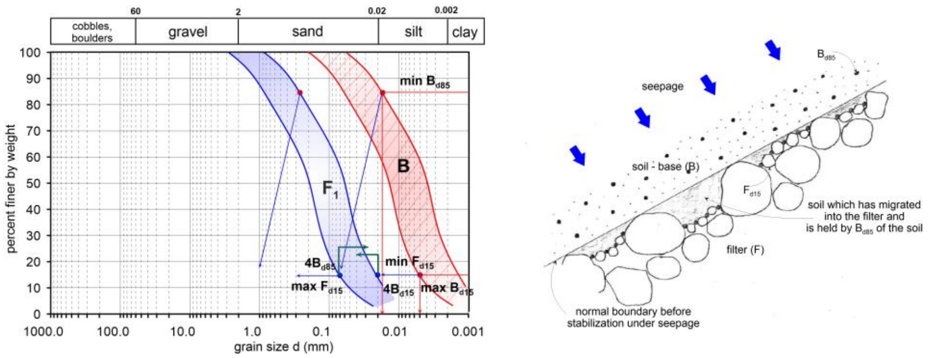


Figure 1 *Terzaghi filter criterion (K. Terzaghi, 1922; Cedergren, 1968)*

The criterion proposed by Terzaghi forms the basis for most of the criteria that were later carefully analyzed and proposed by various authors: Bertram (1940), Hurley and Nanton (1940), Lund (1949), USBR (1947-1974), Sherard and Dunnigan (1985), Honjo and Veneziano (1989) et al. [2, 9, 18, 15, 7]. These were mainly laboratory and theoretical analyzes, related to the justification of selection the grain size, as well as the minimum and maximum ratio depending on the proposed criteria.

In 1947 (1974), the American Land Reclamation Bureau (USBR) proposed the following filter rules:

$$12 < \frac{F_{d15}}{B_{d15}} < 40 \tag{3}$$

$$12 < \frac{F_{d50}}{B_{d50}} < 58 \tag{4}$$

In addition, the filter material should have less than 5% fractions finer than 0.074 mm, and the coarsest particles in filter are 65 - 70 mm. In this filter rule as well, the lines of grain-size distribution of filter are approximately parallel to the lines of grain-size distribution of the base (Figure 2).

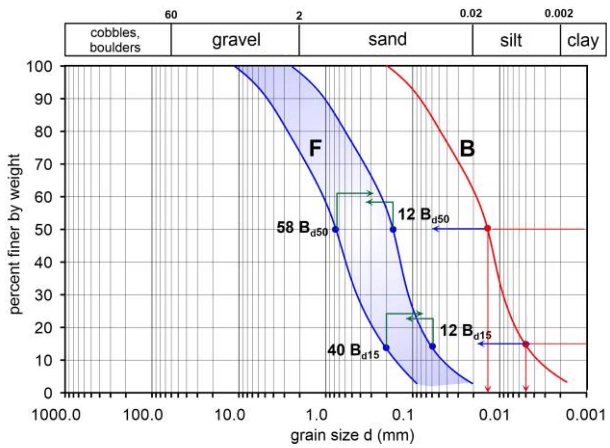


Figure 2 *American Bureau of Reclamation filter criteria (after USBR, 1947-1974)*

Later (1974), this filter rule was supplemented, with a filter rule relating to the crushed stone, as well as for filters relating to the natural uniform materials. In this regard, the ratios of percentage of fractions in the filter material F_{d90}/F_{d10}, have been proposed, in order to obtain granulometric curves that provide a relatively even distribution of particle size and prevent segregation during the installation of filter layers. For the coarse-grained filters made of gravelly and sandy material, the supplement to the criteria is shown in Table 1.

Table 1 *Limitations related to the particle size distribution using the USBR criteria*

min F_{d10}	**max F_{d90}**
< 0.5	20.0
0.5 - 1.0	25.0
1.0 – 2.0	30.0
2.0 – 5.0	40.0
5.0 – 10.0	50.0
10.0 - 50.0	60.0

Sherard et al. studied the filter rules related to dams and embankments. For coarse-grained materials (mainly poor granulation sand), they also performed the laboratory tests in a special apparatus (a plastic cylinder with diameter of 10.16 cm, in which a sample of 13-18 cm in height is installed), and through it a special system allows water flow at pressure of 400 kPa). The Sherard and Dunnigan filter rule [15], implies the division of soil into four groups, for which the criteria are defined (Table 2).

Table 2 *The Sherard and Dunnigan filter rule*

Group	Soil description	Criterion
I	Fine silt and clay: more than 85% of fraction passes through a sieve no. 200, i.e. through a sieve with openings of 0.075 mm.	$\frac{F_{d15}}{B_{d85}} \leq 9 \quad \text{(min 2)}$
II	Silty and clayey sand and sandy silts and clay: between 40% and 85% of fraction passes through a sieve no. 200.	$F_{d15} \leq 7 \quad \text{mm}$
III	Silty clayey sand and gravel: from 15% to 39% of fraction passes through a sieve no. 200.	$F_{d15} \leq \left(\frac{40-A}{25}\right) \cdot \left(4B_{d85} - 0.7\text{mm}\right) + 0.7\text{mm}$ A – weight percentage of grain fraction less than 0.075 mm in diameter of the soil to be protected; If $4B_{d85}$ is less than 0.7 mm, 0.7 mm is adopted.
IV	Silty clayey sand and gravelly sand: less or 15% of fraction passes through a sieve no. 200.	$\frac{F_{d15}}{B_{d85}} \leq 4$

The Sherard and Dunnigan criterion is applied to all soil types, provided that the filter fractions are not less than 0.1 mm. Also, the width of a designed filter range should be such that the ratio of maximum and minimum diameter for all fractions out of which there are 60% finer is ≤ 5. In addition to the above, it is necessary to meet the criterion of water permeability, i.e.

$$F_{d15} \geq 4 \cdot B_{d15} \tag{5}$$

A summary of some of the most commonly applied filter rules used in selection of a filter is shown in Figure 3 [11].

3 FILTER RULES FOR GEOSYNTHETICS

Geosynthetic filters are very thin compared to the classic filters made of coarse-grained materials, which, due to their significantly larger thickness, also have different possibilities to keep the movement of soil particles. Due to this limited possibility of geotextiles, stricter design criteria are applied. The first application of geosynthetic filters of non-woven geotextile was related to the construction of the Valcros dam in 1970 [5]. It is interesting to note that the installation of geosynthetics was not based on certain filter rules, but earlier experiences related to the role of separation were used. After that, a period of intensive work on defining the filter rules for geosynthetics has begun.

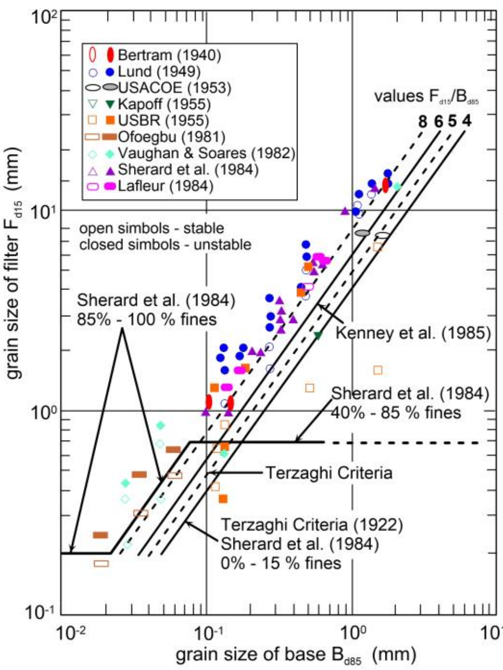


Figure 3 *Summary of filter rules based on the ratio of F_{d15} and B_{d85} (Terzaghi et al. 1996, Park et al., 2001-2003 [17])*

Before designing the geosynthetic filters, it is necessary to define the goal of their application and determine the geotechnical conditions on the site. These are the input data according to which the necessary criteria and external factors that can affect the characteristics of geosynthetic materials are defined. Based on that, a model for analysis is created when the necessary parameters are determined. After the conducted analysis, the most appropriate solution is selected, with consideration the alternative solutions in terms of costs, installation convenience, etc. The chosen solution involves the preparation of detailed plans and specifications, including the specification of mechanization required for the installation of geosynthetics and detailed installation procedures. The selection of geosynthetics should be made on the basis of the results of laboratory tested samples, or if such results do not exist, on the basis of the specifications of geosynthetics manufacturer.

The design of geosynthetic filters is in principle the same as the design of filters made of natural materials. The similarity between geosynthetics and soil is that they also have a void space and solid particles, which in this case replace the geosynthetic threads and fibers. However, due to the shape and arrangement of the fibers and structure of the geotextile itself, the geometric relationships between the fibers and voids are more complex in relation to the soil. In geotextiles, the void dimensions are measured directly, while in soil, a particle size is used to estimate a void size. As a direct determination of void size in geosynthetics is not simple, the relationships between void size and particle size that should be stopped on the filter are relatively complex. Therefore, when designing the geosynthetic filters, the following filtration rules are most often analyzed:

- if the size of the largest void in geotextile filter is smaller than the largest soil particle, the soil will remain on filter. It is similar with the classical filters made of granular materials where coarser soil particles form a “filter bridge” over the perforation, thus retaining finer particles that prevent further introduction of particles into drainage (Figure 4).

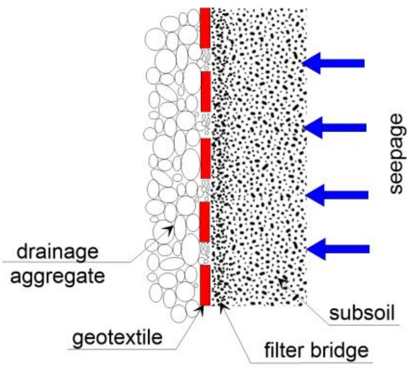


Figure 4 *Formation of filter bridge on geotextiles*

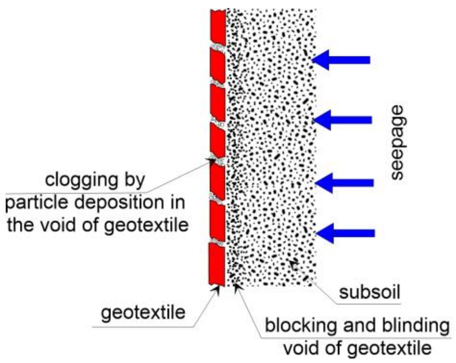


Figure 5 *Clogging and blinding void of geotextile*

- if the smaller openings on geotextile are large enough to allow smaller soil particles to pass through the filter, then the voids on geotextile will not clog or close (Figure 5).
- there must be a sufficient number of voids on filter to allow normal water flow even in the event that individual openings become clogged.

After a detailed study conducted in North America and Europe by Christopher and Holtz [3], on classical and geotextile filters, the procedure for designing the geotextile drainage filters as well as filters for permanent erosion control was established. Consideration the risks and consequences of non-functioning the geotextile filter is very important, especially in capital facilities, and therefore the choice of appropriate geotextile is extremely important. The required level of the project depends on nature of the project itself and complexity of the hydraulic conditions and condition in which the soil is located. In cases where hydraulic conditions are complex, a combination with conventional methods is recommended.

The above rules-criteria and analogies with the classical granular filters can be used to define the design criteria for geotextiles [4,6,10]. These criteria are as follows:

- retention criterion,
- permeability or filtration criterion,
- clogging resistance criterion, and
- wear criterion.

3.1 Retention criterion

This criterion also exists in the classical coarse-grained soil filters, and implies that one of the roles of geotextiles is to retain particles from the protected zone. The criterion is specifically defined for constant flow conditions, and especially for dynamic flow conditions. In the case of a constant flow, the following relation is applied:

$$\text{AOS ili } O_{95\ (\text{geot.})} \leq B \cdot D_{85\ (\text{tlo})} \qquad (6)$$

where:

AOS - apparent opening size (size of the largest soil particle that can pass through geotextile) - apparent opening size (mm),

O_{95} - void size on geotextile out of which there are 95% finer (mm) AOS ≈ O95,

B - coefficient (unnamed number),

D_{85} - size of soil particles out of which there are 85% finer (mm).

The coefficient B varies from 0.5 to 2.0 and depends on the type of soil through which the filtration is performed, its volume weight, coefficient of non-uniformity C_u if the soil is granular, type of geotextile (woven or nonwoven) and flow conditions. For sand, gravelly sands, silty sand and clayey sands (with less than 50% of particles passing through a sieve of 0.075 mm), B depends on the coefficient of non-uniformity C_u, as follows:

$C_u \leq 2$ or ≥ 8: B = 1

$2 \leq C_u \leq 4$: B = 0.5 C_u

$4 < C_u < 8$: B = 8/C_u

If the defended soil also contains some impurities, it is necessary to use only fractions that pass through a 4.75 mm sieve for drainage layers (in other words, all particles larger than 4.75 mm should be removed).

For silt and clay (with more than 50% of particles passing through a 0.075 mm sieve), B depends on the type of geotextile, as follows:

for woven B = 1; $O_{95} \leq D_{85}$

for nonwoven B = 1.8; $O_{95} \leq 1.8\ D_{85}$

for both types AOS or $O_{95} \leq 0.3$ mm

In principle, the non-woven geotextile will retain finer particles compared to the woven ones, if they have the same AOS.

The AASHTO M 288 standard for geosynthetics recommends the following maximum AOS values in relation to the percentage of soil passing through a 0.075 mm sieve:

- 0.43 mm when less than 15 % passes,
- 0.25 mm when passes between 15 - 50 %,
- 0.22 mm when passes more than 50 %.

However, for coherent soils with a plasticity index greater than PI> 7, the maximum AOS is 0.30 mm. The values of AOS adopted in this way are predetermined by the particle size in situ, so it is necessary to perform the test. The test is performed only in the following cases: if the soil is unstable or prone to erosion (e.g. incoherent silt), soil in which sand and silt alternate (in the form of laminations), dispersed clays, etc.

When it comes to dynamic flow conditions, i.e. if the geotextile is not adequately loaded and does not make a constant contact with soil it protects, or if the load conditions (dynamic, cyclic or pulsating) produce high hydraulic gradients, then the soil particles can cross to the other side of geotextile. Therefore, the adoption of constant value for the coefficient B = 1 is not common in such cases, because a network of bridges will not be formed and geotextile will retain finer particles in this case. In case when retention is the primary criterion, the coefficient B is reduced to 0.5, i.e.

$$O_{95\ (geot.)} \leq 0.5 \cdot D_{85\ (tlo)} \tag{7}$$

Dynamic flow conditions often occur in drainage on the roads. To divert water runoff or in a high gradient situation, it is best to maintain the sufficient weight or load on filter to prevent particles from moving.

3.2 Permeability or filtration criterion

If there are less strict conditions, the geotextile filtration coefficient should be greater than or about equal to the coefficient of soil, i.e.

$$k_{f\,(geot.)} \geq k_{f\,(tla)} \tag{8}$$

otherwise, when the strict conditions are set, it is necessary to

$$k_{f\,(geot.)} \geq 10 \cdot k_{f\,(tla)} \tag{9}$$

Permeability largely depends on the thickness of geotextile, and is defined by the permeability coefficient ψ, which is determined from the ratio

$$\psi = k_{f\,(geot.)} / d_{geot.} \tag{10}$$

where d_{geot} is the thickness of geotextile that depends on the hydraulic pressure.

Depending on the percentage of soil that passes through a sieve with diameter of 0.075 mm, ψ has the following values:

$\psi \geq 0.5$ sec^{-1} when less than 15% of soil passes

$\psi \geq 0.2$ sec^{-1} when passes between 15 - 50 % of soil

$\psi \geq 0.1$ sec^{-1} when more than 50 % of soil passes.

3.3 Clogging resistance criterion

If there are less strict conditions, this criterion can be met using the following expression

$$O_{95\ (geot.)} \geq 3 \cdot D_{15\ (tlo)} \tag{11}$$

It is applied when the coefficient of non-uniformity is $C_u > 3$. In case this condition is not fulfilled, i.e., if $C_u \leq 3$, the geotextile is chosen on the basis of the maximum values of AOS. However, when clogging is very likely (with silty sand, etc.), it is necessary to adhere to the following:

- for nonwoven geotextiles, the porosity should be n ≥ 50%
- for woven geotextiles, the percentage of open area should be POA ≥ 4%

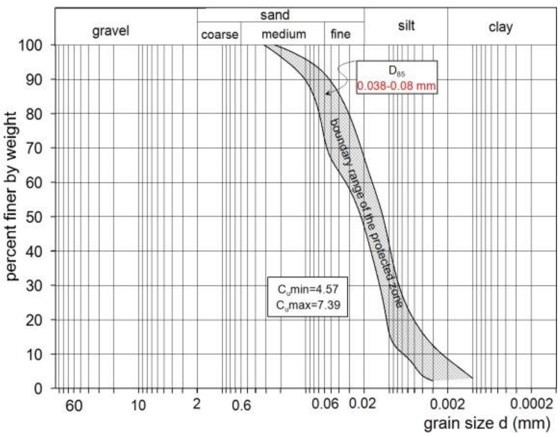
3.4 Wear criterion

This criterion refers to the possibility of damage the geotextile during the process of its installation. Since the retention and drainage criteria also depend on certain properties such as the strength and durability of geotextile (tearing, puncture, cracking), this implies that the geotextile should "survive" the installation process. This criterion is essentially not based on the specific and systematic research, but on the characteristics of geotextiles which, on the basis of numerous applications, and in accordance with predefined specifications, have met the criterion of durability.

4 APPLICATIONS OF SOIL AND GEOTEXTILE FOR REHABILITATION THE LANDSLIDE "MELJAK"

As an example of application of the geosynthetics for the needs of drainage, the rehabilitation of the landslide "Meljak" on the main road Belgrade - Ljig will be presented. The rehabilitation measure included the construction of a drainage system, in order to reduce the groundwater level in the field. In addition to collecting the groundwater, this system is aimed to drain the terrain in the most efficient way.

The basis of the terrain is built of clayey silty soil whose grain size distribution curve is shown in Figure 6.



coefficient B za $4<C_u<8$	$BxD_{85} \geq AOS(mm)$
B = 1.75	4.57x0.08=0.14
B = 1.08	7.39x0.038=0.28

AOS(mm) ≤ 0.15 mm

Figure 6 *Grain size distribution curve with basic numerical data*

In order to select the appropriate geotextile, its functions (primary, secondary, filtration, separation), required properties (AOS, absorption capacity, durability/"survival") as well as the specifications of geotextile that can be found on our market were analyzed. Based on the grain-size distribution of soil, the basic data for selection of geotextiles were defined (Figure 6). Based on the retention criterion for a constant flow, the value of parameter B and diameter D_{85} was defined, and based on that, the value for AOS ≤ 0.15 mm was adopted. The presented curves of grain-size distribution were used to determine the approximate values of the soil filtration coefficient $k_{f(soil)}$, which range from $k_{f(soil)} = 4x10^{-5} - 5x10^{-4}$ cm/sec, using the Hazen equation. The results served to apply stricter conditions, to define the filtration coefficient of geotextiles, i.e. $k_{f(geotextil)} \geq 5x10^{-3}$ cm/sec.

Since more than 50% of soil passes through a sieve with diameter of 0.075 mm, the permeability coefficient $\psi \geq 0.1$ sec^{-1} was defined, i.e. using the filtration criterion min. geotextile thickness d_{geot}=0.5mm.. For less strict conditions according to the criterion of resistance to clogging, the void sizes on geotextile are defined, out of which 95% finer, i.e. $O_{95} \geq 0.012$ - 0.03 mm, so due to these reasons $O_{95} \geq 0.012$ mm was adopted, but not over 0.3 mm, since the plasticity index of natural material Ip <7. As it is soil with more than 50% fractions finer than 0.075 mm, the nonwoven geotextiles with a porosity of over 50% and the Percent Open Area (POA) of over 4% should be selected [19]. Based on the presented results, it was established that the class II geotextiles can be used for the proposed drainage system, which also include the geotextiles of type 200 (200 g/m^2 with thickness d_{geot} = 1 mm). The installation scheme as well as the field installation procedure are shown in Figure 7.

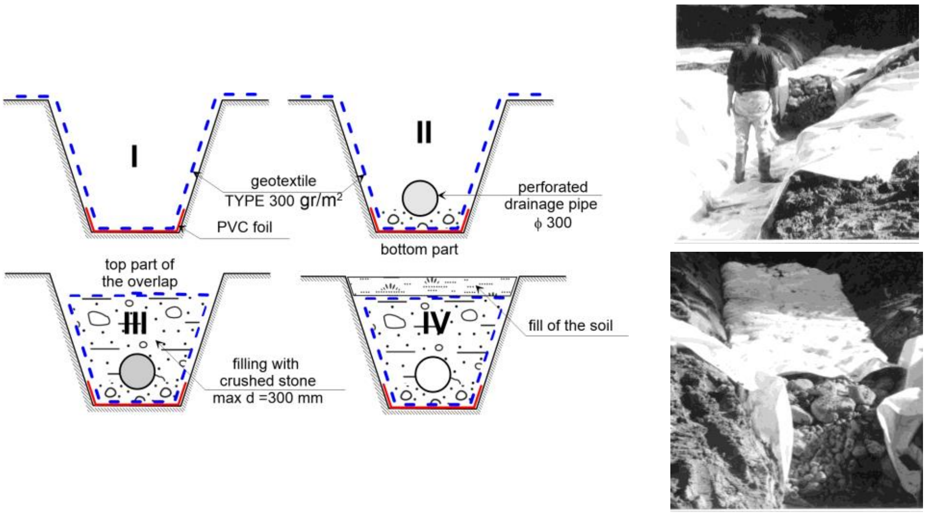


Figure 7 *Phase construction of a drainage trench with geotextile filter*

The drainage system itself consisted of one longitudinal trench 96 m long, and one transverse drainage trench with a drainage ditch on the right side of the road (in the direction of Ljig) 70 m long. The drainage filling in the drainage trenches consisted of the well-granulated crushed stone with the largest diameter of fraction d = 300 mm. The infill is covered with geotextile type 300 (1.4 mm thick), with the PVC foil placed at the bottom of drainage trenches.

5 GENERAL ON THE COSTS OF SOIL AND GEOTEXTILE USE

Determining the cost-effectiveness of geotextiles in relation to the conventional soil drainage systems is a process that is analyzed for each facility separately. Based on that, a decision is made on the economic profitability of the project, which is based on extending the service life of the facility and reducing the maintenance costs. Selection of geotextiles should not be based solely on price [14]. The price of geotextiles is usually negligible compared to the other components and construction costs of the entire system. Also, the savings related to the elimination of laboratory tests that define the behavior of soil-geosynthetic systems are not large, so they should be anticipated during the design phase. The use of geosynthetic materials is increasing, as it is often the case that the majority of manufacturing companies offer free design services, training, effective support on the construction sites, and even design software, which are made on the basis of recognized methods.

In order to reach an economically acceptable solution, it is simply necessary to compare the costs of geotextiles with the costs of conventional granular filter layers, taking into account the following:

- the total material costs, which means the price of geotextiles in relation to the conventional system,
- the costs of installing the geotextiles (in most cases the price is lower than the costs of construction a two-layer granular filter, which are often needed as a supplement to the conventional filters and fine-grained soil),
- possibilities of reduction the dimensions of drainage system (for exam-

ple, reduction of dimensions entails a reduction in excavation volume, volume of the required filter material and even the construction time).

Typical costs of geotextiles for drainage systems range from 0.5 to 2.5 EUR/m^2 depending on the type and technical characteristics (type of fiber, weight, thickness, mechanical properties). Installation costs depend on the project specifics and experience of the contractor. They usually vary from 0.5 to 1.5 EUR/m^2 of geotextile. Higher costs can be expected in the case of underwater works and use the innovative geotextiles (trend of development the "intelligent geotextiles", nanofibers) or geotextiles developed within the so-called "green concept" (geotextiles made of natural fibers). The overall costs of installing the geotextiles pays off quickly because the construction takes place faster, and the installation process allows for more reliable prevention of segregation and contamination of granular filter materials, so the multilayer granular filters are usually not necessary.

