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Academic Ph.D. Milenko Ljubojev,
Principal Research Fellow
Mining and Metallurgy Institute Bor
Full member of ESC
E-mail: milenko.ljubojev@irmbor.co.rs
Phone: +38130/454-109, 435-164

Editor

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English Translation

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19210 Bor, Zeleni bulevar 35
E-mail: milenko.ljubojev@irmbor.co.rs
Phone: +38130/454-110

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CONTENS
SADRŽAJ

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Daniel Kržanović, Vedran Kostić*, Radmilo Rajković*, Ivana Jovanović**

ESTABLISHING THE SPATIAL CONDITIONS AT THE SOUTH MINING DISTRICT MAJDANPEK TO ACHIEVE THE CONTINUITY IN ORE MINING: A PROPOSED TECHNOLOGY FOR SEDIMENT LAYER REMOVAL**

Abstract

Development of mining works at the South Mining District Majdanpek in the following short-term period requires removal of water, sludge and sediment from the water collector on the open pit bottom in order to create the necessary exploitation and spatial conditions for undisturbed operation of mining equipment.

This paper presents the technology of sediment removal from the inactive water collector on the bottom of open pit, which is a condition for maintaining the continuity of copper ore mining and processing at the South Mining District the Majdanpek Copper Mine. The technology is designed from the aspect of ensuring the maximum safety of people and mining equipment.

Keywords: *Majdanpek Mine South Pit, technology, water collector, sludge and sediment layer, safety*

1 INTRODUCTION

The South Mining District Majdanpek operates within the company Copper Mine Majdanpek, which is a part of the company Zijin Bor Copper doo Company (former Mining and Smelter Basin Bor Group).

The Copper Mine Majdanpek, in the production, technical and technological sense, represents a complex mining system that has the activities from geological explorations the mineral resources, ore exploitation and processing to a number of supporting activities as the necessary support to the core activities [1]. The ore production and processing in the Copper Mine Majdanpek is currently developed at the Open Pit South Mining District and is of great importance for the copper production in the system of company Mining and Smelter Basin Bor Group (RTB Bor Group) [2].

Mining activities at the open pit mine South Mining District of the Majdanpek Copper Mine currently take place in the eastern side of the open pit. The ore excavation currently takes place at the bench B 215. Based on the current exploitation conditions and situation on the site, the mining operations can be developed to the bench B 140. According to the planned capacity, the operation would take place over a period of six months. The amount of ore that can be excavated in that period is about 4,000,000 tons.

* *Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia*

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In order to achieve the planned capacity of copper ore excavation and processing in the next short-term period of 600,000 t ore per month, it is necessary to provide the exploitation and spatial conditions for the undisturbed operation of mining equipment at the South Mining District Majdanpek [3].

This means that it is necessary to enable the development of mining operation at the benches B 215 to B 110. This requires the drainage and removal of materials from the inactive water collector at the level L+150 m to the bottom of the open pit, which is at the level of L+122 m. This is necessary in order to create the conditions for ore excavation to be carried out smoothly.

2 MATERIAL CHARACTERISTICS IN THE INACTIVE WATER COLLECTOR

Figure 1 shows the location of inactive water collector at the level L+150 m on the bottom of the South Mining District Majdanpek.

Figure 1 *Location of the water collector at the level L+150 m on the bottom of the South Mining District Majdanpek Mine (north side view)*

It is estimated that the three layers can be separated in the water collector:

- Clear water layer
- Sludge layer
- Sediment layer

It is estimated that the clean water layer is about 8 m deep with its solid phase concentration of below 20% and the total water volume of 350,000 m^3. The sludge layer is about 4 m deep; its solid phase concentration is 20% - 40%, and the total volume is 156,000 m^3. The sediment layer is about 18 m deep; its solid phase concentration is greater than 40%, and the total volume is 460,000 m^3.

Figure 2 shows a profile of accumulated layers.

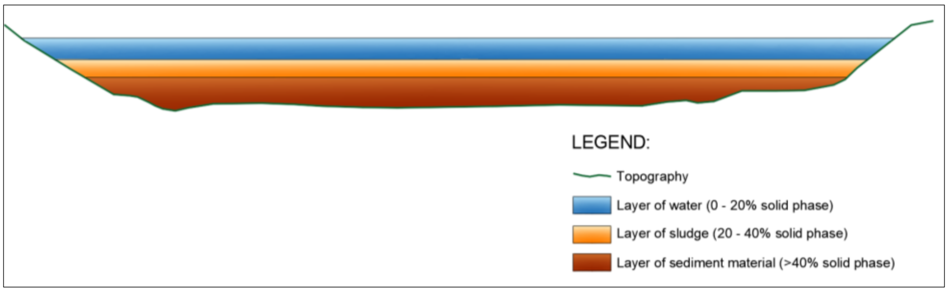


Figure 2 *Profile of the accumulated layers [3]*

3 TECHNOLOGICAL PHASES OF MATERIAL REMOVAL FROM THE INACTIVE WATER COLLECTOR

According to the defined layers, there are three phases:

1) Phase 1: Clear water layer dewatering
2) Phase 2: Slurry layer removal
3) Phase 3: Slurry layer removal.

3.1 Phase 1: Clear water layer dewatering

The drainage system of this water will be a cascade type. Submersible pumps will be installed in the accumulation to pump water to the water collector at the level L+180 m, from where it will be pumped by the stable pumps to the precipitator for the physical treatment of solid particles at the level L+350 m, next to the crushing plant. This purified water goes into the existing precipitator with zeolites from which it is discharged into the river Mali Pek.

3.2 Phase 2: Slurry layer removal

Slurry is planned to be transported by the slurry pumps. The main parameters of the slurry pumps: flow rate is 1271 m^3/h, lifting height is 64.6 m, rotation is 590 r/min, and mortar power is 355 kw. Slurry is transportted to the hydrocyclone system for classification. The processing rate (considering the fluctuation, coefficient 1.1) is 1019.46 m^3/h, feed size is not above 10 mm, concentration is 20 - 40%, pressure is 0.1 MPa, slurry concentration is 70%, settling rate is 221 m^3/h, overflow concentration is 7.5 - 20%, and overflow volume is 438.44 - 1240.48 m^3/h. The settled sediments will be disposed by the excavator loading + truck transportation. The overflowing water is pumped into the clear water drainage system and flow to the outside ditch by the relay submersible pumping and fixed pumping station.

3.3 Phase 3: Sediment layer removal - proposed technology

Sediment layer was formed by material deposition that collapsed from the mine slopes with a larger participation of small fractions, with the expected presence of a solid phase in the average of 65% (minimum 40%). The sedimentary layer thickness, depending of the bottom of excavation, and it is variable and assumed that the maximum thickness is 18 m, i.e. from L+138 m to L+120 m. Prior to the excavation, i.e. after water draining of the sludge layer and removal the sludge, it is necessary to make a paved path to the presumed sediment layer level of L+ 138 m, so that a direction of sediment excavation is from the north to the south.

A technology of sediment layer excavation, which enables the safe movement of machinery during operation, is proposed. This can be achieved by formation a ramp of about 8 m width and up to 5 m height from the bulk material, obtained from the waste excavation at the open pit. The bulk material would have reached the location by the trucks, and a ramp formation would be done by a bulldozer, gradually with the excavation progression of the sedimentary layer. The northern part of the sediment bed is optimal for the start of loading work. The ramp will be gradually made from the north to the south, i.e. from the level L + 138 to about L + 125, with a constant angle.

Considering that the real situation of the pit bottom in the area below the sediment layer is not known, but will be gradually discovered during the excavation of the sediment layer, the position of the ramp will be adapted to the situation on site. By analyzing the problem, the initial ramp can be constructed on the eastern side of the sediment layer, which would also serve to excavate the depressions for water accumulation. Depressions for water accumulation will be excavated in the area within the excavation radius of the loading equipment, while the equipment itself is on stable ground (excavation ramp), Figure 3. Accumulated water in depressions will be pumped out, unless the depressions are filled back with sediment material. During the material excavation from the sediment layer, the accumulation of water near the excavation ramp can be expected due to the proposed backhoe excavation technology. Also in this case, the water needs to be pumped out of the work site.

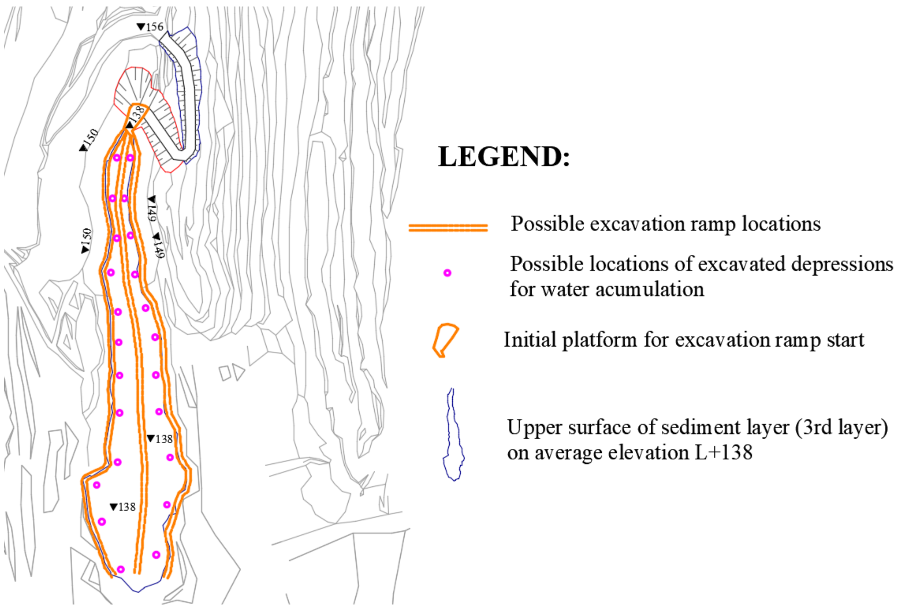
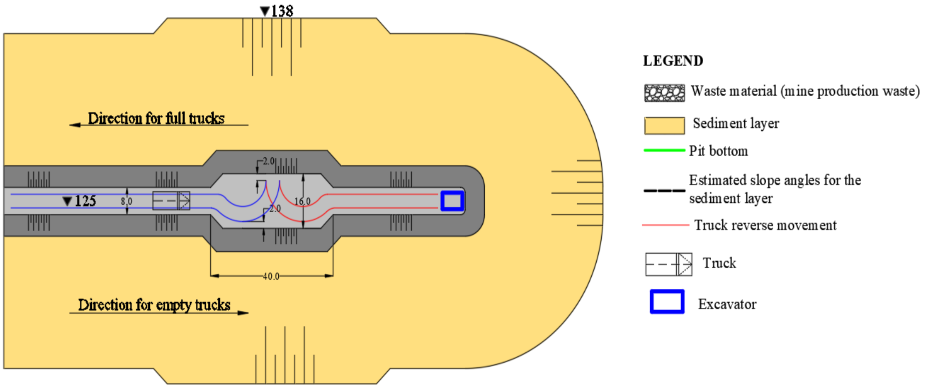


Figure 3 *Possible excavation ramp locations for the sediment layer excavation [3]*

The ramp will also enable the safe operation of mechanization during drainage of the sedimentary layer. Figure 4 (a, b and c) presents the technological scheme for loading material from the sediment layer.

a)



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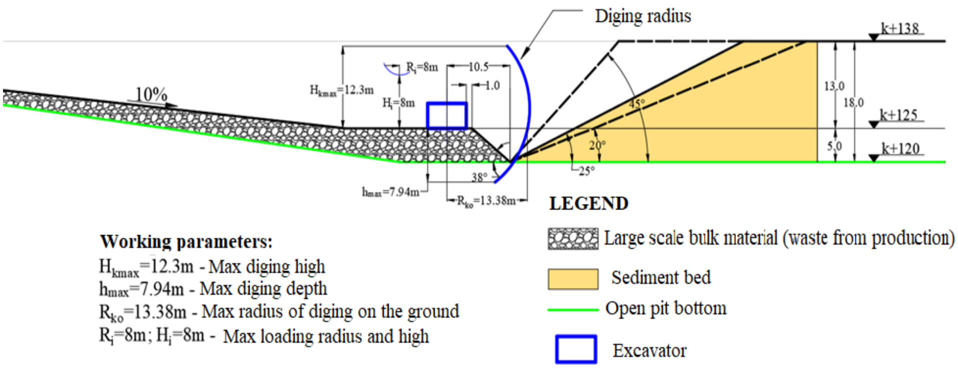

c)

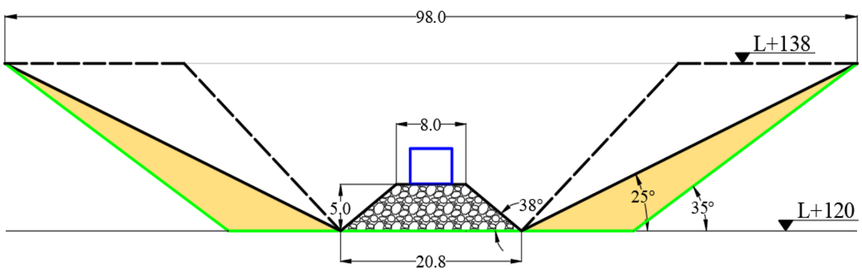

Figure 4 *Technological operating scheme excavator-truck system on the loading material from the sediment layer (a, b and c) [3]*

According to the sedimentary layer, made of a non-cohesive material, where a certain amount of sludge can be expected, as well as the climatic conditions in the Republic of Serbia in the spring period, the slopes of sedimentary layer in the excavation process will be at the estimated angle of 20-45°.

Due to the simulation and calculation of loading and transport operations, the equipment for loading and transport the sediments, i.e. a hydraulic excavator (backhoe) with a bucket capacity of 6.5 m^3 and trucks with a capacity of 70 tons, will be used. The same trucks will be used to estimate the bulk material with a large-granulation for ramp construction. The loading of sediments will be carried out above and below the excavator level, in accordance with the ground conditions, as described by the technological scheme. Considering the length of the open pit bottom, where the sediments will be loaded (max. up to 500 m), and according to the working conditions, the ramp should be constructed with width from 8 m to 16 m on a part with length of about 40 m, for every 50-100 m. These parts should provide a passage and turning of trucks near the loading area. In a part of the open pit bottom, due to the terrain conditions, with a larger width of the sedimentary bed, where it is difficult to excavate from one central ramp; two or three parallel ramps can be formed from the central one. With these parallel ramps, the sedimentary bed would be covered in the entire width.

Loaded material from the sedimentary layer will be transported by trucks to the location of disposal, so called the "Bugarski potok", south-west of the southern part of the open pit. In case of material loading with a higher amount of liquid phase, it is suggested that the trucks would not be loaded up to maximum, but 50% of the "struck" volume of the truck's hopper. This scale of loading can be increased if it is permitted by the material characteristics.

At the place of disposal, the formation of ramps and safety ramparts with 1-2 m height is proposed. This would protect the trucks in a case of unloading the grain material, and also, to make place for maneuverring the trucks on the unloading point easier to maintain. The disposal site can be divided into several unloading locations, which will allow more efficient drying of the unloaded material.

Figure 5 shows the locations for loading and unloading of sedimentary material, the location for loading the ramps for ramps construction and the transport lines for transport the sedimentary material and waste.

4 CONCLUSION

In order to ensure the realization of the 600,000 tons of excavation and processing copper ore monthly, it is necessary to create the exploitation and spatial conditions at the Open Pit South Mining District Majdanpek.

To fulfill these requirements, it is necessary to remove the layers of water, sludge and sediment from inactive water collector at the level L + 150 m. Materials will be removed in three stages. First, clear water layer will be dewatered, then slurry layer will be removed and finally slurry layer will be removed.

The proposed technology envisages the operation of existing equipment for loading and transport of materials. Also, the proposed technology was designed from the aspect of ensuring safe operation of people and equipment during the mining operations.

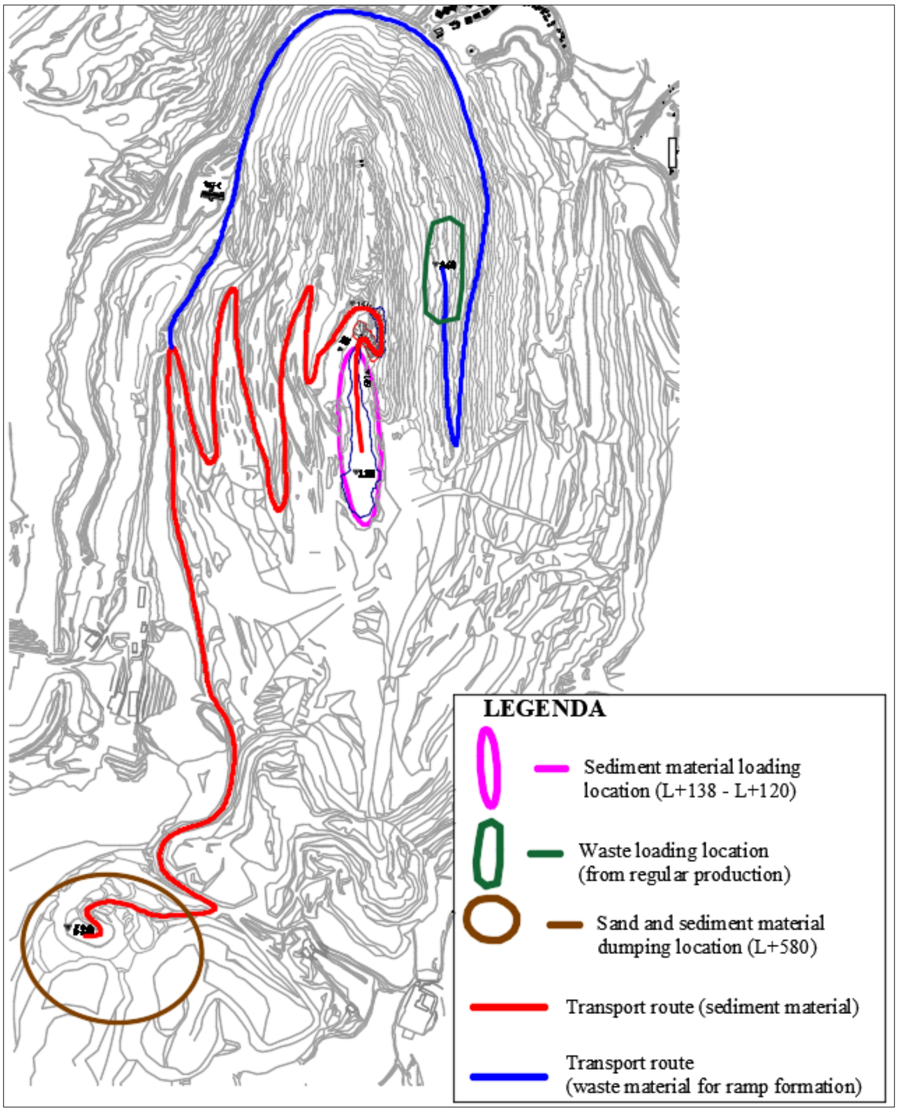

Figure 5 *Transport lines for material from the sedimentary bad (pink) and waste form the ramp construction (orange) [3]*

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Radmilo Rajković[*], Ljubiša Obradović[*], Daniel Kržanović[*], Miomir Mikić[*]

STABILITY OF THE DAM "PREVOJ ŠAŠKA" OF THE FLOTATION TAILING DUMP 'VALJA FUNDATA" IN MAJDANPEK[**]

Abstract

The existing dam "Prevoj Šaška" is located on the active flotation tailing dump "Valja Fundata" in Majdanpek. Since there is no valid documentation for the current maximum height of dam K+538 m, and disposal of tailings into this landfill is continued, the stability of dam has been carried out. Stability is calculated with the software SLIDE v6.0.

Keywords: *dam "Prevoj Šaška", stability analysis, software SLIDE v6.0*

INTRODUCTION

From the beginning of the work of the Copper Mine in Majdanpek, the flotation tailings are deposited in two tailing dumps, out of which one is the main and the other auxiliary, that is, accidental. The tailing dump "Valja Fundata" is the main tailing dump. This tailing dump has been formed in the valley of the Valja Fundata stream, which starts right in front of the Copper Flotation Plant in Majdanpek. In order to enable the use of the valley Valja Fundata for deposit of flotation tailings and formation an accumulation reservoir lake for the return of technological water back to the flotation process, it was necessary to adequately close all karst channels in order to prevent the leakage of tailings and water, where it was allowed the leachate water to flow smoothly into the Veliki Pek River.

The beginning of formation the tailing dump "Valja Fundata" dates back to 1961. The tailings were discharged in part of a limestone massif directly from the canal, since the system for separation the bulky tailings was not in a function, which, as a general consequence, has an anisotropic character - sludge and bulky tailings together. The proximity and position of the cleaned water collector, combined with a large drainage surface, compared to the initial precipitation lake, prevented mowing away of the clear water from the limestone massif. This was directly influenced by the surface ore parts that, due to the presence of large quantities of clay material under water, occupy a small drop, almost horizontal.

The dam "Prevoj Šaška" was built up to the level K+538 m, length of 460 m, width of 180 m basically and the width of crest is 12 m. It has a drainage system at the level K+518 m, which is in function, and at the level K+524 m, which is fore

[*] *Mining and Metallurgy Institute Bor, e-mail: radmilo.rajkovic@irmbor.co.rs*

[**] *This work is the result of the Project No.TR37001 "Implementation of the Modern Technical, Technological and Ecological Design Solutions in the Existing Production Systems of the Copper Mine Bor and Copper Mine Majdanpek", funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia*

seen for future overtops. In the central profile of the dam, two piezometers were placed as well as five piezometers on the natural terrain toward the accidental tailing dump "Šaški Potok". It is the only dam on this tailing dump that is in contact with water, although in recent years the water has been rejected from the dam by formation a beach of the unclassified tailings, width of 80 - 100 m. In this sector, there is also a floating pump station that has not been moved in time, and therefore the water level has increased to ensure the normal operation of the pump station.

This paper presents a stability checking of the dam "Prevoj Šaška" for the current operating conditions, as well as in case of further operation for the next 2 m at each 0.5 m of the water level increase from the current level. The aim of this checking is to determine the maximum water level in which the stability of the dam "Prevoj Šaška" and safe operation of the "Valja Fundata" landfill are ensured.

BASIS FOR THE STABILITY CHECKING

The stability checking analysis of the dam "Prevoj Šaška" of the flotation tailing dump "Valja Fundata" in Majdanpek was carried out on a profile placed through the piezometers in the dam body. The geodetic state of the dam was recorded in October 2018 by the Geodetic Department of the RBB. The water levels were taken in September 2018. The position of profile is given in Figure 1.