6 CONCLUSION

Water filtration through the soil is one of the most important engineering processes that affects the stability of various structures, erosion and general interaction of terrain and structures. For the needs of controlled filtration conditions, the natural or artificial materials are used. In order for the effects of water filtration to be successful, the materials used for these needs must have certain characteristics, and their installation is done applying the appropriate filter rules that are constantly changing and improving. The reason for that is that despite the application of defined filter rules in the design of drainage systems, various types of deformations still occur in the form of demolition of dams, embankments, functionality of underground structures, due to the inadequate water control. Therefore, the choice of appropriate filter material (natural or artificial), as well as the method of its installation, is very important when modeling the action of filtration forces that occur at the contacts of different types of soil or soil and artificial geosynthetic materials.

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Original Scientific Paper
Geotechnics

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GEOTECHNICAL INVESTIGATIONS FOR DEFINING THE BUILDING CONDITIONS OF THE NEW QUARRY CRUSHER PLANT IN BOR**

Abstract

Geotechnical investigations were conducted at the construction site of the new crushing plant at the open pit "Kriveljski kamen" in Bor. The construction of parts of this plant is planned on an unstable slope. The aim was to define the lithological-geotechnical material and terrain structure as a basis for determining the optimal conditions of construction, excavation methods, funding and undertaking the reclamation measures in the area intended for accommodation of facilities.

Keywords: *geotechnical investigations, crushing plant, unstable slope, construction conditions*

1 INTRODUCTION

As part of an increase in the production capacity of stone aggregate at the open pit "Kriveljski kamen", it is necessary to renew the limestone preparation plant. Geomechanical investigations were performed at the place planned for location of the new crushing plant. The location of facilities planned for construction is on the southern edge of the open which is located approximately 4 km as the crow flies northwest of Bor. Micro-locally, the position is on a steep slope, right next to the already existing crushing plant. Field observations, exploratory drilling, core mapping and geomechanical sampling of rocks and soil on the slope were performed. After that, a geotechnical model of terrain was designed, in order to observe the object-engaged soil interaction.

2 REVIEW OF INVESTIGATIONS

In accordance with the investigation program, the following geomechanical investigation works were performed:

- Engineering geological mapping of the terrain;
- Exploratory drilling - the achieved depth for all boreholes were from 10.8 to 31 m, i.e. the total of 104.9 m of drilling;
- Geotechnical mapping of cores (Figure 1);
- Laboratory geomechanical tests on two soil samples and thirteen samples of rock material.

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Figure 1 *Marking core for geotechnical mapping*

3 INVESTIGATION RESULTS

Based on all obtained data, the characteristic geotechnical cross - sections of terrain was constructed, within which the calculated values of important geomechanical parameters were presented. The calculated values of physical and mechanical parameters of rock material were obtained on the basis of results of the laboratory tests and statistical processing of the obtained results, field classification of cracked rock masses RMR [1], as well as using the software package RocData [2].

At the investigated location, based on the lithological and geotechnical composition, the eight geotechnical units were separated (as it is shown in Figure 2):

1 Technogenic material-embankment,
2 Sandstone debris,
3 Broken limestone,
4 Massive limestone,
5 Broken sandstone,
6 Compact sandstone,
7 Broken andesitis,
8 Compact andesits.

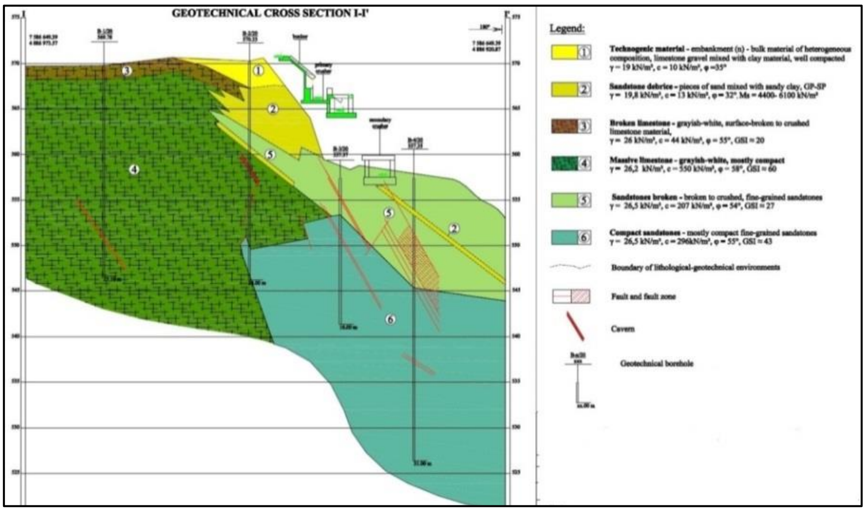

Figure 2 *Geotechnical cross sections of terrain with disposition of objects*

4 GEOTECHNICAL CONDITIONS OF FOUNDATION AND ANALYSIS OF THE SLOPE STABILITY

GEO5-Spread Footing version 5.2019.80 of the company "FINE civil engineering software" was used for calculation the bearing capacity of soil, which was done according to Eurocod 7 (2004).

The primary crusher facility with accompanying equipment will be founded on two foundation slabs. It is planned to fund the so-called "Massive gravitational foundation." The foundation will be laid shallow on terrain surface. The results of conducted calculation are shown in Figure 3.

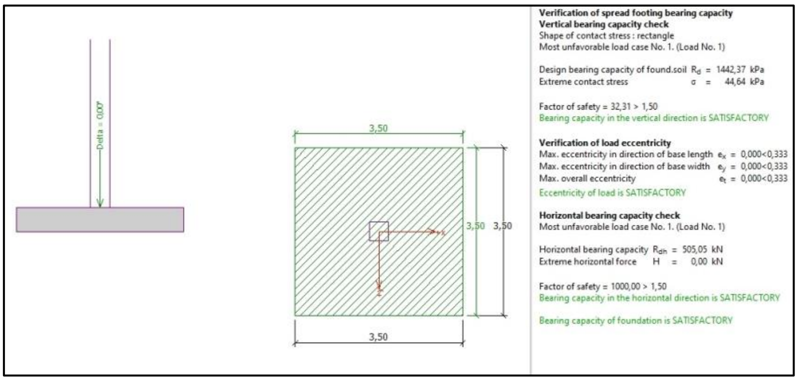

Figure 3 *Foundation bearing capacity calculation*

Funding on AB foundation board	*L x B = 3.5 x 3.5 m*
Fund depth	$D_f = 1$ *m*
Bearing capacity of soil	$\underline{q_a = 1442\ kN/m^2}$

For the purpose of designing all constructive solutions of facilities of the new crushing plant, an analysis of the current slope stability was performed where the stability problems were observed (Figure 4). Also, a stability analysis was performed to determine the area on slope of the cross section with the safety factor Fs less than 1.2 (Figure 5). The stability calculation was done with the *Rocscience* program *Slide v6.0*. With the Slide program, the stability calculation is performed in the conditions of boundary equilibrium. The calculation was done according to the *Janbu* method.

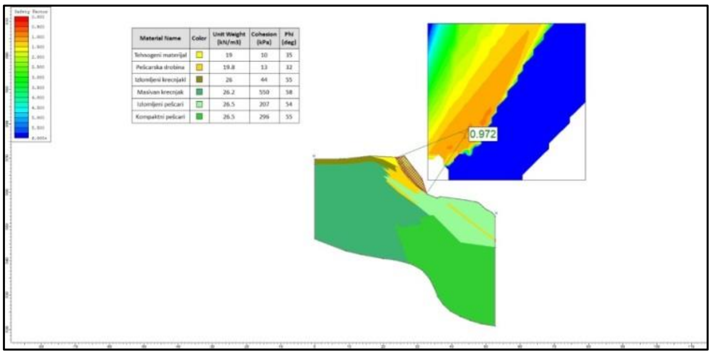

Figure 4 *Analysis the stability in current state of slope - Janbu method*

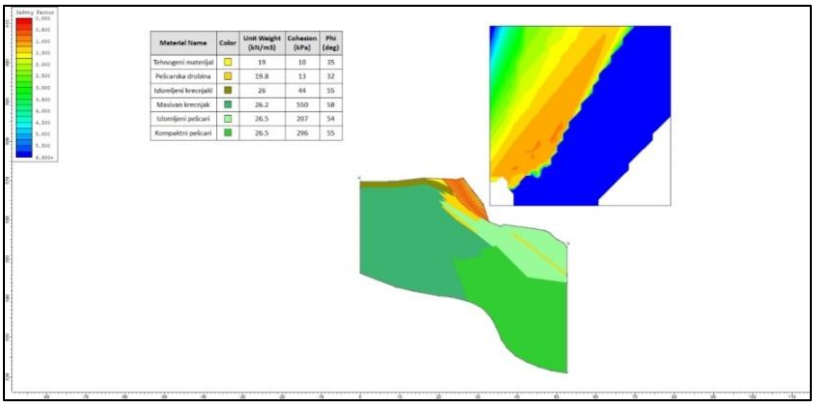

Figure 5 *Specify the area in which Fs < 1.2 - Jambu method*

Based on the conducted analysis of slope stability provided for accommodation the facilities and equipment (bunker, primary crusher), it can be seen that the subject slope is not stable in the current conditions (obtained values of Fs are 0.98 and 0.97). During the construction of facilities, the reclamation measures must be performed, in order to bring the slope into a stable condition. In this case, the designer decided to apply the anchoring of retaining wall by fixing the anchors to the rock mass, which the analysis showed to be stable.

CONCLUSION

For the need to build a new crusher plant in Bor, a certain amount of geotechnical exploration work was performed. There was a problem related to the engineering-geological conditions of the field, which was reflected in the fact that construction was planned on an unstable steep slope. Based on the investigation results, a geotechnical terrain model was formed, which defined the geotechnical conditions of construction and provided data to the designers for adequate positioning of reclamation measures in the field.

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EFFICIENCY OF THE TRANSPORT SYSTEM OPERATION IN SEPARATION AT THE OPEN PIT "DIMNJAČE"

Abstract

This paper sets out the methodology and presents the results of calculation the efficiency of transport system in separation of the OP "Dimnjače", based on the data of monitoring the operating time and downtime/failure. Properly determined state of operation of the transport system, allows preventive measures and selection of maintenance strategy. Data collection lasted a year, and the data were analyzed, and thus the results are given by month for the transport system as a whole.

Keywords: *efficiency, belt transport, time, downtime, failure, open pit, reliability, availability, functional suitability, separation, maintenance*

1 INTRODUCTION

The coal mine “Gračanica” D.O.O. is engaged in the production and preparation of lignite coal. It started operating in 1938 as a mine with the underground exploitation until 1975, when it began with the surface exploitation at the OP "Gračanica", which was located in the municipality of Bugojno, as well as the separation facilities.

Currently, the mine has the coal exploitation at the OP "Dimnjače". The open pit "Dimnjače" as well as the coal separation facilities, and accompanying facilities, mechanical workshop and administrative building are located on the territory of the municipality of Gornji Vakuf - Uskoplje.

Exploitation at the open pit "Dimnjače" began in 1986, and the coal separation was performed with separation whose capacity was approximately 50 t/h and mostly coal fraction (0-60 mm) was obtained.

Since the placement of coal was increased, and the open pit "Gračanica" was in the final phase of exploitation, the construction of a new separation at the open pit "Dimnjača" began. In a very short period, the construction of separation facilities was completed by 1987.

The coal separation capacity of the OP "Dimnjače" is approximately 200 t/h, and the annual approximately 700,000 t/ear. Figure 1 shows the technological scheme of separation of ZD Coal Mine "Gračanica" D.O.O. Gornji Vakuf - Uskoplje.

Coal mining at the OP ”Dimnjače”- Coal mine “Gračanica” is carried out by the bucket excavators. The excavated coal is loaded directly into trucks, which are transported to the primary crusher. The crusher grinds coal with a granulation of up to 400 mm. The rakes transport coal to the T1A belt conveyor, which is B = 1000 mm wide and 210 m long.

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The transport system in separation has thirteen belt conveyors (T1A, T1, T3, T4, T6, T8, T11, T12, T13, T14, T15 T16 and T17), three rakes, caliber sieve 80x80 mm, caliber sieve 120x120 mm, single-level sieve and control panel [4,5,6,7].

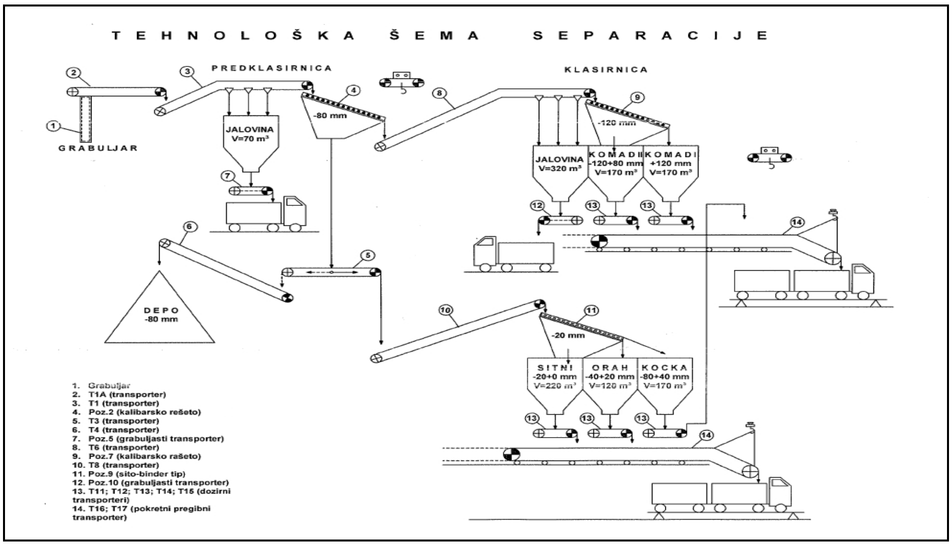

Figure 1 *Transport system in separation [7]*

2 METHODOLOGY OF DETERMINING THE EFFICIENCY OF THE TRANSPORT SYSTEM OPERATION

Data on operating conditions and failure/downtime of individual elements of the separation transport system were used to determine the distribution law and calculation of reliability indicators.

Effectiveness of the complex is expressed by the basic formula [9]:

$$E(t) = A(t) \cdot R(t) \cdot FP$$

E (t) - efficiency as a function of operation time; expressed as probability

A (t) - availability of the complex as a function of time; expressed as probability

R (t) - reliability of the complex as a function of time; expressed as probability

FP - functional similarity. It does not depend on time; it is a measure of meeting the required performances or degree of adaptation to the working conditions

Efficiency of the complex, expressed as the probability of successful start of operation, maintenance of the function within the framework defined by the function criteria, and adaptation to the changes in external working conditions is in the range: $0 \leq E \leq 1$ [9].

Component of the total effectiveness of availability the complex A(t) and reliability R(t) are functions of time (t), and their value ranges from 0.0 to 1.0, and therefore the total effectiveness is also limited to the interval 0.0 to 1.0. The value of FP, in common efficiency calculations is equal to one. During development of the complex, the value of functional suitability is analyzed in the range: 0 < FP < 1 [9].

The availability is defined as the probability that the complex will be able to take effect at the time of need. This component is especially important for the transport complexes that have been out of operation for some time. In principle, the availability depends on reliability, but also on the maintenance system, i.e. the speed of returning the complex from the state of failure to the state of operation. The availability can be calculated via the appropriate ratio of time of the correct state of complex and time of the state of complex in failure [1]:

$$A(t) = \frac{T_{er}}{T_{kal}} = \frac{T_{er}}{T_{er} + T_{ot}} = \frac{\sum_{i=1}^{n} t_{er}}{\sum_{i=1}^{n} t_{er} + \sum_{i=1}^{n} t_{er}}$$

$T_{er} = \Sigma_{ter}$ - total time that the complex spends in operation

T_{kal} – calendar operation time

$T_{ot} = \sum_{i=1}^{n} t_{ot}$ - total time that the complex spends in failure

$$A(t) = \frac{1}{1 + \frac{T_{ot}}{T_{er}}}$$

The effect of complex availability on the system effectiveness is reflected in realization the maximum time in operation, and minimum time in failure.

Reliability characteristics are determined on the basis of failure time data. These data are obtained by monitoring the elements of transport complexes in real operation and performing the special tests. Data processing is performed by the statistical methods and methods of probability theory. The choice of distribution law implies a way of determining the type of distribution that best corresponds to the data being processed. The normal or Gaussian distribution and the Weibull distribution have the greatest application. In both distributions (t) is a random variable, i.e. the operating time until failure occurs. The two-parameter Weibull distribution is the most acceptable in the reliability analyzes of the elements of transport complexes. The two-parameter form of the Weibull distribution is given by the formula [1]:

$$R(ti) = 1 - F(ti) = \exp\left[-\left(\frac{t}{\eta}\right)^{\beta}\right]$$

The parameters of this distribution are: β-shape parameter and η-scale parameter. The shape parameter directly determines the shape of density function. For β = 1, the Weibull distribution is identical to the exponential distribution. For β <1, the spans of randomly variable magnitudes are larger than for the exponential distribution. For β = (2.5-3.5), the Weibull distribution coincides with the Gaussian distribution. The scale parameter of the Weibull distribution represents a quantity proportional to the mean value of distribution, i.e.:

$$m = \eta\Gamma\left(1 + \frac{1}{\beta}\right)$$

Value (Γ) of the gamma function Γ(1+1/β) for different values of the shape parameter (β) is shown in tabular form in literature [1].

Based on the previous analytical expressions in Microsoft Excel, a program was created to facilitate the calculation of individual reliability functions and check the distribution law (Figures 2 and 3).

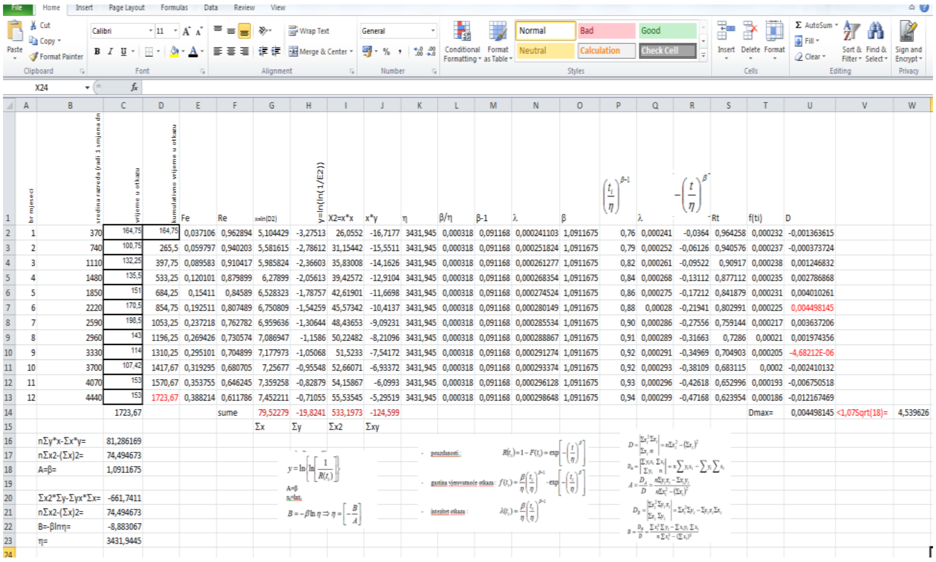

Figure 2 *Calculating the reliability of transport system in Microsoft Excel*

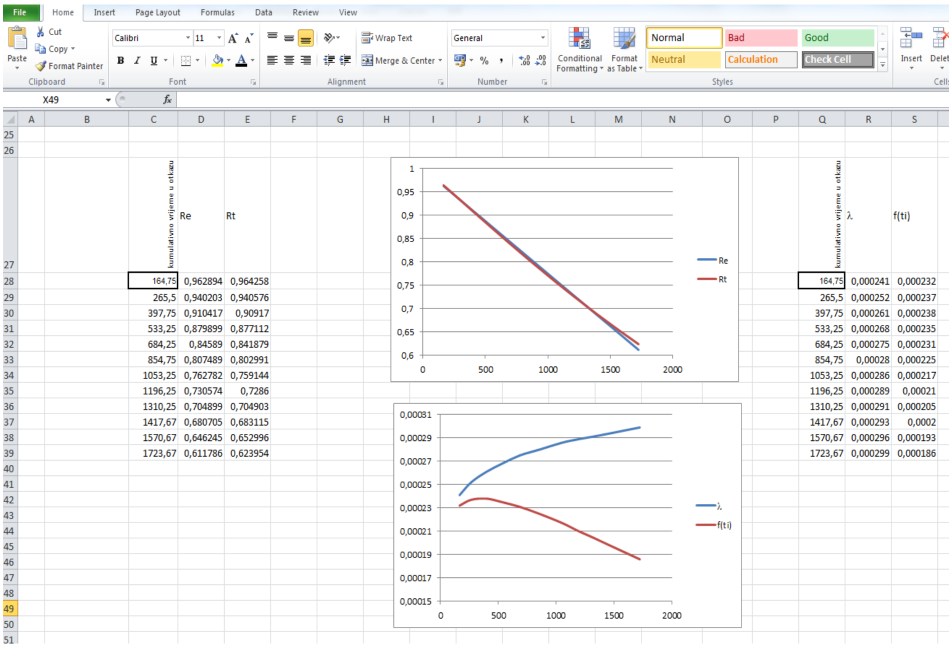

Figure 3 *Graphic representation of the reliability of transport system in Microsoft Excel*

3 EFFICIENCY OF THE TRANSPORT SYSTEM OPERATION IN SEPARATION

Data on the state of operation and failure/downtime of transporter were used to determine the distribution law and calculation of reliability indicators. Based on the data on electrical, mechanical, technological and total failures/downtimes, the law of distribution of reliability indicators has been determined. Based on the above, the following were determined: reliability, failure intensity function and failure density function. Based on the time in operation and failure/downtime, the values of operational readiness and functional suitability of all considered trucks were also calculated.

Table 1 and Figure 4 show the efficiency of transport system in the separation of the OP "Dimnjače" D.O.O. Gornji Vakuf-Uskoplje.

Based on the obtained parameters of reliability, operational readiness and functional suitability, the efficiency of operation was calculated.

Table 1 *Efficiency of the transport system in separation of the OP "Dimnjače" DOO Gornji Vakuf-Uskoplje*

Transport system of separation				
Month/2013	**Efficiency based on electrical downtime / failure E(e)**	**Efficiency based on machine downtime / failure E(m)**	**Efficiency based on technological downtime / failure E(t)**	**Efficiency based on the total downtime / failure E(u)**
January	0.930342	0.952068	0.537412	0.501271
February	0.95686	0.959926	0.670057	0.629226
March	0.983467	0.964304	0.584552	0.562317
April	0.987346	0.962068	0.550532	0.529722
May	0.99414	0.966666	0.477851	0.46325
June	0.924534	0.978227	0.446081	0.417078
July	0.977827	0.982375	0.362167	0.349964
August	0.958514	0.963655	0.450868	0.422935
September	0.971996	0.970446	0.490038	0.463107
October	0.959136	0.93563	0.504492	0.457153
November	0.975736	0.934607	0.424473	0.388909
December	0.970037	0.954668	0.42099	0.387004

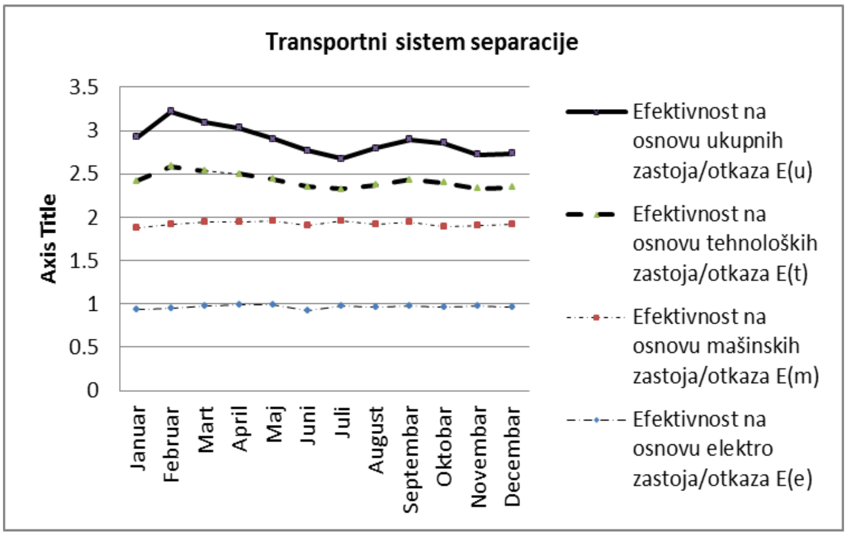

Figure 4 *Efficiency of the transport system in separation of the OP "Dimnjače" DOO Gornji Vakuf-Uskoplje*

The minimum efficiency based on the total failures/downtimes was achieved in the seventh month of monitoring and amounts to 35.00%. The maximum efficiency based on the total failures/downtimes was achieved in the second month of monitoring and amounts to 62.92%.

4 PREVENTIVE MEASURES AND SELECTION OF MAINTENANCE STRATEGY

The obtained values of efficiency of the transport system operation in separation for the monitored transporters as a whole were low during the entire monitoring period of transporter operation. Based on the conducted research, it can be concluded that most of the time the transport system did not work due to the following registered technological downtimes:

- human factor,
- waiting for a loader,
- frequent downtimes on the T6 belt due to waste separation,
- empty bins,
- cleaning and washing of a dispenser,
- separation is not included in separation.

Proposed activities to reduce these downtimes to a tolerable level:

- ✓ human factor downtimes amounted to 246 hours due to delays at work place. With a strict supervision by the technical and supervisory staff, these downtimes can be reduced to a tolerable level;
- ✓ in production, it is necessary to have at least 2 loaders, but in order to reduce a downtime in waiting for separation of the transport system due to a loader, there is a need for a third one;
- ✓ transporter T6 is a transporter from which the waste is separated. The

content of waste that does not separate from it is crucial for the quality of coal in the bins. Therefore, in the period when there is a high content of waste in material that occurs on the conveyor belt T6, that transporter is often stopped, which leads to the stopping of the other transporters. For less downtime of a transporter, it is necessary to ensure better quality of run-of-mine coal and increase number of labors on waste separation from T6 transporter;

- ✓ empty bins are connected to the dosing conveyors and they are in standby mode. In order to improve the production system and flow of material on belts, it is necessary to evenly distribute material on belts, and this is achieved only with two loaders that transfer the material from a landfill to a rake which transports it further to the separation. In this way, the bins would be filled more evenly and faster, and the dosing conveyors would have less technological downtime;
- ✓ due to a need to clean and wash the separation, the separation work must be stopped. By turning off the electricity, the separation does not work, but during that time, the old separation works, which crushes the material that is transported to the landfill so that the production is not endangered.

5 CONCLUSION

The presented methodology of processing, analysis and extraction of important information on operating parameters and downtimes/failures of the transport system in the separation in this way and in our area was done for the first time and can be repeated for a continuous transport system in other separations. The contribution of this paper to the professional literature is that for the first time the efficiency of transport system on separation was determined on the basis of collected data on working hours and failures based on the set methodology. Operational efficiency based on electrical, mechanical, technological and total failures/downtime is used to determine the preventive measures and maintenance strategies of the transport system in order to increase the effective operating time.

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Scientific paper
Environmental Protection

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ENVIRONMENTAL RISK ASSESSMENT FOR THE UNREGULATED WASTE DISPOSAL SITES OF MUNICIPAL WASTE IN THE CITY AREA OF BOR[*****]

Abstract

The problem of unregulated waste disposal sites is present not only in Serbia but in the other parts of the Republic of Serbia. Therefore, it is necessary to locate these waste dumpsites, investigate their negative impact on the environment, make environmental risk assessment and start solving this problem. This presentation shows a methodology of the environmental risk assessment for the unregulated waste disposal sites in the city area of Bor. The idea, presented through this methodology, suggests how to understand the risk, how to make the risk assessment so that the owner is informed about possible consequences. In this way, a possibility can be avoided that in fear of unknown and incapable of understanding, the owner might take the precautionary measures at random. With regulated categorization a remediation of waste disposal sites can be done.

Keywords: *unregulated waste disposal sites, municipal waste, environmental impact, risk assessment*

INTRODUCTION

Waste management is considered an activity of public interest. Waste management is performed in a manner which shall ensure the lowest risk in terms of endangerment the human health and environment by control and implementation the measures to reduce pollution of water, air and soil, dangers to animals and plants, risk of accidents, explosions or fire, negative effects to the natural landscape and natural resources of special value, level of noise and odors. Waste management is defined by these legal acts: The Waste Management Strategy for the period 2010-2019 ("Official Gazette of RS", No, 29/10 and revised draft from 2015), Law on Waste Management ("Official Gazette of RS, No. 36/09 and 88/10,14/16), Council Directive 75/442/EEC on Waste (Framework Directive) and Council Directive 99/31/EC on landfills.

The problem with formation of unregulated landfills is particularly pronounced, both in the city of Bor and in other local communities and surroundings, that is, in the entire territory of the Republic of Serbia. It is obvious that unregulated landfills of municipal waste are formed by the roads, often in the immediate vicinity of cities, watercourses, in watercourses in

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forests and so on. Illegal formation of landfills and their uncontrolled expansion has a negative impact on land, watercourses (surface and groundwater), as well as flora and fauna. It should be noted that this way of disposing municipal waste must be prohibited and prevented because it causes the soil degradation and can increase the concentration of heavy metals in the soil, which can result in deteriorating the environmental quality and quality of human health. Therefore, it is necessary to identify and locate all unregulated landfills in the city of Bor, as well as in the other local communities, to carry out the environmental risk assessment and their impact on the environment and then propose measures for remediation, protection and improving the environmental quality.

For that purpose, in the city of Bor, a project was launched within which the following activities were carried out:

- identification and mapping of area polluted by the illegal landfills for municipal waste,
- consideration of the needs for improvement the technical capacities of waste management equipment and establishment a laboratory for testing the waste samples,
- consideration of possibilities for cleaning up the identified illegal landfills,
- elaboration of a study on local and best practices in the field of municipal waste management,
- implementation of forums and education for raising the awareness of improvement the municipal waste management practices.

The expected results of research are:

- identification, risk assessment and remediation the illegal landfills for municipal waste,
- map of contaminated areas from illegal municipal waste
- defined equipment for the improved waste management and establishment of a laboratory for testing waste samples,
- consideration of the scope of needs for remediation the illegal landfills for municipal waste,
- elaboration strategy, politics and study about best practices in the field of municipal waste management,
- elaborated directives for implementation the forums for raising awareness for improvement the municipal waste management practices.

Background

Bor is a city and administrative center of the Bor District in eastern Serbia. Map of the city is shown in Figure 1.

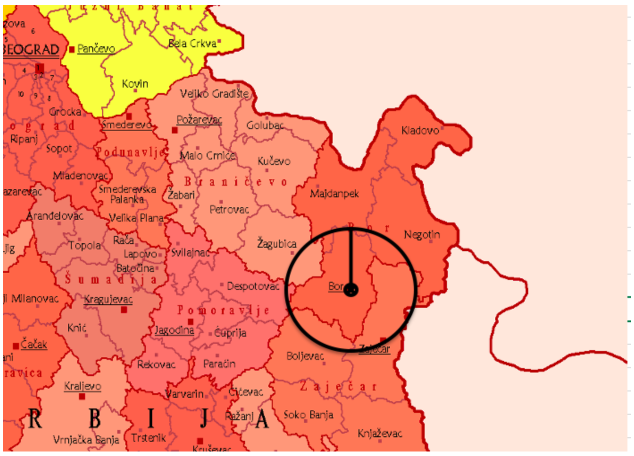

Figure 1 *Map of the city administrative area and Bor District*

Basic information about the city of Bor are shown in Table 1.

Table 1 *Basic information about the city of Bor(4)*

Info/the city of Bor	
Area	856 km^2
Number of settlements	1 urban+13 rural
Total on register*	48.615(34.160 in the urban settlement)

*According to the 2011 census

2 MUNICIPAL WASTE MANAGEMENT IN THE CITY OF BOR

The municipal waste management system in Bor is based on the collection, transport and disposal of municipal waste. The number of inhabitants who receive the provisional services of taking waste in the city of Bor is 48.615. Containers of different loads (from 1 to $5m^3$), dump trucks and loaders are used for the waste collection with the predominant share of biodegradable waste being 51,73%. Other types of waste are paper, cardboard and plastic bags (Figure 2).

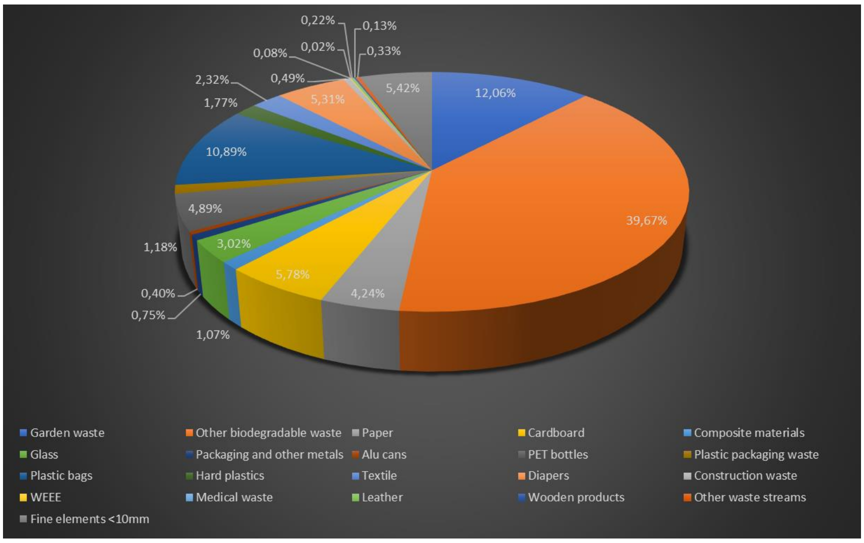

Figure 2 *Composition of municipal waste in Bor* [5]

In the city of Bor decisions were made related to the field of waste management, which derive from the laws and by-law acts that define this area:

1) The decision to determine the location for temporary disposal of construction waste and waste from demolition of buildings on the territory of the municipality of Bor, No.501-89/2010-I of 25/05/2010 ("Official Gazette of the Municipality of Bor", No.9/10)

2) Decision on the adoption of the Local Waste Management Plan for the territory of the Municipality of Bor 2010-2020, No.501-18/2011-I of 28/01/2011 ("Official Gazette of the Municipality of Bor", No.2/11).

Decision on determining the location of the center for separate collection and storage of recyclable components of municipal waste, No. 353-2/2012-I of 7/7/2012 ("Official Gazette of the Municipality of Bor", No.8/12).

3 IDENTIFICATION OF THE ILLEGAL LANDFILLS IN THE AREA OF THE CITY OF BOR

An illegal landfill is a place, a public area, where the unregulated landfill types of waste are located and which does not meet the conditions established by the regulation governing the disposal of waste in landfills.[6] The Bor city Authority has initiated a process to identify and map illegal municipal landfills in all local communities including the urban and rural areas, and database has been established containing a description of locations, their number and other useful data. 63 illegal landfills of municipal waste were identified, out of which 26 in urban areas and 37 in rural areas.[5]

After identification of the illegal landfills, it was necessary to do the mapping and perform an environmental impact assessment. Mapping is performed according to *By-law on Methodology for Collecting Data about Composition and Amounts of Municipal Waste on the Territory of Local Government Unit ("Official Gazette RS", No. 14 of 21/02/2020).*

Mapping and identification of illegal landfills include sampling and laboratory analysis of collected samples. These data are put into map so that a spatial arrangement of a chart can be made.

Table 2 *Records of illegal landfills in the city area of Bor* [9]

RECORD OF ILLEGAL LANDFILLS IN THE CITY AREA OF BOR						
LOCAL COMMUNITIES	**STREETS-LOCATION**	**NORTH**	**EAST**	**SURFACE AREA**	**DEPTH**	**VOLUME**
LC NOVO SELIŠTE	Vase Pelagića 121	44.07°	22.09°	200m²	0.4m	80m³
LC STARI CENTAR	Bus station fence	44.0751°	22.1025°	40m²	0.3m	12m³
	Majdampečka	44.0766°	22.1034°	100m²	0,5m	50m³
	Čočetova	44.0769°	22.1026°	40m²	0,5m	20m³
	Gradska bolnica	44.0793°	22.0928°	80m²	0.3m	24m³
LC SEVER	Kestenova 53	44.0832°	22.0978°	40m²	1m	40m³
	Dositeja Obradovića 38	44.0868°	22.0915°	15m²	0.5m	7.5m³
	Homoljska 15	44.0825°	22.0894°	70m²	0.4m	28m³
	Vojske Jugoslavije 32 i 34	44.0899°	22.0907°	375m²	0.2m	75m³
LC BREZONIK	At the stadium	44.0984°	22.0904°	30m²	0.2m	6m³
	Dečanska	44.0961°	22.0912°	20m²	0.2m	4m³
	Zmajevo 1	44.0953°	22.0950°	40m²	0.4m	16m³
	Landfill of the open pit	44.0953°	22.0869°	600m²	0.6m	360m³
LC RUDAR	Overpas	44.0698°	22.1034°	40m²	0.5m	20m³
LC SLOGA	At the stadium	44.0600°	22.1061°	115m²	0.4m	46m³
	Flee market	44.0614°	22.1081°	45m²	0.5m	22.5m³
	Pavla Orlovića	44.0584°	22.1173°	35m²	0.2m	7m³

LC NOVI GRADSKI	Rubber dump at the brickyard	44.0500 °	22.1126 °	45m²	0.6m	27m³
	Cementary landfill	44.0480 °	22.1137 °	800m²	4m	3200m³
	Under the brickyard	44.0500 °	22.1143 °	300m²	0.4m	120m³
LC METALURG	Ljube Nešića at the bridge	44.0515 °	22.0947 °	30m²	0.5m	15m³
LC BANJSKO POLJE	Mihajla Pupina	44.0596 °	22.0555 °	15m²	0.3m	4.5m³
	At the well	44.0692 °	22.0591 °	160m²	0.2m	32m³
LC MLADOST	Dr.Milovanovića	44.0649 °	22.0956 °	30m²	0.4m	12m³
	Kučajna	44.0639 °	22.0943 °	140m²	0.3m	42m³
LC BOR 2	V.Nazora to No.30	44.0580 °	22.0848 °	50m²	0.4m	20m³
LC SLATINA	Mountain embankment	44.0396 °	22.1600 °	40m²	0.2m	8m³
	Pripor	44.0318 °	22.1522 °	32m²	0.5m	16m³
	Exit from the village (along the river)	44.0362 °	22.1740 °	2000m²	0.3m	600m³
	Main landfill (near fattening farm)	44.0313 °	22.1813 °	400m²	0.4m	160m³
LC OŠTRELJ	Ogašu mika-village	44.0684 °	22.1664 °	400m²	0.3m	120m³
	Valja mika	44.0700 °	22.1759 °	200m²	0.5m	100m³
	Danijela Janošević	44.0637 °	22.1770 °	100m²	0.3m	30m³
	Bypass from Antić to Brezonik	44.0744 °	22.1359 °	245m²	0.15m	36.75m³
LC BRESTOVAC	Lakuri (hill above the village)	44.0359 °	22.0872 °	64m²	0.3m	19.2m³
	Next to the Brestovac bridge	44.0468 °	22.0778 °	scattered		
	At the exit from the village towards Metovnica	44.0317 °	22.0991 °	600m²	2m	1200m³
	Next to the transformer near Dokić	44.0339 °	22.0976 °	150m²	2m	300m³
	The old road to Šarbanovac D. Blagojevic	44.0259 °	22.0956 °	2000m²	3m	6000m³
	At the fairgrounds	44.0335 °	22.0908 °	200m²	0.5m	100m³
	At the village cemetery	44.0404 °	22.0973 °	3000m²	2m	6000m³
	Above the fairgrounds	44.0009 °	21.9954 °	600m²	1m	600m³
	The beginning of Dj.Jakšić Street	44.0078 °	21.9868 °	300m²	0,5m	150m³
	The fourth district near Roškić	44.0167 °	21.9861 °	40m²	0.5m	20m³
LC ŠARBANOVAC	Nestor creek	43.9683 °	22.0649 °	rasuto	0.1m	
	Šarbanovac cementary	43.9560 °	22.0874 °	40m²	0.5m	20m³
	Old mill-gap-spring	43.9258 °	22.0851 °	250m²	0.3m	75m³
	Baba Jona	43.9178 °	22.1230 °	50m²	0.3m	15m³
LC METOVNICA	Suva reka entrance to the village	43.9818 °	22.1650 °	60m²	0.3m	18m³
	Exit from the village	43.9638 °	22.1360 °	400m²	0.2m	80m³
	At the train station	43.9319 °	22.1578 °	100m²	0.2m	20m³
LC DONJA BELA REKA	At the confluence of two rivers	44.0725 °	22.2076 °	800m²	0.5m	400m³
	Exit from the village towards Pescar	44.0789 °	22.2127 °	40m²	0.2m	8m³
LC LUKA	At the fairgrounds	44.1721 °	22.1852 °	80m²	0.5m	40m³
	Next to the stadium	44.1693 °	22.1836 °	20m²	0.6m	12m³

LC GORNJANE	Behind the house	44.24409 °	22.0615 °	30m²	0.2m	6m³
	Mala kulma	44.25036 °	22.06306 °	50m²	0.2m	10m³
LC BUČJE	Under the cemetery	44.13893 °	22.14515 °	150m²	1m	150m³
	Under the quarry	44.14663 °	22.13889 °	300m²	2m	600m³
LC KRIVELJ	Banjica near the stadium	44.1370 °	22.0926 °	1200m²	0.2m	240m³
	At the cemetery	44.1195 °	22.10121 °	50m²	1m	50m³
BOR LAKE	Across from the public fountain	44.1031 °	22.1031 °	25m²	0.3m	7.5m³
	Pirot settlement	44.0710 °	22.0316 °	25m²	1m	25m³

4 THE ENVIRONMENTAL RISK ASSESSMENT METHODOLOGY FOR THE UNREGULATED LANDFILLS

Risk assessment takes into account the probability and consequences of events. Methodology is a systematic tool for determining the assessment of the nature, effect and extent of exposure which a sensitive receptor may experience in relation to a particular hazard.

Experiences from the Environmental Protection Agency's Code of Practice in Ireland have been used to optimize this methodology for assessing the risk of illegal municipal waste dumps.[1]

The environmental risk assessment methodology from illegal municipal landfills helps to make decisions that ensure that the sites having the greatest risk to human health and environment are cleaned and rehabilitated.

The environmental risk assessment for the unregulated waste landfills, developed by the methodology, has been adopted and optimized to meet the project objectives using the available data. The key issues taken into account for the environmental risk assessment of municipal waste are:

- Factor A-area contaminated by the municipal waste (area covered by the municipal waste),
- Factor B-receptor (any human habitat and/or settlement and/or wells near an illegal landfill for municipal waste that may be polluted),
- Factor C-distance of public water supply facility (sanitary zones for water supply or public water supply, endangered by the illegal landfills for the municipal waste),
- Factor D-distance of surface watercourses (distance of surface water bodies from the illegal landfills of municipal waste).

To assess the risk to the environment from the illegal landfills of municipal waste, the following criteria are defined for the selected factors, shown in Tables 3-7:

Table 3 *Factor A-area contaminated by the municipal waste*

Waste type	**Criterion of factor A: Area contaminated by the municipal waste (m^2)**			
	≤100	**>100≤200**	**>200≤500**	**>500**
Municipal	0.1	0.2	0.5	1

Table 4 *Factor B-receptor*

Criterion of factor B: Receptor	B1: Presence of human habitat	B2: Presence of water supply wells
On or within 50 m of the waste body	3	5
Greater than 50 m but less than 250 m of the waste body	2	3
Greater than 250 m but less than 1km of the waste body	1	1
Greater than 1 km of the waste body	0	0

Table 5 *Factor C-distance of the public water supply facility*

Criterion of factor C-distance of the public water supply facility	
Within 100 m of the site boundary	5
Greater than 100 m but less than 300 m	3
Greater than 300 m but less than 1km	1
Greater than 1 km	0

Table 6 *Factor D-distance of the surface watercourses*

Criterion Factor D-distance of the surface watercourses	
Within 50 m of the site boundary	3
Greater than 50 m but less than 250 m of the site boundary	2
Greater than 250 m but less than 1km of the site boundary	1
Greater than 1 km of the site boundary	1

The results of the environmental risk assessment from the illegal municipal landfills are obtained using the equation:

$$RISK=A \times (B1+B2+C+D)$$

Table 7 *Risk classification*

Rang of risk scores	Risk classification
Greater than 50% of the sum of points 1 to 16	Very highest risk
Between 30 - 50% of the sum of points 1 do 16	Highest risk
Between 20 - 30% of the sum of points 1 do 16	Moderate risk
Between 10 - 20% of the sum of points 1 do 16	Lowest risk

The following settings are used for identification, analysis and mapping the location of illegal landfills for municipal waste:

- waste that is present in the illegal landfills is mostly municipal waste,
- public water supply is provided for the city of Bor and there are no wells,
- half of rural settlements receive water from the rural water supply systems, and the other half from individual wells,
- presence of people near the illegal dumps is estimated using Google map measuring a distance between the given coordinates and the nearest houses,
- geologically it is considered that the landscape of Bor is mostly karst.

Table 8 *Application of the method for the environmental risk assessment of municipal waste on the field*

Location	Factor A	Factor B1	Factor B2	Factor C	Factor D	RISK
MZ Brezonik Open pit mine area (G15)	1	3	1	1	1	=6 (Highest risk) 37.5 % of the sum of points 1 do 16
Donja Bela reka village -At the confluence of two rivers (S10)	1	2	3	1	1	=7 (Highest risk) 43% of the sum of points 1 do 16
Zlot village The beginning of Djure Jakšića Street (S37)	0.5	2	3	0	1	=3; (Lowest risk) 18.75% of the sum of points 1 do 16
Bor Lake Across the public fountains (S5)	0.1	2	0	0	1	=0.3 (Lowest risk) 1.87% of the sum of points 1 do 16

Practical check of the environmental risk assessment from the illegal landfills for municipal waste for urban and rural conditions, and the village with a water supply network (village Zlot), and rural conditions and the village near the water-course (Donja Bela Reka), as well as the weekend settlement near Bor Lake.

Figure 3 shows the urban and suburban illegal landfills with a risk assessment.

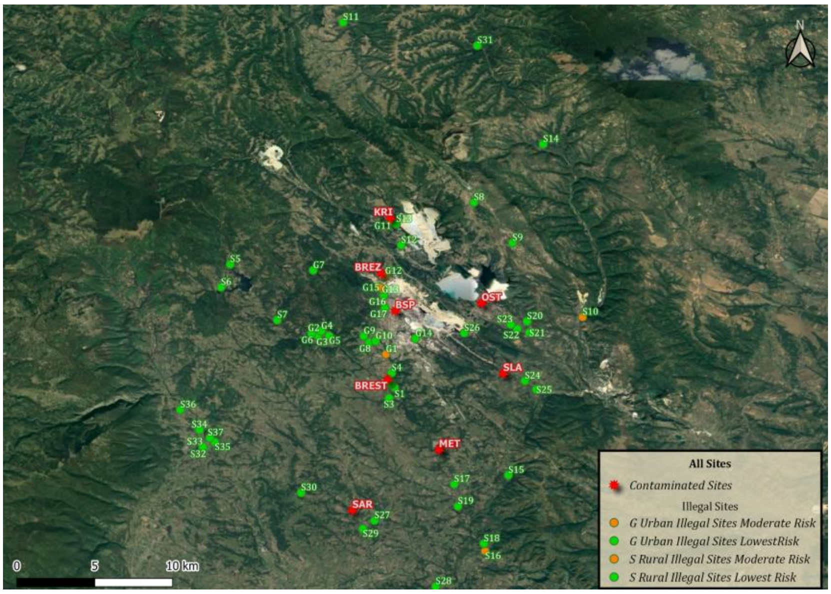

Figure 3 *Shows the urban and suburban illegal landfills with a risk assessment* [7]

5 CONCLUSION

The most significant impact of the illegal municipal waste landfills on the environment and public health are those related to the proximity of watercourses and long-term contamination due to the movement of waste water and of course the uncontrolled incineration of municipal waste where smoke, particles and gases are emitted into the atmosphere. The formation of a team for assessment the risk of illegal landfills for the municipal waste is one of the possibilities that provides a flexible and practical approach to solving this problem. It is concluded that formation a team to assess the risk of illegal landfills for the municipal waste can make significant contribution to the protection of environment and human health. Given the large number of uncertain issues in this research area in the field of risk assessment for the illegal municipal landfills, it is believed that the application of presented methodology of the average risk from various municipal landfills at the local community level is valuable and necessary to improve understanding and inform the public, as well as giving priority to solve the problem of remediation the illegal landfills for the municipal waste at the local community level. The presented methodology is a useful tool for gaining the insight into evaluation of the environmental health and safety management system. As such, it can be used as a relatively quick and inexpensive substitute for research which spends time and money, such as long-term monitoring projects or control studies. This model of the environmental risk assessment for the illegal municipal landfills has the character of an expert assessment and can be widely applied in the other local communities for the environmental health and safety management system and it can provide useful contribution relevant to the operational and strategic planning for the environmental protection.