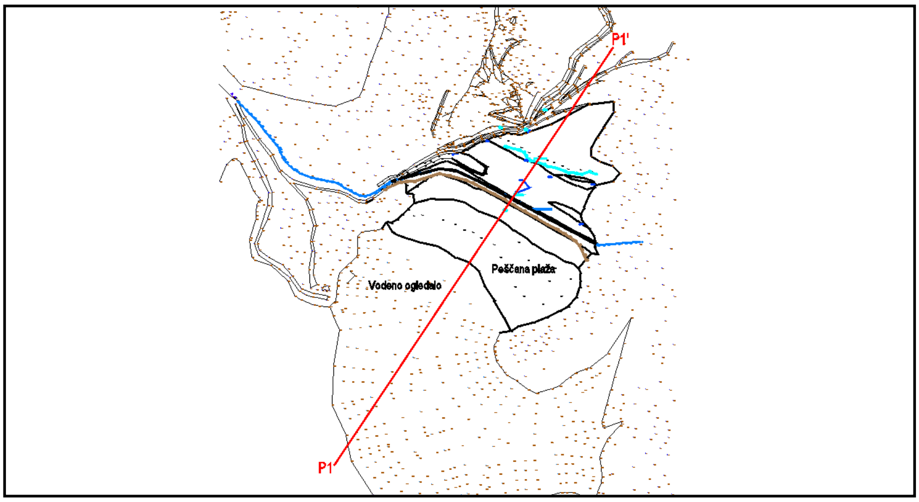


Figure 1 *Position of the analyzed dam profile*

At the location “Prevoj Šaška“, one probe drill hole B-3 with a total depth of 31 m and description was made in the flotation tailings. During drilling, 14 samples were taken from the B-3 drill hole and the tests of grain-size distribution, humidity, bulk mass, water permeability coefficient and direct shear were made on all samples. [1, 2]

Since it was not established whether the cyclonized sand or unclassified pulp composition and at what depths were not found in a drill hole, and arrangement of the cyclonized sand benches during the dam construction is not known, then only on the basis of differences in the results of the above mentioned laboratory tests, the following can be determined:

- The grain size distribution indicates that the grain size of 0.075 mm ranges from 15% to 40%, indicating that the unclassified pulp was embedded, or the cyclone operation was variable.
- The water permeability coefficients range from $1.18x10^{-6}$ m/s to $5.4x10^{-6}$ m/s, which can be the result of changes in the grain size distribution.
- The shear resistance tests range from the angle of friction φ = 24° and cohesion C = 0 to φ = 26° and cohesion C = 6 kPa.
- The bulk density in dry state (compaction) ranges from 1.590 g/cm^3 to 1.857 g/cm^3; the bulk density in wet state from 1.711 g/cm^3 to 2.265 g/cm^3.
- The humidity of samples ranged from 3.3% to 10.5% to 10 m depth, and below that depth from 15% to 27.5%

No shear resistance tests were carried out for the rock mass, while the value of φ= 40°C and C = 60 kPa with bulk density of 2.4 g/cm^3 based on the test from the previous years was adopted for the project of overtop the dam "Pustinjac", but these data were not important for the dam stability since the rock is at a great depth, which is also the case for the dam “Prevoj Šaška“.

According to the presented results, it can be expected that the lowest values correspond to the unclassified pulp, and most the the cyclonic sand. The unclassified pulp was probably used because the amount of overflow is insufficient to follow a dam formation with cyclonized sand, and to achieve the required beach slope of about 1:10, as was the cases with the project of overtop the dam "Pustinjac".

Stability checking [3-11] was done by the SLIDE v6.0 program of ROCSCIENCE. With SLIDE, the stability checking is carried out in the conditions of limit balance. The checking was made according to the Janubu method. For the stability checking, the calculation parameters are given in Table 1.

Table 1 *Calculation parameters for stability checking*

Working environment	Cohesion, kN/m^2	Angle of internal friction, °	Bulk density, kN/m^3
Material in a dam	0	24	15.6
Base	60	40	23.5

The impact of groundwater on stability was modeled with a piezometer line on the analytical profile. Position of the piezometer line for the current condition was determined based on the level of water mirror and measured water levels in the piezometers. The piezometric water level was also defined at every 0.5 m increase in the water level to a height of 2 m.

STABILITY CHECKING

Stability checking was carried out in the static conditions and dynamic conditions for occasional earthquake occurrence with the seismic coefficient, which for the Majdanpek area is K_s = 0.13 for an earthquake of 8° MKS and return period of 475 years. The results of stability checking for the current state and increased water level are shown in Figures 2 - 11 and Table 2.

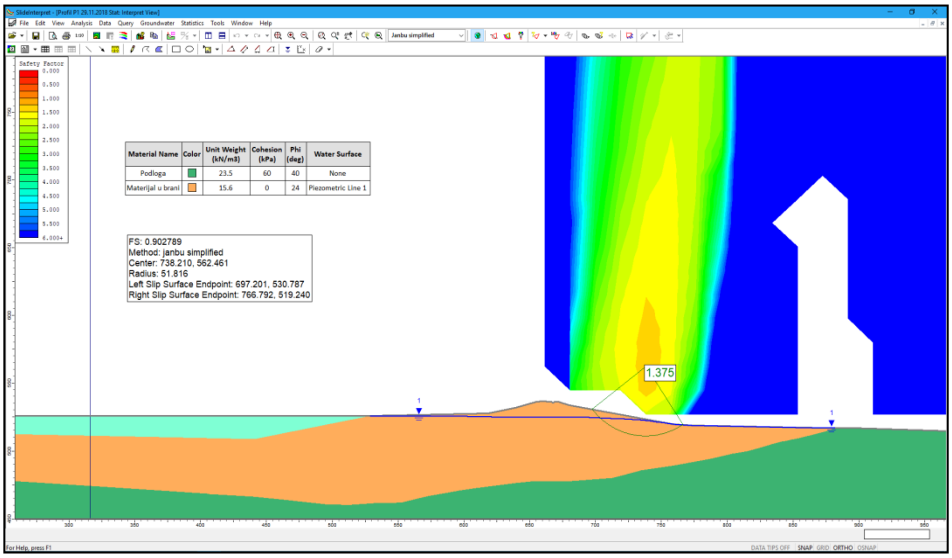


Figure 2 *Static safety coefficients by the Janub method for the existing state*

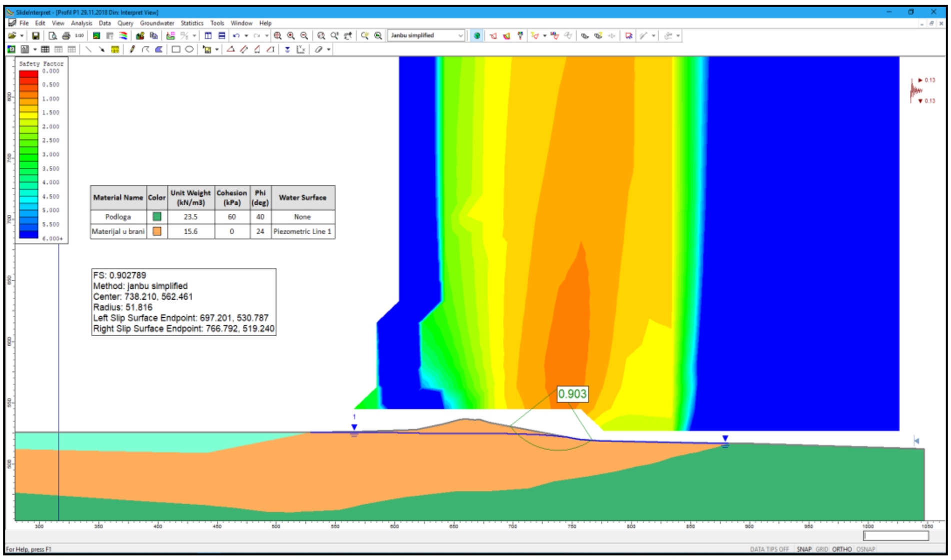


Figure 3 *Dynamic safety coefficients by the Janub method for the existing state*

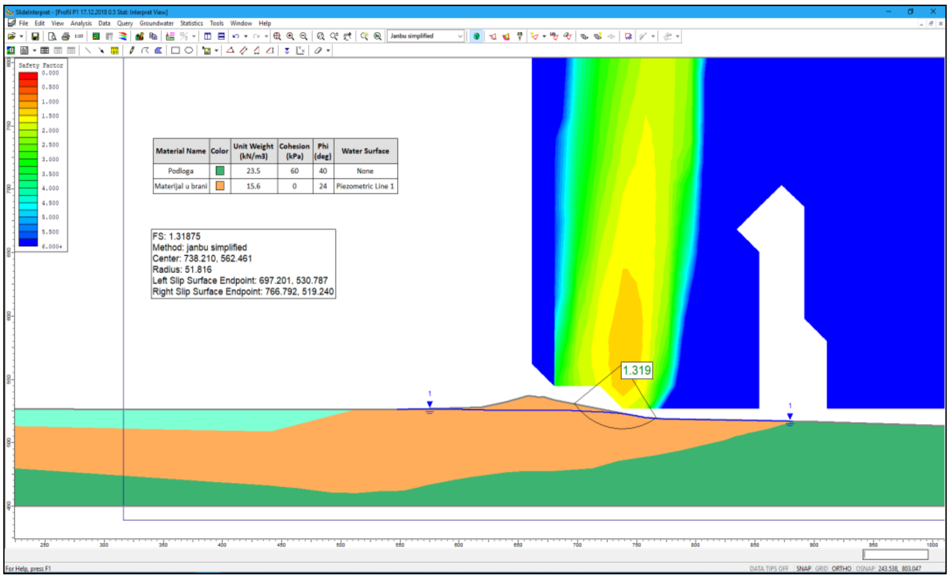
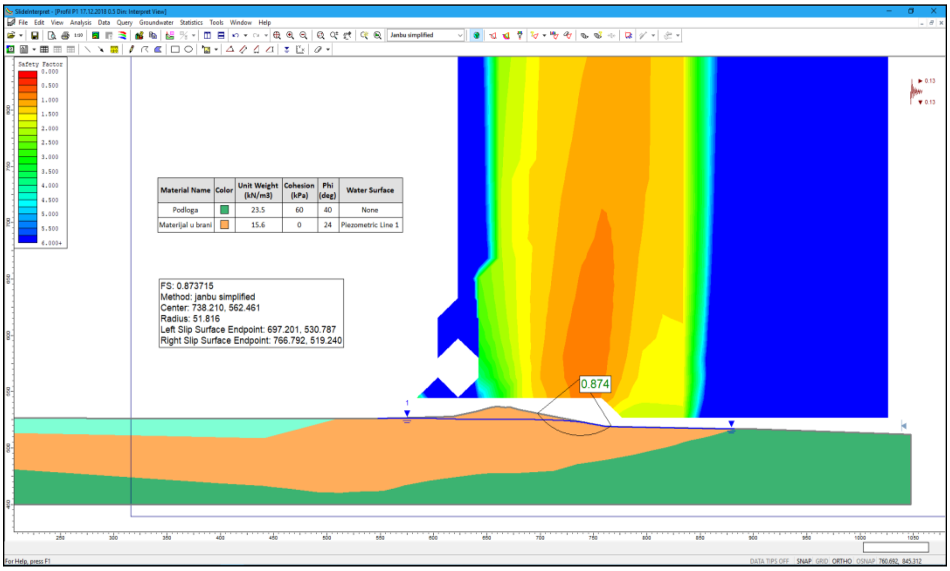


Figure 4 *Static safety coefficients by the Janub method with the increased water level 0.5 m*



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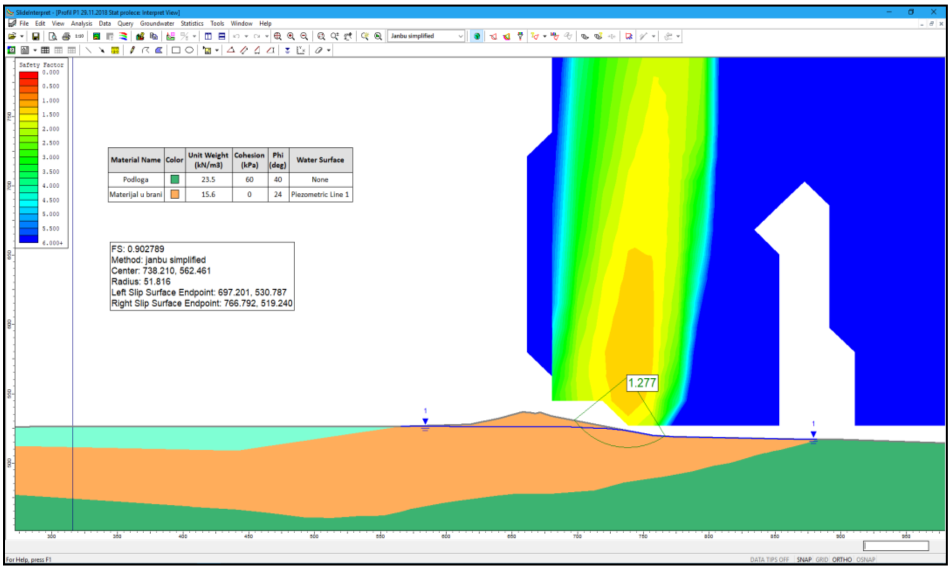

Figure 6 *Static safety coefficients by the Janub method with the increased water level 1.0 m*

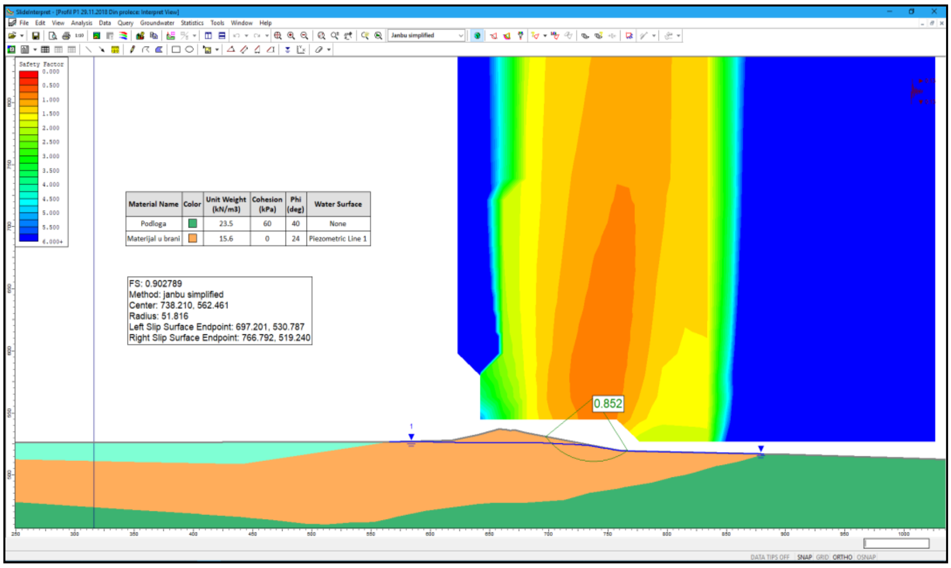

Figure 7 *Dynamic safety coefficients by the Janub method with the increased water level 1.0 m*

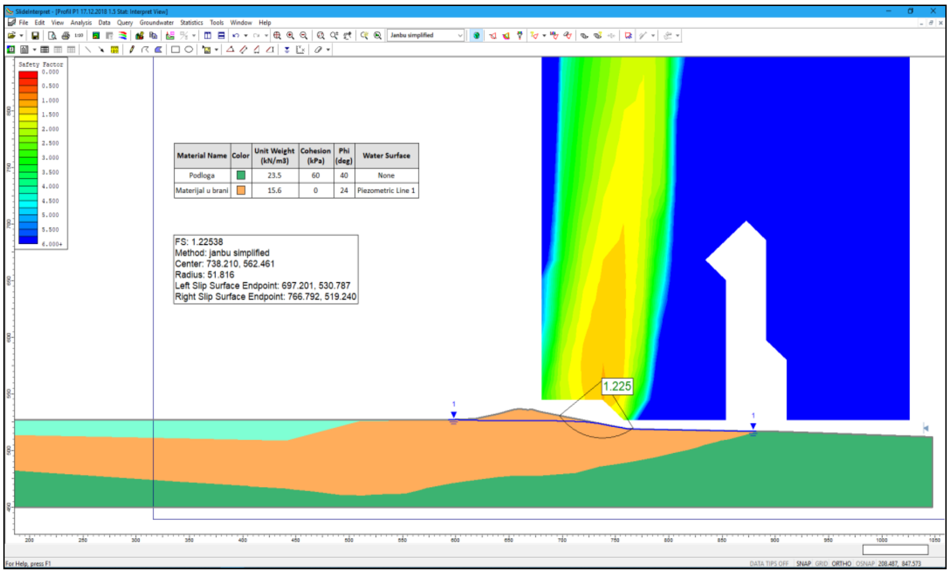

Figure 8 *Static safety coefficients by the Janub method with the increased water level 1.5 m*

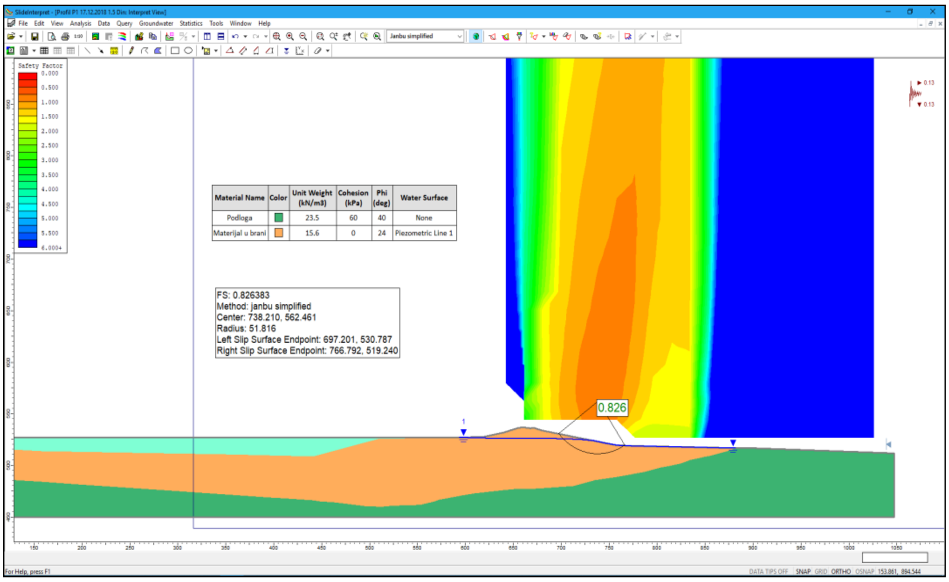

Figure 9 *Dynamic safety coefficients by the Janub method with the increased water level 1.5 m*

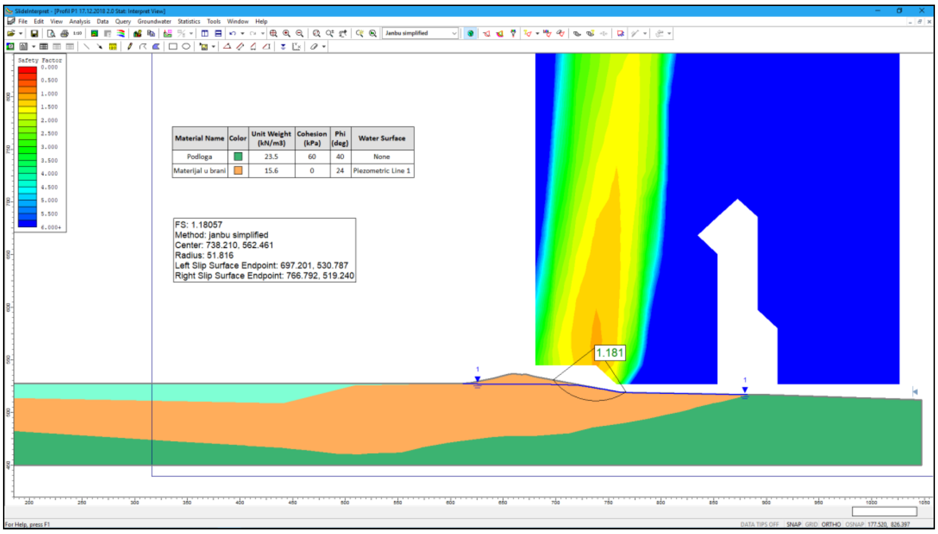

Figure 10 *Static safety coefficients by the Janub method with the increased water level 2.0 m*

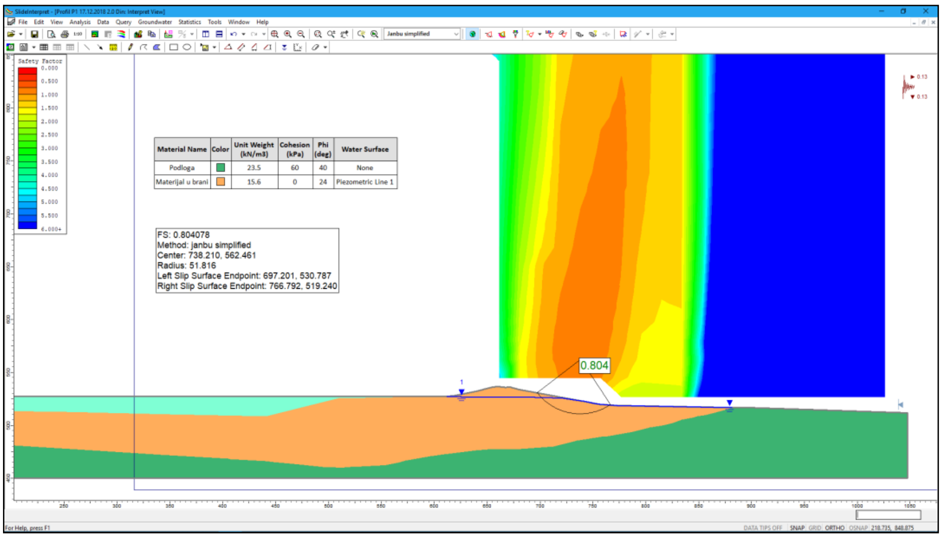

Figure 11 *Dynamic safety coefficients by the Janub method with the increased water level 2.0 m*

Table 2 *Summary overview of the stability coefficient*

Profile P – P'	F_s static	F_s dynamic
Existing state	1.375	0.903
Water level +0.5 m	1.319	0.874
Water level +1.0 m	1.277	0.852
Water level +1.5 m	1.225	0.826
Water level +2.0 m	1.181	0.804

By comparison the obtained safety coefficients of the flotation tailing dump dam with the allowed minimum coefficient, prescribed technical conditions for design of earth dams and hydro technical embankments - SRPS U.C5.020, which for the earth dams above 15 m is minimum $F_s = 1.50$ in case of the constant static load, or $F_s = 1.00$ in case of the occasional dynamic load for the earthquake occurrence, it can be concluded that the obtained safety coefficients for static and dynamic loads are below the prescribed values.

Figure 12 shows the linear dependence of change the safety coefficient for the static and dynamic loads from the water level.

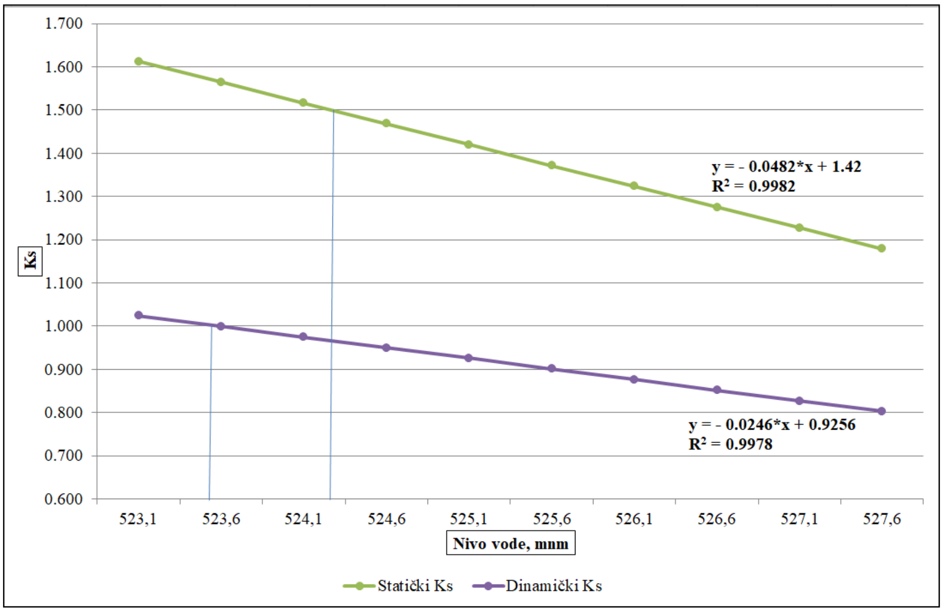

Figure 12 *Dependence diagram of changing the value of safety coefficients from the water level*

CONCLUSION

For deposition the flotation tailing of RBM, in addition to the existing tailing dumps, there is no alternative without large investments. Due to these reasons, a technical – technological solution should be provided for maximum use of their spatial capabilities.

Observation should be carried out in order to prevent a possible damage by timely detection a phenomena and occurrences that adversely affect the stability, as well as to establish a program of works for partial remediation and repair, ongoing maintenance and general rehabilitation of the dam.

The maximum level of water mirror in the tailing dump should not be above the K+23.3 m. This entails the removal of water mirror from the dam crest and displacement of the pump station from the existing location.

For monitoring of the influx water through the dam body, it is necessary to select the characteristic profiles on which the piezometers are placed in a straight line of the embankment. With such arrangement of piezometers, a precise position of the influx level line is reached. With previously performed laboratory tests and with the results of other observations and measu-rements, a complete set of measured values is obtained on the basis of which the dam stability will be calculated.

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Saša Stepanović[*], *Nikola Stanić*[*], *Aleksandar Doderović*[*], *Nada Marković*[**]

SELECTION THE VARIANT TECHNICAL SOLUTION OF THE TRANSPORT AND SERVICE ROAD TO THE EASTERN EXTERNAL LANDFILL AND COLLECTIVE WATER COLLECTOR[***]

Abstract

This work presents the variant technical solutions for transport of waste to the external landfill of the open pit Gacko. The construction of road has several purposes and should ensure the stabilization of the outer landfill in the zone with deposited quaternary sediments as well as the waste transport to the external landfill by the high-capacity trucks. The selection of a more favorable variant was made from the aspect of unit costs for the waste transport and from the aspect of the costs of variant solutions.

Keywords: *technical solution of the road, open pit Gacko, unit transport costs, transport capacity*

INTRODUCTION

Coal exploitation works at the open pit Gacko are currently performed according to the Main Mining Design of the open pit Gacko - Central field for the capacity of $2.3x10^6$ t/year of run-of-mine coal. The coal exploitation is developed in two zones, the roof and central exploitation zone [1].

The exploitation conditions at the open pit Gacko are very complex and expressed through the mining-geological, mining-technical and techno-economic indicators [2]. The exploitation of coal at the open pit Gacko are developed in two zones. The Field C, which is the central exploitation zone and the zone of roof coal series [3]. In order to ensure the undisturbed development of mining operations in the roof coal zone and provide continuity in the coal supply, it is necessary to excavate the quaternary sediments. The quaternary sediments are deposited on the eastern outer landfill. Because of the poor physical-mechanical characteristics, due to the heavy precipitation, the stability of deposited quaternary sediments was disturbed. The road ramp must ensure the stability of external landfill in the zone where the quaternary sediments have been deposited, waste transport from the Central Field, waste transport from the roof zone, transport of equipment and maintenance of the collecting water collector located in front of the Central zone development [4]. A layout of the mining facilities is shown in Figure 1.

[*] *Mining and Metallurgy Institute Bor, e-mail: sasa.stepanovic@irmbor.co.rs*
[**] *Bumech Montenegro Doo. Nikšić, e-mail: nadamarkovic71@t-com.me*
[***] *This work is derived from the Project TR37001 "The Impact of Mining Waste from RTB Bor on the Pollution of Surrounding Water Systems with a Proposal of Measures and Procedures for Reduction the Harmful Effect on the Environment", funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia*

Figure 1 *Layout of the mining facilities at the open pit Gacko*

The route of road (embankment) for waste transport and stabilization of the external landfill

For the needs of waste transport and the need for ongoing maintenance of the water collector, it is necessary to make the route of road from Field C. In addition to the road route, it is necessary to form a protective embankment in the north-eastern part of the external landfill. The main function of the protective embankment is to carry out the landfill stabilization in a part where the quaternary sediments and waste from the Roof zone are deposited, characterized by the poor physical-mechanical characteristics. In addition to the stabilization function of the external landfill, the protective embankment will have a function of the road. Just because of its function, the road and landfill must be built from the high quality marble material from the central exploitation zone of the Field C.

Variant 1

Two variants of the road route were considered. In the Variant 1, the road consists of three sections (Figure 2). Section 1 represents the road route to the protective embankment of the landfill; Section 2 represents the protective embankment, and Section 3, which will be a connection between the protective embankment and the old Kulski road.

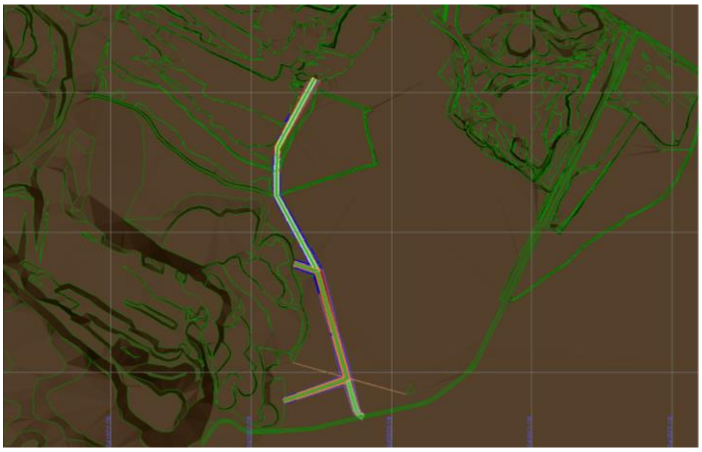

Figure 2 *Overview of the road route section for the waste transport and external landfill stabilization*

Section 1

Section 1 of the road route consists of a part located in a contour of the open pit (Field C) and a part located outside a contour of the open pit. In the contour of open pit, it is necessary to build a ramp from the level of 920 m above sea level to 938 m above sea level. After the ramp construction, the road route on the ground will be done. It is necessary to remove the quaternary sediment and replace it with a marble material. After replacement of the quaternary sediment, it is necessary to overcome the road at a height of 1.5 meters and make a connection up to a level of 750 m above sea level where a crest crown of the protective embankment of landfill will be positioned. The quantities of excavated material on the ramp development are given in Table 1. Table 2 lists the masses of quaternary sediment that need to be excavated. Table 3 lists the quantities of material that need to be filled. The length of the first road section is about 760 m, the width is 18 m. Calculation was made in the Gemcom Gems software package in the Road Construction module.

Table 1 *Quantities of materials that need to be excavated for a ramp construction*

ROCKGROUP	PLANE	Volume m^3
WASTE	N-920	10 672

Table 2 *Quantities of quaternary sediment that need to be excavated*

ROCKGROUP	PLANE	Volume m^3
WASTE	N-940	31 005

Table 3 *Quantities of material that needs to be filled up to the level 750 m above sea level*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-950	113 875

Section 2

After making the Section 1, a protective embankment of the external landfill will be constructed. The embankment is formed of marble material up to the level 750 m above sea level. Table 4 lists the quantities of marls that need to be built in into the protective embankment. The length of protective embankment is about 720 m.

Table 4 *Quantities of material that need to be filled to the level 750 m above sea level*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	98 798

Section 3

In order to establish a connection with a water collector, it is necessary to construct a part of the road from the protective embankment to the old Kulski road. The road will be built from marl. The length of the third section is about 140 m. The quantities of marl needed for road construction are given in Table 5.

Table 5 *Section 3 Kulski road– protective embankment*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	15 355

Variant 2

Variant 2 consists of 3 sections of the road. Section 1 includes the development of road route from the mine road (the road used for transport of coal from the Roof zone) to the old Kulski road; Section 2 enables the connection from the old Kulski road to the protective embankment of the external landfill, and Section 3 represents the protective embankment (Figure 3).

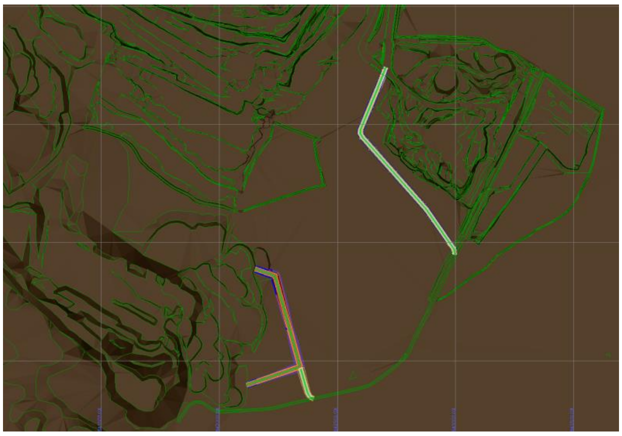

Figure 3 *Variant 1 of the road route*

Section 1

In order to construct the Section 1, it is necessary to replace the mass of quaternary sediment with marl. The length of the Section 1 is about 960 m. The quantities of quaternary sediment that need to be excavated are given in Table 6.

The quantities of marble material that need to be installed instead of the quaternary sediment are given in Table 7. The marble material needs to be filled to the level of 750 m above sea level.

Table 6 *Quaternary sediment cut*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	77 200

Table 7 *Marble material embankment*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	93 332

Section 2

In order to establish a connection with the protective embankment of the external landfill, it is necessary to make a route of the road. The road route is made of marl. The length of the Section 2 is about 140 m. The masses to be built during the construction of this part of road are given in Table 8.

Table 8 *Section 2 Kulski road – protective embankment*

ROCK GROUP	PLANE	Volume m^3
WASTE	N-940	15 355

Section 3

Section 2 is a protective embankment of the external landfill. The embankment is formed of marble material up to the level 750m above sea level. Table 9 list the quantities of marl that need to be built in into the protective embankment. The length of the protective embankment is about 720 m.

Table 9 *Quantities of material that need to be filled up to the level 750 m above sea level (Section 2)*

ROCKGROUP	PLANE	Volume m^3
WASTE	N-940	98 798

CALCULATION THE TRANSPORT CAPACITY PER OPERATIONS FOR THE TRANSPORT ROAD CONSTRUCTION

Belaz 75135 trucks with a capacity of 110 tons are envisaged for the material transport. The hydraulic excavators Komatsu PC 800 or Hyundai R800, bucket volume of about 5 m^3, are envisaged for excavation. Calculation is made in the Talpac software package.

The Talpac computer program was used to calculate the system of excavator - truck. On the basis of the input parameters, the time capacities of a truck for a given route are calculated.

The work organization at the open pit Gacko is 365 days a year, 7 working days a week, in 3 shifts. The total effective time during the year is 3,500 h. Based on the presented organization, the following planned working hours were used for the calculation of loading and transport:

- Total possible number of shift per year: 1,095 shift/year
- Duration of shift: 8 h
- Number of workig hours per year: 8,760 h
- Effective working hours in a shift: 5.5 h
- Effective working hours per year: 3,500 h

Tables 10 and 11 show the results of truck transport calculation per sections obtained in the Talpac software package.

Table 10 *Capacity of truck transport (hm^3/h) in the formation of transport and service roads towards the external landfill*

Transport capacity hm^3/h	Transport of humus (quaternary sediments)	Transport of marl for road formation	Transport of marl for formation the landfill embankment	Transport of marl for formation the road from landfill embankment to the asphalt road
Variant 1	115.54	149.55	139.56	116.39
Variant 2	120.31	132.16	99.27	105.87

Table 11 *Capacity of material transport (hm3/h) in the construction of envisaged facilities*

Transport capacity hm^3/h	Cut and embankment of the road	Embankment of the landfill	Road from the landfill embankment to the asphalt road
Variant 1	265.09	139.56	116.39
Variant 2	252.47	99.27	105.87

CALCULATION THE NORMS OF MATERIAL AND ENERGY ON TRANSPORT BY SECTIONS (FACILITIES)

Variant 1

Tables 12, 13, and 14 show the calculations of the consumption norms for the sections (facilities) that need to be made.

Table 12 *Material and energy consumption norms and unit costs for material transport on construction of road cut and embankment in Variant 1*

Road cut and embankment	**Quantity**	**Unit price (€/unit)**	**Unit costs (€/hm³)**	**Unit costs(€/t)**
Fuel norm (l/hm³)	0.395	0.70	0.277	0.146
Lubricant norm (kg/hm³)	0.040	2.00	0.079	0.042
Oil norm (l/hm³)	0.043	3.50	0.152	0.080
Tire norm (pcs./hm³)	0.000005	2,000.00	0.009	0.005
Norm of spare parts (kg/hm³)	0.004	10.00	0.035	0.018
TOTAL			**0.552**	**0.290**

Table 13 *Materialand Energy Consumption norms and Unit Costs for material Transport on Construction the landfill embankment in Variant 1*

Landfill embankment	**Quantity**	**Unit price (€/unit)**	**Unit costs (€/hm³)**	**Unit costs(€/t)**
Fuel norm (l/hm³)	0.750	0.70	0.525	0.276
Lubricant norm (kg/hm³)	0.075	2.00	0.150	0.079
Oil norm (l/hm³)	0.083	3.50	0.289	0.152
Tire norm (pcs./hm³)	0.000009	2,000.00	0.017	0.009
Norm of spare parts (kg/hm³)	0.004	10.00	0.035	0.018
TOTAL			**1.016**	**0.535**

Table 14 *Norms of material and energy consumption and unit costs of material transport on the road construction from the landfill embankment to the asphalt road in Variant 1*

Road from the landfill embankment to the asphalt road	**Quantity**	**Unit price (€/unit)**	**Unit costs (€/hm³)**	**Unit costs (€/t)**
Fuel norm (l/hm³)	0.900	0.70	0.630	0.331
Lubricant norm (kg/hm³)	0.090	2.00	0.180	0.095
Oil norm (l/hm³)	0.099	3.50	0.346	0.182
Tire norm (pcs./hm³)	0.000010	2,000.00	0.021	0.011
Norm of spare parts (kg/hm³)	0.004	10.00	0.035	0.018
TOTAL			**1.212**	**0.638**

Variant 2

Tables 15, 16 and 17 provide the calculations of the consumption norms for the sections (facilities) that need to be made.

Table 15 *Norms of material and energy consumption and unit costs for the material transport on the construction of road cut and embankment in Variant 2*

Road cut and embankment	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.415	0.70	0.290	0.153
Lubricant norm (kg/hm^3)	0.041	2.00	0.083	0.044
Oil norm (l/hm^3)	0.046	3.50	0.160	0.084
Tire norm (pcs./hm^3)	0.000005	2,000.00	0.010	0.005
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**0.577**	**0.304**

Table 16 *Norms of material and energy consumption and unit costs for the material transport on the construction of landfill embankment in Variant 2*

Landfill embankment	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	1.055	0.70	0.738	0.389
Lubricant norm (kg/hm^3)	0.105	2.00	0.211	0.111
Oil norm (l/hm^3)	0.116	3.50	0.406	0.214
Tire norm (pcs./hm^3)	0.000012	2,000.00	0.024	0.013
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**1.415**	**0.745**

Table 17 *Norms of material and energy consumption and unit costs for the material transport on the construction of road from the landfill embankment to the asphalt road in Variant 2*

Road from the landfill embankment to the asphalt road	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.989	0.70	0.692	0.364
Lubricant norm (kg/hm^3)	0.099	2.00	0.198	0.104
Oil norm (l/hm^3)	0.109	3.50	0.381	0.200
Tire norm (pcs./hm^3)	0.000011	2,000.00	0.023	0.012
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**1.329**	**0.699**

Table 18 shows the unit costs of material transport for the facilities (sections).

Table 18 *Unit costs of material transport (€/hm3) in the construction of envisaged facilities*

	Road cut and embankment	Landfill embankment	Road from the landfill embankment to the asphalt road
Variant 1	0.552	1.016	1.212
Variant 2	0.577	1.415	1.329

Table 19 shows the norms of unit costs of material transport and energy in loading for construction the facilities (sections).

Table 19 *Norms of material and energy consumption for material loading*

Excavation and loading	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.238	0.70	0.166	0.088
Lubricant norm (kg/hm^3)	0.024	2.00	0.048	0.025
Oil norm (l/hm^3)	0.026	3.50	0.092	0.048
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**0.340**	**0.179**

Bulldozer capacity on the road construction

The bulldozer capacity calculation was made according to a methodology proposed by Caterpillar for a mean length of 50 m, which would carry out the transport, planning and compacting of t unloaded material.

According to this methodology, the bulldozer capacity in planning is:

$$Q_{th} = 470 \cdot 0.75 \cdot 0.7 \cdot 1 \cdot 1 \cdot 0.8 \cdot 0.67 \cdot 1 = 132 \text{ rm}^3/\text{h} = 102 \text{ hm}^3/\text{h}$$

The same type bulldozer would be engaged in planning the deposited quaternary layers and its capacity in these works would be increased by 50% due to the operation conditions and material characteristics being disposed, i.e. it would be about 150 m^3/h.

Material and energy norms in marl planning in the road construction are given in Table 20, while the material and energy norms of bulldozer work in planning the deposited humus are given in Table 21.

Table 20 *Norms of material and energy in marl planning in the road construction*

Marl planning	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.453	0.70	0.317	0.167
Lubricant norm (kg/hm^3)	0.045	2.00	0.091	0.048
Oil norm (l/hm^3)	0.050	3.50	0.174	0.092
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**0.617**	**0.325**

Table 21 *Norms of material and energy in planning of disposed humus*

Humus planning	Quantity	Unit price (€/unit)	Unit costs (€/hm^3)	Unit costs (€/t)
Fuel norm (l/hm^3)	0.270	0.70	0.189	0.099
Lubricant norm (kg/hm^3)	0.027	2.00	0.054	0.028
Oil norm (l/hm^3)	0.030	3.50	0.104	0.055
Norm of spare parts (kg/hm^3)	0.004	10.00	0.035	0.018
TOTAL			**0.381**	**0.201**

For the fine planning of the road wearing surface, the graders are engaged, and calculation of the standard consumption for graders is calculated on the example of a grader, power of about 200 kW, i.e. Caterpillar 16H type grader (power P = 201 kW, mass 24.7 t and plow width L = 2.98m). Capacity of this grader is calculated according to the form:

$$Q_h = v \cdot (L_e - L_o) \cdot k_t$$

where:

Q_h – hourly capacity of a grader

v – operation speed of grader movement (v=4.5 km/h – medium speed of movement in planning)

L_e – effective plough width of a grader

$L_e = L \cdot \cos\alpha = 2.98\text{m} \cdot \cos 30^o = 2.58$ m

where:

L – plow width (and plow width l=2.98 m)

α – plow inclination angle relative to the angle (frequently 30^o)

L_o – width of passage overlapping for grader (L_o = 0.3 m)

k_t – coefficient of time utiliyation in a shift (k_t = 0.8) and capacity is:

$$Q_h = v \cdot (L_e - L_o) \cdot 1000 \cdot k_t =$$

$$= 4.5 \cdot (2.58\text{-}0.3) \cdot 1000 \cdot 0.8 =$$

$$= 8208 \text{ m}^2/\text{h}$$

Norms of energy and material consumption for a grade type CAT 16H, power 201 kW and capacity of 8208 m^2/h are given in Table 22.

Table 22 *Norms of grader consumption in fine road planning*

Fine planning	**Quantity**	**Unit price (€/unit)**	**Unit costs (€/m²)**
Fuel norm (l/m²)	0.004	0.70	0.003
Lubricant norm (kg/m²)	0.000	2.00	0.001
Oil norm (l/m²)	0.000	3.50	0.002
Tire norm (pcs/m²)	0.0000001	1,350.00	0.00013
Spare parts norm (kg/m²)	0.004	10.00	0.035
TOTAL			**0.041**

Table 23 gives the unit costs for individual technological procedures for the construction of transport road and landfill embankment.

Table 23 *Unit costs of material transport according to certain technological procedures for transport road construction and landfill embankment*

Technological procedure	Unit	Variant 1	Variant 2
Transport of materials during the construction of the road and road	(€/hm³)	0.552	0.577
Transport of materials in the construction of landfill sites	(€/hm³)	1.016	1.415
Transport of materials during the road construction from embankment landfill to the asphalt road	(€/hm³)	1.212	1.329
Loading material	(€/hm³)	0.34	0.34
Construction of road embankment and rough material planning by bulldozer	(€/hm³)	0.617	0.617
Planning a disposed humus by bulldozer	(€/hm³)	0.381	0.381
Construction of the wearing surface of road and fine material planning by graders	(€/hm³)	0.041	0.041

Table 24 gives the unit costs, material quantities and total costs for variant solutions.

Table 24 *Unit costs, quantities of materialand total costs for variant solutions*

		Unit costs		**Material quantities (m^3)**		**Total costs (€)**	
Technological procedure	Unit	Var. 1	Var. 2	Var. 1	Var. 2	Var. 1	Var. 2
Transport of materials in the road construction and road	(€/hm^3)	0.552	0.577	144,880	170,532	79,974	98,397
Transport of materials in the construction of landfill sites	(€/hm^3)	1.016	1.415	98,798	98,798	100,379	139,799
Transport of materials in road construction from the landfill embankment to the asphalt road	(€/hm^3)	1.212	1.329	15,355	15,355	18,610	20,407
Loading material	(€/hm^3)	0.34	0.34	269,705	284,685	91,700	96,793
Construction of road embankment and rough material planning by bulldozer	(€/hm^3)	0.617	0.617	191,240	185,887	117,995	114,692
Planning a disposed humus by bulldozer	(€/hm^3)	0.381	0.381	62,010	77,200	23,626	29,413
Construction of the road wearing surface and fine planning of matrix by a grader	(€/hm^3)	0.041	0.041	29,408	32,882	1,206	1,348
					SUM	**433,489**	**500,849**

CONCLUSION

In comparison the analyzed variants, the advantage 1 is given to the Variant 1 due to lower cost of production. In addition to this factor, it should be kept in mind that the eastern outer landfill can also be used for placement of layered and inter-layered waste from the central exploitation zone to the extent that the combined system cannot accept the all excavated material. It is also advantageous that the material excavated by a combine and transported by trucks is disposed to the subject location. The road construction in Variant 1 does not interfere the development of works in the upcoming period, and the eventual advance of works in that zone would be possible only by construction a new ramp. In this case, the transport of waste from the return zone would go directly through the old Kulski route. The Variant 1 provides more favorable conditions for waste transport from the central exploitation zone, and the average length of material transport from the center of work in the central zone and in Variants 1 and 2 is about 1800 m and 3600 m, respectively.

The analysis was carried out for equipment with which the open pit already possesses but the other mechanization cold be also applied that meets the characteristics of the working environment. The formation of the road embankment would also have the function of protecting space from water. The disposal of quaternary sediments is envisaged on the final surface of the inner landfill of the central field and this mass would be used in the subsequent stages for remediation of a wider area, and these areas could be immediately rehabilitated by the formation of grasslands.

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Boban Dašić[*], *Radmila Trklja*[*], *Marko Savić*[*]

COMPARATIVE ANALYSIS OF INFLOWS AND SECTORAL DISTRIBUTION OF THE FOREIGN DIRECT INVESTMENTS FLOWS

Abstract

Foreign direct investment is directly dependent on the economic and, therefore, the overall social progress in the world. The decrease or increase of foreign direct investment global flows result in a fall or increase in economic indicators that measure and reflect the economic trends and results of the global economy. Being one of the most important elements, if not the most important, in strengthening the world economy, the foreign direct investment plays a very important role in achievement the sustainable development goals that require investments into the basic infrastructure, energy, water supply, climate change alleviation, education, healthcare, as well as the production capacities in order to generate the new jobs and higher incomes. The aim of this study is to emphasise the significance of foreign direct investment flows, as well as to conduct a comparative analysis of sectoral distribution of these flows, since, depending on the sector, the foreign direct investments have different effects on the economic development of the host country.