Results of the applied methodology for ethe environmental risk assessment for unregulated landfills are:

- identification and mapping of 63 locations of illegal landfills for municipal waste in the area of the city of Bor;
- performed risk assessment and determined risk priority indicators and viewing the scope of needs for sanitation of illegal landfills for municipal waste;
- based on identification, mapping, quantity assessment, environmental risk assessment for the unregulated landfills for the municipal waste, adequate decisions, to supply the required equipment for advanced waste management as well as to establish a laboratory for testing waste samples, can be made;
- based on identification, mapping, quantity assessment, environmental risk assessment for the unregulated landfills for municipal waste, the strategy and politics can be defined in detail, as well as plans and programs for the effective and efficient municipal waste management;
- elaborated guidelines for the implementation of forum for raising awareness of the need for implementing best practices for municipal waste management;

In addition to everything that has been said in this study, an important role will be played by raising the people's awareness on the environmental protection and proper waste management.

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Original Scientific Paper
Environmental Field

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SELECTION OF THE OPTIMAL CONTOUR OF THE OPEN PIT IN MINING THE LEAD AND ZINC ORE DEPOSIT WITH THE INCREASED MERCURY CONTENT***

Abstract

Mining processes are complex and complicated, with many different economic, technical, environmental and other parameters that must be planned before the project gets its practical value. Many of these parameters are evaluated independently of others, due to the expediency and difficulties in predictting values for variables under consideration. Costs, prices, reserves, mining and processing of ore, as well as many social aspects, such as issuing permits for works, are absolutely crucial for the project evaluation. Each ore body is different, but the main steps in the open pit planning, when the main goal is to maximize NPV, follow the same principle. These steps are presented as the linear for simplicity. The actual planning process is an iterative process, in which some steps or a combination of steps are repeated many times with the sensitivity analysis.

Keywords: *software deposit modeling, optimal open pit contour, net present value*

1 INTRODUCTION

The main driving objective of any mining activity is certainly making a profit, but apart from this, the exploitation of mineral resources may be also motivated by the other specific factors such as the maximum (or such higher) resource recovery and economic (industrial) development of the local community where the project is situated, etc.

The problem of the open pit optimization requires a complex analysis that includes a large number of important parameters. As a rule, the exact value of many parameters is unknown or uncertain. For these reasons, the optimization of the open pit boundaries is usually a lengthy and iterative process.

The basic, primary input in the process of planning and designing an open pit is a geological block model of the ore body. Geological models are created on the basis of exploratory drilling data, which is performed according to a certain network and drilling density. Each mini-block in a block model of the deposit is assigned a level of trust supported by the data of exploration works in that area. It is very important to accurately calculate the block value in the optimization, because the wrong calculation leads to a wrong optimal contour of the open pit [1].

The most commonly accepted objective, in such complex production systems, in optimizing the open pit boundary is to ma-

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ximize the net present value of future cash flows [2]. To achieve this objective, the spatial relationship of variables in the deposit (such as the geographical location of the deposit and its geological properties) as well as the temporal relationship of the variables (including the order in which the ore will be mined and processed) must be taken into account, and accordingly the resulting cash flow.

Variable quantities relevant for optimization and production planning at the open pit interact in a cyclical manner. Without knowing one variable, the value of next variable in the cycle cannot be determined, Figure 1. The time required to excavate all open pits in the sequence represents the open pit life, while the shape of the last open pit in the sequence determines the final boundary of the open pit. In order to make the division between ore and waste, it is necessary to determine the cut-off grade for processing, which is a function of the final price of manufactured goods, as well as the price of excavation and processing.

It can be seen in Figure 1 that it is first necessary to establish the costs and revenues and, based on that, the limit ore content, in order to further spatially define the ore body and calculate the economic value of blocks. Then, the final boundary of the open pit is defined which is then used to make a production plan that includes the annual production and excavation plan. Further, the selected annual production and excavation plan are used to revise the costs and revenues.

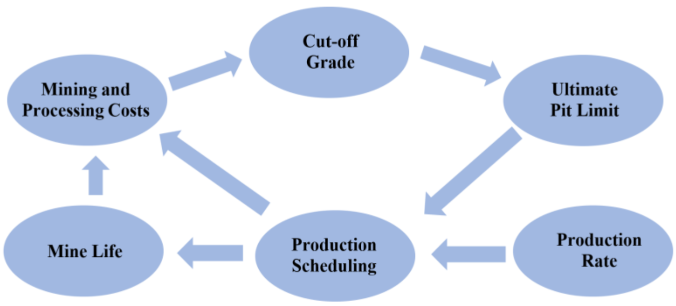


Figure 1 *Circular flow of production optimization at the open pit [3]*

2 SOFTWARE MODELING OF THE DEPOSIT

Block model of the deposit, created by the geostatistical modeling, with separate areas of useful ore blocks and non-profit waste blocks, allows engineers to choose the appropriate excavation methods and to plan the necessary equipment and infrastructure facilities necessary for the ore exploitation process. The block model of a deposit represents the main input in the process of open pit optimization.

Interpretation of the deposit and its immediate surroundings through the appropriate block model, implies their division into blocks of regular dimensions. The size of block depends on numerous factors of the mathematical and statistical character, degree of complexity of the geological structure of the deposit, etc. Blocks in general should not be too small, because in this way the error of calculation of the total volume of minefield ("assessment") increases, but not too large, because they must be adjusted to the characteristics of planned exploitation method.

3 ECONOMIC MODEL FOR OPTIMIZATION THE OPEN PIT BOUNDARY

Developing an economic model for optimizing the open pit boundary is the basis for generating an economic block model. The economic block model aims to calculate for each block model the expected net value of a block, which would arise in the event of its excavation. The economic block model was created in Whittle software, which is specialized for the open pit exploitation analysis and optimization of design solutions.

The economic model is based on the following economic and technological parameters:

- Operating costs
- Waste excavation costs
- Ore mining costs
- Total mineral processing costs (including crushing, sorting, grinding, flotation and other general and administrative costs)
- Costs of metal sales (smelter, refining, concentrate transport and fees for use of mineral resources/ore rent)
- Metal prices
- Discount rate
- Capital investments
- Ore mining capacity
- Recovery and depletion at excavation
- Recovery of metals (on sorting, flotation, metallurgical + payability of metals)

Modern planning procedures imply the possibility of considering the variant solutions and selection the optimal solution. The standard economic measure for optimization the open pit boundary is the Net Present Value (NPV).

Net Present Value (NPV) is calculated by discounting the estimated annual cash flows to the present time using a discount rate, which represents the investment risk.

$$Net\ Present\ Value\ (NPV) = \sum_{t=0}^{N} \frac{Cash\ Flow\ (CF)}{(1+k)^t} \qquad (1)$$

where: k – discount rate
t – number of years

4 DEFINING THE OPTIMAL CONTOURS OF THE PHASE DEVELOPMENT OF THE OPEN PITS

In the optimization process, the results are generated for individual boundaries of the open pit, i.e. the calculated profit is shown as the Present Value (PV) for three variants of analysis - *"best case", "worst case"* and *"specified case"* which define the way of spatial development of the open pit [4].

The "best case" means a phase excavation where each of the generated boundaries of the open pit within a particular mine represents one phase of excavation, i.e. the working angle of the open pit is the maximum possible. This case has the most favorable NPV, but in practice it is very rarely possible, among other things due to the inadequate distance between successive pushbacks.

The "worst case" means excavation in depth successively floor by floor, where each floor is excavated to the final boundary of the open pit, i.e. the working angle of the open pit slopes is approximately equal to zero. The NPV for this case is the lowest possible.

The "*specified case*" is a combination of the previous two scenarios.

Optimization involves a software analysis in order to determine the final open pit and adequate pushbacks based on the following criteria [5]:

- Maximum possible profit (NPV),
- Optimal service life,
- Optimal overburden ratio,
- Maximum possible utilization of deposits (balance reserves)

In practice, the mentioned criteria are interdependent and the final result implies their optimal relationship.

5 CASE STUDY

Selection of the optimal contour in planning the open pits was considered on the example of lead and zinc ore deposits Žuta Prla-Višnjica and Brskovo, which are located about 6 km east of Mojkovac and belong to the municipality of Mojkovac. The characteristic of these deposits is the increased mercury content in the ore. In the Žuta Prla-Višnjica deposit, the average mercury content in the ore is 54.427 g/t, and in the Brskovo deposit 26.719 g/t.

Block models for the lead-zinc ore deposits Žuta Prla-Višnjica and Brskovo were made in the Geovia Gems software package and represent the block models with regular blocks, size 10x10x5. The economic value of the deposit is determined on the basis of the value of metals present in the ore, i.e. lead, zinc, copper and silver. The economic effects of ore exploitation are calculated on the basis of the selling price of payable metals in the ore, i.e. lead, zinc, copper and silver. Based on this, the cut-off grade of the equivalent metal lead and zinc (Pb + Zn) in the ore was determined, which is 0.6% Pb + Zn. Blocks with content for Pb + Zn below the cut-off grade are treated as waste.

A block model was formed for the Brskovo deposit with:

- 160 rows
- 115 columns
- 110 levels
  (+1300/+1295 to +510/505).

A block model was formed for the Višnjica-Žuta Prla-Razvršje:

- 125 rows
- 150 columns
- 110 levels
  (+1300/+1295 to +510/505).

By creating a block model, the following values were defined for each block:

- Rock type;
- Volume mass;
- Content of useful components: Pb (%), Zn (%), Zn+Pb (%), Au (g/t), Ag (g/t), Cu (%) and harmful components: Hg (g/t), As (g/t), Sb (g/t), Bi (g/t) and Cd (g/t).

Determining the content of these components in blocks, began with development of variograms, which are the basis for calculation ("assessment") of the content.

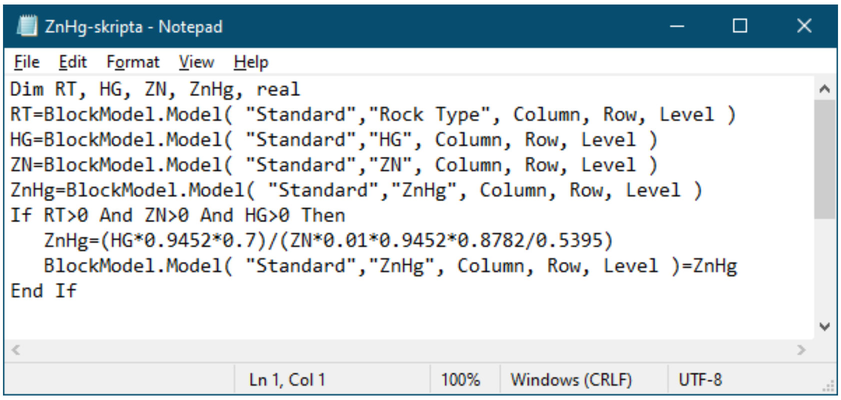
Variograms can be made from all or selected individual or composite samples. For the deposits Brskovo and Višnjica-Žuta Prla-Razvršje, the "extract files" were made, which contain data on the exact location of data in space, as well as values on the quality of mineral raw materials and type of hydrothermal alteration. The extract files were made for composite tests (Pb, Zn, Au, Ag, Cu, Hg, As, Sb, Bi and Cd), for the Brskovo deposit, as well as separately for the Žuta Prla-Višnjica deposit, in order to determine the distribution of useful components in each alteration. The sample centers were taken as the reference points of all extract files, either individual or composite samples in order to perform the three-dimensional interpretation of the subject mineralized spaces as correctly as possible.

One of the key factors in creating an economic model for the Žuta Prla-Višnjica and Brskovo deposits is the evaluation of mercury content in concentrate, i.e. the value limit to 900 ppm. To estimate the mercury content in concentrate, the following formula was developed, based on the conducted experimental investigations:

$$Hg_{\_CON} = \left(\frac{Hg[ppm]}{Zn[\%]\cdot 0.01}\right)\cdot 0.406 \quad [ppm] \tag{2}$$

The formula is based on the mean contents of mercury (Hg, ppm) and zinc (Zn,%) in the run-of-mine ore. The next step is to create a new attribute of mercury content called ZnHg, which contains ≤900 ppm Hg. Using a scripting language, a script is written defining the ore with mercury content of ≤900 ppm.

The panel in Figure 2 shows a script that uses Gems software to separate the ore with mercury content ≤900 ppm and the ore with mercury content >900 ppm.



```
Dim RT, HG, ZN, ZnHg, real
RT=BlockModel.Model( "Standard","Rock Type", Column, Row, Level )
HG=BlockModel.Model( "Standard","HG", Column, Row, Level )
ZN=BlockModel.Model( "Standard","ZN", Column, Row, Level )
ZnHg=BlockModel.Model( "Standard","ZnHg", Column, Row, Level )
If RT>0 And ZN>0 And HG>0 Then
   ZnHg=(HG*0.9452*0.7)/(ZN*0.01*0.9452*0.8782/0.5395)
   BlockModel.Model( "Standard","ZnHg", Column, Row, Level )=ZnHg
End If
```

Figure 2 *Script used by Gems software to separate defined ore types*

Optimization of the open pits at the Brskovo site was performed on the basis of two block models of deposits and defined the input techno-economic parameters.

Optimization of the open pits was performed on the balance reserves using Whittle software, which is the industry standard for this area. The Whittle software package uses a modified *Lerch Grosmman* algorithm in the optimization process, according to which the optimal contour of the mine is obtained based on the economic value of individual mini-blocks in the deposit. The software has the ability to apply the *Revenue Factor* to metal prices to change the size of revenue and thus generate more possible contours of the open pits [6].

Taking into account the amount of exploitation reserves affected by the open pit with a coefficient (factor) of income of 1, which corresponds to the optimal open pit based on undiscounted profit, ore excavation capacity, minimum width between intermediate excavation of 50 m, the decision was made to determine the final boundary of the optimal open pit for discounted profit based on excavation the final open pit in two intermediate excavations.

Based on this solution, an analysis of potential contours of the first pushback and optimal final contour of the open pit Žuta Prla-Višnjica was performed. The results of performed analysis are shown graphically in Figure 3.

The analysis of optimal development of the open pit Žuta Prla-Višnjica, for the case of phase development with one intermediate excavation (open pit 12 in the analysis), gave the result that the optimal final contour of the open pit Žuta Prla-

Višnjica, the open pit under ordinal number 30, income coefficient = 0.94). The open pit 30 provides the maximum discounted cash flow (NPV for the *"Specified case")* for the analyzed phase development. The optimal contour of the Žuta prla-Višnjica open pit covered 57.90% of the balance reserves.

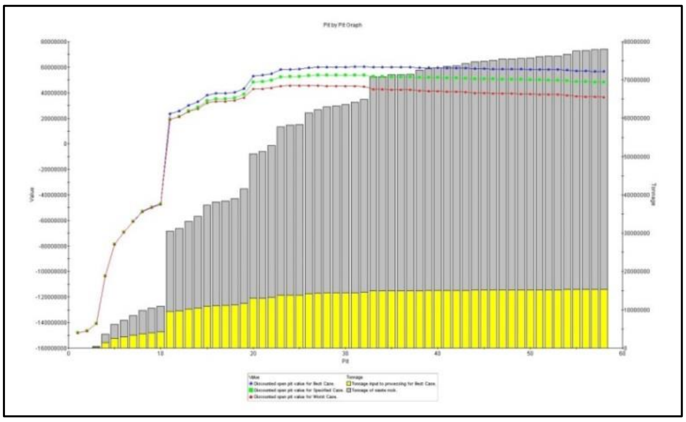


Figure 3 *Graph of the NPV analysis for the optimal boundaries of the open pit ZPV*

The analysis of optimal development of the open pit Brskovo, for the case of phase development with one intermediate excavation (open pit 16 in the analysis), gave the result that the optimal final contour of the open pit Brskovo, the open pit under ordinal number 33 (income coefficient = 0.96), Figure 4. The open pit 33 provides the maximum NPV *("Specified case")* for the analyzed phase development. Also, the analysis results of the Brskovo open pit showed a low sensitivity to NPV in the selection of potential intermediate excavation, which is evident in a small difference in NPV values between the *"Best case"* and *"Worst case"* analysis. The reason for the small difference in NPV values between the analyzed variants is a short service life for the Brskovo open pit. The optimal contour of the Brskovo open pit covers 75.13% of the balance reserves.

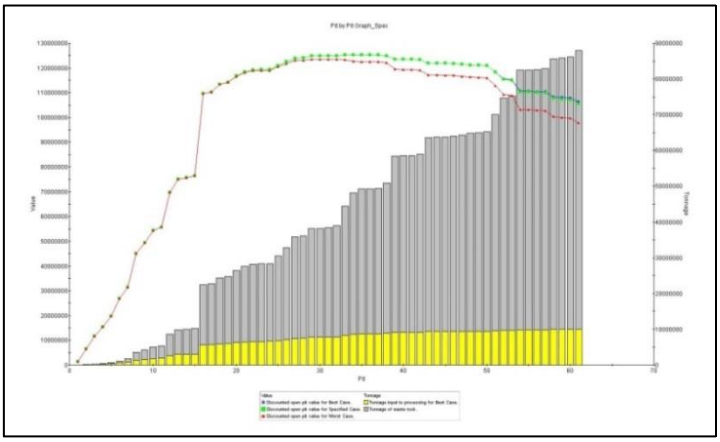


Figure 4 *Graph of the NPV analysis for the optimal boundaries of the open pit Brskovo*

Construction of the open pit Žuta Prla-Višnjica, i.e. Brskovo, according to the defined phases of development, was performed in the Gems software. Contours of the open pits (final open pits and pushbacks), obtained in the process of deposit optimization in the Whittle software, were used as the starting point for construction.

The appearance of the open pit Žuta Prla-Višnjica at the end of exploitation is shown in Figure 5.

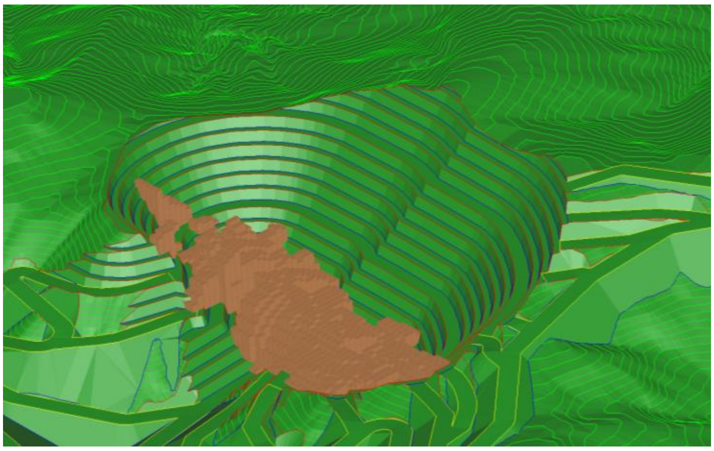


Figure 5 *The appearance of the final contour of the open pit with a presentation of the block model for the Višnjica-Žuta Prla-Razvršje deposit (Gems software)*

The appearance of the open pit Brskovo at the end of exploitation is shown in Figure 6.

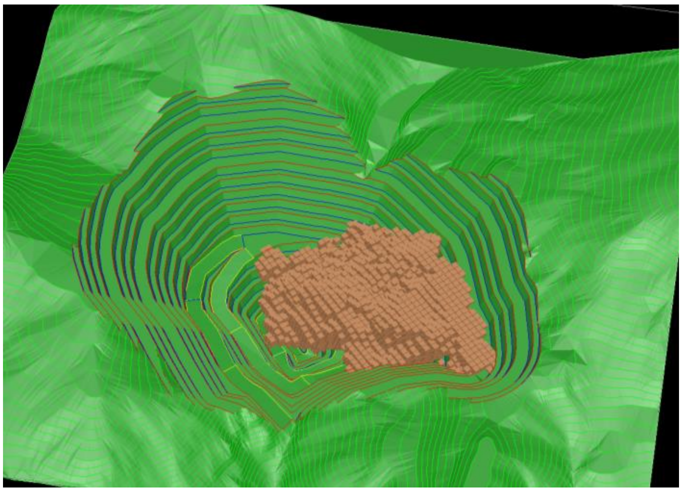


Figure 6 *The appearance of the final contour of the open pit with a presentation of the block model for the Brskovo deposit (Gems software)*

CONCLUSION

The main objective of every mining operation is to make a profit. Basically, the mining processes are complex and complicated, with many different economic, technical, environmental and other parameters that must be planned before the project gets its practical value. Therefore, the costs, prices, reserves, as well as many restrictions on the content of useful and harmful minerals in the ore, which affect the possibility of its processing, i.e. the realization of economic profit, are of the key importance for the project evaluation.

On a real example, for the lead and zinc ore deposits, with increased mercury content, using Whittle software, the analysis was performed based on two block models of deposits and defined the input techno-economic parameters and optimal contours of the open pits Žuta Prla - Višnjica and Brskovo were selected. One of the key limitations in the optimization process is to limit the value of mercury content in concentrate to 900 ppm. As a result, the utilization of the balance quantities of ore in the deposits are as follows:

- Žuta prla - Višnjica 57.90 %
- Brskovo 75.13 %.

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ANALYSIS OF THE DIGITAL TECHNOLOGY IMPACT IN THE MINING AND METALLURGICAL COMPANIES****

Abstract

Dissemination of the new technologies brings the new challenges in business of the mining and metallurgical companies, as well as the care of accepting changes by the employees. This paper deals with an analysis of impact the digital technology development in the mining and metallurgical companies in Serbia. The research methodology is focused on measuring and interpreting the digitalization by the qualitative and quantitative methods. The research findings show how the business of mining and metallurgical companies is transformed into a digital age and provides everything that is needed to combine the mining and metallurgical processes with a new technology for sustainable development.

Keywords: sustainable development, digital technology, mining and metallurgy companies

1 INTRODUCTION

Dissemination of the new technologies brings the new challenges in business of the mining and metallurgical companies, but also a worry for the job security. Thus, the digital technologies provide a new way of managing in the modern business processes [1]. As the impact of digital business is important to many companies, many authors call it the industrial revolution [2,3]. The technological revolution provides to the mining and metallurgical companies a competitive advantage that enables them the potential benefits. Digital technologies bring the positive and negative changes to the companies both for managers and employees. Successful application of digital technologies surpasses the existing technology and requires creation of a transformative vision, elimination a lack of skills of the employees, changing the organizational structure and culture and enabling the creation of a skillful and agile organizational structure and development of digital strategy [4].

Development of the mining and metallurgical companies in Serbia is not a choice but an inevitability. Excessive exploitation of the non-renewable mineral wealth (mi-

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neral raw materials) is not the basis for survival. Optimal exploitation of mineral resources is a necessary precondition for survival and sustainable development. Rapid economic growth and sustainability, as an indicator of economic and social development, requires the implementation of digital technology.