Keywords*: foreign direct investments, economic indicators, world economy, sustainable development, sectoral distribution*

1 INTRODUCTION

Individuals and groups of people exchanged the goods and services across borders of their countries, invested in the mines and factories in other countries for centuries. An indicator that reveals how fast is the international business expansion, is a foreign direct investment (FDI). [10] FDI, as a form of international capital movement, has been dated since the ancient times. Until the beginning of the 20th century, it was difficult to assess the world stock and total FDI flows based on the data about total foreign investments, since they consist of the direct and portfolio investments. [5]

[5] As time passed by, the FDIs have become an increasingly important form of international business and international capital flows for all countries. For developed countries, the FDIs represent a form of international capital flows of growing importance, and for developing countries and countries in transition, the most significant form of international capital movements. [11] The end of the 20th and the beginning of the 21st century represent a period of intensive growth of the international orientation and international activities of companies, and consequently, a growth of the international business and international investment.

Compared to the other two forms of international capital flows (loan capital and portfolio investment), the FDIs are highly represented in financing the global world economy and national economies of individual countries. The growth of global FDI flows is conditioned by:

[*] *High Economic School Vocational Studies Pec in Leposavic*
e-mail: bobandasickg@gmail.com, savic22@yahoo.com

a) liberalization and deregulation of the international capital market,
b) codification of the foreign capital protection system (the so-called national treatment), which has recently encouraged the reinvestment of profits,
c) the growing technological gap between the certain categories of countries (high and unachievable financial threshold for entry into areas of the new technologies);
d) the new approaches in development and economic policies (the concept of an open economy with a flexible exchange rate), based on a new ownership (privatization in Central and Eastern European countries) and foreign trade (free customs zones in PR China) regimes, creating a stimulating ambient for the foreign capital inflows,
e) the successful stabilization and macroeconomic policies of a number of significant developing countries (Brazil, Mexico, ...) with a high external debt service coefficient and
f) the emergence of the new countries with excess capital and need to create the new markets (the countries of Southeast Asia, the so-called "Little Tigers"). [9]

Among the many effects that the FDI produces, their development potential is certainly the most important, since by unifying trade, the capital and technology flows into a whole under unified control and governance, they significantly influence the establishment of international relations, as well as the overall efficiency of functioning the world economy. Under the modern business circumstances, in the new global world and under the conditions of the new economic order, the FDIs play a role of an important lever of economic growth and development.

Funding through the FDI can be realized through the Greenfield or Brownfield investments, joint ventures and international Merchants and Acquisitions (M & A). Please note that after several years of business, it is not possible to differentiate the FDI by the way of entry, although at the moment of entering the country and in the short term period, the host country in some aspects has more benefits from the Greenfield than the other types of FDI. [2]

2 GLOBAL FDI FLOWS

Since 1991, the United Nations Conference on Trade and Development (UNCTAD) has been issuing the World Investment Report (WIR) once a year. The Figure 1 shows that in 2007 the total FDI inflow was 1,978 billion. USD, the year with the highest inflow of FDI in the history of mankind. [13] The global financial crisis in 2008 led to a collapse of international capital flows, as the investors became more cautious and banks were reluctant to borrow the capital internationally. In addition to the global economic crisis, recession and turmoil in financial markets in the world have had a negative impact on global FDI flows. Thus, over the past three decades, one of the most significant characteristics of the global economy is the shift in the period of rise and fall of the total international capital flows in the world. Only in 2015 (USD 1,921 billion) the approximate inflow of FDI flows was the same as it was in 2007 (the year with the highest inflow of FDI in the history of mankind). After that, in 2016, there was a slight decline in the world investment flows (USD 1,867 billion).

According to the latest World Investment Report 2018, the FDI flows globally dropped to 1.429 billion USD in 2017, which is a 23% decrease compared to 2016. Developed economies (37%) and transitional economies (27%) did worse than the global average, while developing economies kept the FDI volume at the 2016 level, leaving them the most valuable and most regular external source of financing for these economies (see Figure 1). Developed economies still have dominant participation in the world investment flows. The connection of FDI flows and economic activity in developed economies is obvious. Looking at 2017, out of the total FDI inflows in the world, 712 billion USD or almost 50% goes to the developed economies; 670 billion USD or over 46%, goes to the developing economies, whereas 64 billion USD or less than 5% of the total FDI inflow in the world (see Table 1) goes to the economies in transition. The FDI remained the most valuable and most regular external source of financing for these economies, compared to the portfolio investments, remittances and official development aid programs. [4]

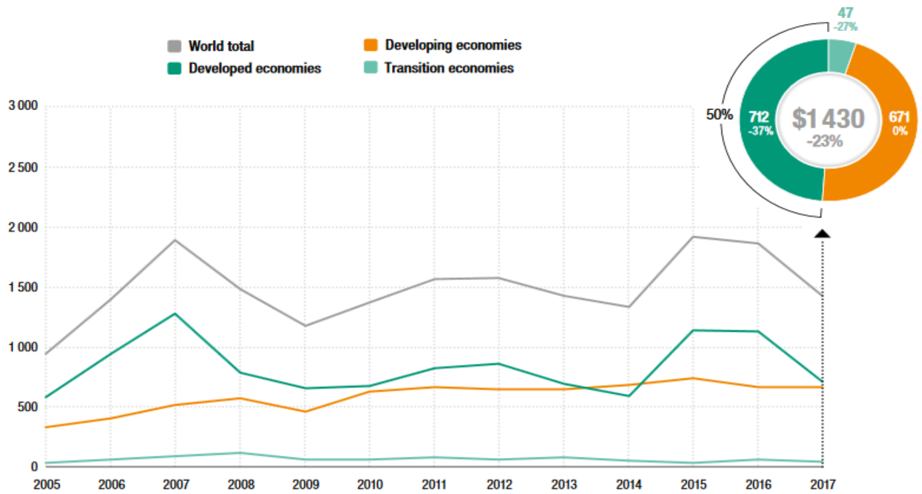

Figure 1 *Flows of the FDI inflows in the world and by groups of countries, 2012-2017 (in billion USD and %) [14, p. 184-187]*

Table 1 *Flows of the FDI inflows in the world and per groups of countries, 2012-2017 (in billion USD) [14, p. 184-187]*

Economy/year	2012	2013	2014	2015	2016	2017
Developed economies	858	693	596	1,141	1,133	712
Developing economies	651	648	685	744	670	670
Transitional economies	64	83	56	36	64	47
World total	1,574	1,425	1,338	1,921	1,867	1,429

A decline in the FDI inflows compared to 2016 is particularly high in the countries of the European Union (42%), North America (39%), in other developed non-EU countries (26%) and Africa (21%). The Asian countries kept the FDI inflow at the 2016 level. The FDI inflow growth has a group of countries in the "Other Developed Economies" (7%) and Latin America and the Caribbean (8%) (see Figure 2).

The decrease of the FDI flows in 2017 was resulted by decrease in the net value of M & As, from 887 billion USD to 694 billion USD in 2016 (decline of 22%).

Moreover, decline of the Greenfield investments value was noted by 14% ($ 833 billion in 2016 versus $ 720 billion in 2017).

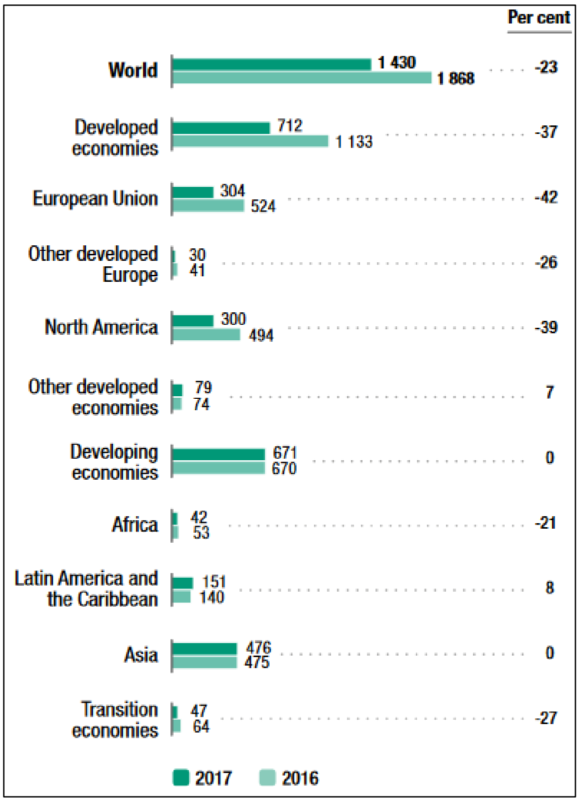

Figure 2 *Inflow of the FDIs, worldwide and per regions, 2016-2017 (in billion USD and %) [14, p. 3]*

Most FDIs in the world were received by the USA (275 billion USD). In the leading 20 host/countries of the FDI from a group of developed economies the US is followed by the Netherlands (USD 58 billion), France (USD 50 billion), Australia (USD 46 billion), Switzerland (USD 41 billion), Germany 35 billion USD), Ireland (USD 29 billion), Canada (USD 24 billion), Spain (USD 19 billion), Israel (USD 19 billion) and Italy (17 billion USD).

Of the developing economies, China has the highest FDI inflow in the amount of 136 billion USD (thus being the second in the world, right behind the US). It is followed by Hong Kong (USD 136 billion), Brazil (USD 63 billion), Singapore (USD 62 billion), India (USD 40 billion), Mexico (USD 30 billion), Indonesia (USD 23 billion)) and the Republic of Korea (USD 17 billion).

Regarding to the transition economies, Russia (USD 25 billion) is ranked the 14th of the 20 leading host countries. Half of the top 10 host countries belong to the developing economies (see Figure 3).

These 20 leading host countries account for around 80% of the global FDI inflows, while the all other countries account for just over 20%.

Political uncertainty over the global trade, not only with Brexit, but also with the US pulling out of the Trans-Pacific Partnership (TPP), renegotiating the North American Free Trade Agreement (Oil), and taking a generally aggressive view on global trade, has also created significant uncertainty for location decisions – especially in the export-oriented industries that are dependent on the free-market access. The other big factor in the decline of FDI in 2017 was the Chinese FDI policy, with the reimposition of controls on overseas FDI which curtailed the FDI in certain targeted sectors. [6]

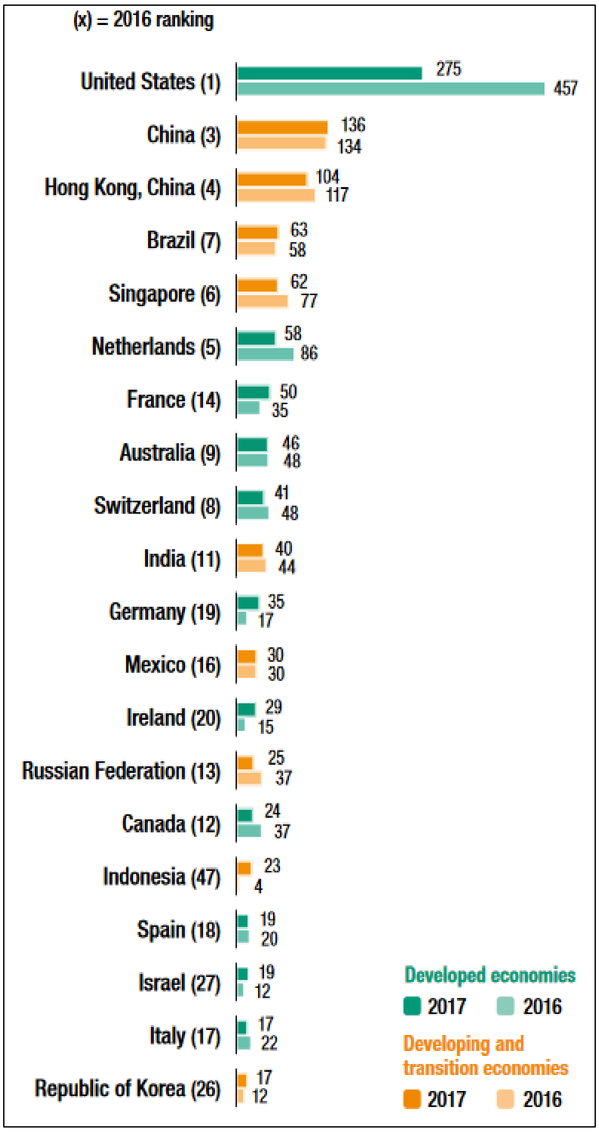

Figure 3 *Inflow of the FDIs, per regions, 2016-2017 (in billion USD and %) [14, p. 3]*

3 FDI DISTRIBUTION PER SECTORS

The sectoral distribution of the FDI flows worldwide has changed over the years. In the beginning of the 20th century (1914), 55% of the FDIs recorded at the global level went to the exploitation of natural resources, while the ratio of services and industrial production was 30%: 15%. [7] Based on this data, it can be concluded that during that period the FDIs were largely focused on the primary sector (provision of raw materials and production materials) and the economic infrastructure related to this production. [3]

A rapid decline in the FDI in exploitation the natural resources was observed in the eighties of the twentieth century, while it was increased in the secondary sector (industrial production) and service activities.

The last decade of the XX and the first decade of the 21st century are characterized by the reorientation of the FDI flows towards the service sector. The FDIs grew in all three sectors, primary, secondary and tertiary, but the largest, growing part went to the tertiary sector. In the period 1990-2009, a share of services in the total stock of FDIs input in the world increased from 49% to 63%, while a share of the other two sectors dropped significantly: the primary from 9.4% to even lower 7.3%, and especially the secondary from 41% to 27.6%. [12]

Nowadays, we are at the daybreak of the fourth industrial revolution. We are witnesses of advancement the new technologies and robotics that make production faster, cheaper and better than ever before, creating huge opportunities for economic growth and sustainable development, so it is to be expected that the FDI flows will mostly go to these types of sectors.

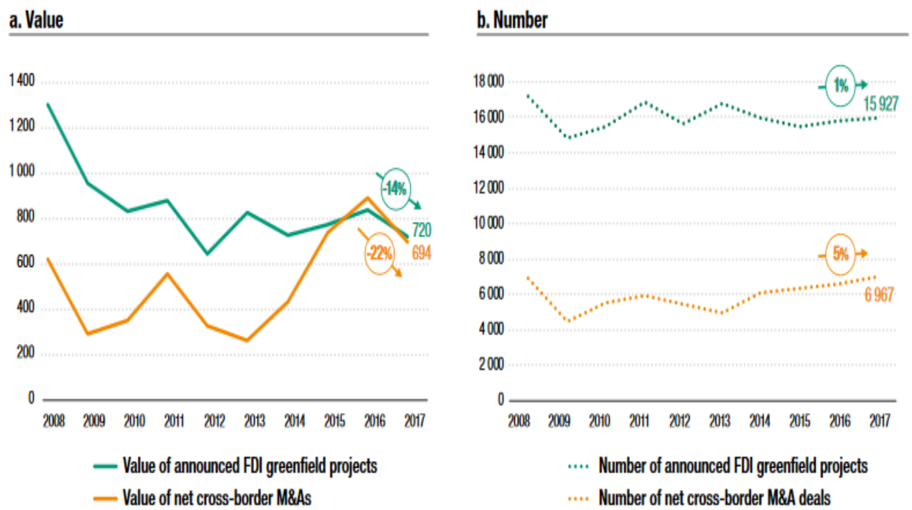

Figure 4 *Value and number of net cross-border M & As and announced SDI Greenfield projects, 2008-2017 (billion USD and number) [14, p. 7]*

As noted, in 2017 there was a decrease in the value of M&A, as well as the values of Greenfield foreign investments in comparison to 2016. On the other hand, there was an increase in the number of M&A operations by 1% (6,607 in 2016 versus

6,967 in 2017) and announced Greenfield foreign projects by 5% (15,766 in 2016 versus 15,927 in 2017). Observing the period 2008-2017, there were periods of decline and growth in both the value and number of net cross-border M&A and the Greenfield foreign projects (see Figure 4 under a and b).

Table 2 *Value and number of net cross-border M&A, per sectors and selected industries, 2016-2017 [14, p. 8]*

	Value (billion of dollars)			Number		
	2016	2017	%	2016	2017	%
Total	**887**	**694**	**-22**	**6607**	**6967**	**5**
Primary	83	24	-70	206	550	167
Manufacturing	406	327	-19	1745	1690	-3
Services	398	343	-14	4656	4727	2
Top 10 industries in value terms:						
Chemicals and chemical products	130	137	5	345	322	-7
Business services	75	107	43	1716	1817	6
Food, beverages and tobacco	138	88	-36	200	227	14
Finance	97	59	-39	585	617	5
Electricity, gas and water	66	54	-18	209	171	-18
Machinery and equipment	32	52	63	195	183	-6
Information and communication	24	39	66	618	611	-1
Electrical and electronic equipment	75	26	-66	349	307	-12
Transportation and storage	46	23	-51	293	306	4
Mining, quarrying and petroleum	79	23	-71	138	466	238

A decline in the value of net cross-border M&A, for the period 2016-2017, was reduced in all three sectors (see Table 2). The largest decline was recorded in the primary sector (-70%), production (-19%) and services (-14%). The number of M&A deals in extractive industries (mining, quarrying and petroleum) got almost tripled, however the value of these transactions was lower by 71% compared to 2016.

At the level of the industry, in addition to the extractive industry, there was also a decline in the industry of electrical and electronic equipment (-66%) and the food, beverage and tobacco industry (-36%). On the other hand, there was the growth of M&A's value in the information and communication industry (66%), machinery and equipment industry (63%), business services (43%) and the chemicals and chemical industries (5%). Only M & A business services had a positive result both in terms of value (43%) and number of projects (6).

By observing the value of announced Greenfield FDI projects, there was a drop of value in the primary sector (-61%) and services (-25%), while production was growing (14%). The value of Greenfield projects in production and services is approximately the same and amounts was about 350 billion USD in 2017, thus these two sectors participated with more than 97% in the Greenfield

FDI projects (less than 3% goes to the primary sector). The Greenfield FDI projects value drop was recorded in construction (-51%), public utilities - electricity, gas and water (-26%), transportation, storage and communication (-26%) and business services (-16%).

Table 3 *Value and number of announced FDI Greenfield projects per sectors and selected industries, 2016-2017 [14 p. 8]*

	Value (billions of dollars)			**Number**		
	2016	2017	%	2016	2017	%
Total	**833**	**720**	**-14**	**15766**	**15927**	**1**
Primary	54	21	-61	52	63	21
Manufacturing	295	338	14	7703	7678	0
Services	484	362	-25	8011	8186	2
Top 10 industries in value terms:						
Electricity, gas and water	129	95	-26	404	296	-27
Business services	96	80	-16	4125	4278	4
Motor vehicles and other transport equipment	56	62	12	1077	1103	2
Construction	126	62	-51	322	276	-14
Chemicals and chemical products	43	61	42	804	856	6
Electrical and electronic equipment	44	52	20	1005	958	-5
Transport, storage and communications	56	41	-26	935	903	-3
Trade	27	32	21	902	1001	11
Food, beverages and tobacco	24	29	17	596	664	11
Textiles, clothing and leather	28	28	1	1558	1476	-5

The number of Greenfield FDI projects is similar to 2016, with a the growth of 21% in the primary sector, and drop of value for 14%. With regards to the number of Greenfield FDI projects per industry, the utility services - electricity, water and gas (-27%), construction (-14%), electrical and electronic equipment (-5%) and transport, storage and communication (-3%) recorded drops, while the growth of the number of FDI Greenfield projects is recorded by other sectors (see Table 3).

The sectoral distribution of the FDIs has largely depended on the strategic and economic motives of investors. [8]

According to the sectoral analysis done by FDI Intelligence (it only monitors Greenfield investment projects, that is, it does not include M & A, intercompany loans, equity investments, or other forms of cross-border investment, but exclusively those that involve starting business from the very beginning without the previous infrastructure, business premises and workers) key trends in 2017 include:

- Coal, oil and natural gas reclaimed the top spot for capital investment in 2017 with $79.6 billion of FDI recorded.
- The top three sectors by number of projects in 2017 were software and IT

services, business services, and financial services, with financial services replacing the third-ranked sector of 2016, industrial machinery, equipment and tools.

- Software and IT services again maintained its place as the top sector for project numbers, with 2237 in 2017, up 5% from 2016.
- Of the top five sectors by number of projects, software and IT services and financial services were the only two to achieve growth.
- Communications witnessed a 14% decrease, by the number of projects after showing an increase in 2016.
- Real estate saw an increase of 16% in project numbers in 2017, though the capital investment dropped by 49% to $79.5 billion.
- Chemicals saw a 58% increase in capital investment in 2017, with a slight drop in the project numbers of 2%.
- The biggest decline in the project numbers comprised the sectors of communications (-14%), automotive components (-14%) and business services (-7%). [6]

Sectoral composition of the FDI flows plays an important role and impact on the economic growth. [1]

A trend of sectoral distribution of the FDI shows different patterns. In developed economies, foreign investments in the tertiary sector and the service sector are the most represented. Developing and underdeveloped economies have a relatively high share of investment into the primary and secondary sectors, although the service sector shows significant growth.

CONCLUSION

The FDI, whose bearers are transnational company (the main leverage through which the international transfer of capital is carried out), represent the dominant form of international capital movement, recording expansive growth, affirming and increasing the role of international production in the world economy. The role of FDI as a very important form of financing the global economy has been particularly strong in the last two decades of the twentieth century, while in the beginning of the 21st century they were a predominant form of financing, especially in developing economies and economies in transition. Such a trend will continue in the years to come. Developed economies are predominant in the global FDI flows, followed by developing economies and at the end of the economies in transition. When it comes to the sectoral distribution, the service sector is represented by more than 50% of the total value of the realized FDI.

Development of the country is in direct correlation with the sectoral distribution of FDIs. Developed economies attract the most foreign investments in the tertiary sector, while investments in the primary and secondary sectors are prevalent in develo-ping and transition economies. Investments into the primary sector, i.e. the production and exploitation of the natural resources, oil and gas, are likely to continue in the same scale, if not even more, because of a high demand for energy in the world.

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Nikola Stanić, Saša Stepanović*, Nada Marković**, Miljan Gomilanović**

DETERMINATION THE LIMIT CAPACITY OF PRODUCTION THE ROOF COAL SERIES AT THE OPEN PIT GACKO-CENTRAL FIELD IN A FUNCTION OF USE A DISCONTINUOUS-COMBINED EXPLOITATION SYSTEM***

Abstract

This paper presents the methodology of determining and analysis results of the limit production capacity of coal in the roof exploitation zone of the open pit Gacko-Central Field in a function of configuration and parameters of the combined system. The coal exploitation system at the open pit Gacko-Central Field mine is a system of exploitation characterized by the complex conditions under which it operates, with the use of continuous, combined and discontinuous coal and waste exploitation systems. It is also characterized by the existence of two spatially dislocated sites, in which the exploitation is carried out under significantly different conditions. A complex solution for coal exploitation is the result of optimization a large number of mutually determined technological processes and systems, both in terms of the possibility of applying a certain complex of mechanization, as well as in terms of individual capacities at the site of excavation. As a criterion for success the exploitation system, a unit cost of exploitation was adopted including the capital and operational costs of a variable part of combined system.

Keywords: *combined system of exploitation, selective exploitation, transport by belt conveyors, truck transport, coal*

BASIC CONDITIONS AND CHARACTERISTICS OF THE SURFACE COAL EXPLOITATION AT THE OPEN PIT GACKO – CENTRAL FIELD

Intensive coal exploitation in the Gacko Coal Basin began with opening the Open Pit Gračanica in the western part of the basin in 1977, in order to open the open pit in 1982. In mid 1983, the Thermal Power Plant Gacko has started its operation with the installed power of 300 kW. From then onwards, the coal exploitation is developed with the almost exclusive intention of providing the corresponding amount of fuel for the thermal power plant, that is, in a function of electricity generation.

In the previous exploitation period, the coal production is developed in different parts of the deposit, in various structural, geomechanical, hydrogeological, qualitative

* *Mining and Metallurgy Institute Bor, e-mail: nikola.stanic@irmbor.co.rs*
** *Bumech Montenegro Doo. Nikšić, e-mail: nadamarkovic71@t-com.me*
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and other working conditions, as well as various legislative, social, infrastructural, market and economic conditions. All of this has resulted in the necessary adjustment of the exploitation system in order to ensure the required capacity and quality of coal, and the elements and parameters of the system were most often conditioned by numerous limiting factors [1].

Also, numerous project solutions have been formed on the basis of previous research results that have not been of sufficient reliability. The lack of knowledge about the characteristics of the working environment resulted in the fact that the applied exploitation systems worked with lower efficiency than the designed ones. Within the factors that particularly influence the efficiency of production, the geomechanical characteristics of detection (occurence of layers with extremely high excavation resistance above the guaranteed excavation force of the rotary excavators) and the structural characteristics of a coal seam (stratification of a coal seam with a frequent change of coal and waste interbeds) can be distinguished.

This should include the added variability of parameters of the working environment and structural and qualitative characteristics of coal. In order to fulfill the basic goal of exploitation, i.e. to provide the corresponding quantity of coal of the given quality, it was necessary to adapt to concrete conditions in the field. Initially conceived as an open pit with a continuous exploitation system, the open pit Gračanica, formed in the west part of the deposit, has undergone a series of transformations by introduction a discontinuous equipment. Discontinuous equipment was introduced first of all on coal within the combined system (hydraulic bucker excavator - trucks - crusher – belt conveyors - landfill) and then on overburdem within the discontinuous system. With the completion of works in the western part of the deposit, the extension of the open pit Gračanica was also done in a part of the Field C, that is, in the central part of deposit.

This relocation of works was accompanied by the introduction of a combined system on overburden with retention also on a combined system on coal, continuous systems on overburden as well as a discontinuous system, primarily designed for exploitation the interbed and layered tailings. Problems related to the implementation of production plans, mainly related to the inability to provide the designed structures of the basic and auxiliary mechanization, led to a need of providing a part of coal from the roof coal series which is characterized by a lower quality of coal, distinct stratification and favorable relationship between waste/coal. The coal exploitation from the roof coal series is spatially dislocated in relation to the rest part of the open pit (Figure 1).

Also, the beginning of work realization, according to the Main Mining Design of the open pit Central Field for capacity of $2.3x10^6$ t/year of the run-of-mine coal, has started the coal exploitation on a new open pit. This project has continued the exploitation of main and footwall coal seams in the area of the Central field of the Gacko deposit, but also the coal exploitation is planned in a part of the roof coal series [2]. In addition to being spatially dislocated, the site in the roof coal series is characterized by the specific exploitation conditions (structural and qualitative coal characteristics) and resources that, besides the natural limits of expansion the coal seams, are limited by the administrative boundary of concession. All these factors represent limitations in determining the production capacity of coal from the roof coal series. On the other hand, the production capacity is an important factor for defining the most favorable system of exploitation and techno-economic parameters of the applied system.

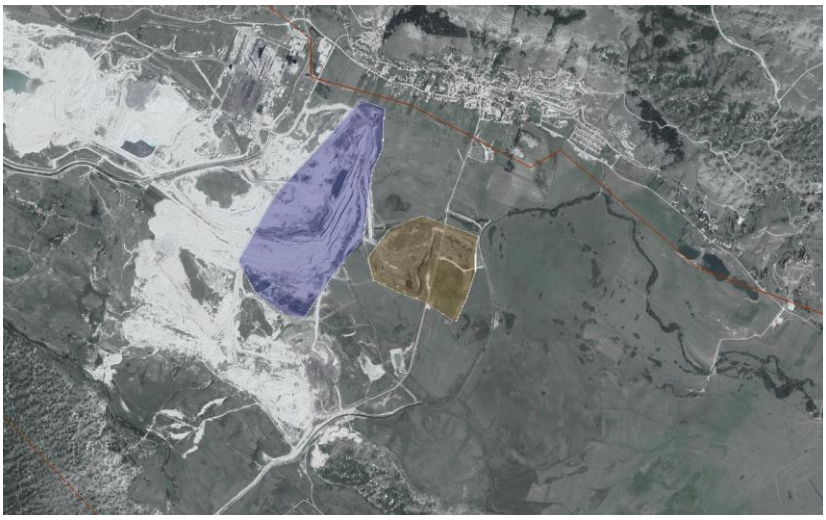


Figure 1 *Location of the open pit site Gacko-Central field* ■ *- site of the roof coal series,* ■ *- site of the Central exploitation zone*

Currently, the coal exploitation in the roof coal series is carried out by selective excavation of coal and waste with hydraulicbucket excavators. Transport of waste is discontinuous to the external landfill, and transport of coal is combined, discontinuous to the crusher, positioned in the northern part of the central exploitation zone. Position of the crusher is conditioned by the available belt conveyors and position for coal transport in the northern part of the central exploitation zone.

The existing design solution has taken into account the analysis results of application the combined system in the existing form and conditions of increasing the length of continuous transport to the site in the roof exploitation zone. In order to select a more favorable combined system in terms of length of continuous and discounted transport, the number of belt conveyors, number of trucks in discontinuous transport, the existing system configuration was analyzed as well as the combined system with extension of continuous transport in a length of about 1400 m with two additional belt conveyors [3]. A new position of the existing coal crusher is determined on the edge of the roof coal series at the shortest distance from the center of works for the next five-year period. The conveyor lines are such that they do not interfere with development the front of works or have a stationary character. The adopted belt conveyors have a width of 1200 mm and speed of 4.5 m/s meet the needs in terms of capacity, grain-size distribution of crushed

In calculation the capital and operating costs, they are not deducted to the present value, since their relative absolute value is not important for comparison the variants, but the relative value.

Considering that the open pit has already has the certain elements of the system (crusher, part of the conveyor belt and excavation - loading equipment), and that these elements are common to the considered variants, the techno-economic parameters of the combined system are compared only in the areas in which they differ.

CALCULATION THE TRANSPORT PARAMETERS WITHIN THE COMBINED SYSTEM OF THE ROOF COAL ZONE

Figure 2 presents the coal transportation routes in the Variant 1 and Variant 2. The Variant 1, the case where there is a crusher in the old location and the transport is discontinuous (line of purple color) by trucks with capacity of 55 t. The Variant 2, a crusher on a new location, continuous transport (red line), two belt conveyors and discontinuous transport inside the open pit (green line) by trucks with capacity of 55 t.

Figure 2 *Coal transportation routes in the Variant 1 and Variant 2*

Table 1 lists the transport lengths that have been included in the budget of the transport capacity.

Table 1 *Quantities of materials that need to be excavated for a ramp construction*

	Length of discontinuous transport	Length of continuous transport
Variant 1	2100	0
Variant 2	700	1400

The Talpac computer program was used to calculate the system of excavator - truck. On the basis of the input parameters, the time capacities of trucks for the Variant 1 and Variant 2 are calculated.

The Talpak software package is a simulation model of loading and transport process at the open pits. Software enables the optimization of transport fleet, calculation the technical-economic parameters of the equipment operation, such as a cycle length, capacity, etc. [4]. In this particular case, this program was used to determine the parameters for coal transport from the roof zone in the Variant 1, when there is only a truck transport and, in Variant 2, when there is a truck transport just inside the open pit. Figure presents the calculation results for the Variant 1. Figure 4 presents the calculation results for the Variant 2.

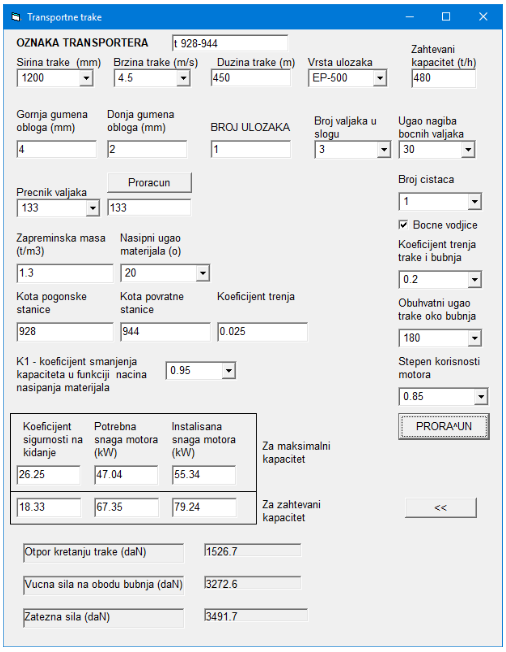
Production Summary - Full Simulation			
Haulage System: Haulage System-1		Haul Cycle: [PRJ] Trasa	
Material: [PRJ] Ugalj		Roster: [PRJ] Roster-1	
Loader		[PRJ] KOMATSU PC 800 -G	
Availability	%	100.00	
Bucket Fill Factor		0.92	
Average Bucket Load Volume	cu.metres	5.46	
Average Payload	bcm	4.55	
Operating Hours per Year	OpHr/Year	3,500.00	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	500.00	Shifts factored by availability
Average Bucket Cycle Time	min	0.50	
Production per Operating Hour	bcm	354.91	
Production per Loader Operating Shift	bcm	2,484	Max. prod. based on 100% avail.
Production per Year	bcm	1,242,171	Avg. production factored by avail.
Wait Time per Operating Hour	min	6.47	
Truck		[PRJ] BELAZ 7555 (22.33:1 Gear Ratio)	
Availability	%	100.00	
Payload in Template	bcm	27.36	
Operating Hours per Year	OpHr/Year	3,500.00	
Average Payload	bcm	27.59	
Production per Operating Hour	bcm	177.45	
Production per Loader Operating Shift	bcm	1,242	
Production per Year	bcm	621,086	
Queue Time at Loader	min/ Cycle	0.35	
Spot Time at loader	min/ Cycle	0.40	
Average Loading Time	min/ Cycle	2.53	
Travel Time	min/ Cycle	3.53	
Spot Time at Dump	min/ Cycle	0.30	
Average Dump Time	min/ Cycle	0.20	
Average Cycle Time	min/ Cycle	7.31	
Fleet Size		2	
Average No. of Bucket Passes		6.06	
Haulage System			
Production per Year	bcm/Year	1,242,171	
Discounted Capital Cost	$/bcm	0.00	Loading Methodology
Discounted Operating Cost	$/bcm	0.00	Single Sided
Discounted Average Cost	$/bcm	0.00	Full Truck
Excavation Target	bcm	1,077,000.00	Average for 150 Shifts
Time to move Excavation Target	Days	316.68	
Loader Hrs to move Target	Op. Hours.	3,035	
Total Truck Hrs to move Target	Op. Hours.	6,069	
Total cost to move Target	$	0	

Figure 3 *Calculation results of the truck transport for the Variant 1*

Production Summary - Full Simulation			
Haulage System: Haulage System-1		Haul Cycle: [PRJ] Trasa 2	
Material: [PRJ] Ugalj		Roster: [PRJ] Roster-1	
Loader		[PRJ] KOMATSU PC 800 -G	
Availability	%	100.00	
Bucket Fill Factor		0.92	
Average Bucket Load Volume	cu.metres	5.46	
Average Payload	bcm	4.55	
Operating Hours per Year	OpHr/Year	3,500.00	Op. hrs factored by availability
Average Operating Shifts per Year	shifts/Year	500.00	Shifts factored by availability
Average Bucket Cycle Time	min	0.50	
Production per Operating Hour	bcm	396.76	
Production per Loader Operating Shift	bcm	2,777	Max. prod. based on 100% avail.
Production per Year	bcm	1,388,672	Avg. production factored by avail.
Wait Time per Operating Hour	min	1.04	
Truck		[PRJ] BELAZ 7555 (22.33:1 Gear Ratio)	
Availability	%	100.00	
Payload in Template	bcm	27.36	
Operating Hours per Year	OpHr/Year	3,500.00	
Average Payload	bcm	27.58	
Production per Operating Hour	bcm	79.35	
Production per Loader Operating Shift	bcm	555	
Production per Year	bcm	277,734	
Queue Time at Loader	min/ Cycle	2.24	
Spot Time at loader	min/ Cycle	0.40	
Average Loading Time	min/ Cycle	2.53	
Travel Time	min/ Cycle	10.59	
Spot Time at Dump	min/ Cycle	0.30	
Average Dump Time	min/ Cycle	0.20	
Average Cycle Time	min/ Cycle	16.26	
Fleet Size		5	
Average No. of Bucket Passes		6.06	
Haulage System			
Production per Year	bcm/Year	1,388,672	
Discounted Capital Cost	$/bcm	0.00	Loading Methodology
Discounted Operating Cost	$/bcm	0.00	Single Sided
Discounted Average Cost	$/bcm	0.00	Full Truck
Excavation Target	bcm	1,077,000.00	Average for 150 Shifts
Time to move Excavation Target	Days	283.27	
Loader Hrs to move Target	Op. Hours.	2,714	
Total Truck Hrs to move Target	Op. Hours.	13,572	
Total cost to move Target	$	0	

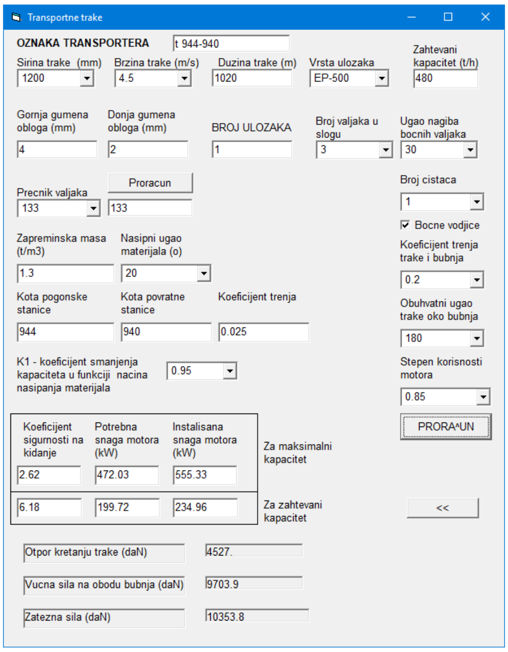
Figure 4 *Calculation results of the truck transport for the Variant 2*

Calculation of the transport parameters for belt conveyors was done using the appropriate software solution according to the method prescribed by the technical standards [5]. In Figures 5 and 6, the output form of the program is shown, and a part of the output listing for the T1 and T2 belt conveyors is given.



Transporter: T1
Length of conveyor (m): 450
Level of drive station (m): 944
Level of return stations (m): 940
Altitude difference (m): 4.
Slope of conveyor (%): .89
Track width (m): 1200
Bandwidth (m): 4.5
Velocity resistance (daN): 2297.1
Tensile force on the rim of drum (daN): 4923.9
Tensile force (daN): 5253.7
Maximum capacity (t/h-m^3/h): 2882.96 - 2217.66
Required capacity (t/h-m^3/h): 480. - 369.23
Installed engine power (kW): 119.22

Figure 5 *Program form and a part of the output listing for the T1 conveyor*



Transporter: T2
Length of conveyor (m): 1020
Level of drive station (m): 944
Level of return stations (m): 940
Altitude difference (m): 4.
Slope of conveyor (%): .39
Track width (m): 1200
Bandwidth (m): 4.5
Resistance to movement of the band (daN): 4527.
Tensile force on the rim of the drum (daN): 9703.9
Tensile force (daN): 10353.8
Maximum capacity (t/h-m^3/h): 2882.96 - 2217.66
Required capacity (t/h-m^3/h): 480. - 369.23
Installed engine power (kW): 234.96

Figure 6 *Program form and a part of the output listing for the T2 conveyor*

Based on the results obtained in calculation for truck transport and transport by belt conveyors, the unit normative costs for the Variant 1 and Variant 2 have been determined and shown in Table 2. In Table 3, the unit costs for transport by belt conveyors are given.

Table 2 *Unit costs for truck transport according to the variant solutions*

	Variant 1		Variant 2	
	Quantity	Unit costs (€/t)	Quantity	Unit costs (€/t)
Fuel norms (l/cm^3)	0.66998	0.26571	0.29993	0.11895
Lubricant norms (kg/cm^3)	0.06700	0.07592	0.02999	0.03399
Oil norms (l/cm^3)	0.07370	0.14614	0.03299	0.06542
Tire norms (pcs.)	0.00002	0.00685	0.00001	0.00307
Spare parts norms (kg/cm^3)	0.00500	0.02833	0.00500	0.02833
TOTAL (€)		0.52296		0.24976

Table 3 *Unit costs for transport by belt conveyors for the Variant 2*

Type	Norm (unit/m^3)	Unit costs (€/t)
Electric power (kWh/t)	0.0000	0.01729
Oil (kg/ t)	0.0000	0.00851
Lubricant (kg/t)	0.0000	0.00208
Sets of rollers (pcs./m^3)	20%	0.02682
Sets of lower rollers (pcs./m^3)	20%	0.00670
Sets of shock absorber rollers (pcs./m^3)	50%	0.00102
Drums (pcs.m^3)	20%	0.00653
Rubber belt B=1200 mm (m/m^3)	15%	0.02857
Wipers (pcs.)	100%	0.00004
Buffer plates (pcs./m^3)	100%	0.00076
Sealing rubber (pcs.)	100%	0.00229
	TOTAL	**0.10062**

Table 4 gives the annual labor costs for the variant solutions. Labor costs are taken as the total operating costs. In addition to the operational costs, the capital costs are calculated per year, and for the variant solutions are shown in Table 5.

Table 4 *Yearly labor costs for the variant solutions*

Yearly labor costs	€/year
Variant 1	204,000
Variant 2	148,800

Table 5 *Capital costs per year for the variant solutions*

Capital costs per year	€/year
Variant 1	340,000

Based on the previously calculated values in Table 6, the capacities of a variable part of combined systems are shown and calculated for the unit costs of the standardized material and energy are calculated for them.

Table 6 *Capacities of a variable part of combined systems and their unit costs of standardized material and energy*

	Hourly capacity of truck (hm^3)	Hourly capacity of belt (hm^3)	Unit normative costs (€/t)
Variant 1	79.35	0	0.523
Variant 2	177.25	369.23	0.350

DISCUSSION

Capacity of the exploitation system is the basic techno-economic parameter, which, in addition to defining the type, number and individual capacities within the individual technological processes that make it, is also a key factor in the system efficiency [6]. The principle of system optimization in terms of capacities in the surface exploitation is based on comparison of several variants, and the techno-economic indicators have the abrupt passes in a function of capacity, type of application the basic equipment, transport lengths, automation possibility, etc. [7,8]. In the concrete case, based on the calculated parameters of a variable part of the combined systems, a diagram of change in total costs (capital and operational) was defined, depending on the production capacity of coal, and as such shown in Figure 7.

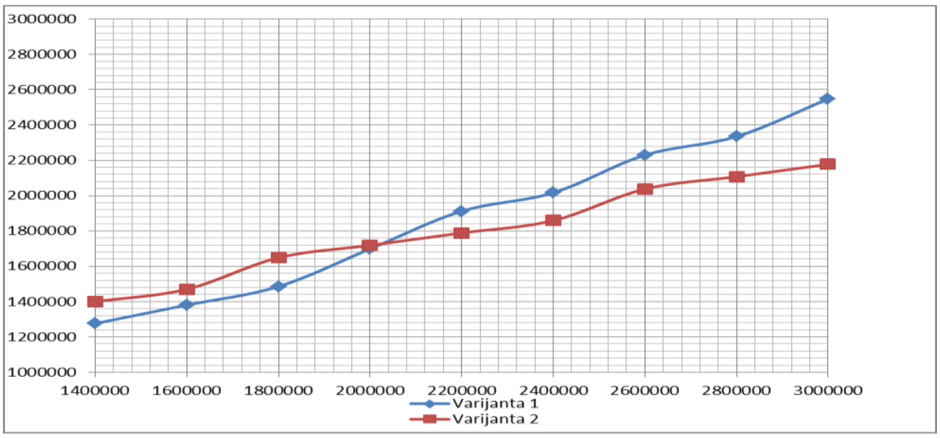


Figure 7 *Diagram of the total cost changes in a function of production capacity*

The illustrated diagram shows that the introduction of new conveyors and extension the continual part of transport is a more favorable solution in the production of over 2 000 000 t. This is applied only to a specific case involving a specific type of unloading loading and transport equipment, pre-defined routes and transport conditions, and specific working environment parameters.

The obtained result is in a domain of a number of applicability analyses of combined system, which were carried out in our country and in the world. Factors that can be further analyzed, and which can significantly influence the analysis result are: the possibility of system automation, application of modern materials and more energy efficient equipment, application of mobile crushers and optimization the transport routes in terms of their elements (length, inclination, radii of curves, etc.).

Within the Strategy of mining and technology opening, development, optimization and maintenance the continuity of coal production with introduction the process of coal enrichment by dry separation at the open pit Gacko, several cases of coal production from roof coal series were considered, with a maximum capacity of 3 000 000 tons per year. In the current development stage of the open pit, the production capacity of the roof coal series is around 1 000 000 t per year. This is due to the optimization of available resources, which are, inter alia, limited by the artificial boundary of the concession. The carried out also analysis took into account the specific natural conditions of the working environment and artificial limitations, which in this case are both administrative and economic. In order to optimize the exploitation system at the open pit Gacko Central Field, it is necessary to consider the other elements that are not a part of this analysis, but which influence the overall efficiency of the open pit (production in the Central Exploitation Zone, pro gress the front of continuous work systems, transport length to the landfill site, seam and interbed waste, etc.).

CONCLUSION

The limit of use a discontinuous, that is, a combined system is in a function of a number of factors, among which the system capacity is the most significant. Depending on the specific exploitation conditions, available or designed basic equipment, level of labor engagement, available resources and other factors, a change in the total production costs by a particular exploitation system is not unified in terms of capacity. In addition to the costs that have a relative character, that is, directly dependent on capacity, there are also costs that have a relatively fixed character and which belong to a group of capital expenditures. In particular, these relatively fixed costs relate to the procurement of necessary equipment for achieving the target capacity. The cost comparison methodology, used in the two capacity exploitation systems, can be applied to the other similar facilities, given the increasing standardization of coal production capacities for the needs of thermal power plants.

The obtained result is within the values stated in many other analyzes of the use of discontinuous-combined systems in the world. These analyzes are usually done for the needs of the equipment manufacturer and the need to dimension the elements of exploitation system (basic equipment) and only in a small part analyze the impact of work environment characteristics as they are performed for a specific object and unique conditions. The presented analysis was carried out precisely on this principle, but the variation in influence of natural factors would certainly contribute to a more precise determination the efficiency limit of a particular discontinuous-combined system.

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Slavica Miletić, Dejan Bogdanović**, Miroslav Ignjatović****

INNOVATIVE SOLUTIONS FOR ASSESSMENT THE MOTIVATION OF EMPLOYEES IN THE MINING COMPANIES****

Abstract

Today in the modern business of the mining companies, the management puts emphasis on assessment the motivation of employees. Motivation of employees is a precondition for the successful operation of the company. This paper is aimed to present an innovative solution applying the multi-criteria method (MCDM) for assessment the motivation of employees in the mining companies. The obtained results show that the most effective is the theory of motivation for implementation in mining companies. Innovative solution as an auxiliary tool gives managers a complete view for assessment the motivation of employees in mining companies in order to increase profits.