Digitalization is today one of the main trends that creates faster and radical changes in society and companies [5]. Digitalization is the basic transition of society into digital generations where digital technologies are rooted in their everyday practice and culture [6]. In this context, the companies conduct research on the positive and negative criteria of digital technology.

The aim of research: A new current business including the information and communication technology creates the new business models for the mining and metallurgical companies. Business management is changed and there is a change in human resources development as well. This means that the society as a whole is undergoing a radical change due to the development of digital technologies [7]. This paper analyzes the impact assessment of the positive and negative criteria of digital technology by implementation the qualitative and quantitative methods of multicriteria decision making.

The Analytical Hierarchical Process, AHP method, was implemented of the qualitative and quantitative methods. The AHP method belongs to the group of multicriteria decision-making methods (MCDM).

2 LITERATURE REVIEW

Digitalization, one of the names of digital technology, brings the new ways of transformation to the key business operations and management practices [8]. Such a rise in the new technologies, digital technologies such as social networks and mobile devices, makes it possible for today's companies to conduct research and analyze their advantages [4,9]. The digital age has been identified as one of the most important trends changing the current business [10], which has gained in importance during the pandemic caused by COVID - 19.

The impact of digital business brings the new challenges. Dissemination of the new technologies brings the organizational changes. Much of the literature that focuses on organizational changes in the business processes points to a resistance among employees for fear that the changes will affect them either positively or negatively, as well as concerns about the job position stability [11].

The employees in companies are afraid of changes that could lead to the changes in comfortable social dynamics, to desirable and undesirable jobs [12]. Organizational changes affect a job satisfaction due to stress because with greater stress, the job satisfaction decreases [13-15]. Some factors of organizational change have a positive impact on the job satisfaction, while the others have a negative impact [16,17]. The level of employee satisfaction depends on the effectiveness of changes in the organization [18]. Changes are constant and they are the only ones that are safe in today's business. The changes are: technological, structural and systematic, products and services are changed, as well as the employees [19]. But the change management is important for a company and it represents a modification of organization [20, 21]. Change management is one of the most difficult tasks for the company managers [22].

Forecasts show that the demand for mineral resources worldwide has increased due to the increase in the number of inhabitants on the Earth. With the introduction of digital technology, it is important to ensure that the benefits of digital transformation are felt by both the customer and organization [23]. Thus, the managers of mining and metallurgical companies can use digital technology to build the innovative business models and mineral resource management.

The research methodology is focused on measuring and interpreting the positive and negative effects of digital technology in the mining and metallurgical companies. The analysis of positive and negative effects was done by a qualitative and quantitative method, the AHP method developed by the mathematician Satie, [24]. The AHP method is an effective tool that serves as an aid to the managers in making the realistic decisions. It assists the decision makers in solving complex problems by structuring a hierarchy of criteria and alternatives to assess the priorities. The AHP method is one of the most applicable MCDM methods. In a number of studies, the MCDM methods have been successfully used for the purpose of: assessment a progress towards the Europe 2020 goals using the MULTIMOOR method [25]; assessment an organizational culture by the AHP method [26]; solving the problem of personnel selection by the Fuzzy method [27]; staff assessment and selection by the integrated AHP and PROMETHEE method [28], etc.

3 RESEARCH METHODOLOGY

The research model was built on the basis of a previous review of literature using the AHP method presented in Figure 1. Objective, assessment the impact of positive and negative impacts of digital technology are at the top (LEVEL 0) while the alternatives are at the level II and criteria at the level I.

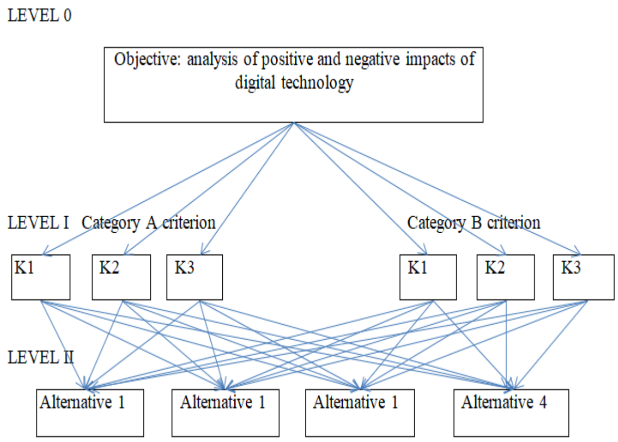

Figure 1 *Implementation of the AHP method*

The criteria depend on the given objective set by the decision maker. They determine the way in which the digital technology affects the business of stakeholders. The objective of research is aimed at assessment the positive and negative effects of application the digital technology in the mining and metallurgical companies.

Criteria category A, the positive effects of digital technology:

- Criterion C_1 – Electronic business and management. The digital transformation has led to the creation of a new way of doing business and management, e-business and management.
- Criterion C_2 – Improving the operation way. Digitalization improves the operation way through digital means such as e-mail, video tools and other systems [29]. Companies invest into mobility, common technology and connect facilities to provide the value-added services to the employees to improve the quality and efficiency of work [30]. Dissemination of digital

technology creates the new business models, which facilitates and simplifies the production process in the mining and metallurgical companies.

- Criterion C_3 – Reduction of costs. Digital business models differ from traditional ones because the product and service are made with almost zero marginal costs [31]. Digitalization of the information-intensive processes can reduce costs by up to 90 percent and can improve turnaround times by several orders of magnitude [32].
- Criterion C_4 – Job automation. Digitalization is one that can improve the work of employees through automation, which leads to an increase in their satisfaction [32]. Throughout history, the companies have used automation to speed up the processes and reduce manual labor.
- Criterion C_5 – Increasing profits. With the progress of digitalization, the quality of products and services in the industrial sector is improved, and the income of companies is increased. Internal optimization of the company's business provides a great benefit (profit) [34].
- Criterion C_6 – Increasing the customer (consumer) satisfaction. Relationship between the users (consumers) and company with the advancement of digital technology enables their greater connection [35], trust in the product and services [36] and meeting the changeable needs of consumers [37]. Companies build a theory of possibility analysis regarding changes in a consumer behavior due to better understanding of a given process [38].
- Criterion C_7 – Innovative business models. The latest advances in digital technology, linking of information, communication and computing create the innovative business models [39].
- Criterion C_8 – Competitiveness. Digital technology gives a company a competitive advantage based on making better decisions. Making decisions based on facts with the help of digitalization makes companies more competitive. Companies that were characterized as digital (data-driven) were on average 5% more productive and 6% more profitable compared to the competitors [40].

Criteria B, negative impacts of digital technology:

- Criterion C_1 – Employee resistance to the changes (fear of the unknown). The employees are the ones who determine whether they will accept the changes or not. Successful organizational change requires the acceptance of employees [41]. The employees are the ones who always offer resistance when it comes to a change due to the personal fear for their existence.
- Criterion C_2 - Uncertain jobs. With digitalization, we get the organizationnal changes that require a reduction of employees.
- Criterion C_3 - Digital application security. Digitalization in companies is not safe because it is still in development.
- Criterion C_4 - Organizational changes. Much of the literature that focuses on organizational change shows that the changes often fail due to the employee resistance. Resistance arises out of personal fear. The employees are afraid that the changes will cause them to lose comfort or get heavier jobs from less desirable jobs.
- Criterion C_5 – Lack of skills. The employees often face difficulties and tensions in maintaining the previous levels of performance, adapting to a new job requirement [42].

Using Satie 's Scale, Table 1, the criteria are compared

Table 1 *Satie's scale of comparison of two elements*

$$S=\left\{\frac{1}{9},\frac{1}{8},\frac{1}{7},\frac{1}{6},\frac{1}{5},\frac{1}{4},\frac{1}{3},\frac{1}{2},1,2,3,4,5,6,7,8,9\right\}$$

Value a_{jk}	Analysis of the results
1	Elements *j* and *k* are equally important
3	Element *j* is somewhat more important than *k*
5	Element *j* is more important than *k*
7	Element *j* is much more important than *k*
9	Element *j* is absolutely more important than *k*
2,4,6,8	Intermediate value between two elements

If criterion C_1 is slightly better, more desirable than criterion C_2, then C_1 is graded 3, and C_2 is graded 1/3. The degree of consistency CR is calculated to precisely determine the weight coefficients of all given elements that are compared with each other. Sometimes there is inconsistency in solving the problem and then the results are not reliable. CR should be less than 0.10. Then the result is correct and there is no need to recalculate.

Empirical assessment the comparison of two elements, positive criteria is shown by the matrix 8x8 - Table 2. Calculation was done using the software SuperDecisions, Figure 2.

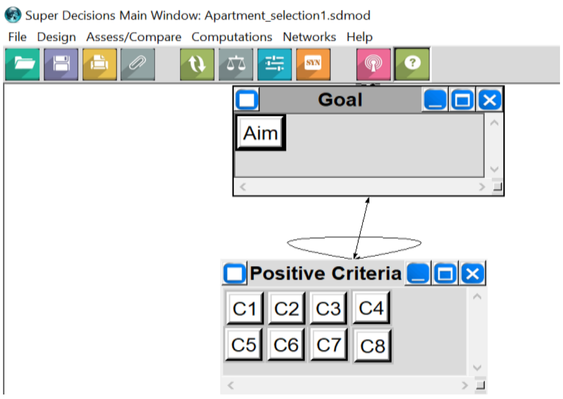

Figure 2 *View the calculation of positive criteria using the Super Decisions*

Table 2 *Matrix of comparison the positive pairs for weight coefficients of criteria*

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	1	3	1/2	1	1/3	1/3	3	1/3
C_2		1	3	1	1/2	1/3	3	1/2
C_3			1	2	1	1/3	1	1
C_4				1	1/2	1/2	1	1
C_5					1	1	3	1
C_6						1	3	3
C_7							1	1/2
C_8								1

Table 3 *Results obtained by the AHP calculation*

3. Results

Normal | Hybrid

Inconsistency: 0.09427

C1	0.10265
C2	0.10681
C3	0.10729
C4	0.08333
C5	0.16948
C6	0.23597
C7	0.05850
C8	0.13596

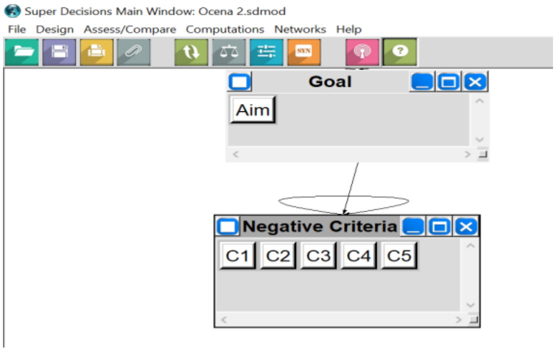

Figure 3 *View the calculation of negative criteria using the Super Decisions*

Empirical assessment the comparison of decision makers of negative criteria is shown by the matrix 5x5 - Table 4.

The calculation was done using the software SuperDecisions, Figure 3.

Table 4 *Matrix of comparison the negative pairs for weight coefficients of criteria*

Criteria	C_1	C_2	C_3	C_4	C_5
C_1	1	1/3	3	3	5
C_2		1	5	3	5
C_3			1	1/3	1/3
C_4				1	3
C_5					1

Table 5 *Results obtained by the AHP calculation*

3. Results

Normal | Hybrid

Inconsistency: 0.09238

C1	0.26778
C2	0.44255
C3	0.05779
C4	0.14915
C5	0.08273

4 ANALYSIS OF THE RESULTS

When making decisions, it is important that the criteria are relevant for solving the relevant problem. That is, the criteria should be complete to cover all important aspects used in decision-making to achieve objectives. It depends on the adopted criteria which final decision will be made by the manager (decision maker).

4.1 Analysis of the assessment of positive criteria

Based on the calculation of positive criteria (Table 3), criterion C_6 has the highest score and takes the first place. Criterion C_6, increasing the customer satisfaction has the weight coefficient of 0.23597. The connection and understanding of users and companies, the trust of users in products and services and satisfaction of changeable needs of consumers by the company makes it to increase the customer satisfaction with the advancement of digital technology.

The second place is evaluated by criterion C_5, increase in profit, with the weight coefficient of 0.16948. Internal business optimization provides the high profits. The quality of products and services in the industrial sector is constantly improved with digital technology which increases profits.

Criterion C_8, competitiveness, was evaluated on the third place, because its weight coefficient is 0.13596. Companies with the help of digital technology are more competitive than those companies that have not introduced digital technology because they make decisions based on facts and are guided by data.

Evaluations of criterion C_1 (electronic business and management), criterion C_2 (improvement of operation methods) and criterion C_3 (reduction of costs) are approximate and by ranking these criteria take the third place. The weight coefficient for criterion C_1 is 0.10265; criterion C_2 is 0.10681 while for criterion C_3 is 0.10729. Digital technology has created a new way of doing business and managing. Mobility, e-mail, interconnection and networking bring the decreased costs to the companies and improve the way they operate. Digital business creates the e-business, management and payment. All this shows that criteria C_1, C_2 and C_3 are interconnected, integrated.

Job automation (criterion C_4) was evaluated with 0.08333. It ranks at the fourth place in the ranking order. Automation speeds up the business processes, reduces manual labor and increases customer satisfaction.

The evaluation of innovative models, criterion C_7 is 0.05850. It ranks at the fifth place in the ranking of criteria. With the development of digitalization, linking of information, communication and computing, the new models of work are being created.

The degree of consistency is $CR = 0.09427 < 0.1$, which means that the criteria are relevantly evaluated by the decision maker.

4.2 Analysis of the assessment of negative criteria

In the case of negative criteria (Table 5), criterion C_2 (unsecured job positions) was rated with the highest value because its weight coefficient is 0.44255 (first place in terms of negative criteria). Digital technology brings about such changes that change or abolish the organizational units. As a result, the dissemination of job digitalization reduces the number of employees, which is perceived as the biggest problem in this process.

Criterion C_1, resistance of employees to the changes was evaluated with a value of 0.26778. According to the assessment of negative criteria, it is at the second place.

Digital technology changes the way of business in the mining and metallurgical companies. Digitalization in business brings great technological changes that have a negative effect on employees due to fear for their existence. This fear of the unknown usually leads to the resistance to changes given by the employees.

Criterion C4, organizational changes, is at the third place. C_4 was rated 0.14915. Digital technology creates the organizational changes that affect employees. Employees are resisting to the changes due to the possible job losses. However, the organizational changes can positively and negatively affect employees.

Lack of skills, criterion C_5 was rated with 0.08273. According to the assessment of negative criteria, it is at the fourth place. Adapting of employees to the digital technology often brings difficulties and tensions. Training and education are inevitable for employees.

Criterion C_3, the safety of digital technology application ranks at the fifth place because its weight coefficient is 0.05779. Digitalization in the mining and metallurgical companies is still in development.

The degree of consistency in the negative criteria, CR is 0.09238 and is less than 0.1, which is considered as a good level of consistency.

5 CONCLUSION

This work presents the results of research, evaluation of digital technology development in the mining and metallurgical companies using the AHP method. The AHP method is the most effective means of assessment the criteria. The results of assessment the positive criteria using digital technology in the mining and metallurgical companies are as follows:

1. Criterion C_6 - increase in customer satisfaction was rated with the best score of 0.23597,
2. Criterion C_5 - profit increase was rated with 0.16948,
3. Criterion C_8- competitiveness was rated with 0.13596,
4. Criteria C_1 - e-business and management was rated with 0.10 65, C_2 - improving the way of operation with 0.10681 and C_3 - cost reduction with 0.10729,
5. Criterion C_4 - job automation was rated with 0.08333,
6. Criterion C_5 - innovative models was rated with 0.05850.

Successful application of digital transformation in the mining and metallurgical companies:

- Overcomes the outdated and creates a new technology,
- Creates e-business and payment,
- Elimination of deficiencies of the employee skills,
- Creates a new way of engaging the organization,
- Creates the skillful and agile organizational structures,
- Digitally connects the user with the company,
- Customer trust in products and services,
- Increase customer satisfaction,
- Decisions are made on the basis of facts,
- Reduce manual labor,
- Increases the company's profit,
- Companies are more competitive,
- Reduces costs,
- Creates innovative models,
- Requires creation of a transformative vision, and
- Develops the new digital strategies.

The results of assessment the negative criteria using digital technology in the mining and metallurgical companies were obtained in the following order:

1. Criterion C_2 - insecure job positions with the highest value of 0.44255,

2. Criterion C_1 - resistance of employees to the changes with a score of 0.26778,
3. Criterion C_3 - organizational changes with a score of 0.149,
4. Criterion C_5 - lack of skills with a score of 0.08273, and
5. Criterion C_3 - security of digital technology application with a score of 0.05779.

Negative impacts of digital technology:

- Reduction the number of employees,
- Training and retraining of employees are performed,
- Eliminate the old and create the new digitized jobs,
- Organizational structure and culture are changed,
- Creation the difficulties and tension for employees from the resulting digital changes, and
- Development the employees' perceptions for digitalization.

The results indicate that business is more efficient applying the digital technology. Negative effects are indicators of how and in what way they should be overcome. It is necessary to invest into appropriate measures to adapt to the digital transformation because the producers will eventually have higher profits, productivity and competitiveness [43].

In this way, an opportunity is created for further research of the customer satisfaction applying a digital change in business.

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QUALITY INVESTIGATION OF SAND FOR THE PRODUCTION OF AGGREGATES ON THE VINOGRADI LOCALITY (DELIBLATSKA PEŠČARA)[**]

Abstract

This paper represents a study which was made to evaluate and interpret the variations in the quality of sand as a potential raw materials for the production of adregate on the Vinogradi locality (Deliblatska peščara). Since deposits of sand constitute a valuable resource for a region, it is desirable that extent and quality variations of these deposits are known. It was hoped that an evaluation of certain properties of sand would assist in determining the value of the Vinogradi locality (Deliblatska peščara) as an undeveloped aggregate source indicating the relative quality of sand from alternate sites of the Deliblatska peščara.
Keywords: aggregate, quality investigation, sand, Deliblatska peščara, production of agregates

1 INTRODUCTION

The largest European continental sandy terrain is located in the south-east part of the Pannonia Plain, i.e. Banat, covering the area of nearly 35,000 ha (Figure 1). It is of elliptical shape and extends from the south-east to the north-west. It was formed during the Ice Age from the vast layers of silica-carbon sand. In the Modern Age, the east wind called "košava" formed a clear dune relief, rising between 70 and 200 meters above sea level. The Vinogradi locality is spatially located on the territory of the municipality of Alibunar (Figure 2).

The Aeolian paragenetic complex is the youngest layer that completely forms the morphological unit of Deliblatska peščara. It can be divided into two stratigraphic units: the older one, created during the younger Pleistocene (ris and virm), deposited in the conditions of cold and dry periglacial climate, which is confirmed by the fossil remains of terrestrial gastropod fauna, and the younger one Holocene age. The Pleistocene Aeolian sand lies beneath a thin layer of "living sands" or "branches" deposited in the Holocene (Davidović et al., 2003).

Samples submitted for partial tests, in addition to the existing field markings that contain the place (locality) of geological research, the mark of exploration work and testing interval, have also received the laboratory markings of analyzes (Table 1). The weight of individual samples was about 20 kg. Table 2 shows the laboratory markings of composite tests and method of their formation (four individual tests in the manner required by the customer).

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2 EXPERIMENTAL

Testing the quality of natural aggregate (sand) of the Vinogradi locality, Banatski Karlovac was performed in accordance with Article 202 of the Rulebook on classification and categorization of reserves of solid mineral raw materials and keeping records on them (Official Gazette of SFRY, No. 53/79), i.e., in accordance with the standards prescribing the quality of mineral raw materials for a given application:

SRPS B.B2.009: 1982 (withdrawn) - Natural aggregate and stone for the production of concrete aggregates. Technical conditions.

Figure 1 *Position of the Deliblatska peščara on the relief map of Vojvodina (by https:// geografijazasve, 04.04.2020)*

Figure 2 *Sand on the Vinogradi locality (territory of the municipality of Alibunar); by https:// geografijazasve, 04.04.2020*

- SRPS B.B2.009: 1982 (withdrawn) - Natural aggregate and stone for the production of concrete aggregates. Technical conditions.

Table 1 *General data on individual samples on the Vinogradi locality*

Serial number	Well mark	Field rehearsal mark	Trial interval (m)	Sample length (m)
1.	К-1	P-1/19	2.00-7.00	5.00
2.		P-2/19	7.00-12.00	5.00
3.	БК-2	P-3/19	1.00-6.00	5.00
4.		P-4/19	6.00-12.00	5.00
5.	БК-3	P-5/19	2.00-7.00	5.00
6.		P-6/19	7.00-12.00	5.00
7.	БК-4	P-7/19	3.00-8.00	5.00
8.		P-8/19	8.00-13.00	5.00

Table 2 *General data on composite sampless on the Vinogradi locality*

Serial number	Well mark	Field rehearsal mark	Trial interval (m)	Composite (m)
1.	К-1/19	P-1/19	2.00-7.00	20.00
		P-3/19	1.00-6.00	
		P-5/19	2.00-7.00	
		P-7/19	3.00-8.00	
2.	К-2/19	P-4/19	6.00-12.00	20.00
		P-2/19	7.00-12.00	
		P-6/19	7.00-12.00	
		P-8/19	8.00-13.00	

- SRPS B.B3.100: 1982 (withdrawn) - Fractionated stone aggregate for concrete and asphalt. Technical conditions.
- SRPS B.B2.010: 1986 (withdrawn) - Fractionated stone aggregate (granulate) for concrete. Technical conditions.
- Rule book on technical requirements for fractional aggregate for concrete and asphalt ("Official Gazette of RS", No. 78/2020).

The methods used in the scope of testing partial and complete sample analyzes are presented by the following standards (Table 3 and Table 4).

3 RESULTS AND DISCUSSION

Individual samples were tested by the methods: Granulometric composition, Content of fine particles, Content of clay lumps, Bulk density in loose and compacted state and Bulk density (Table 3). The test results are shown in Table 3, Table 4, Figure 3 and Figure 4.

Table 3 *Test results of individual samples*

	Bulk density in loose state γr [kg//m^3]	**Bulk density in compacted state γz [kg/m^3]**	**Bulk density γρ [kg/m^3] (pycnometric method)**	**Water absorption < 4 mm [%]**
standard deviation	48.85	62.25	41.06	1.80
coefficient of variation	0.05	0.05	0.01	0.34
coefficient of variation [%]	5.47	4.98	1.46	33.60
Minimum	824	1192	2780	3.39
Maximum	988	1390	2880	7.86
Range	164	198	100	2
Mean	894	1251	2815	5.35
Median	884	1237	2800	4.87
Varianse	2385.93	3875.27	1685.71	3.23

The analysis of the results led tests to the following conclusions:

- ❖ Granulometric tests determined that the tested sand was the following granulometric composition:
- ❖ Grains up to 0.125 mm in size: the average value of the passage is 92.9%, that is, grains smaller than 2 mm and larger than 0.125 mm in sample are of medium content of 7.1%.
- ❖ The calculated grain modulus the mean value of 0.059.
- ❖ Content of particles smaller than 0.063 mm (also tested by the wet seeding) is in the range from 27.4 to 57.6%. The mean value of pass is 44.4%.
- ❖ Content of light particles ranges from 5.1% to 34.2%. The mean value pass is 14.2%.