***Keywords**: Motivation, multi-criteria methods, mining companies*

1 INTRODUCTION

In the modern business of mining companies, the motivation of employees is gaining more and more. The word motivation among employees is their driving agent, their inner strength giving them the strength to achieve their goals and needs. In order to successfully manage of the mining company, the company's management must find an optimal combination of material and non-material incentives for motivation of the employees.

The key to the sustainable organizational success and survival of a company lies not only in practical, quantitative approaches, but also in the commitment of employees to motivate them to work [1].

The paper assesses the motivation of employees by the Analytical Hierarchical Process (AHP). As the offered solutions for assessment the most effective alternative, the following motivation theories were used: the expectation theory, the justice/equality theory, the integrative theory and the goal setting theory.

The motivation theories are assessed by the following criteria: criterion C1 - salary, criterion C_2 - rewarding of employees, criterion C3 - Benefits and criterion C4 - gratitude for the work done.

Multi-criteria methods (MCDM) are used by managers or decision makers as the auxiliary tools in solving the real problems or deciding in different areas of economy. Recently, many MCDM methods are used, such as AHP, ELECTRE, PROMETEJ, TOPSIS, ARAS, SVARA and many others [2-8]). The combined MCDM methods [9, 10] are also used as well as the new models [11].

* *Mining and Metallurgy Institute Bor, Zeleni Bulevar 35, Bor, slavica.miletic@irmbor.co.rs*
** *Technical Faculty Bor, University in Belgrade, V. Jugoslavije 12, 19210 Bor, e-mail: dbogdanovic@tfbor.bg.ac.rs*
*** *Chamber of Commerce of Serbia, Belgrade. miroslav.ignjatovic@pks.rs*
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The applied methodology gives managers the opportunity to implement the most effective motivation theory for successful operation of the mining companies and increase the satisfaction and needs of the all interested parties.

Each company uses different models to analyze the motivation of its employee and makes a decision to accept the most effective motivation theory.

2 THEORETICAL BASIS

The business success of a mining organization depends on many factors, and one of these factors is the motivation of employees. Motivation is a complex process of organizing, guiding the behavior of employees in order to meet their own and organizational needs [12]. It is a significant element of an organization affecting their working performance.

The working performance consists of three general factors [13]:

Work performance of employees $= f$ (S, K, M)

Where in:

- S-ability of employees to perform the work activities
- K-knowledge and use of rules, procedures and principles
- M-motivation for performing the work tasks.

According to the authors Srivastav and Barmol [14] and Hong and his associates [15], the employee motivation is equated in some cases with productivity. Motivation for work originates from the attitude of individuals toward work and achievement of goals, because it is a psycho-sociological category [16]. Modern business requires from the menageress of organizations to better organize and motivate their employees in the occurred situation in order to achieve the better working results [17]. Because the employee motivation is one of the irreplaceable factors for performing the work activity [18].

When the employees are motivated, then the work goals are achieved and thus increases the profit of organization and employee satisfaction. Employee satisfaction is defined as a favorable, i.e. positive emotional state [19]. The key factor in motivating the employees are managers, who are responsible for creation the working environment, representing the company's attitude toward employees and consciously or unconsciously affecting their behavior. Very important motivators of employees, the motivation of the employee and his inters for performance depend on the highest percentage of creative management [20]. Managers are those who choose which of the motivating methods or theories of motivation for their employees is the most effective. Implementation of motivation theory in the mining companies contributes to greater productivity, good positioning, competitiveness and sustainability.

Many research has been carried out and many theories have been developed, but the factors that motivate employees to perform their activities are still controversial in the modern business with mining companies.

Theories of motivations in the modern world are considered to be powerful motivators that are divided into two groups: content theory and process theory [21]. The content theories are: the theory of hierarchies of the needs of Abraham Maslow and Herchrberg's dual-factor theory or motivational hygiene theory. These two theories are directed to the needs of individuals and are fairly represented, but the managers of modern companies turn to the process theories.

The process motivation theories are on employees who focus on performing the work tasks with expectations of rewards or benefits. The most commonly implemented process theories in the modern business are: Theory of Justice - Adams's Theory of Equality, Expectancy Theory - Vroom's Cognitive Expectancy Model, Integrative

Theory of Motivation and Theory of Setting Objectives.

Alternative A_1: Theory of Expectation or Vruman's Theory of Motivation is leading in the process theories and is valid for the theory that most explains how the employees need to be motivated. It is often referred to as the VIE theory because it indicates the initial three letters of this theory, such as valence, instrumentality, and expectancy [22].

- Valency or value - means the attraction of the prize.
- Instrumentality or belief that employees will be adequately rewarded for their work.
- Expectation is an employee's assessment of performing a work activity.

Employees perform their work tasks more efficiently if they bring them the desired goal (instrumentality), where there is a value (valency) and where the expectations are likely. The advantages of this theory are the association of advocacy and achievement the desired goals. The negative side of the VIE's theory of expectation is the irrationality, impulsibility and emotionality of the employees.

Alternative A2: The theory of justice or as it is called the Adams's theory of equality is a motivator where the employees for a particular type of work should be justly rewarded. But the question arises whether they do it fairly or not. This is a key part of this theory. The fair distribution of rewards to the employees is when a balanced relationship between dedication and rewarding is otherwise unjust. In the event of unfair distribution, the employees are demotivated and do not invest their efforts to perform the work goals of the organization. In large cases, they are so dissatisfied with leaving the organization. The problem of this theory is the personal assessment of employees on the reward assessment for the work done.

Alternative A_3: The integrative motivation theory is an extended model of expectation theory where the following variables are added: role perception, capability and employee satisfaction. This method contains the relationships of variables of the content and process theory of motivation and integrated needs, where the needs are the basis for determining the preferences by which the name is called an integrative process model [23].

Two reverse links are built into this model [24]:

- The first between the variance of performance and variance of effort and rewards
- Another feedback between the satisfaction and value of prizes.

Alternative A_4: Goal Setting Theory: The very title of this theory tells us that the motivators of this method are the goals. The employee goals are motivated if they are clear, precisely defined, desirable, difficult but feasible, and if the employees are allowed to define them together.

According to Jordan [25], the goal should be divided into several smaller goals, so that the accomplishment of goals can be relatively easy, but nevertheless be awkward enough to provide the necessary satisfaction in their accomplishment.

The Goal Setting Theory provides managers with the following lessons [26]:

1. Define clear and specific objectives;
2. Define difficult or achievable goals, and
3. Give employees the feedback information on achieving the organizational goals.

In order for managers to choose the most effective motivation theory, they have a task to determine the criteria. The criteria serve to rank the given alternative, that is, the criteria that have been operationalized in relation to the premise of assessment: the expected or accomplished achievement. The criteria depend on the expectations of the decision maker. The criteria can also be conflicting.

Criteria for the assessment of alternatives are proposed by the mining team's management team: criterion C1 - wage, criterion C2 - employee rewards, criterion C3 - benefits and criterion C4 - gratitude for the work done.

Criteria C1 - wages, wages of employees are determined in accordance with the organization 's strategy. For every work done in the organization, there must be compensation, salary or salaries. The greater the compliance of the organization and the salary system, the organization is more successful.

Criterion C2 - employee rewards, is a process by which the employees are provided with funds for work performed as a supplement with a certain remuneration.

C3 Criteria - benefits, benefits are very important for employees. Organizations with their benefits attract the best workers to retain them and thus achieve the positive results. There are various benefits: vacation, life insurance, hot meals, etc.

C4 Criteria - acknowledgment for the work done, acknowledgments of the employees' gratification for the work done is related to care and support to employees.

3. MODEL OF RESEARCH

The AHP method (analytical hierarchical process) [27], by implementing, allows us to rank the motivation theory. It is based on a hierarchical analysis of decision problems. The hierarchy of the problem of decision making was constructed through defining its goal, assessing criteria and sub-criterion, and finally variance. On each level of the hierarchy, based on the comparison of criteria, subcriteria and variants, the professional information DM is defined in the form of relative weights [27].

The AHP method algorithm focuses on finding a solution for the so-called inherent value problem [27] at each level of the hierarchy. As a result, a set of vectors containing normalized, absolute values of weight for criteria, subcriteria and variants are generated. The collection of vector elements is 1 (100%).

Based on the Saati scale (Table 1), the relative importance between the two criteria is determined (Table 2). The relative importance of the criteria is made by the decision makers or team managers together with the experts from a particular field.

Table 1 *Scale of criteria comparison*

Value_{jk}	Interpretation of results
1	j and k are equally important
3	j is a little important than k
5	j is more important d k
7	j is very important than k
9	j is absolutely more important than k
2,4,6,8	intermedia value

Table 2 *Matrix of criteria comparison*

Criteria	C_1 (wage)	C_2 (rewarding of employees)	C_3 (beneficiations)	C_4 (appreciation for done work)
C_1	1	3	5	7
C_2		1	3	1
C_3			1	1/2
C_4				1

Table 3 shows the results obtained by calculating the AHP method using the Criterion Decision Plus software. The degree of consistency should be less than 1, which in this calculation was 0.054.

The obtained results are shown in Table 3. It was obtained that criterion C1, the employees wage has the greatest influence on the motivation of employees and it depends on which theory of motivation as a recommendation is most effective for implementation in the mining companies to managers.

Table 3 *Final results*

Criteria	C_1	C_2	C_3	C_4
m	0.602	0.183	0.079	0.136
Consistency coefficient,	0.054<0.1			

Figure 1 Displays the hierarchy of criteria obtained with the software.

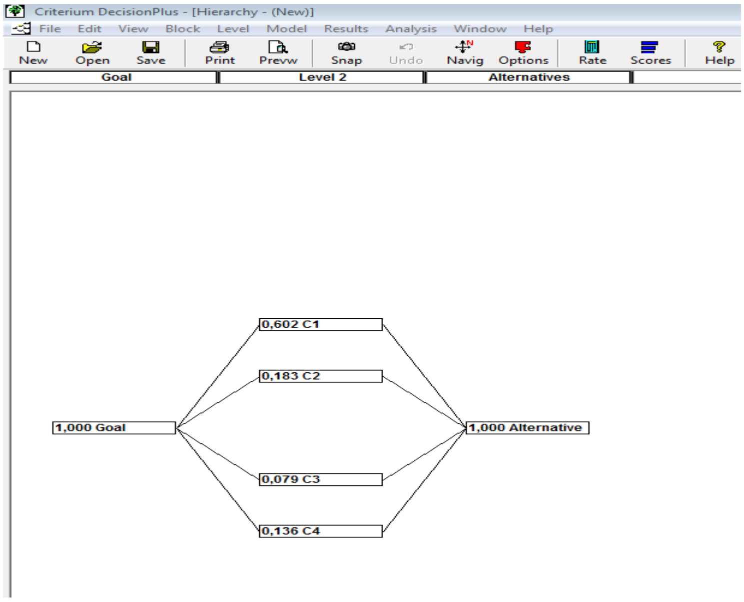

Figure 1 *Hierarchy of criteria*

Figure 2 Show the criteria by the values of activity on the motivation of employees.

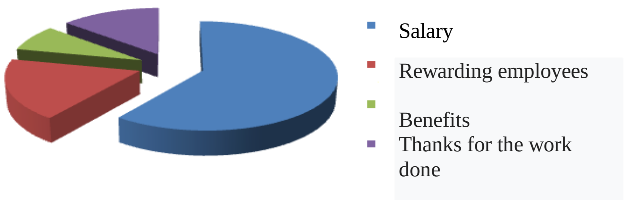

Figure 2 *View of crteria by the values of activity on he motivation of employees*

The next step of the AHP method is to rank the individual alternatives with each of the criteria Table 4-7.

Table 4 *Comparison of alternatives regarding to the criterion C_1*

Alternative	A_1	A_2	A_3	A_4
A_1	1	1/2	1/3	1
A_2		1	1/2	1/2
A_3			1	1
A_4				1
Consistency degree 0.077<0.1				

Table 5 *Comparison of alternatives regarding to the criterion C_2*

Alternative	A_1	A_2	A_3	A_4
A_1	1	2	1/2	3
A_2		1	3	2
A_3			1	1
A_4				1
Consistency degree 0.099<0.1				

Table 6 *Comparison of alternatives regarding to the criterion C_3*

Alternative	A_1	A_2	A_3	A_4
A_1	1	2	3	2
A_2		1	1/2	2
A_3			1	3
A_4				1
Consistency degree 0.097<0.1				

Table 7 *Comparison of alternatives regarding to the criterion C_4*

Alternative	A_1	A_2	A_3	A_4
A_1	1	2	3	2
A_2		1	1	1
A_3			1	2
A_4				1
Consistency degree 0.044<0.1				

The results obtained with software are shown in Table 8.

Table 8 *Final results*

Alternative	Results
Expectation theory A_1	0.245
Theory of Justice A_2	0.217
Integrative Theory A_3	0.310
Theory of goal setting A_4	0.228

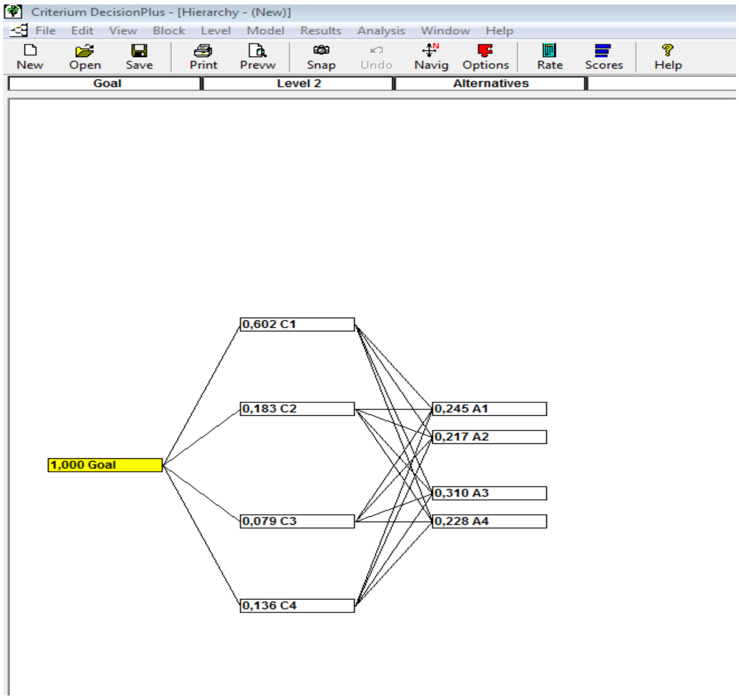

Figure 3 *Hierarchy of criteria and alternatives*

4 ANALYSIS OF THE RESULTS - DISCUSSION

The algorithm of the AHP methodology for finding the solution of the most effective theory of motivation for the so-called problem results show that this is the integrativity theory, an extended model of the theory of expectation of the alternative A_3. The integrativity theory occupies the first place for efficiency and is recommended to the managers of the mining company as the most efficient for its implementation. Its weight coefficient is 0.310 or in percentages of 31%. For this theory, the motivation of employees is not only a psychological and sociological problem of work and work behavior, but the behavior of employees is directed towards an operational goal that arouses the needs caused by it, and the goal is to behave in meeting their needs.

In the second place, it is obtained by calculation the AHP method by efficiency that it is alternative of A_1 the theory of expectation. Its weight coefficient is 2.45, or in percentages 24.5%. The theory of expectation is valid for the theory that explains the best way and how to motivate the employees in mining companies. Expectation theory or VIE is a product of valency, instrumentality and expectation.

In the third place according to the efficiency of the given alternatives, it was obtained as the method of goal setting theory, that is an alternative to A_4 whose weight coefficient is 0.228. Clearly de fined, specific, difficult but achievable goals are strong motivators for the employees. In addition to getting the feedback information for their realization, it initiates a higher motivation for the employees. When the employees are motivated, the management expectations are justified for the success of mining company.

In the fourth place in terms of efficiency of the theory of motivation, the results show that this is the theory of righteousness alternative A_2. Its weight coefficient is 0.217. In the theory of justice, equity in salaries is of relevance to the employees in mining companies. And this is a true motivator for all employees.

Figure 4 gives a schematic representation of the given motivation theories. Between the given theories there are no big differences because the results of weight coefficients are approximate. All estimated motivation theories are important for the motivation of employees in the mining companies and can be used by the managers. But it's very rare for managers to remember that they exist.

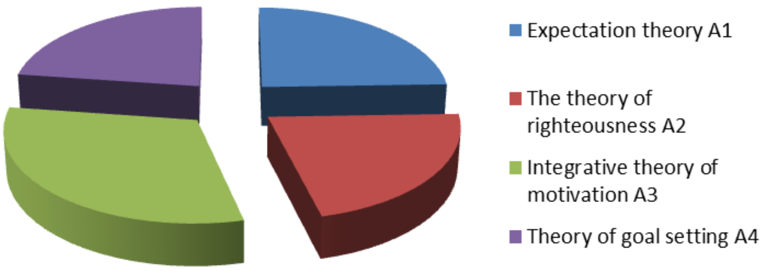

Figure 4 *Schematic representation of the estimated motivation theories*

The C1 criterion is for the employee of an organization the largest motivator, a payroll for completing a work assignment so that most acts on the evaluation of motivation theory. Salary is the largest motivator of employees, occupying the first place because the weight coefficient is 0.602. Salary satisfaction is direct, linked to the motivation of employees.

For the employee reward the criterion C2 is in the second place, which as a motivator acts to the evaluation of motivation theory. Its weight coefficient is 0.183. The rewarding of employees brings better organization of the employees themselves and the mining organization which contributes to higher profit.

In the third place is the criterion C4, a gratitude for the work done with the weight coefficient of 0.136. Caring for employees and providing support is a motivator that drives the employees to easily carry out the work tasks.

Benefits, the criterion C3 is in the third place with a weighting coefficient of 0.079. If the employees receive various benefits, a retention of the best workers who can achieve positive results in mining companies is achieved.

5 CONCLUSION

This paper shows the possibility of using the multicriterial decision making (MCDM) as an innovative solution in selecting the most effective motivation theory.

The algorithm of AHP method for finding the solution for the most efficient theory of motivation for the problem of motivation assessment in the mining companies shows that the theory of integrity, the expanded model of the theory of expectation, the alternative A_3 is the most effective for implementation.

Salary in the mining companies is the biggest motivator of employees, criterion C_1, so that it mostly works on the evaluation of motivation theory. The motivation of employee is directly linked to the salaries of employees.

The task of managers in the mining companies is to understand the particularity of motivation theory and human complexity, so that, depending on their specific business, they select and apply the most effective motivation techniques.

By applying the theory of motivation the managers will involve the employees and motivate them to work.

The key methodology chosen is the survival, sustainability and organizational and financial success of the mining companies.

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Danijela Vujić, Darjan Karabašević**, Mlađan Maksimović**, Srđan Novaković***

THE ROLE OF LEADERS IN CREATING AN ORGANIZATIONAL CULTURE THAT FOSTERS THE CONCEPT OF PRESERVATION THE NATURAL RESOURCES

Abstract

Leadership becomes an important topic of research in the organizational theory as it is an essential factor for the success of organizations. Leadership can be understood as a process of influencing followers based on the clear values and beliefs. Organizational culture is largely evolving under the influence of leadership, and the culture of an organization in some segment can also affect the leadership. The efficient organizations in order to survive in increasingly competitive business conditions require a tactical and strategic thinking as well as the creation of a culture by the leader. Vision and mission of the organization can be realized only if the leader creates a culture dedicated to the support of this vision. Bearing in mind that the natural resources are a factor necessary for the functioning of societies in the modern world, the aim of the manuscript was to determine the role that a leader has in creating an organizational culture that fosters the concept of preserving the natural resources.

***Keywords**: leadership; leader, organizational culture, natural resources.*

1 INTRODUCTION

Leadership as a phenomenon takes a special place in the world and it becomes a highly desirable attribute in a competitive business conditions. Research on the phenomenon of leadership dates back nearly a century [23].

The importance of leadership and leaders is especially important in the modern organizations. Organizations have realized that the leaders contribute to achieve and maintence competitive advantage [7]. For this reason, the focus of organizations that have leaders among the employees is increasing, and that is why the process of recruitment and selection elect people who possess the leadership skills. Leadership is an essential element of functioning of all organizations. Leaders with their own strengths create a confidence in the organization as well as a desire of their followers to achieve the goals of a group or organization. Leadership is directly related to the ability to influence the people's behavior.

Very rapid industrialization as well as the increasing level of industrial production in the world has caused the rapid depletion of natural resources and emergence of environmental problems, which directly affects the environment. For this reason, the entire world is affected by serious environmental problems, so it is increasingly difficult to find a balance between the production and ecology [1]. The basic objective of preservation the natural resources is reflected primarily in the balance of their use. Balance is needed between the exploitation of re-

* *Military Medical Academy, Crnotravska 17, 11000, Belgrade*
** *Faculty of Applied Management, Economics and Finance, University Business Academy in Novi Sad, Jevrejska 24, 11000 Belgrade, Serbia. E-mail: mladjan.maksimovic@mef.edu.rs*

sources, economic interests, social interests and interests of environmental protection. This implies the use of resources in accordance with the concept of sustainable development, respecting the three essential imperatives on which the very concept is based, ecological imperative, social and economic imperative [13; 16].

Leadership is important for the organization. Organizational culture is largely developed under the influence of leadership, and also the culture of an organization in some segment can affect the leadership. The efficient organizations to survive in increasingly competitive business conditions require a tactical and strategic thinking as well as creating a culture by the leaders. Vision and mission of the organization can be realized only if the leader creates a culture dedicated to the support of this vision [20].

Based on the above, the aim of this paper is to examine the role of leaders in creating an organizational culture that fosters the concept of preservation the natural resources. Accordingly, the manuscript is structured as follows: Section 1 presents the introduction; Section 2 presents a literature review; Section 3 presents the materials and methods while Section 4 presents the results of research with discussion. The final conclusions were given at the end of the paper.

2 LITERATURE REVIEW

Leadership is the ability to focus the group on the organization's vision and goals. It can be said that it represents one of the managerial features of a company or organization that interacts with the employees and which has a major impact on the organization's turnover rate. Without leadership, achieving tasks and achievements is impossible [17].

There are different approaches when defining leadership, one of the more interesting approaches proposed by Bass and Stogdill [4] in which they see the leadership with a particular emphasis on the group processes. From this perspective, i.e., the point of view, the leader is the initiator and center of changes and activities in one group, thereby consolidating the will of the group. In other definitions of leadership, the leader is viewed from the perspective of personality, so the leadership is seen as a combination of special characteristics that the individual possesses and which allow him to impose the tasks on others. The rest of the definitions refer to the leadership in a form of activities or behaviors, in the sense that the leadership consists of all activities the leader does to bring about changes in the group. Leadership implies the attitude, leading an organization or some of its work in a new direction, problem solving, creativity, launching the new programs, building the organizational structures and improving the quality in an organization [3].

From the standpoint of classical theorists of organizational behavior, the leadership is viewed from the point where a leader leads followers toward fulfilling organizational objectives. So Davis and Gardner [9] consider the leadership as a human factor that connects members of the group and motivates them to achieve the goals. On the other hand, a similar definition is proposed later by Bass and Bass [3], where they emphasize that leadership can turn the followers, creates a vision of the goals that need to be fulfilled, and where followers are articulating ways of realizing the organizational goals.

The theme of leadership and organizational culture attracts a significant attention and is increasingly becoming the subject of researchers' interest. Most of the research interests for the two areas are based on explicit and implicit claims that the leadership and culture are linked to the organizational performance.