Table 4 *Methods used in the scope of testing of complete sample analyzes and presents of the results*

Ordinal No.	Characteristic		Test method	Results (Mean)	Technical requirements
1.	Mineralogical-petrographic composition		Annex III-Z	**Fine grains quartz sand**	1)
2.	Ingredients that prevent hydration of cement		Annex III-Z	**not contain**	Must not contain
3.	Bulk density γρ [kg/m^3] (pycnometric method)		SRPS ISO 7033	**2815**	2000-3000 kg/m^3
4.	Water absorption		SRPS ISO 7033	**5,35**	Max 1.5%
5.	Resistance to frost		Annex III-O	**2.5**	Loss max 12%
6.	Total sulfur as SO_3		Annex III-NJ	**0.002**	Max 1.0%
7.	Chloride content		Annex III-NJ	**≤0.001**	Max 0.10% Max 0.02% 2)
8.	Content of organic matter		Annex III-M	**Color lighter than standard**	Color lighter than standard
9.	Grain shape		Annex III-S	**0**	Min 0.18
10.	**Grain-size distribution, passage through a sieve, %**	2.00 mm	Annex III-I	**100**	1)
		1.00 mm		**99.9**	
		0.5 mm		**99.7**	
		0.25 mm		**99.3**	
		0.125 mm		**92.9**	
11.	Content of fine particles [%]	0,09 mm	Annex III-K	**44.4**	1)
		0.063 mm		**14.2**	
12.	Content of clay lumps [%]		Annex III-E	**0**	1)
13.	Grain moduls			**0,20**	1)
14.	Content of crumbly grains [%]		Annex III-LJ	**0**	1)
15.	Content of light particles [%]		Annex III-J	**14.17**	1)
16.	Grain surface coverage [%]		Annex III-Z	**0**	1)
17.	Resistance to crushing and wear [%]		Annex III-P	**5.0**	Max 35%
18	Bulk density in loose and compacted state [kg / m^3]		SRPS ISO 6782	**893** **1251**	**1)**

1) Technical requirements are not determined, but the test results are stated in the Test Report

2) If the aggregate is used for the production of prestressed concrete

Figure 3 *Microscopic appearance of fraction 0.250 / 0.125 mm, binocular magnification 40X*

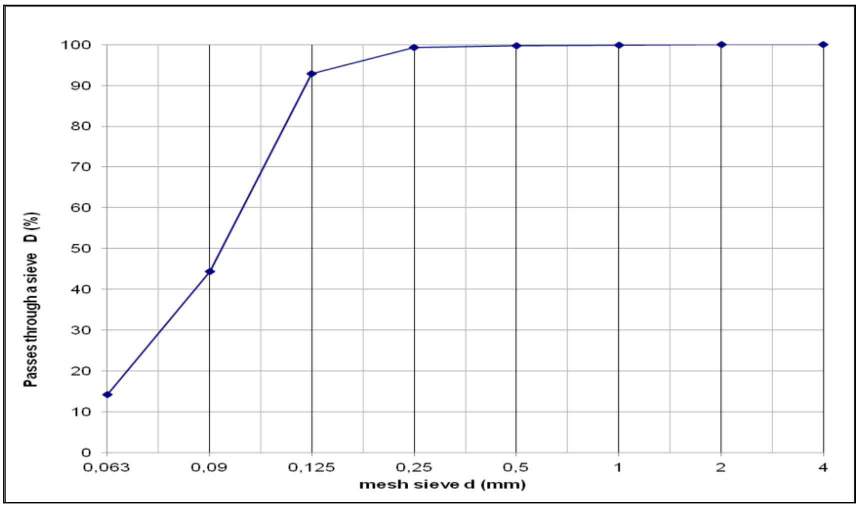

Figure 4 *Grain-size distribution of raw material*

4 CONCLUSION

The analysis of the results of raw material quality testing was performed on the basis of the above results of testing and in accordance with the requirements quality for stone aggregate of the Rule book on technical requirements for fractional aggregate for concrete and asphalt ("Official Gazette of RS", No. 78/2020).

In accordance with the requirements quality for stone aggregate of the Rule book on technical requirements for fractional aggregate for concrete and asphalt ("Official Gazette of RS", No. 78/2020), the raw material is not satisfactory, but, the fine-grained quartz sand from the Vinogradi locality, can be used for the production of lower bearing mechanically stabilized (tampon) layers of pavement structures according to the technical specification of JP PUTEVI SRBIJE of 29/12/2009 for the lower base layer: a layer of unbound stone material - sand.

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Original Scientific Paper
Mining Engineering

Sandra Milutinović, Miomir Mikić*, Miloš Stojanović**

THE USE OF MULTICRITERIA DECISION-MAKING METHODS IN DETERMINING THE OPTIMAL SOLUTION IN THE FORM OF SELECTION THE PRIORITY IN EXPLOITATION THE ORE DEPOSIT IN EASTERN SERBIA**

Abstract

Using the methods of AHP, VIKOR and TOPSIS, the methodology of ore deposit selection was determined. Selection of the best deposit is presented, as well as a comparative analysis of the output values of the applied methods.

Keywords: *AHP, TOPSIS, VIKOR, VKO, MCDM*

INTRODUCTION

Decision-making is a selection of action between several alternatives. The result of a decision is a decision. Decision-making at the social and business level is mostly of multi-criteria, and often of a collective type. Many factors are taken into account, also more stakeholders participate in the decision-making process. Most often, these factors are in conflict with each other, and even direct interests are opposed there.

In order to reach the best (compromise) solution, in the last five or six decades, the decision support methods of this type have been developed, the so-called multi-criteria decision - making (VKO) methods. Numerous methods have been developed for these purposes and applied in practice.

Some of the best-known methods to support multi-criteria decision making are:

- PROMETHEE (I, II) - *Preference Ranking Organization Method for Enrichment Evaluation [4], Jean-Pierre Barns*
- ELECTRE (I, II, III, IV) - *Elimination Et Choix Traduisant la Realité (Elimination and Choice Expressing Reality) [5], Bernard Roy*
- AHP - *Analytical Hierarchy Process [1], Thomas L. Saaty*
- TOPSIS - *Technique for Order of Preference by Similarity to Ideal Solution [3], Ching-Lai Hwang*
- VIKOR - *Multi-criteria Optimization and Compromise Solution [2], S. Opricovic*

Three VKO methods - AHP, VIKOR and TOPSIS, are applied in this paper.

The analyzed area of Eastern Serbia has several deposits on which the base metal that can be found is copper, followed by a certain amount of silver and gold. If the right ore deposit, which has the best characteristics, is chosen for exploitation, the contribution will be of great importance, especially for the economic growth in Eastern Serbia. The compari-

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son was performed for five deposits, as follows:

A_1 – Čukaru Peki – Upper Zone (located about 6 km from the urban area of Bor),

A_2 – Veliki Krivelj (north from the urban area of Bor),

A_3 – Majdanpek – South Mining District,

A_4 – Majdanpek – North Mining District,

A_5 – Cerovo (located in the ore field Mali Krivelj - Cerovo).

In this paper, using the VKO method, it will be analyzed which deposit should have priority in exploitation.

The basic criteria for selection of ore deposit are:

- k_1 - Copper content in the ore (%) - the higher copper content in the ore, the more favorable deposit,
- k_2 - Silver content in the ore (g/t) - the higher silver content in the ore, the more favorable deposit,
- k_3 - Gold content in the ore (g/t) - the higher gold content in the ore, the more favorable the deposit,
- k_4 - Tested quantities of minerals in the ore deposit - better tested deposits have priority,
- k_5 - Location - Better traffic infrastructure and spatial position are an advantage,
- k_6 - Mining-geological parameters - include many characteristics of the ore deposit that have an impact on the costs of exploitation.

Other criteria, such as harmful and dangerous substances in the deposits, environmental protection, economic aspect, etc. are not taken into account in this paper.

The basic data required for preparation of this paper are given in Table 1

Table 1 *Basic data*

Alternative/Criteria	Cu content (%) k_1	Ag content (g/t) k_2	Au content (g/t) k_3	Tested quantities of minerals in the ore deposit k_4	Location k_5	Mining-geological parameters k_6
Čukaru Peki – Upper Zone	2.71	3.16	1.7	Very high	High	High
Veliki Krivelj	0.322	0.79	0.7	High	Medium	High
Majdanpek – South Mining District	0.316	1.365	0.178	High	Medium	High
Majdanpek – North Mining District	0.298	1.730	0.238	High	Medium	High
Cerovo	0.340	1.8	0.11	High	Low	Very low

APPLICATION OF THE AHP METHOD

Analytical Hierarchical Process (AHP) is one of the most well-known methods of scientific scenario analysis and decision making by consistent evaluation of hierarchies whose elements are goals, criteria, sub-criteria and alternatives.

The conceptual and mathematical setting of the AHP method was given by Thomas Saaty (Saaty, 1980). Analytical hierarchical process belongs to the class of methods for soft optimization. It is basically a specific tool for forming and analyzing the decision-making hierarchies. The AHP first enables the interactive creation of a hierarchy of problems as a preparation of decision-making scenarios, and then evaluation in pairs of elements of the hierarchy (goals, criteria and alternatives) in the top-down direction. In the end, the synthesis of all evaluations is performed and weight coefficients of all elements of hierarchy are determined according to a strictly determined mathematical model. The sum of the weight coefficients of the elements at each level of hierarchy is equal to 1, which allows the decision maker to rank all the elements in the horizontal and vertical sense.

The application of method it self is very wide, with the possibility of adapting to the specific circumstances. A great advantage of the AHP method is that although it is basically easy to use, it still provides extremely high-quality output data. The basic principle of the AHP method is to break down a complex problem into simple factors, which are then compared in pairs. Each component in the model hierarchy is compared in pairs using the Saaty scale of relative importance, shown in Table 2.

Table 2 *The Saaty scale of relative importance*

Importance	Definition	Explanation
1	Same significance	Two elements are of identical importance in relation to the goal
3	Weak dominance	Experience or reasoning slightly favors one element over another
5	Strong dominance	Experience or reasoning significantly favors one element over another
7	Demonstrated dominance	Dominance of one element confirmed in practice
9	Absolute dominance	Dominance of the highest degree
2,4,6,8	Intermediate values	Compromise or further division is needed

The basic result of comparison the elements is the numerical value of priority significance coefficient (W).

By calculation the significance coefficient of each element of the analysis by the equation:

$$W = \sum_{j=1}^{n} \frac{W_i}{W_j} = W_i \left(\sum_{j=1}^{n} \frac{1}{W_j} \right), \qquad i = 1, \dots, n \tag{1}$$

a possibility of forming a mathematical matrix M is created by calculation that gives a solution according to a certain criterion or sub-criterion.

$$M = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \cdots & \cdots & \cdots & \cdots \\ w_n/w_1 & w_n/w_1 & \cdots & w_n/w_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n1} & \cdots & a_{nn} \end{bmatrix} \tag{2}$$

Error checking is the last step in the AHP method, i.e. checking the consistency of a decision maker. Mathematical verification of the CI consistency index is performed using the following equation:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (3)$$

In which λ_{max} represents the maximum value of calculated matrix and is determined by the following equation, while n is the number of analyzed objects.

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n} \lambda_i \quad (4)$$

The random CR consistency index is determined by the following equation:

$$CR = \frac{CI}{RI}$$

Where RI is a random index that depends on the number of analyzed objects n (Table 3, Saaty, 1991).

Table 3 *Values of random RI index*

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

The condition for the correctness of method is that the result of calculated value of the random consistency index is less than 0.1 (i.e. less than 10%).

In this paper, a mathematical model is applied in order to determine the optimal solution in the form of selection the priority in deposit exploitation.

The initial decision matrix is shown in Table 4.

Table 4 *Initial decision matrix*

Alternative/ Criteria	**Cu content (%) k_1**	**Ag content (g/t) k_2**	**Au content (g/t) k_3**	**Tested quantities of minerals in the ore deposit k_4**	**Location k_5**	**Mining-geological parameters k_6**
	max	max	max	max	min	max
A_1 - Čukaru Peki – Upper Zone	2.71	3.16	1.7	Very High	High	High
A_2 - Veliki Krivelj	0.322	0.79	0.7	High	Medium	High
A_3 – South Mining District	0.316	1.365	0.178	High	Medium	High
A_4 – North Mining District	0.298	1.730	0.238	High	Medium	High
A_5 - Cerovo	0.340	1.8	0.11	High	Low	Very low

The first step is to define the weighting factors (preference factors) of considered criteria using the Sarty scale, after which their mathematical calculation should be performed.

The next step is to check the consistency of a decision maker (using formula (4)): λ_{max} = 6.3232, n = 6.

From Table of values of the random index, RI is 1.25 and according to formula (3), the value of 0.06464 was obtained for the consistency index CI and random consistency index CR is 0.051712 ~ 5.2% <10%

So, the value of the preference vector is shown in Table 5.

Table 5 *Preference vector value*

Criteria	Preferences
Cu content (%) k_1	0.275
Ag content (g/t) k_2	0.021
Au content (g/t) k_3	0.146
Tested quantities of minerals in the ore deposit k_4	0.075
Location k_5	0.036
Mining-geological parameters k_6	0.446

The next step in analysis is the evaluation of alternatives in selection, in relation to the defined criteria.

The first sub-criterion to be analyzed is the copper content (%). All necessary input values for calculation the alternatives according to the criterion of copper content are:

Table 6 *Input values according to the criterion of Cu content*

	Cu content (%)	A_1	A_2	A_3	A_4	A_5
A_1	2.71	1	9	9	9	9
A_2	0.322	1/9	1	3	5	1/3
A_3	0.316	1/9	1/3	1	3	1/5
A_4	0.298	1/9	1/5	1/3	1	1/5
A_5	0.340	1/9	3	5	5	1

After calculation the matrix of weight coefficients according to the copper content, the consistency is checked:

$\lambda_{max} = 5.39$ n=5

From Table of values of the random index, RI is 1.11, and according to formula (3) the value of 0.0975 was obtained for the consistency index CI and the random consistency index CR is 0.0878 ~ 8.8% <10%.

Other sub-criteria are checked in the same way: silver content, gold content, tested quantities of minerals in the ore deposit, location, mining-geological parameters.

Table 7 shows the last step in application of AHP method, which is the weighting of calculated coefficients of significance of alternatives in selection according to different criteria, and coefficient of significance (preference) of these criteria:

Table 7 *Final report of parameters for defining the value of alternatives according to all criteria*

Criteria	Significance factor		A_1	A_2	A_3	A_4	A_5
Cu content (%)	0.275	k_1	0.669	0.09	0.044	0.076	0.17
Ag content (g/t)	0.021	k_2	0.51	0.03	0.06	0.12	0.27
Au content (g/t)	0.146	k_3	0.51	0.27	0.06	0.13	0.03
Tested quantities of minerals in the ore deposit	0.075	k_4	0.44	0.14	0.14	0.14	0.14
Location	0.036	k_5	0.04	0.2	0.23	0.23	0.3
Mining-geological parameters	0.446	k_6	0.24	0.24	0.24	0.24	0.04

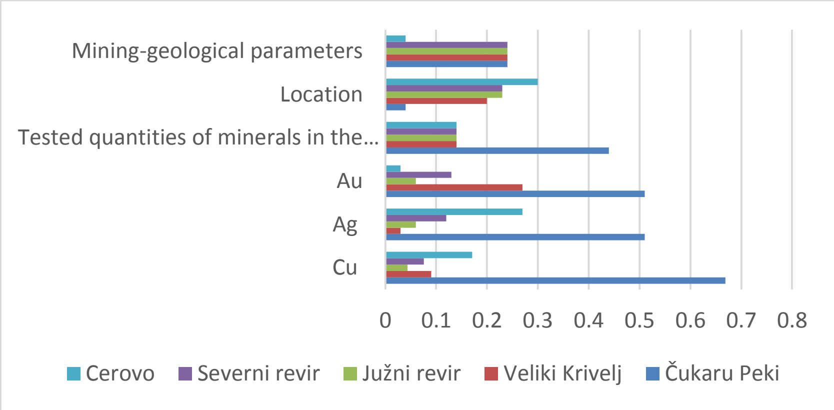

Figure 1 *Analysis of results according to the criteria and alternatives analyzed*

Figure 1 shows the analysis of criteria and alternatives, and Table 8 shows the results of this method application, where it can be seen that the best ranked deposit is Čukaru Peki.

Table 8 *Results of application the AHP method*

Ore deposit	coeff.	%	Rank
Čukaru Peki – Upper Zone	**0.3165**	**31.65**	**1**
Veliki Krivelj	**0.1616**	**16.16**	**2**
Majdanpek – South Mining District	**0.129**	**12.9**	**5**
Majdanpek – North Mining District	**0.156**	**15.6**	**4**
Cerovo	**0.1585**	**15.86**	**3**

APPLICATION OF THE VIKOR METHOD

The VIKOR method is a very commonly used method for multi-criteria ranking, suitable for solving various decision-making problems. It is especially suitable for situations where criteria of a quantitative nature prevail.

The VIKOR (Multi-criteria Optimization and Compromise Solution) is a multi-criteria method for optimization and decision-making developed by Serafim Opricović, for the purpose of solving the decision-making problems when considering conflicting and heterogeneous criteria that affect the decision-making. The method is based on the assumption that a compromise is acceptable for resolving the conflict, that a decision maker wants the solution that is closest to the ideal, and that the alternatives are evaluated according to all set criteria. This method ranks alternatives and determines the compromise solution that is closest to the ideal. In essence, the method represents a compromise between desires and possibilities.

The mathematical calculation of method begins with the formation of a decision matrix:

$$M = \begin{array}{c} \\ \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{cccc} C_1 & C_2 & \cdots & C_m \\ w_1 & w_2 & \cdots & w_m \\ \end{array}$$

$$M = \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}$$

The VIKOR method consists of 4 Steps, as follows:

1. Determining the maximum (x_i*) and minimum (x_i^-) values of a given criterion. When a decision matrix is formed, the maximum and minimum values are required for each criterion.

$$x_i^* = \max_j x_{ij}$$

$$x_i^- = \min_j x_{ij}$$

2. Calculationthe values of S_j of the pessimistic solution and R_j of the expected solution. The decision maker prefers what weight coefficients will be assigned to these values.

$$S_j = \sum_{i=1}^{n} w_i \, {(x_i^* - x_{ij})}\Big/{(x_i^* - x_i^-)}$$

$$R_j = \max_i \left[w_i \, {(x_i^* - x_{ij})}\Big/{(x_i^* - x_i^-)} \right]$$

where w_i – criterion weight

3. Calculation the values of Q_j - compromise solution

$$S^- = \min_j S_j \; ; \; S^* = \max_j S_j$$

$$R^- = \min_j R_j \; ; \; R^* = \max_j R_j$$

4. Ranking is performed by sorting the alternatives according to measures R_j, S_j and Q_j. The best alternative is the one for which the value of measure is the lowest and it takes the first place on the Rank list. Alternative *a*j is better than alternative even if Qj <Qk. This is how three Rank lists are obtained. The measure Qj is a linear function of the weight of strategy that satisfies most of the criteria (*v*), so the position on the Q list is a linear combination of the position on the R and S lists. The order according to the VIKOR method can be performed with different weights, thus considering the effect of weights on the proposal of compromise solution.

The results of these steps are the basis for deciding and adopting the final solution (multi-criteria optimal solution).

Table 9 shows the input values for application the VIKOR method, and for the preference functions the same values were adopted as for the AHP method.

Table 9 *Input values for application the VIKOR method*

Alternatives/Criteria	**Cu content (%) f_1**	**Ag content (g/t) f_2**	**Au content (g/t) f_3**	**Tested quantities of minerals in the ore deposit f_4**	**Location f_5**	**Mining-geological parameters f_6**
	max	max	max	max	min	max
A_1 - Čukaru Peki – Upper Zone	2.71	3.16	1.7	9	1	7
A_2 - Veliki Krivelj	0.322	0.79	0.7	7	5	7
A_3 – South Mining District	0.316	1.365	0.178	7	5	7
A_4 – North Mining District	0.298	1.730	0.238	7	5	7
A_5 - Cerovo	0.340	1.8	0.11	7	7	1

For each criterion, the maximum and minimum values for all five ore deposits analyzed are derived.

Table of intermediate values is formed in the following step by formula:

$$(f_i max - f_{ij}) / (f_i max - f_i min) \cdot w_i$$

Table 10 *Intermediate values*

0	0	0	0	0	0
3.601	47.4	6.451	13.157	18.518	0
3.609	35.9	9.819	13.157	18.518	0
3.636	28.6	9.432	13.157	18.518	0
3.573	27.2	10.258	13.157	27.777	2.242

The pessimistic *Sj* and optimistic *Rj* values are formed, presented in Table 11:

Table 11 *Pessimistic Sj and optimistic Rj values*

	Sj	***Rj***
A_1	0	0
A_2	89.127	47.4
A_3	81.003	35.9
A_4	73.343	28.6
A_5	84.207	27.777
max	89.127	47.4
min	0	0

Table 12 shows the intermediate results *QSj* and *QRj*, calculated by the following formulas:

$$QS_j = (S_j - minS_j) / (maxS_j - minS_j)$$

$$QR_j = (R_j - minR_j) / (maxR_j - minR_j)$$

Table 12 *Intermediate results QSj and QRj*

	QSj	***QRj***
A_1	0	0
A_2	1	1
A_3	0.910	0.757
A_4	0.823	0.603
A_5	0.944	0.586

The last step in the VIKOR method is the analysis of calculated results for three different rates *v* (0.5; 0.6 and 0.7). The values of Qj obtained for three rates *v* are shown in Table 12.

The used formulas are:

$$Q_j = (S_j + R_j)/2$$

$$Q_j = v \times QS_j + (1 - v) \times QR_j$$

Table 13 *Results of the VIKOR method*

	v=0,5		v=0,6		v=0,7	
	Qj	**Rank**	**Qj**	**Rank**	**Qj**	**Rank**
A_1	0	1	0	1	0	1
A_2	1	5	0.24	2	0.21	2
A_3	0.8335	4	0.8488	5	0.8641	5
A_4	0.713	2	0.735	3	0.757	3
A_5	0.765	3	0.801	4	0.8366	4

On the basis of results, shown in Table 13, it can be concluded that with this method, similar results were obtained applying different rates and that, as with the AHP method, the best ranked deposit is Čukaru Peki.

APPLICATION OF THE TOPSIS METHOD

In the TOPSIS method, the idea of selection the best alternative based on the distance from the positive ideal solution (PIS) is expanded with the additional requirement that this alternative be at the same time as far away from the so-called negative ideal solution (NIS).

Problem solving comes down to the following seven steps [5]:

- Step 1: Collecting the input data on performances for *n* alternatives with *k* criteria. It is necessary to normalize the input data.
- Step 2: Determining the weights for each criterion and multiplying the weights with quantitative indicators of criteria for each alternative.
- Step 3: Identification of the ideal positive solution A^*.
- Step 4: Identification of the ideal negative solution A^-.
- Step 5: Calculate the distance of all alternatives in relation to the ideal positive solution A^* and in relation to the ideal negative solution A^-.
- Step 6: For each alternative form the function $D_p(a_i)$.
- Step 7: Ranking of alternatives according to the results from the previous step.

The mathematical model of this idea requires that in addition to the ideal solution

$$A^* = (f_1^*, f_2^*, f_3^*, \dots, f_k^*)$$

which in this method is called a positive ideal solution with components

$$f_j^* = \max_{a_i \in A} f_j(a_i)$$

introduce also a negative ideal solution

$$A^- = (f_1^-, f_2^-, f_3^-, \dots, f_k^-)$$

with components

$$f_j^- = \min_{a_i \in A} f_j(a_i).$$

A distance of alternative i *a* from the negative ideal solution is denoted by:

$$d_p^-(a_i) = \left(\sum_{j=1}^{k} w_j^p \left(f_j - f_j(a_i) \right)^p \right)^{1/p}$$

In order to identify in a set of alternatives the alternative that is closest to the positive ideal solution, and at the same time the furthest from the negative ideal solution, it is necessary to form a function for selected metric:

$$D_p(a_i) = \frac{d_p^-(a_i)}{d_p^*(a_i) + d_p^-(a_i)}$$

The best alternative (there may be more) is the one for which this function takes the maximum value. If it is necessary to make a Rank list of alternatives, it is formed by decreased values of this function.

Based on the step to be performed, the input data was normalized (Table 14), the sum of square matrixs (Table 15), obtaining the rij - normalization (Table 16), multiplied by wi - weighing (Table 17); the ideally and anti-ideal solutions should be shown.

Table 14 *Initial matrix and preference value*

	K1(max)	**K2(max)**	**K3(max)**	**K4(max)**	**K5(min)**	**K6(max)**
A1	2.71	3.16	1.7	9	1	7
A2	0.322	0.79	0.7	7	5	7
A3	0.316	1.365	0.178	7	5	7
A4	0.298	1.73	0.238	7	5	7
A5	0.34	1.8	0.11	7	7	1
Preferences	0.275	0.021	0.146	0.076	0.036	0.446

Table 15 *Matrix of square sum*

A1	7.3441	9.9856	2.89	81	1	49
A2	0.103684	0.6241	0.49	49	25	49
A3	0.099856	1.863225	0.031684	49	25	49
A4	0.088804	2.9929	0.056644	49	25	49
A5	0.1156	3.24	0.0121	49	49	1
Sum	7.636444	18.705825	3.480428	277	125	197
Root	2.76341166	4.325023121	1.865590523	16.64331698	11.18033989	14.03566885

Table 16 *Obtaining rij – normalization*

A1	0.980671841	0.730631932	0.91123962	0.540757591	0.089442719	0.49872935
A2	0.116522632	0.182657983	0.375216314	0.420589238	0.447213595	0.49872935
A3	0.114351403	0.315605249	0.095412148	0.420589238	0.447213595	0.49872935
A4	0.107837715	0.399997862	0.127573547	0.420589238	0.447213595	0.49872935
A5	0.12303632	0.416182746	0.058962564	0.420589238	0.626099034	0.07124705

Table 17 *Multiplication with wi - aggravation*

A1	0.269684756	0.015343271	0.133040985	0.041097577	0.003219938	0.22243329
A2	0.032043724	0.003835818	0.054781582	0.031964782	0.016099689	0.22243329
A3	0.031446636	0.00662771	0.013930174	0.031964782	0.016099689	0.22243329
A4	0.029655372	0.008399955	0.018625738	0.031964782	0.016099689	0.22243329
A5	0.033834988	0.008739838	0.008608534	0.031964782	0.022539565	0.031776184

Table 18 *Ideal solution*

	0.269684756	0.015343271	0.133040985	0.041097577	0.022539565	0.22243329

Table 19 *Negative ideal solution*

	0.029655372	0.003835818	0.008608534	0.031964782	0.003219938	0.031776184

The next step is to calculate the relative proximity to the ideal solution and anti-ideal solution.

Table 20 *Deviation from ideal solution*

							SUM	SQRT(SUM)
A1	0	0	0	0	0.000373248	0	0.000373248	0.019319627
A2	0.05647326	0..000132421	0.006124534	8.34079E-05	0.000041472	0	0.062855096	0.250709186
A3	0.056757402	7.5961E-05	0.014187385	8.34079E-05	0.000041472	0	0.071145628	0.266731378
A4	0.057614105	4.82096E-05	0.013090849	8.34079E-05	0.000041472	0	0.070878044	0.266229307
A5	0.055625113	4.36053E-05	0.015483435	8.34079E-05	0	0.036350132	0.107585693	0.328002581

Table 21 *Deviation from negative ideal solution*

							SUM	SQRT(SUM)
A1	0.057614105	0.000132421	0.015483435	8.34079E-05	0	0.036350132	0.109663502	0.3311548
A2	5.70423E-06	0	0.00213195	0	0.000165888	0.036350132	0.038653675	0.196605378
A3	3.20863E-06	7.79466E-06	2.83198E-05	0	0.000165888	0.036350132	0.036555343	0.191194516
A4	0	2.08314E-05	0.000100344	0	0.000165888	0.036350132	0.036637196	0.191408453
A5	1.74692E-05	2.40494E-05	0	0	0.000373248	0	0.000414767	0.020365819

Determining the Rank (shown in Table 22), the conclusion was made that, as with the other two methods, the best Ranked deposit is Čukaru Peki.

Table 22 *Rank*

A1	0.944875786	**1**
A2	0.439523757	**2**
A3	0.417522832	**4**
A4	0.41825319	**3**
A5	0.058460582	**5**

CONCLUSION

Based on the obtained results from calculation of all three methods, it was concluded that the ore deposit Čukaru Peki - Upper Zone is the best choice in the existing conditions, for all three methods. After it, the Veliki Krivelj deposit is at the second place. For other deposits, all three methods give different results.

Based on the results of application all three methods in selection the best deposit, it is concluded that Čukaru Peki is the best deposit with the most optimal parameters for its exploitation, what could be concluded through the amount of useful components and good operating conditions.

A methodology based on these three methods helps in selection the ore deposit and can be useful in the preliminary analysis. Selection of ore deposits can be based on other criteria, not only those given in this paper, so that different results can be obtained.

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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.

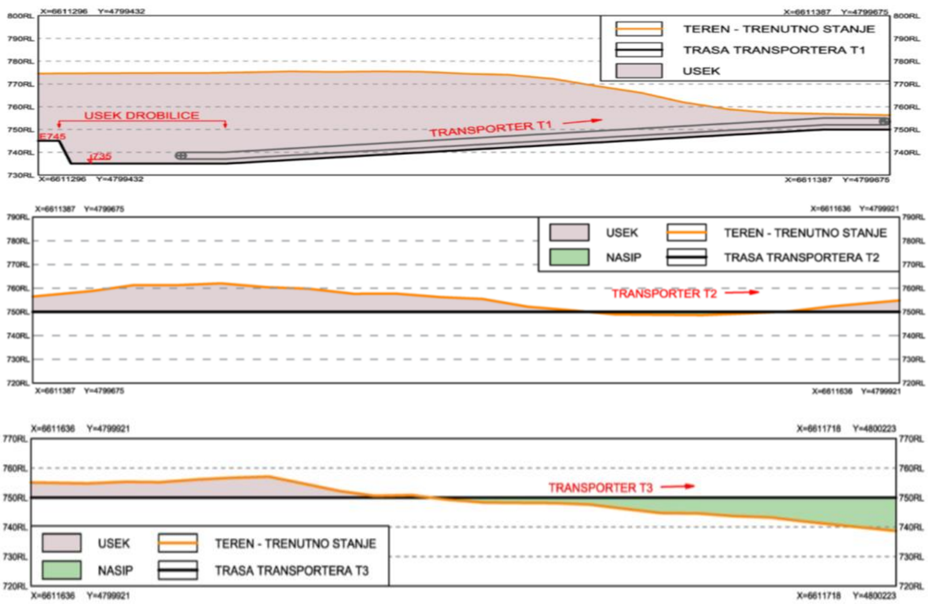

Figure 1 *Longitudinal profiles of connecting conveyor routes according to the valid DRP 2020-2025*

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.

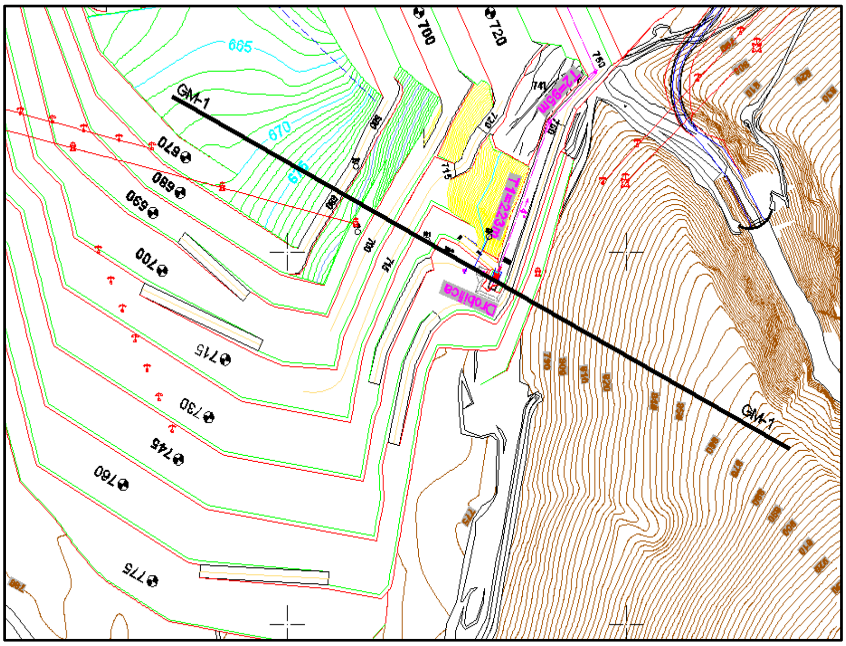

Figure 2 *Position of the analyzed GM-1 profile at the open pit "Potrlica" - condition of works at the end of 2025 according to the valid DRP 2020-2025*

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.

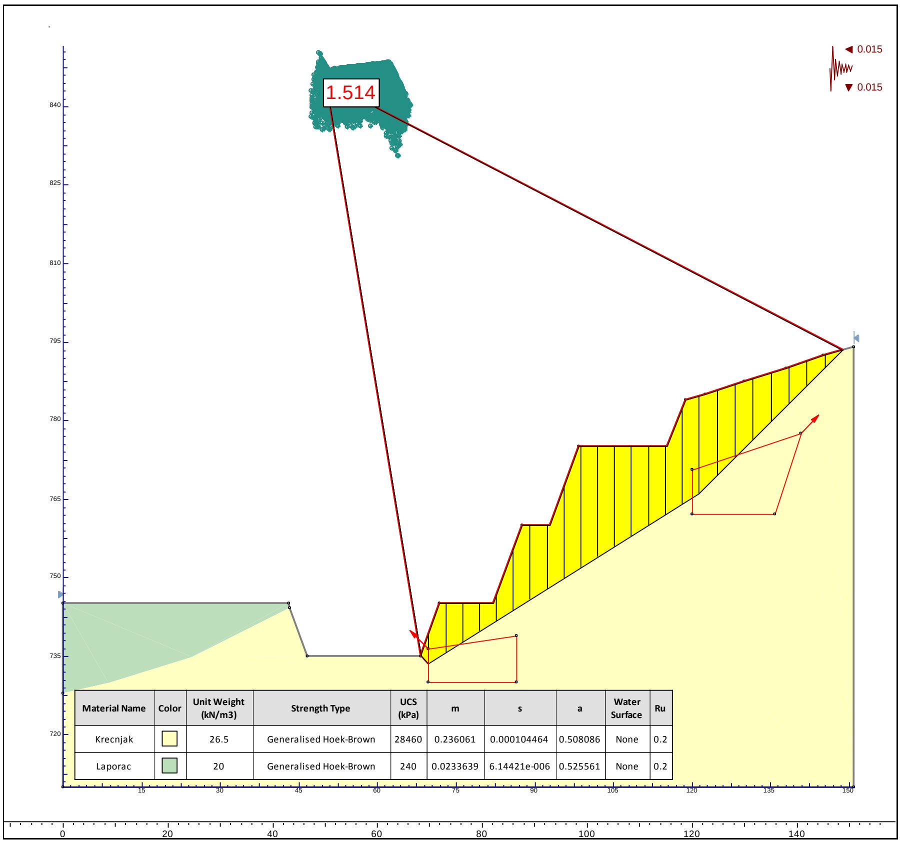

Figure 3 *Example of calculation of the safety factor of the cut slope formed in limestone*

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.

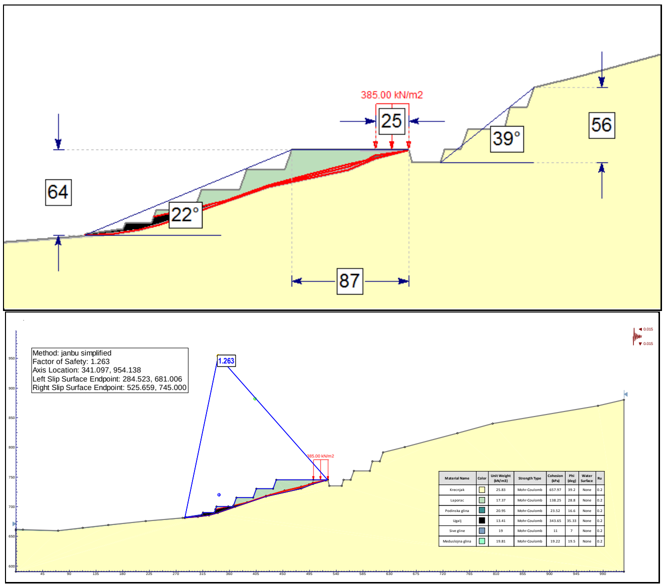

Figure 4 *Geomechanical model of the designed slope in the zone of crushing plant and plateau of truck on a map of the condition of works designed for 2025 with a detail of profile for Variant 2*

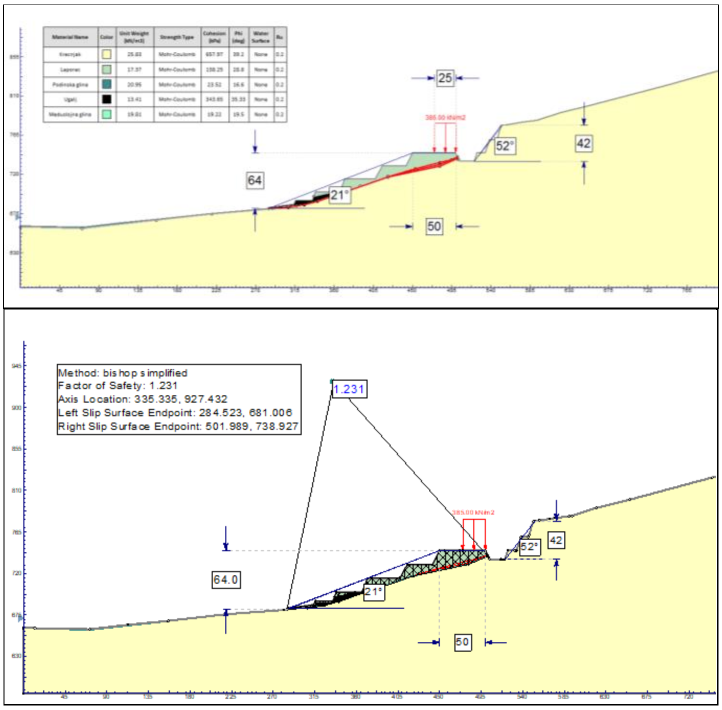

Figure 5 *Geomechanical model of the slope of cutting trench position for Variant 1 with an example of the calculated safety factor*

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).

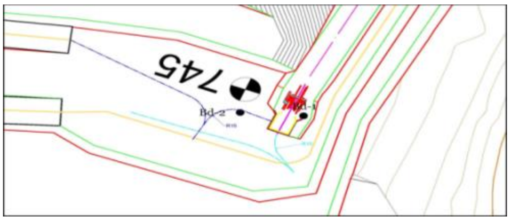

Figure 6 *New positions of the crushing plant*

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 blas-ting 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 con-struction 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 land-fill 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 tech-nological 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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Applied Economics

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EWALLET- INNOVATION OF TECHNICAL PROGRESS AND COMPETITION

Abstract

Globalization has produced a growing uncertainty, but also a decrease in the probability of outcome the events caused by changes. The changes have brought about technical progress and competition. The condition for implementing change is the ability to master and understand. The use of smartphones with the possibility of Internet access is increasing exponentially, and thus the popularity of electronic payment for goods and services. Consumers are willing to absorb the information technology as well as to take the certain risks using the mobile applications. The theory of acceptance, use of technology and innovation is offered to the consumers around the world in the form of e-wallets. That is why it is said that the innovation is not one-time action, but a process.

Keywords: *e-wallet, digitalization, changes, e-business*

INTRODUCTION

In addition to the traditional method of payment, consumers around the world use the modern technology and innovations. The synergy of electronic business and applications on smartphones has conditioned the emergence and development the new ways of mobile business. The business platform Statista.com states that in 2018, about 1.8 billion people worldwide will buy goods via the Internet. Namely, the global sales in e-retail, during the same year, amounted to 2.8 billion US dollars. In 2019, the online trade worldwide amounted to 3.53 billion US dollars, with a tendency to grow by 2022 to 6.54 billion dollars. The three largest global online stores: Alibaba.com, Amazon and Ebay had a turnover of almost 100 billion US dollars in 2017. Modern technology and Internet are the main drivers of the new payment methods in e-commerce. Mobile technologies offer a number of alternative electronic payment methods thanks to the technology and distribution channels they use. The interconnectedness of e-commerce and e-payment offers numerous benefits to the consumers making e-commerce more enjoyable compared to the traditional ones. Globally, the number of transactions performed using the mobile devices has increased.

According to the eMarketer 2019 Global Ecommerce Forecast, it is estimated that the global trade will increase to 20 billion dollars by 2021. Globally, the Asia-Pacific region expects e-commerce growth of 25% or $ 2.227 billion, accounting for 64.3% of

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global e-commerce use. The Latin America and Middle East/Africa region will have a growth rate of around 21.3% while the North America with 14.5% and Western Europe with 10.2% will be below the global average of 20.7% [1]. Also, it should be noted that the six of ten countries with the fastest growing e-commerce in 2019 are India 31.9% and the Philippines with growth over 31% as well as China 27.3%, Malaysia 22.4%, Indonesia 20.6 % and South Korea 18.1%. Mexico, 35%, Argentina with 18.8%, Canada with 21.1% or 49.8 billion dollars and Russia with 18.7% are also in a group of ten countries with the e-commerce growth.

In 2019, China was the largest e-commerce market with revenue of $ 1.935 billion, or three times that of the United States, which had $ 586.92 billion in e-payment transactions. Thus, China represents 54.7% of the global e-commerce market. Of the European countries, the United Kingdom leads with 141.93 billion dollars, Germany with 81.85 billion dollars and France with 69.43 billion dollars.

The first part of this paper contains data on the global market related to e-commerce. The second section explains the mobile wallet system, ranking of the use of mobile wallets, the advantages offered by this method of digital shopping and the difficulties for its adoption. Also, the paper presents the architecture of e-wallet with application components.

1 E-WALLET

A new method of e-payment is the e-wallet, which includes a business vision, project requirements, platform selection and design.[2] The trend of mobile phone payments has become common in everyday transactions. The use of mobile phones to use this technology is logical due to a large use of mobile phones and possibility of installing a large number of applications (Pasquet, Reynaud, Rosenberg, 2008). The mobile wallet service allows the user to install applications on smartphones and use them for payments and purchases over the Internet, which facilitates purchases without entering details from the card or without the physical use of a payment card. An e-wallet is defined as an online prepaid account into which money can be replenished and transactions can be performed offline and online via a computer or smartphone (Pahwas, 2017). E-wallets can be used to perform the various financial transactions: money transfers, payment of bills, payment of goods and services, payment of e-commerce, etc. A mobile wallet is considered a useful way to pay via mobile devices because it improves the overall performance of users (Amoroso and Magnier-Watanabe, 2012). Google Wallet, the first digital wallet, was created in 2011 and provided payments in retail and online shopping using the so-called NFC technology. Google Wallet (GW) is the first functional "digital wallet" created by Google. The idea of GW was to take an advantage of growing potential of smartphones with the integrated NFC readers and growing diffusion of contactless POS terminals based on the PayWave and PayPass solutions.[3]

Leading mobile wallet services are provided by: Alipay, WeChat Pay, Paytm, PhonePe, LINE Pay, Rakuten Pay, GO-PAY, Apple Pay, Google Pay, Samsung Pay and others.

According to the GATE (Global Acceptance Transaction Engine) data, in 2019, 2.07 billion consumers worldwide will use the e-wallet services for shopping. Also, the GLOBE NEWSWIRE in the report "The Global Digital Payment Forecasts 2019-2022" predicts that the e-wallets will take over a half of all e-commerce transactions from payment cards by 2022.

The development of e-wallet applications is continuous thanks to the significant role of applications such as AliPay, PayUMoney and Momoe. Interaction between the mobile phone and applications, such as adding or downloading the personal data from the card or when making a purchase, is possible after verifying the user card confirming the PIN number or verifying the fingerprint. The system enables the initialization of a card with personal data, credit accounts, the management of credit card transactions as well as a system for tracking cards that may have been lost or stolen.

The e-wallet enables the initiation of transactions on mobile devices at points of sale that have the POS[1] terminals with NFC (Near Field Communication) short-field technology based on RFID (Radio Frequency Identification) two-way communication or Magnetic Secure Transmission (MST) - security magnetic transmission. RFID establishes automatic identification and transmission of data by the electromagnetic waves and contains an active reader that is powered by energy and a passive receiver that is connected to the active reader by magnetic induction (Burkard, 2011). The RFID receivercontains an antenna for receiving and transmitting a radio signal and an integrated circuit for processing and storing the information and adjusting the signal. The NFC chip is built into mobile telephones that are very small in size.

1.1 E-wallet Models

Today, there are five different e-wallet models that use the different platforms, processes, and security tools:[4]

1. Mobile proximity wallet aimed at the device,
2. Wallet in the device-oriented application,
3. Filesystem,
4. Wallet with QR code,
5. Digital billing wallet.

- The first model of e-wallet is considered an open wallet because it accepts all credit and debit cards of any financial institution that is in the e-Wallet system, and can be used at any point of sale that has a POS or MST terminal. Also, it should be noted that the e-Wallet applications in the mobile phone are integrated with a device operating system (IOS or Android). his type of e-wallet supports the "EMV Payment Tokenization Specification - Technical Framework." (Tokenization specification for the EMV payment-technical framework) in which the payment application in a wallet generates a dynamic cryptogram that is with the token until the end of the entire transaction.
- An in-app mobile wallet aimed at a device used without a card in a mobile store, using the EMV payment tokenization and an issuer ID&V for payments using the application.
- The file system uses previously stored consumer payment data and allows the consumer to make the subsequent or automatic payments without re-entering the payment creditor. Consumers who use this type of e-wallet must open an account with the merchant and enter the necessary data from the payment card that will be used for the future purchases. For security reasons, the consumer is required to create a username and password, but also to select and create answers to security questions tailored to the consumer for verification and additional authentication.
- A wallet with a QR code works by connecting the application to a consumer bank account or credit card, so that the customer can pay for goods or services with their phone and by scanning the QR code. Initiating such a flow is similar to the requesting regular payments but further specifies the e-wallet application that the customer will use for the transaction. In that way, the transaction is directed to the terminal so that the customer can scan the QR code and check the payment.
- **Cloud-Based Wallets** - a wallet for digital billing.

[1] ***POS terminal (Point Of Sale)*** *- A terminal that allows payment for goods and services. It is equipped with software for processing transactions with payment cards (reading card data, forwarding to the accepting bank and accepting the response of the issuing bank, based on when the payment for the purchase of goods is made). It is used in service and trade shops.*

The e-wallet in the cloud stores payment information on a secure and remote server and not in a phone memory. Prestored payment letters of credit are used to activate a payment transaction authorization. The e-wallet from the server sends only tokens or authorizations to the phone to initiate and approve the transaction. In order for the transaction to be performed, an Internet connection is required, either mobile (GSM) or WiFi. After the transaction, you will receive a payment notification via e-mail or text messages. For merchants, services paid via mobile devices that use a server may be more flexible as this avoids some of the restrictions imposed by the POS terminals.

The applied technology and processes determine a design of an e-wallet to be used for transactions and how the credentials will be stored. The choice of wallet application includes: method of interaction for payment, storage of payment letters of credit, payment options (application, proximity to the store, remote e-commerce), method of accepting the card, use of confidential payment data.

1.2 E-wallet Architecture

The e-wallet system uses the J2EE platform, which is a set of standard specifications that describe the application components. The J2EE applications consist of components such as JavaServer Pages (JSP),[2] Java servlets[3], and the Enterprise JavaBeans (EJB)[4] module. These components provide software developers with the ability to create the large distributed application applications.

The J2EE platform provides service for applications including:

- Naming — this naming and directory service binds objects to the names. A J2EE application can locate an object searching its Java Naming and interface name (JNDI).
- Security-Java Authorization Contract for Containers (JACC) is a set of security agreements defined for the J2EE containers. Based on the customer identities, the containers may restrict access to the container resources and services.
- Transaction management - a transfer of funds between the bank accounts is a transaction.
- Messaging services communicate with each other by exchanging the messages using the Java Message
- Service (JMS). The JMC is an integrated part of the J2EE platform and facilitates the use of integrating heterogeneous business applications.

The Java servlets technology allows you to easily extend the functionality of a web server with a variety of applications. The Java provides the interaction of important components with the smart card readers in the following way: the smart card runs a Java application - applets (small Java programs) associated with the HTML page developed by IBM. The information from the smart card is transferred to the Java Virtual Machine to become functional.