Leadership is a highly desirable attribute in the modern and increasingly competitive business conditions. Leaders believe in their own strengths and create the enthusiasm in the organization as well as the aspiration of the followers in order to achieve the goals of the group or organization. Near the "real" leaders, the employees feel more competent and safer. Leadership is also directly related to the ability to influence the people's behavior.

Janićijević [12] stands the view that organizational culture represents the phenomenon of behavior in the organization, i.e. organizational behavior, and that it marked the area of management in the last decade of the XX and the first decade of the XXI century. Numerous researches in the field of organizational culture confirm the role of leaders in creating and maintaining a certain type of culture in organizations [20]. On the other hand, Hennessey [11] indicates the importance of understanding and working within a culture as a prerequisite for a successful leadership.

One of the approaches to discover the relationship between the organizational culture and leadership is to examine how culture is conceived in the organizational theory. Smircich [22] points out two approaches to the study of organizational culture: culture as an organizational variable and culture that is seen as something that can be manipulated. According to Brown [6], organizational culture is defined as "a system of assumptions, values, norms and attitudes manifested through symbols, which members of one organization developed and adopted through a shared experience and which helps them to determine the meaning of the world that surrounds them and how to behave in it" [12].

Fishman and Kavanaugh [10] suggest that the culture of an organization and the way people respond to certain changes and innovations significantly shape the behavior of the leaders. Kavanaugh and Ashkanasy [14] emphasize the view that the role of leaders is important in the process of creating and maintaining a certain type of organizational culture; however, Bass and Avolio [2] state that a particular culture is a prerequisite for the leadership success and point to a mutual relationship between then leadership and organizational culture, that is, the organizational culture and leadership are intertwined.

In his research, Schein [20] thoroughly examined the concepts of organizational culture and leadership, and he also expressed the view that the organizational culture and leadership are two sides of the same coin and can not be understood by themselves. Also, leadership as a process is not separated from a wider situational context in which the leadership takes place, unless a culture supports the leaders, in which case leadership based on common values is not possible. Therefore, culture determines a large part of what the leaders are doing and how they do it [18].

Lately, the link between the organizational culture and leadership has been increasingly mentioned as the basic postulates for creating a sustainable organization. In his research, Baumgartner [5] examines the impact of organizational culture and leadership on creation a viable corporation, and points out that the organizations have a great importance in creating sustainable communities. The extent to which the concept of sustainable development will be applied depends on the leader in an organization as well as the organizational culture.

The culture of one group changes over time and is the result of the most common change in various influential factors such as the business environment, leadership, management practice and formal and informal socialization processes [24]. Organizations face the challenge of applying the concept of sustainable development; however, this is possible with the active role of the leader, which Schmidheiny confirms in his research [21].

Roorda [19] in its extensive research examines the key competences of sustainable development that are an essential step for implementing the concept of sustainable development. It also notes that the emotional intelligence of the leader represents a significant competence necessary for the implementation of concept itself, among other, also are mentioned competencies such as the responsibilities, system orientations, future orientations and action skills.

Creating an organizational culture and initiating change in the organization almost always starts from the leader. So, the leaders are those who initiate changes in the organization and who have an impact on creation an organizational culture that will respect the concepts of sustainable development.

3 MATERIALS AND METHODS

Research on the role of leaders in creating an organizational culture that fosters the concept of preservation the natural resources was carried out in the period from 15.05.2017 - 30.06.2017. The research includes four economic entities on the territory of Belgrade who, in addition to their regular daily work activities, respect the principles of sustainable development and maximally care about the preservation of natural resources. A survey questionnaire was used as a research instrument. The research was anonymous, while a total of 300 questionnaires were distributed. The number of validly filled questionnaires relevant to the research is 260, which represents 86.66% of respondents. The response level and validly filled questionnaires is expected and corresponds to the results that are recommended in the literature [8; 15].

In addition to the basic demographic characteristics, such as gender, age, education, respondents evaluated the following statements using the five-step Likert scale with grades of 1 (I do not agree at all) to 5 (I totally agree):

- The leader in my organization provides the greatest contribution in creating an organizational culture and demonstrates how employees should behave in terms of preserving natural resources.
- The leader in my organization directs followers to use resources respecting the principles of savings and host behavior.
- The leader in my organization, by his own example, demonstrates the use of resources, respecting the principles of savings and host behavior.
- The leader in my organization creates a desirable way for others to revitalize the values and reliability of the principles of preserving natural resources.
- In my organization, the leader nurtures values in terms of preserving natural resources.
- The leader in my organization shows the conformity of my beliefs and actions regarding the creation of an organizational culture aimed at preserving natural resources.
- Employees in the organization guided by the action of the leader align their behavior towards the conservation of natural resources.
- My leader possesses the competencies necessary for creating an organization that in its focus has the preservation of natural resources.
- The leader in my organization, with his attitudes and behaviors, has an impact on raising the environmental awareness of employees.
- The leader in my organization realistically sees reality, assesses the current situation of reality, and makes a decision in the direction of preserving natural resources.

Factor analysis was used to process the results, which is currently one of the most common analyzes of multivariate techniques that has the following goals:

- To identify and understand the basic idea of common characteristics for a number of variables, and
- To reduce the number of variables in the analysis when there are a number of variables, where some of them overlap and have similar meanings or behavior.

The basic objective of factor analysis is that on the basis of mutual variation between the variables that are manifested in the analysis determine a smaller number of variables (factors) that explain this so-called cognition between the perceived variables.

In order for factor analysis to be effective, there must be a minimal matching of the variables in its meaning. In this case, a pattern can be detected in the behavior of the variable, that is, the basic idea or factor.

4 RESEARCH RESULTS AND DISCUSSION

The research was attended by the total number of respondents from all four subjects, 47.86% of male respondents and 52.14% of female respondents. Then, out of the total number of respondents from all four companies / entities, 10.71% of respondents were aged 18 to 24 years; 15.71% of respondents aged 25 to 30 years; 32.86% of respondents aged 31 to 45 years; 27.86% of respondents aged 46 to 60 years and 12.86% of respondents were 60 years old and above. Out of the total number of respondents, there were 61.43% of those with secondary education; 35.0% of those with higher education and 3.57% of those with completed faculty, and according to the status of employment in the organization for all four economic entities, there were 99.29% of employees and 0.71% of leaders.

When it comes to creating an organizational culture that fosters the concept of preserving natural resources, the respondents gave the highest average grade (4.20) for conclusion that the leader in my organization realistically sees reality, assesses the current situation of reality and makes a decision in the direction of preserving natural resources, with the standard deviation 0.670. While the lowest average score (3.80) was attributed to the claim that the organization's leader directs followers towards the using of resources, respecting the principles of savings and host behavior with the standard deviation of 0.648.

Table 1 *Correlation matrix between variables*

		Q_1	**Q_2**	**Q_3**	**Q_4**	**Q_5**	**Q_6**	**Q_7**	**Q_8**	**Q_9**	**Q_10**
Correlation coefficients	**Q_1**	*1.000*	*0.180*	*0.354*	*0.252*	*0.241*	*0.277*	*0.236*	*0.186*	*0.087*	*0.192*
	Q_2	*0.180*	*1.000*	*0.367*	*0.293*	*0.308*	*0.194*	*0.135*	*0.192*	*0.154*	*-0.007*
	Q_3	*0.354*	*0.367*	*1.000*	*0.464*	*0.334*	*0.225*	*0.207*	*0.193*	*0.203*	*0.043*
	Q_4	*0.252*	*0.293*	*0.464*	*1.000*	*0.600*	*0.208*	*0.329*	*0.288*	*0.237*	*0.137*
	Q_5	*0.241*	*0.308*	*0.334*	*0.600*	*1.000*	*0.307*	*0.459*	*0.443*	*0.368*	*0.244*
	Q_6	*0.277*	*0.194*	*0.225*	*0.208*	*0.307*	*1.000*	*0.401*	*0.363*	*0.326*	*0.293*
	Q_7	*0.236*	*0.135*	*0.207*	*0.329*	*0.459*	*0.401*	*1.000*	*0.376*	*0.423*	*0.355*
	Q_8	*0.186*	*0.192*	*0.193*	*0.288*	*0.443*	*0.363*	*0.376*	*1.000*	*0.548*	*0.399*
	Q_9	*0.087*	*0.154*	*0.203*	*0.237*	*0.368*	*0.326*	*0.423*	*0.548*	*1.000*	*0.525*
	Q_10	*0.192*	*-0.007*	*0.043*	*0.137*	*0.244*	*0.293*	*0.355*	*0.399*	*0.525*	*1.000*

Table 1 shows the strength of the relationship between the variables from the analysis through the correlation coefficient, which indicates the relationship between variables from the questionnaire, i.e. those variables that are related to creating an organizational culture that fosters the concept of preservation the natural resources. Correlation coefficients range from -1 to +1. The dependency coefficient level between the variables for this analysis is over ± 0.3. Table shows that there are the correlation coefficients that are greater than 0.3 and that the following analysis is justified; also, the obtained data are suitable for a decision-making.

The methodology of the analysis indicates the need for another analysis in which it is approached with the following tests to even more accurately assess the significance of the use of the passing test.

Table 2 *Passing test for the main component analysis*

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.807
Bartlett's Test of Sphericity	**Approx. Chi-Square**	373.611
	df	45
	Probability	0.000

The value of the Kaiser-Meyer-Olkin Measurement of the Sampling Adequacy test is greater than 0.5 while the other Bartlett's Test of Sphericity is significant at an error level of 0.000. The obtained values of conducted tests for the analysis of the main components show that the data, used for the survey or scale by which the respondents were surveyed, are justified as a method of measuring this phenomenon.

After previous checks, the methodology suggests calculating the common variation that variables have among themselves through the so-called extracted variance. The maximum variation tends to number one, which means that the values closer to it are more common in terms of variation with other variables.

Table 3 *Communalities explained by variance of variables*

Indicators	Initial	Extracted variance
1. The leader in my organization provides the greatest contribution in creating an organizational culture and demonstrates how employees should behave in terms of preservation the natural resources	1.000	0.287
2. The leader in my organization directs followers to use resources respecting the principles of savings and host behavior	1.000	0.428
3. The leader in my organization, by his own example, demonstrates the use of resources, respecting the principles of savings and host behavior	1.000	0.599
4. The leader in my organization creates a desirable way for others to revitalize the values and reliability of the principles of preservation the natural resources	1.000	0.582
5. In my organization, the leader nurtures values in terms of preservation the natural resources	1.000	0.580
6. The leader in my organization shows the conformity of my beliefs and actions regarding the creation of an organizational culture aimed at preserving natural resources	1.000	0.374
7. Employees in the organization guided by the action of the leader align their behavior towards the conservation of natural resources	1.000	0.496
8. My leader possesses the competencies necessary for creating an organization that in its focus has the preservation of natural resources	1.000	0.564
9. The leader in my organization, with his attitudes and behaviors, has an impact on raising the environmental awareness of employees	1.000	0.642
10. The leader in my organization realistically sees reality, assesses the current situation of reality, and makes a decision in the direction of preservation the natural resources	1.000	0.617

Extraction Method: Principal Component Analysis.

Between the indicators there is a common variability explained by absolute variation over variance. The stated amount of variance (saturation of the component) can be maximal up to number one to correlate with a larger number of indicators.

The purpose of the analysis is to determine the indicators that simultaneously vary and where in this way they also correlate to a new dimension that actually forms a group of common factors that affect a particular phenomenon. Therefore, this analysis further implies the use of a test that calculates the total variability or quantity. By further using the Kaiser's criteria, through which the total variability is extracted and which is downgraded by a score higher than the number one.

Which indicators will remain in the analysis, it is decided after applying the so-called factor space rotation in order to facilitate the interpretation of the results. Using orthogonal rotation through one of the default (Virimax) will show the indicators that vary with high variance values in the new impact factors.

Table 4 *The totally explained variability of analysis of the main components*

Components	Basic equivalents of variance			Extracted summarized variability of components		
	Total	% from variance	Cumulative %	Total	% from variance	Cumulative %
1	3.664	3.635	36.635	3.664	36.635	36.635
2	1.506	15.059	51.694	1.506	15.059	51.694
3	0.941	9.413	61.107			
4	0.805	8.047	69.154			
5	0.722	7.215	76.369			
6	0,586	5.857	82.226			
7	0.568	5.684	87.91			
8	0.508	5.075	92.985			
9	0.362	3.616	96.601			
10	0.34	3.399	100			

Table 4 shows the number of common extracted factors, the possible values associated with these factors, the percentage of total variation explained by each factor and the cumulative percentage of total variance explained by the factors. Using the criterion for retaining only those factors with possible values of 1 or more, in this case, two factors are retained for rotation. These two factors explain 36.64% and 15.06% of the total variance, which together account for 51.7% of cases with which variance of indicators correlates.

Figure 1 shows a diagram of a factor transitions showing a clear fracture point behind another component (factor). In further discussion of the research results, two factors (factors) are retained that were obtained by the factor analysis, which is considered as two dimensions, or subscales. The first component explains 36.6% variation and the other 15.1% of variation.

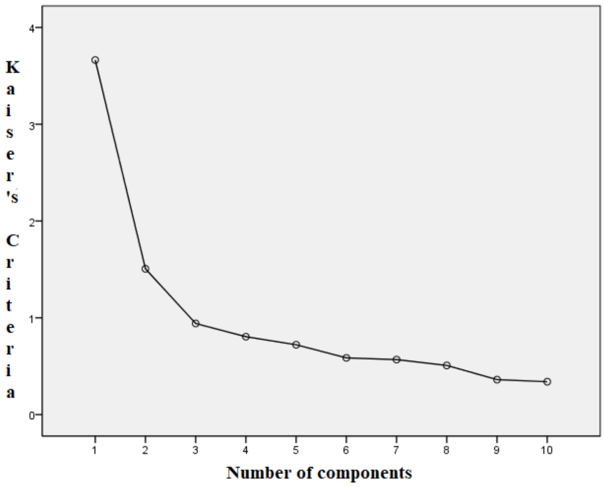

Figure 1 *Skater diagram*

The methodology of the analysis involves a correlation matrix for two factors, to determine which of the variables has the highest coefficient correlating with the factor - which means closer to the number one.

Table 5 *Matrix of original components with its saturation based on each indicator*

	Component	
	1	2
1. The leader in my organization provides the greatest contribution in creating an organizational culture and demonstrates how employees should behave in terms of preservation the natural resources	0.459	0.277
2. The leader in my organization directs followers to use resources respecting the principles of savings and host behavior	0.427	0.496
3. The leader in my organization, by his own example, demonstrates the use of resources, respecting the principles of savings and host behavior	0.537	0.557
4. The leader in my organization creates a desirable way for others to revitalize the values and reliability of the principles of preservation the natural resources	0.643	0.411
5. In my organization, the leader nurtures values in terms of preservation the natural resources	0.744	0.164
6. The leader in my organization shows the conformity of my beliefs and actions regarding the creation of an organizational culture aimed at preservation the natural resources	0.596	-0.135
7. Employees in the organization guided by the action of the leader align their behavior towards the conservation of natural resources	0.676	-0.200
8. My leader possesses the competencies necessary for creating an organization that in its focus has the preservation of natural resources	0.688	-0.299
9. The leader in my organization, with his attitudes and behaviors, has an impact on raising the environmental awareness of employees	0.668	-0.443
10. The leader in my organization realistically sees reality, assesses the current situation of reality, and makes a decision in a direction of preservation the natural resources	0.533	-0.577

For easier interpretation, the following is the rotation of component saturation, but only in the case that the first and second factors are not in a great correlation.

Table 6 *Matrix of rotated components with its saturations based on each indicator of the first component*

Indicators	First component
1. The leader in my organization provides the greatest contribution in creating an organizational culture and demonstrates how employees should behave in terms of preservation the natural resources	**0.171**
2. The leader in my organization directs followers to use resources respecting the principles of savings and host behavior	**0.006**
3. The leader in my organization, by his own example, demonstrates the use of resources, respecting the principles of savings and host behavior	**0.05**
4. The leader in my organization creates a desirable way for others to revitalize the values and reliability of the principles of preservation the natural resources	**0.225**
5. In my organization, the leader nurtures values in terms of preserving natural resources	**0.462**
6. The leader in my organization shows the conformity of my beliefs and actions regarding the creation of an organizational culture aimed at preservation the natural resources	**0.542**
7. Employees in the organization guided by the action of the leader align their behavior towards the conservation of natural resources	**0.645**
8. My leader possesses the competencies necessary for creating an organization that in its focus has the preservation of natural resources	**0.719**
9. The leader in my organization, with his attitudes and behaviors, has an impact on raising the environmental awareness of employees	**0.796**
10. The leader in my organization realistically sees reality, assesses the current situation of reality, and makes a decision in a direction of preservation the natural resources	**0.779**

It is seen from Table 6 that after the matrix development of rotated components with its saturations based on each indicator of the first component (factors), four variables are grouped into the first component that we will name as:

- **Existence of real attitudes in accordance with knowledge and action.**

It is seen from Table 7 that after the matrix development of rotated components with its saturations based on each indicator of the second component (factors), also four variables are grouped into the second component that we will name as:

- **Creativity as an example to the fo-llowers for not giving up the set objective.**

Table 7 *Matrix of rotated components with its saturations based on each indicator of the second component*

Indicators	Second component
1 The leader in my organization provides the greatest contribution in creating an organizational culture and demonstrates how employees should behave in terms of preservation the natural resources	**0.508**
2. The leader in my organization directs followers to use resources respecting the principles of savings and host behavior	**0.654**
3. The leader in my organization, by his own example, demonstrates the use of resources, respecting the principles of savings and host behavior	**0.772**
4. The leader in my organization creates a desirable way for others to revitalize the values and reliability of the principles of preservation the natural resources	**0.729**
5. In my organization, the leader nurtures values in terms of preservation the natural resources	**0.606**
6. The leader in my organization shows the conformity of my beliefs and actions regarding the creation of an organizational culture aimed at preservation the natural resources	**0.282**
7. Employees in the organization guided by the action of the leader align their behavior towards the conservation of natural resources	**0.284**
8. My leader possesses the competencies necessary for creating an organization that in its focus has the preservation of natural resources	**0.216**
9. The leader in my organization, with his attitudes and behaviors, has an impact on raising the environmental awareness of employees	**0.093**
10. The leader in my organization realistically sees reality, assesses the current situation of reality, and makes a decision in a direction of preserving natural resources	**-0.097**

CONCLUSION

Leadership becomes a significant topic in the organizational theory and a necessary factor for the success of any business endeavor. Leader in the organization plays a significant role reflected through: determining and realizing goals, motivating and supporting the followers towards achieving goals, supporting unity and empowering group values. Leaders always strive to work within the framework of the roles that require change, while maintaining continuity in meeting the needs of constituents or stakeholders (stakeholders).

Based on the conducted research, it can be concluded that the employees in the organization are always guided by the actions of their leader, and on the case of the organizations that participated in this survey, the employees permanently align their behavior in a direction of preservation the natural resources. Leaders in such organizations that are focused on preservation the natural resources must possess the competences necessary for creating such organizations with a focus on preserving natural resources. By its attitudes and behavior, the leader has an impact on raising the environmental awareness of employees. Therefore, the leader must always realistically see reality, assess the situation before making any decision, and the decision should be directed towards the preservation of natural resources. The leader in the specific organizations directs followers towards using of resources, respecting the principles of savings and host behavior. Therefore, on a personal example, he must always demonstrate this host behavior because it creates a desirable way for others to revitalize the values and reliability of the principles of preservation the natural resources. Naturally, the leader would have to preserve, after creating the desired paths, for as long a period as possible and to nourish the values that lead to the preservation of natural resources.

Also, research shows that a leader in the organization mainly deals with people, their behavior and knowledge, their potentials and abilities and their stimuli and results. The leader directs his communication towards rational use of resources, and when employees give an opinion, the leader always asks and what others think. The leader in the organization actively communicates and shares information on the rationalization of resource use and always consults with the followers and provides guidance on resource preservation. Employees in the organization give an open and honest feedback to each other, making it easier for the leader to cooperate with all stakeholders in order to meet the mutual needs of organization. Aware of its role and importance, the leader always has an influence on an organizational culture that is focused on preservation the natural resources and always seeks for ideas and opinions that are not always in a line with his personal, in that way he establishes the values that strengthen and support the business ideas.

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Zoran Dragičević, Saša Bošnjak***

DIGITAL TRANSFORMATION IN THE MINING ENTERPRISE: THE EMPIRICAL STUDY

Abstract

Digital transformation (DT), as a result of digitalization process, rapidly and fundamentally changes the business entities and organizations, which involves a radical review of the use of technology to change the strategy, value streams, operations, and business models, with a significant impact on customers, business partners and employees. Enterprises are launching the DT initiatives examining the wishes and needs of customers and creating operational models that use the new opportunities to increase competitiveness. In this regard, the key responses to changes in the digital era are the reshaping customer value propositions and reconfiguration the operation model. In the basic industries, where the product is mainly a raw material, such as the mining industry, the companies launch the DT initiative to improve operations. The operating model is adjusted so that user preferences and expectations affect each activity in the value chain. This requires the integration of business activities and the optimization of the way to manage and track data related to each key activity in the value chain. However, although there is a great potential for future growth, the current state of digital transformation in mining is at a low level. Therefore, the question arises as to how to launch and effectively realize the DT initiative for improvement the operational model in the mining enterprise. This paper, in general, discusses the importance of the DT, with particular reference to the key aspects of the DT, challenges and success factors in the mining industry. As a result of research, the key aspects of realization the DT initiative for improving the operational model in the large, diversified mining enterprise are presented; challenges and success factors are identified and classified in a given context. The complete research efforts, as well as the obtained results, are dedicated to the role and significance of the DT phenomenon in the mining industry, with the goal of wider and more effective use the digital technologies in the mining enterprises.

Keywords*: digital transformation, challenges, success factors, mining, empirical study*

1 INTRODUCTION

Digital technologies, such as mobile, cloud, big data, analytics, sensors, IoT (Internet of Things) and artificial intelligence (AI), with the possibility of combining them in innovative ways, exponentially accelerate the progress through the digitalization process with a great impact on business and society [1]. Considering that DT, as a result of the digitalization process, permeates all aspects of society, it may be defined as a "*business model driven by the changes associated with the application of digital technology in all aspects of human society*" [2].

The DT involves an integration of digital technologies in all areas of business, whereby at a high speed and thoroughly changes the way in which an organization carries out its business operations and delivers value to customers.

* Company *Boksit, Milići, Republic of Srpska, Bosnia & Herzegovina*
** *University of Novi Sad, Faculty of Economics, Subotica, Serbia*

Companies implement the DT initiative changing the way they work, learn, communicate and collaborate, in order to 1) identify more easily the values relevant to customers - *what is being offered*, and 2) redesign the business and operational models on the basis of new possibilities - *how it is delivered*, all with the aim of increasing competitiveness [3,4,5,6].

Although the DT can be realized using different digital technologies in different scenarios, it has more implications for the business transformation of the enterprise than on the technological infrastructure itself, changing business processes and business models, which has a significant impact on organizational culture and employees [7,8,9,10].

In order to successfully respond to the market changes, the companies radically reconsider the use of digital technology to improve the customer experience, operational processes, business models and business strategies [6,9,11,12,13,14,15,16], focusing on one of the aforementioned areas and applying the specific initiatives, wherein some industries much more rapidly find ways to implement the DT initiative than in others [17]. However, each enterprise must individually find the best way for the DT, depending on its strategic goals, industrial context, competitive pressure, and customer expectations. Also, there are unique combinations of individual industries and their contribution to national economies in different countries, and as a result, the DT has different characteristics, while digital strategies have different objectives, even when looking at the same industries in different parts of the world [3,18].