2 NFC TECHNOLOGY

The NFC is a standard wireless communication protocol that operates on 13.56 MHz radio frequency technology enabling the exchange of data between the devices up to 424 kbps in a few centimeters (Grassie, 2007). The NFC payment transactions between the mobile devices and POS terminals use the same ISO / IEC 14443 standard communication protocol used by the contactless credit and debit cards. Based on this

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[2] JavaServer Pages (JSP) is a set of technologies that help software developers create dynamically generated web pages based on HTML, XML, SOAP or other types of documents.
[3] Java servlet is a component of Java software that extends server capability. Servlets typically implement web containers to host web applications on web servers. Such web servlets are similar to other dynamic web content technologies such as PHP and ASP.NET
[4] Enterprise JavaBeans (EJB) is used to gather multiple parts into one usable unit. The EJB module is stored in a standard Java archive file

protocol, the mobile device is allowed to simulate a contactless card.

The Host Card Emulation (HCE) is a payment card emulation software solution that allows a mobile phone application to communicate using an NCF controller to send the payment card credentials or payment symbols to a contactless NCF POS terminal or reader. The Host Card Emulation (HCE) redirects requests for NFC transactions to the mobile application.

3 BENEFITS OF E-WALLET

We all have a number of cards in our classic wallet. If we lose our wallet, we need to call several banks to secure our money and identity. With an e-wallet, we only need one call to deactivate. An e-wallet eliminates the need for more cards. The user chooses which card he/she wants to use for the e-wallet shopping application. The e-wallet provides a number of security features, increased security measures and comfort that make this project useful.

The e-wallet has a stored value function, which eliminates the need to carry cash. It means like carrying real money in your wallet. This is the so-called the whole value that represents the monetary amount. The entire value can be transferred from the cardholder to the merchant absolutely as a real cash. Also, the cardholder can constantly add an overall value.

The identification subsystem is in charge of the security of information on the identification card and enables that information to be viewed by several people on special request. The system is designed so that any change to the card requires some kind of authentication. The electronic wallet provides all the functions from a smart card eliminating the need for multiple cards. The e-wallet provides a host of security features that are not available to the regular wallet operators. Namely, an identification is required during every credit card transaction and the smart card is equipped with a disabling system if the card is misused. All these increased security measures and convenience make this process useful.

Paying with the help of a mobile phone is very simple and practical and saves time. In addition to this, it is also possible to pay at payment terminals, pay and buy at the WEB-shop stores, transfer money to another e-wallet, transfer funds via e-mail, SMS, withdraw cash at the bank and ATMs.

According to the NALED, in accordance with the above, the VISA estimates that the application of digital payment technologies (payment cards, internet and mobile phones) would bring a direct net benefit in Belgrade of 324.3 million dollars every year. Out of that, $ 27 million net to the consumers, $ 200 million to the companies (when the cost of infrastructure is deducted and $ 68 million to the state, through higher taxes and lower administration costs.

Taking into account all the advantages that this type of payment brings, a large number of countries from all over the world actively promote cashless payments, and for that purpose develop various forms of incentives and subsidies that try to make it more acceptable and profitable, both for businesses and citizens. Some of the most common models are the introduction of POS terminals1 in public institutions, the reduction of VAT, subsidizing the costs of setting up terminals and the purchase of mobile phones.

3.1 E-wallet Safety

Various researchers such as Varsha and Thulasiram’s study (2016) in their research on consumer behavior towards the e-wallet services indicate that the secured privacy and secure transactions are the main reasons for the progressive acceptance of said innovation.

There are other opinions, such as (Holland and Dyke, 2015) that consider security to be one of the main reasons for not using the mobile payments. (Abrazhevich, 2001) indicates that the consumers are reluctant to use the electronic payment methods due to the problems of trust, security and reliability. Back in 1989, Ram and Sheth claimed that an innovation was influenced by the functional and psychological barriers.

The ultimate goal should be a complete replacement of credit, debit, loyalty, prepaid and other cards, which users carry en masse in their wallets. (Coskun at all, 2014, p. 144).

4 E-COMMERCE IN THE REPUBLIC OF SERBIA

VISA listed Belgrade as the actual or potential "cities without cash" according to a research conducted for the period 2012-2015. Based on those researches, the non-cash trade brought Serbia 150 million euros. It is estimated that there is currently 10% of the non-cash economy in Serbia and that this trend will increase to 35% in a few years.

For many years, the system of online payments via computers and mobile phones has been functioning in Serbia. In recent times, the commercial banks, following modern trends and innovations, have applied a way to pay without cash and cards in stores, restaurants and other places.

There is a constant increase in the number of regular users of e-commerce in Serbia. It increased from 18% of the total number of Internet users in 2011 to 30.9% in 2018, the Ministry of Trade, Tourism and Telecommunications of the Republic of Serbia announced.

It is predicted that by 2030, more than 85% of companies will be engaged in the e-commerce globally, and that it is necessary for Serbia to develop this area in order to use all the technological potentials for economic progress. According to the ministry, the biggest challenge in strength-hening e-commerce in Serbia is how to increase the trust of citizens in this form of buying and selling and prevent the gray economy in that trade.

According to the data of the Ministry of Labor, Employment, Veterans and Social Affairs of the Republic of Serbia, it is stated that in 2018, 1.8 million citizens bought over the Internet, which is 50% more than in 2015. Electronic commerce in 2018 of $ 317 million, an increase of about 9% over the previous year. The forecasts for 2019 say that the Internet sales will record a turnover of around 350 million dollars.

Serbia is becoming part of a group of countries that recognize the digital economy as one of the main generators of the entire economy development.

CONCLUSION

Mobile wallets are not widely accepted in many countries, but the use of technology and user features will lead to a greater acceptance. In order to increase the number of e-wallet users, it is necessary to point out their potential. It is estimated that over 1.7 billion adults (21% of the total world population) do not have access to a traditional bank account but about a billion residents have a mobile phone and may be potential users of mobile wallets.

The e-wallet shall become a global standard as consumer confidence in e-commerce grows. The mobile wallet is a benchmark for many international brands in mobile banking. The e-commerce enables the domestic economy to more easily place products in the country and on the global market. Using the e-wallet provides retailers with the greater efficiency, cost savings, and greater customer loyalty.

As more and more purchases are made remotely, the losses of online payment fraud are increasing. Thus, mobile biometrics will become popular for digital shopping due to its increased security.

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THE IMPORTANCE OF CASH FLOWS IN THE ECONOMIC ASSESSMENT OF THE MINING PROJECTS

Abstract

The economic assessment and analysis of investment projects is aimed to show what the value will be achieved by the project for enterprise, region and wider community. The overall assessment of the project should be given by the investor, financier and ecology. The positive results of the project are certainly acceptable from the point of view of investors, but they do not have to be acceptable from the point of view of financiers and ecologists. This imposes a need for balancing the demands of all three sides. In the static evaluation of the project, the profit and loss account, profitability, is observed, which is higher than in costs, which is a gain (profit). In the dynamic project evaluation, the following cash flows are monitored: financial, economic and social. The financial cash flow points to the liquidity of the project during its lifetime, if the inflow is constantly greater than the outflow of funds, the project is liquid. The economic flow indicates the project profitability, period of return on investment, net present value and internal rate of return. The social cash flow deals with the national economy, excludes the government's contributions to cash outflows and determines the social net present value as well as the social rate of profitability.

Keywords: *economic assessment, investment projects, cash flows, net present value, profitability rate, repayment period*

1 INTRODUCTION

The value of investments, revenues, costs and cash flows are the basic criteria for assessment the acceptability of an investment project. The goal of every investor is that the money invested in a certain period of time results in a higher value than the value of interest for the same money in the bank. There are numerous criteria for objective evaluation the projects in theory and practice depending on the economic activity they cover. There are also projects whose results cannot be evaluated and valorized on the market, but have a positive impact on the environment or are implied by the legislation (waste disposal, wastewater treatment before discharge into watercourses).

The subject of this paper is the mining project of production expansion, its static and dynamic assessment. Static assessment in the analysis procedure does not take the time factor, but uses data from only one, representative year of the exploitation period. A representative year is one whose results (income, expenditure, gross and net profit) are close to the average results. This assessment is based on the income statement and does not include the investment period.

The dynamic assessment takes into account the period of investment and life of exploitation, so the obtained indicators are much more reliable. The indicators of dynamic assessment are: net present value,

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payback period, internal rate of return, profitability index and return on investment. Dynamic analysis is based on the cash flows: financial, economic and social.

2 INCOME STATEMENT

The income statement is one of the basic accounting reports for presenting the business results. In the investment projects, the income statement is prepared on the basis of planned revenues, expenses and business results. Revenues are planned on the basis of projected technological production capacities and market prices, more precisely, only the operating revenues are included. These revenues, reduced by the costs of the smelter, are subject to a fee for the use of mineral resources (a rate regulated by the law). This fee has the character of immaterial costs. Material costs are planned on the basis of technical specifications of the basic and auxiliary raw materials, energy, fuel and labor and corresponding constant prices expressed in hard currency (USD, EUR). Capital costs are calculated in accordance with the planned investments during the construction period and replacement of equipment during production. Financial costs are calculated depending on the amount and terms of the loan. The difference between planned income and planned expenses is the result of operations and is reported as a profit or loss.[1] In the first years of a project life, the balance sheet may also show a loss due to the insufficient capacity utilization or high credit liabilities.[1] In this example, the gross profit is realized, to which the legal rate of profit tax is applied, and after this reduction, the planned net profit remains. If there is no profit, there is no income tax.

Table 1 *Income statement*

Project item / year	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**TOTAL(US$)**
REVENUES FROM SALES	**35.021.515**	**52.565.523**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**502.360.712**
Variable costs	19.041.600	33.353.083	36.493.894	36.493.894	36.493.894	36.493.894	36.493.894	36.493.894	36.493.894	**307.851.944**
Material	7.205.064	17.243.712	19.149.510	19.149.510	19.149.510	19.149.510	19.149.510	19.149.510	19.149.510	**158.495.346**
Gross earnings	4.102.000	4.102.000	4.102.000	4.102.000	4.102.000	4.102.000	4.102.000	4.102.000	4.102.000	**36.918.000**
Other variable costs	7.734.536	12.007.371	13.242.384	13.242.384	13.242.384	13.242.384	13.242.384	13.242.384	13.242.384	**112.438.598**
Fixed costs	7.545.188	11.181.910	11.967.473	11.967.473	11.967.473	11.967.473	11.967.473	11.967.473	11.967.473	**102.499.406**
Gross earnings	1.758.000	1.758.000	1.758.000	1.758.000	1.758.000	1.758.000	1.758.000	1.758.000	1.758.000	**15.822.000**
Depreciation	1.078.518	2.157.035	2.157.035	2.157.035	2.157.035	2.157.035	2.157.035	2.157.035	2.157.035	**18.334.798**
Other fixed costs	4.708.670	7.266.875	8.052.438	8.052.438	8.052.438	8.052.438	8.052.438	8.052.438	8.052.438	**68.342.608**
Financial costs (interests)		1.198.524	1.077.430	949.070	813.009	668.784	515.906	353.855	182.081	**5.758.659**
TOTAL COSTS	**26.586.788**	**45.733.517**	**49.538.797**	**49.410.437**	**49.274.376**	**49.130.151**	**48.977.273**	**48.815.222**	**48.643.448**	**416.110.008**
GROSS PROFIT	**8.434.728**	**6.832.006**	**9.714.585**	**9.842.945**	**9.979.006**	**10.123.231**	**10.276.109**	**10.438.160**	**10.609.934**	**86.250.704**
Income tax	1.265.209	1.024.801	1.457.188	1.476.442	1.496.851	1.518.485	1.541.416	1.565.724	1.591.490	**12.937.606**
NET PROFIT	**7.169.518**	**5.807.205**	**8.257.397**	**8.366.503**	**8.482.155**	**8.604.746**	**8.734.693**	**8.872.436**	**9.018.444**	**73.313.098**

The income statement determines the project profitability. This project covers the total production costs and makes a profit every year during its lifetime.

The income statement contains:

1. Operating revenues (revenues from sales of finished products)
2. Operating expenses

   2.1. Material costs (raw materials, intermediate goods, parts, energy sources, investment maintenance and depreciation),

   2.2. Gross earnings,

   2.3. Immaterial costs,

   2.4. Financial costs.
3. Gross profit
4. Income tax
5. Net profit

3 FINANCIAL CASH FLOW

Cash flows indicate the planned inflows and outflows of funds [1] from the beginning to the end of the project life. The cumulative financial cash flow indicates the liquidity of the investment project during the construction period and its production life. During construction, the inflows and outflows must be equal, and during production, it is desirable that the inflows would be higher than the outflows. Only in that case the project is considered as a liquid, which is necessary in assessment its acceptability. As in the income statement, in the initial years when production is running to the full capacity, it may happen that the outflows are higher than the inflows and the financial cash flow is negative.

The following table presents the cash flow of the proposed mining production expansion project with an investment period of 1.5 years.

Table 2 *Financial cash flow*

Project item / year	1	2	3	4	5	6	7	8	9	10	TOTAL(US$)
TOTAL INFLOWS	**12.597.400**	**48.399.515**	**52.565.523**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**535.976.714**
Inflows from funding sources	12.597.400	13.378.000									**25.975.400**
Own resources		6.000.000									**6.000.000**
Long-term credits	12.597.400	7.378.000									**19.975.400**
Short-term sources											**0**
Inflows from operations		35.021.515	52.565.523	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	**502.360.712**
Revenues from sales		35.021.515	52.565.523	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	**502.360.712**
Interests on short-term placements											**0**
Rest of the value of fixed&current assets											**7.640.602**
TOTAL OUTFLOWS	**12.597.400**	**39.408.998**	**47.063.431**	**51.276.843**	**50.997.531**	**51.017.940**	**51.039.574**	**51.062.506**	**51.086.813**	**51.112.580**	**456.663.616**
Increase in fixed assets	12.597.400	10.378.000									**22.975.400**
Investments in fixed assets	12.597.400	10.378.000									**22.975.400**
Total pre-production expenses											**0**
Increase in net current assets		2.257.519	443.915	298.566							**3.000.000**
Business costs		25.508.270	42.377.958	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	**392.016.552**
Marketing costs											**0**
Income tax		1.265.209	1.024.801	1.457.188	1.476.442	1.496.851	1.518.485	1.541.416	1.565.724	1.591.490	**12.937.606**
Interests			1.198.524	1.077.430	949.070	813.009	668.784	515.906	353.855	182.081	**5.758.659**
Loan repayment			2.018.233	2.139.327	2.267.687	2.403.748	2.547.973	2.700.852	2.862.903	3.034.677	**19.975.400**
FINANCIAL CASH FLOW		**8.990.517**	**5.502.092**	**7.976.539**	**8.255.851**	**8.235.442**	**8.213.808**	**8.190.876**	**8.166.569**	**8.140.802**	**7.640.602**
FINANCIAL CASH FLOW CUMULATIVE		**8.990.517**	**14.492.609**	**22.469.148**	**30.724.999**	**38.960.440**	**47.174.248**	**55.365.125**	**63.531.693**	**71.672.496**	**79.313.098**

Table of financial cash flow contains:
1. Inflows,
2. Outflows,
3. Differences between the inflows and outflows (financial cash flow),
4. Cumulative financial cash flow.

The total inflows are formed by:
- operating inflows (sales revenues and interest on short-term placements),
- inflows from financing sources (own funds, long-term and short-term credits),

- residual value (unamortized value of fixed assets and current assets).

The total outflows are formed by:

- investments into fixed and current assets and expenses before production,
- operating costs (excluding depreciation and interest on credits),
- marketing costs,
- corporate taxes (income tax),
- interest on credits,
- credit repayments.

The example of this project shows the balance between the inflows and outflows in the first investment year, and from the second year when production begins, and further, the project achieves a positive difference between the inflows and outflows. The cumulative financial cash flow grows from year to year and proves the permanent liquidity of the project.

The improvement in liquidity is affected by an increase in cash inflows from external sources such as: new share capital, new long-term credits, sale of fixed assets.

The weakening of liquidity is caused by an increase in cash outflows through interest, taxes and dividends, repayments of long-term credits and capital expenditures.

4 ECONOMIC CASH FLOW

Economic cash flow is the basis for assessment the main parameters of project value: return on investment period, net present value and internal rate of return. These parameters assess the effectiveness of investments. Investment efficiency is observed from an aspect of investor (mesoeconomics) and from an aspect of wider social interest (macroeconomics) [2].

Period of return on investment is the project year in which the cumulative net economic flow is positive for the first time. If there are several similar projects, the one with a shorter payback period is chosen. This parameter looks at the time dimension of the project and represents the time period of exploitation required to return the invested funds. The invested funds must be returned during the project life and that period depends on the value of investment and amount of realized annual net inflow in the economic flow. The higher the investment, the longer the payback period

Net present value is the sum of discounted annual net receipts from the economic flow of the project at a rate corresponding to the price of capital, which means at the interest rate on the credits used. If the investor does not use credits, a discount rate corresponding to the real interest rate on investment credits applied by banks is taken. A project is eligible if the net present value is positive. If there are several variants of the project, the one with the highest realized net present value is chosen.

Internal rate of return is the discount rate that ensures that the net present value is reduced to zero. It is arrived at by an iterative procedure consisting of calculating the net present value applying different discount rates until the net present value is 0. It is practically located between a discount rate that has a positive net present value but is close to 0 and discount rate that has a negative net the current value is close to 0.

The following table shows the economic cash flow of the assumed mining project.

Table clearly shows the difference between the financial and economic flow. Both flows in the inflows contain the sales revenue and residual value of fixed and current assets. Cash flow into inflows includes the sources of funds (own funds + credits). Outflows of both flows include investments in the fixed and current assets, operating expenses (excluding depreciation and interest on credits) and income tax. The cash flow includes the additional interest and credit repayments. These two items are not included in the economic flow.

Table 3 *Economic cash flow*

Project item / year	1	2	3	4	5	6	7	8	9	10	Ukupno (USD)
TOTAL INFLOWS		**35.021.515**	**52.565.523**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**59.253.382**	**510.001.314**
Inflows from operations		35.021.515	52.565.523	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	**502.360.712**
Revenues from sales		35.021.515	52.565.523	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	**502.360.712**
Interests on short-term placements											**0**
of the value of fixed&current assets										7.640.602	**7.640.602**
TOTAL OUTFLOWS	**12.597.400**	**39.408.998**	**43.846.674**	**48.060.086**	**47.780.774**	**47.801.183**	**47.822.817**	**47.845.748**	**47.870.056**	**47.895.822**	**430.929.557**
Increase in fixed assets	12.597.400	10.378.000									**22.975.400**
Investments in fixed assets	12.597.400	10.378.000									**22.975.400**
Total pre-production expenses											**0**
Increase in net current assets		2.257.519	443.915	298.566							**3.000.000**
Business costs		25.508.270	42.377.958	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	**392.016.552**
Marketing costs											**0**
Income tax		1.265.209	1.024.801	1.457.188	1.476.442	1.496.851	1.518.485	1.541.416	1.565.724	1.591.490	**12.937.606**
NET CASH FLOW	**-12.597.400**	**-4.387.483**	**8.718.849**	**11.193.296**	**11.472.608**	**11.452.199**	**11.430.565**	**11.407.634**	**11.383.326**	**11.357.560**	**7.640.602**
NET CASH FLOW CUMUL	**-12.597.400**	**-16.984.883**	**-8.266.034**	**2.927.262**	**14.399.871**	**25.852.070**	**37.282.635**	**48.690.269**	**60.073.595**	**71.431.155**	**79.071.757**
NET PRESENT VALUE	**-12.597.400**	**-4.139.135**	**7.759.745**	**9.398.107**	**9.087.380**	**8.557.749**	**8.058.098**	**7.586.728**	**7.142.040**	**6.722.522**	**4.522.461**
NET PRESENT VALUE CU	**-12.597.400**	**-16.736.535**	**-8.976.790**	**421.317**	**9.508.697**	**18.066.447**	**26.124.544**	**33.711.272**	**40.853.312**	**47.575.834**	**52.098.295**

Net present value	6,00%	**52.098.295**
Internal return rate	**44,77%**	
Modified internal return rate	22,10%	
Period of investment return	0,00%	**3,74 year**
Discounted return period	6,00%	3,96 year

The following parameters can be seen from the attached Table:

- internal rate of return (IRR) = 44.77%
- Net present value (NPV, disk.6%) = 52,098,295 US $
- Recovery period (RP) = 3.74 years

5 SOCIO-ECONOMIC FLOW

The effectiveness of investments from the point of view of mesoeconomics, i.e. from the aspect of investor have been considered until now. In fact, the investment has a broader significance. Investment strengthens the material basis of society and provides the accelerated economic and social development. Investments in mining start the development of other economic branches, for example, machine industry, special purpose industry (production of explosives, reagents, balls, bars), processing industry, service activities, etc. Investments drive an economic growth, so in evaluation an investment project, its macroeconomic effects should be taken into account.

The project contribution to the socio-economic development is reflected in:

- meeting the needs of society for certain goods,
- increase in employment,
- improvement the balance of payments,
- faster regional development,
- protection and preservation of the environment.

From the aspect of ecology, the mining projects cannot be highly ranked, since they impair the quality of air, land and water, whether it is surface or underground exploitation. The relief of a certain area changes significantly and the reclamation process is poorly implemented and takes a long time.

In relation to the economic cash flow, the socio-economic flow does not include the so-called transfer payments [2], on the revenue side these are the export premiums, recourses, subsidies and grants, and on the expenditure side there are the taxes, contributions, customs duties, taxes, etc. Due to the exclusion of these elements, the social net present value (SNPV) is higher than the net present value (NPV) and the social internal rate of return (SIRR) is higher than the internal rate of return (IRR). This can be seen in the following Table.

Table 4 *Socio-economic cash flow*

Project item / year	1	2	3	4	5	6	7	8	9	10	TOTAL(US$)
TOTAL INFLOWS		35.021.515	52.565.523	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	510.001.314
Inflows from operations		35.021.515	52.565.523	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	502.360.712
Revenues from sales		35.021.515	52.565.523	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	59.253.382	502.360.712
Rest of the value of fixed&current assets											7.640.602
TOTAL OUTFLOWS	12.597.400	38.143.789	42.821.873	46.602.898	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	417.991.952
Increase in fixed assets	12.597.400	10.378.000									22.975.400
Investments in fixed assets	12.597.400	10.378.000									22.975.400
Increase in net current assets		2.257.519	443.915	298.566							3.000.000
Business costs		25.508.270	42.377.958	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	46.304.332	392.016.552
NET CASH FLOW	-12.597.400	-3.122.274	9.743.650	12.650.484	12.949.050	12.949.050	12.949.050	12.949.050	12.949.050	12.949.050	7.640.602
NET CASH FLOW CUMUL.	-12.597.400	-15.719.674	-5.976.024	6.674.460	19.623.510	32.572.560	45.521.610	58.470.660	71.419.710	84.368.760	92.009.363
SOCIAL NET PRESENT VALUE	-12.597.400	-2.945.541	8.671.814	10.621.590	10.256.860	9.676.283	9.128.569	8.611.858	8.124.394	7.664.523	4.522.461
SOCIAL INTERNAL RETURN RATE	-12.597.400	-15.542.941	-6.871.128	3.750.463	14.007.323	23.683.607	32.812.176	41.424.034	49.548.428	57.212.951	61.735.411

Social net present value	6,00%	**61.735.411**
Social internal return rate	**51,61%**	

6 CONCLUSION

The objective assessment of investment projects is not easy at all, being objective means assessment and evaluation, the benefits and damages caused by the project from the point of view of micro, meso and macroeconomics.

It is not enough that the project brings benefits not only to the company and the region, but also to the national economy. It is necessary to realistically look first at the mineral resources that are available and that want to be exploited, then, the long-term movement of market prices for the designed production, investments for selected technological processes, labor engagement and demographic opportunities.

Continuous supply of raw materials and transport conditions are also the key elements for project assessment, and the socio-political situation and legislation of a particular country in which the investment project is planned should not be neglected.

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[1] Willis B. A., Mineral Procesing Technology, Oxford, Pergamon Press, 1979, pg. 35. (for the chapter in a book)

[2] Ernst H., Research Policy, 30 (2001) 143–157. (for the article in a journal)

[3] www: http://www.vanguard.edu/psychology/apa.pdf (for web document)

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