In basic industries, that offer physical products, semi-products or raw materials, such as mining, DT generally starts with initiatives that aim to improve operations, i.e. internal processes. The operating model is aligned with customer preferences and requirements so that it affects each activity in the value chain. This requires the integration of all business activities in the value chain and the optimization of the way in which these activities are monitored and managed [3].

Great expectations are when it comes to the future of digitalization in mining. In this regard, it is expected that the application and connection of devices and things containing electronics, sensors, and software for mutual communication and data exchange over the Internet or in some other way will be of special importance [19].

Among the various potential benefits of digital transformation in mining, the possibilities for using digital technologies in improving the quality management process, maximizing productivity, improving working conditions and product quality are highlighted [20]. In all this, it is necessary to avoid traps, such as lack of resources, knowledge, cooperation, lack of awareness about the importance of digitalization and its underestimation [21], on the one hand, and so-called productivity paradox, that is, the situation of non-selective application of new technologies which leads to increased complexity and productivity decline, on the other hand [22].

Existing findings from the relevant literature indicate the great potential and low level of the current state of the DT in the mining industry. Therefore, the question arises as to how to initiate and effectively implement the DT initiative in the mining enterprise. In this regard, having in mind the observed lack of DT research in the mining industry, this paper aims to better understand key aspects related to the initiation and realization of the DT initiative in the mining industry, along with identifying challenges and success factors in a given context. For this purpose, empirical research was conducted on the implementation of the DT initiative in the mining enterprise.

The rest of the work is structured as follows: Section 2 presents the prevailing attitudes in the relevant literature, and Section 3 defines research questions and describes the applied research method. In Section 4, the results of the conducted empirical research - a descriptive and explorative case study of the implementation of the DT initiative in the mining enterprise - were presented. Section 5 specifies the research limitations, and finally, conclusions are drawn and future works delineated.

2 RELATED WORK

DT is a complex process that is difficult to understand [9, 22] and is viewed differently in different companies and industries due to different visions, stakeholders, values and levels of maturity [14], as well as due to differences in customer expectations and degree of development of existing systems. Therefore, every industry, under the pressure of inevitable changes applies different ways of implementing DT [3].

Accordingly, there is no one, generally accepted definition of the DT. For Raab et al. [7] the DT is more a matter of business transformation of the entire enterprise and less technology. Westerman et al. [11] define the DT as "*the use of technology to radically improve performance or reach of enterprises*", while Fitzgerald & Kruschwitz [12] see the DT as the use of the new digital technologies (social networks, mobile, analytics, cloud, and IoT, also known under the acronym SMACIT) to enable a significant business improvement - enhancing customer experience, streamlining operations or creating new business models. For Konde & Tundalwar [4], DT is the integration of digital technologies in all business segments, which fundamentally changes the way of working and delivering values to customers. That is partly in line with Osmundsen et al. [15] attitude that the DT is the result of digitalization or digital innovation process, which "*enable major changes to how business is conducted, leading to a significant transformation of an organization or an entire industry*".

On the other hand, Liere-Netheler et al. [9] observe a broader context and define the DT as a „*metamorphosis that is based on the intensive combination of present and future technologies that will change the paradigm of how value-generating processes in and between enterprises as well as with customers take place. DT will affect business models and corporate strategies.*".

2.1 Challenges of DT

The DT is a complex venture that brings with it significant challenges, so several authors have been dealing with challenges of DT in different industries and organizations. Starting from the point that the key for successful DT is a review of the vision and initiation of changes in the business model, Westerman et al. [11] argue that the most significant challenges are related to the management and employees, not just the technology, regardless of whether the new or old technologies are applied. They classify challenges by implementation phases on: *initiation challenges* (lack of impetus, regulation and reputation, unclear business case), *execution challenges* (missing skills, culture issues, ineffective IT) and *governance challenges* (incremental vision and coordination issues). Depending on whether DT has the focus on reconfiguring customer value or customer modeling, Berman [3] sees the key challenges as monetization of the new proposals in offering value to the customers or defining business requirements to improve operations.

For Earley [22], challenge is not only to recognize innovative technology, but also how to apply it in an existing business model, taking into account increase in the level of additional costs for the new tools and infrastructure, while avoiding the so-called *productivity paradox* - a situation that the new technologies, in the given context, increase complexity to such an extent that reduces productivity. In this regard, given the complexity of DT, Early, as a big challenge, sees the making of the right decisions regarding the adoption of new technologies.

Emphasizing the importance and value of data in Industry 4.0, De Carolis et al. [23], as the most important challenges for traditional manufacturing companies, see the creation of awareness of the added value that DT brings, and then managing large amounts of data and information. In connection with the growing significance of data Erjavec et al. [8] note that the biggest challenge for digitization is people's problems due to the adoption of new technologies, and as an additional challenge, they note a lack of flexibility in the existing IT infrastructure, especially when it comes to collecting and processing unstructured data from different sources, and connecting existing systems with a new front-end systems.

On the other hand, Nahrkhalaji et al. [14], exploring non-profit organizations, notes that along with organizational, strategic and managerial challenges, a critical challenge in the digitization process is the change in the organization's culture, since the engagement of new IT staff and the CDO (Chief Digital Officer) does not guarantee success. Wolf et al. [21] as the main challenges, or obstacles for the DT success, see isolated thinking, poor knowledge management, underestimation of digitalization, lack of knowledge and resources, and lack of awareness about the importance of digitalization.

2.2 Challenges of DT in the mining industry

The mining industry has been confronted with the generic challenges since its emergence, such as an increasingly old workforce, high operating costs, a reduction in the quality of ore deposits and difficult working environment. The DT is a significant initiative that can contribute to over coming these challenges, but it requires hard work, investment, wisdom and patience [6]. Gao et al. [6] have observed that while the DT accelerated changes, many companies are not agile enough to respond to these changes, while those who fail to recognize this opportunity are faced with different challenges in an attempt to apply complementary improvements competitively in different parts of the enterprise. In this regard, they identify the following challenges in terms of how companies in the metal and mining industry are able to take advantage of opportunities to improve business operations using digital technologies: *lack of competencies* (unwillingness for radical change, lack of staff, commitment and investment), *goal ambiguity* (obsolete skills and governance model, unclear expectations and scope of change, lack of focus), *technological constraints* (poor connectivity, cyber threats, lack of the IoT standards, inapplicability or immaturity of technologies, redundancy due to mistrust) and *external constraints* (complex operating environment, safety, legislation, social responsibility).

Exploring global trends in the mining industry, Deloitte [24] said in its annual report that the lack of staff in the mining industry with digital knowledge and competencies undermines the digitalization process, and therefore, the challenge is to attract digitally competent staff from other industries.

Ernst & Young [25], in their article dedicated to DT in mining, emphasize the importance of the so-called *digital disconnection*, as a gap between the potentials of digital transformation and lack of data and knowledge of successful implementation examples, in order to overcome the growing challenges of increasing productivity, access to capital, increasing transparency, maintaining licenses (concessions) and cybersecurity.

2.3 Success factors of DT

Several researchers dealt with the factors of success of digital transformation, both from the perspective of the organization, as well as from the perspective of customers [16]. While Berman [3] argues that companies with a cohesive plan for the integration of digital and physical components of operations can successfully transform their business model, for Westerman et al. [17] leadership capabilities are the key to a successful implementation of DT, i.e. to convert a digital investment into a digital asset. This is supported by Earley [22], for which the leadership implies developing a viable vision of digital experience, whether for internal or external users. In doing so, the digital experience must influence the content and functionality adjustment to the current needs of users. In all this, the data play a crucial role, so organizations need to manage data and information as a strategic resource.

Khan [26] as a key factor of DT sees leadership capabilities for successful operationalization and implementation of DT, whereby framing the digital challenge, focusing investment, mobilizing the organization (creating a sense of urgency) and sustaining the transition is crucial for operational leadership. Sebastian et al. [27] identify three main elements for a successful DT: a digital strategy - that defines a value proposition based on digital technologies, an operational backbone - that facilitate operational excellence and a digital service platform - which enables rapid innovation and responsiveness to new market opportunities.

Bearing in mind the need to optimize the process applying the tools, concepts and, most importantly, involving people for de Sousa et al. [20] it is crucial to raise awareness and training, both the managers and the employees. This may contribute to the easy access to data and reports, and monitoring in real time. For Erjavec et al. [8] the key for a successful DT is a cultural change. Pflaum & Gölzer [10] agrees with that, emphasizing the importance of creating a digital enterprise vision, matching operational goals, and see DT as a race with time, where speed depends on the existence of a digital department and a supporting business ecosystem.

According to Nahrkhalaji et al. [14], in order to raise the level of maturity, in the context of DT, organizations must review existing business models, improve the decision-making process, find the right leadership, solve the complexity and insecurity imposed by new models of competition and collaboration, and engage customers. The DT is a combination of old and new technologies, a revolution and an evolution, therefore Wolf et al. [21] as the key success factors of the DT sees the creation of innovative areas, linking across the boundaries of the organization, the application of agile methods, the motivation to try new things and active management. In addition to the initiator, goals and implycations of DT, Osmundsen et al. [15] identify the following success factors: supportive and agile organizational culture, good management of transformation activities, knowledge management, participation of managers and employees, enhancement of information system capabilities, development of dynamic capabilities, development of digital business strategy, business compliance and information system. Liere-Netheler et al. [9] propose a working framework for a successful DT, while various researchers have dealt with the success factors of individual technologies or aspects of DT, such as the user experience [16, 28,29,30].

2.4 Success factors of DT in the mining industry

Deloitte [24] notes that in mining there are changes in the way in which value creation is observed, how well a enterprise extracts resources, to how the enterprise uses the information to optimize production, reduce costs, increase efficiency and improve security. With this in mind, Deloitte [24] claims that the success of DT does not depend on the adoption of the latest applications and technologies that will continue to evolve, but from integrating the digital thinking into the very center of business strategy and business practice in order to change the way corporate decision-making. This requires the evolution of leadership competencies and a clear vision of how a future, digital mine can transform the processes of realization, information flow, and support processes.

Starting from the fact that the increase in productivity is one of the key goals in mining, in order to get DT in the right way Ernst & Young [25] emphasizes the importance of understanding 3 key elements: harmonizing the DT and productivity agenda, *end-to-end* approach to business (from the markets to mines) and a focus on eliminating waste, especially when it comes to the influence of leadership and organizational culture.

Although several authors dealt with the identification and research of the challenges and success factors of DT, in general, there is a lack of research in the mining industry. Therefore, the need for further research on the DT phenomenon in the mining industry is evident, in order to overcome the gap of digital disconnection, validate existing knowledge and identify new, in different situational contexts.

3 METHODOLOGY

The aim of research is a better understanding of the key aspects regarding the initiation and implementation of DT initiatives in the mining industry, as well as identifying the challenges and success factors in this context. In this respect, defined the research questions are:

RQ1: How to initiate and realize the DT initiative in the mining enterprise?

RQ2: What are the challenges of DT in the mining enterprise?

RQ3: What are the success factors of DT in the mining enterprise?

In order to answer the research questions, empirical research was conducted in a large diversified mining enterprise – Company Boksit. For the needs of research, the case of development and implementation of the analytical business software system for organization unit (OU) Surface mines is selected (hereinafter Mining Portal). OU Surface mines is part of the Mining division and performs surface exploration of ore sites at several remote locations, with different exploitation conditions, different types and quality of ore resources.

The main purpose of the Mining Portal was to support the improvement of the operational model, i.e. improvement of key business processes in the value chain related to surface exploitation of ore sites. The development and implementation of the Mining Portal implied the application of various digital technologies, such as advanced analytics, cloud, and mobile, as well as integration with the existing ERP system and external data sources.

Combining a descriptive and explorative case study provides a better understanding of the problems in its natural environment and defining a framework for further research [31]. Therefore, the descriptive case study was first applied in the realization of the research, in order to describe the key aspects regarding the initiation and the realization of the DT initiative for the improvement of the operational model of OU Surface mines, and in order to better understand the context, motives and drivers, the purpose and objectives, the results achieved, advantages and disadvantages of the DT initiative, as well as opportunities to launch future DT initiatives.

Subsequently, in the same context, an explorative case study was carried out to identify the challenges, success factors, and the possibilities for further research. Various sources, including documents, an implemented software system, and semi-structured interviews, were used to collect data and to better understand how key correspondents see the research problem.

In order to examine the problem of research for both, business and IT perspectives, a semi-structured interview was conducted with the key persons responsible for implementing the DT initiative. From the business part, this was the Technical manager of surface mines (hereinafter Technical Manager), and from the IT part of the enterprise, one of the authors, a former CIO (hereinafter ex CIO).

KWIC (Key Word in Context), qualitative analysis, and thematic analysis were used for selection, extraction, coding, and analysis of empirical data. Qualitative analysis is used to analyze data, because it supports a more detailed description of the observed phenomenon, while qualitative data allow for better insight into the complex processes [32]. The obtained results were discussed and compared with the existing knowledge and results of similar research, both in the mining and in other industries.

Bearing in mind that one of the authors (ex CIO) was actively involved in the realization of the DT initiative, as a key IT member, in order to reduce the risk of bias, the research was carried out by two authors.

4 RESULTS AND DISCUSSION

In accordance with the described research method, the results of the descriptive case study are presented, which describe key aspects of the DT initiative for the improvement of the operational model in the mining enterprise by the development and implementation of the Mining Portal for OU Surface mines, as the most important part of the Mining division in the Company Boksit. In addition, the results of an explorative case study are presented, which identify and discuss the challenges and success factors of the DT initiative realization in a given context.

4.1 Key aspects of the DT initiative in the mining enterprise

In this section, the results of a descriptive case study are presented in order to get an answer to the *RQ1: How to initiate and realize the DT initiative in the mining enterprise?*

The presented results of the descriptive case study describe the context, motivation and initiators, the purpose and objectives, the results of the DT initiative in the form of the implemented functionalities of the Mining Portal, and the advantages and disadvantages. Finally, identified opportunities for future DT initiatives are presented. The results obtained were discussed on the basis of existing knowledge in the relevant literature.

Context

The Company Boksit was founded in 1959 as an enterprise for bauxite ore exploitation. Other activities, such as traffic, construction, mechanical and electrical engineering, catering and tourism, commercial activities, food production, furniture production, health care, etc., have been successfully developed by a continuous growth and development from the bauxite ore industry. As a threefold winner of the most successful enterprise in the Republic of Srpska, it is one of the most important companies in the Republic of Srpska and Bosnia & Herzegovina. In its 60-year long mining tradition, over 31 million tons of bauxite ore has been produced, more than 195 million tons of waste material has been removed, and more than 3 million tons of nonmetallic raw materials (limestone, quartz sand) have been produced. Annual production of surface mines is about 300,000 t of bauxite ore and 1.350 million m^3 of waste removed, with the engagement of own and subcontractor's equipment. In order to plan, organize, implement and control business processes, ERP and QMS (Quality Management System) are used, while all key locations are connected to the LAN/WAN network [www.ad-boksit.com].

Motivation and initiator of the DT initiative

Key motivation factors for initiating the DT initiative were growing demands for information and analyzes related to the implementation of the operational process of surface exploitation of bauxite ore, in all key phases and activities, in order to improve the operational model, to establish better control, and to make faster, more effective and efficient decisions at operational, tactical and strategic levels. The required information and analyzes mostly relate to the indicators of the results and activities of the surface exploitation process, as well as the indicators of the associated processes from value chain, such as the stock of products, essential materials and raw materials, the availability of equipment, the status of the realization of current purchases, etc.

The initiator of DT in the mining sector was Technical Manager, for whom digitization is a "*data revival, which in digital form can be used in a variety of ways, for various purposes, in a much faster and simpler way*".

Problems of the previous situation were caused by the fact that the records related to the realization of the production and maintenance process on the surface mines were guided in paper form, because due to the limitations of the existing ER system, unlike other business processes (Purchase, Inventory, Sales, HR, Financials...), it could not be adequately parameterized and customized to support the production of bauxite ore and the maintenance of mining machinery, due to the specific nature and complexity of the process. For this reason, no automated analytical processing of operational data from the ore production process was possible, but everything was done manually. It was time-consuming and error-prone, and as a result "*we needed at least 5 to 7 days to produce a monthly or annual report... it was not possible to obtain timely, accurate and reliable information*" (Technical Manager).

Purpose and goals of the DT initiative

The focus of improvement was the operational model, that is, the key processes of realization in the value chain related to the surface exploitation of the bauxite ore, but indirectly in the focus was the customer, having in mind that *"if timely information regarding the quality of individual deposits is available, as well as information that influence the timely taking of measures and making decisions from which parts of the deposit, when and in what quantities they are to be exploited, all together influence the dynamics of delivery, price and quality of the goods delivered to the customer"* (Technical Manager).

The main purpose of the DT initiative was to improve the existing operational model enabling a faster access to information and better information flow, faster analysis and decision making, in order to achieve the goals of increasing productivity, reducing costs, better control and preventing misuse. The realization of the stated goals should have enabled the development and implementation of business software for *"fast and reliable recording of data from realized business activities, and quick reporting for different time periods and different analytics"* (Technical Manager).

Results of the DT initiative

Bearing in mind the shortcomings of the existing ERP system, the focus has been on the development of the Mining Portal - analytical business software system "*which will work exactly as we need it and which will serve its purpose*" (Technical Manager).

A so-called *lean* approach is applied, the essence of which is the focus on data and information that has the highest value for the user in a given context. In this regard, the aim was to offer the content for which the user is authorized, which has significant value for that user, which the user will find and use quickly and with minimal effort and which will be presented by clearly transmitting messages or information in a given context.

The Mining Portal is realized using the iterative-incremental approach for different segments of processes, phases, and activities, with a special focus on key activities of the highest priority, because "*e.g. the activities of loading and transport of ore and waste have had greater relevance than waste disposal*" (Technical Manager).

Figure 1 *Mining Portal*

The Mining Portal automatically adjusts the presentation depending on the user device (Figure 1) to each user, according to the privileges, providing up-to-date, accurate and clear key information on different levels of detail, which are essential for effective and efficient operational decision-making and management.

Information and data are available and accessible on the mobile phone anytime, anywhere, supporting the continuous improvement of the operations model, so as to "*support better visibility of business processes and promotes operational agility and flexibility, resulting in increased productivity and reduced costs*" (ex CIO). In order to enable all this, the following functionalities are implemented:

- <u>Dashboards</u> - as a set of several independent, personalized segments (web parts) that provide key information from internal and external sources, the purpose of which is to present key information, goals, results, time series (trends) and status at the highest level realization of defined goals. Static segments provide information in the form of a summary report, while analytical segments provide more detailed analytics and drill-down options to "*combine all-in-one, intuitive presentations (dashboard) with drill-down options suitable for display on mobile devices to increase the visibility of process*" (ex CIO).
- <u>Digitization of business data</u> - enabling effective CRUD (create, read, update and delete) of data into the database and/or existing ERP, because "*efficient data digitization, with applying the rules for automated data quality control, increase the potential for their reuse*" (ex CIO).

- Performance management - various views and analytical processing of KPIs (Key Performance Indicator) provide a detailed analytical insight into the values or ratings of indicators at different levels of aggregation, because "*setting measurable targets for KPIs, monitoring, reporting and control contribute to the increase in agility and sense of urgency*" (ex CIO).
- On - line analytical processing (OLAP) - to quickly generate complex reports (Web pivot tables), support projection and restriction (slice & dice), aggregation, sorting and analyzing large amounts of data, independently of their original layout by simply dimensions and facts drag and-drop to the appropriate positions in the settings form. On-line pivot reporting, multi-dimensional calculations, and drill-down across different analytics "*increase efficiency and flexibility, in the sense that the same data set can easily display in many different ways*" (ex CIO).
- Automatization of scheduled reporting - periodically generating and sending pre-defined reports, alarms and notifications by e-mail, because "*automation of reporting directly contributes to increasing productivity and reducing costs*" (ex CIO).
- Integration with other systems – like ERP and sources of meteorological data, in order to "*maximize the value and usability of the data from legacy systems*" (ex CIO).

Advantages and disadvantages of the implemented DT initiative

The key advantage of the realized DT initiative is the possibility of simple and fast recording, control and integration of data, and the provision of timely and accurate information, which are at any time, and almost everywhere, available through the mobile phone, based on which decisions and responses are made faster in changing business conditions. High level of automation of data control reduces the probability of occurrence of errors and enables their easier detection and correction during entering of data. The results of the DT significantly influenced the improvement of the operational model, i.e. the way the business process was realized, for example, "*it was noticed that the drilling system does not produce the expected results, which were directly demonstrated by analyzes based on data related to the effects, consumption, and availability of machinery*" (Technical Manager). Even if the software is custom-made, due to delays in documentation delivery and recording them on a daily basis, the effects are minimized to monitor the performance and the indicators at the daily level. Enabling the recording of data closer to the source of origin would contribute to solving this problem, "*e.g. machine operators can use a mobile phone to record data*" (Technical Manager, ex CIO). Although from a technical point of view, such a possibility already exists, legislation requires compulsory filling of worksheets in writing. This means that the work of the operators would be doubled when it comes to recording data (paper and electronic forms).

Identified opportunities for the future DT initiatives

Future DT initiatives could go towards greater application of sensors, IoTs and automated data readings from such devices in real time, e.g. "*it would be a good thing to detect and read sudden changes in machine's fuel level in real time...or the use of devices that measure idle work time to make savings and prevent misuse of machines whose effect is measured by motorcycle hours, e.g. bulldozer*" (Technical Manager).

New machines have some of the above-mentioned options, but the problem is the high price and the restriction of user access to the machine's data and vendor lock-in. There are also possibilities for the application of artificial intelligence (AI) techniques "*in order to deepen the analysis or to obtain new knowledge from a large amount of data*" (Technical Manager, ex CIO).

Discussion

The results of the research confirm the thesis that in basic industries, such as mining, DT starts focusing on the improvement of the operational model [3,18]. The results also indicate the need for a proactive approach, due to growing expectations for increasing the efficiency of the process [21], in order to reduce costs, increase productivity and employee safety [18,19].

Though encouraged by growing information requests from top management, it can be noticed that the DT initiative was initiated and guided by a technical manager, i.e. from middle management level, with the emphasis on the equally important role of a key IT member, what is a significantly different position relative to Westerman et al. [11] that a successful DT initiative must be guided by the top management. On the other hand, when it comes to the problems of the existing operational model, there is a noticeable need to eliminate waste, delays and insufficient flexibility in the design, structure, and implementation of operational processes, which is in line with Deloitte's standpoint [24].

Although, in general, there are different expectations of DT at different levels of the organization [21], the results point to the need to improve the operational model in order to achieve faster data access, advanced analytics, reporting and decision making in order to increase productivity, as a key operational risk in the industry mining [25], which is in line with Deloitte's standpoint [24]. In this way, the ability to respond to the changes quickly increases, by what Berghaus & Back calls "*digital readiness"* [33].

The developed and implemented analytical software system supports the realization of the stated goals because 1) it is based on cloud and mobile technologies [30, 13, 20, 18, 24], 2) enables automation of data capture, data control and integration of data from existing systems [8,9,20,24], and 3) provides advanced analytical processing and reporting [6, 8, 18, 20, 24] using personalized dashboards and OLAP tool.

Finally, although the realized DT initiative allows timely and accurate information to be obtained, it is not always possible to achieve up-to-date day-to-day reports due to various external constraints, such as the obligation to keep paper records, the limitation of access data to machine and vendor lock-in, communication restrictions on remote locations, etc. Regardless of all this, it can be noticed that the realized DT initiative creates a solid foundation and good preconditions for the wider use of digital technologies, such as different measurement and control sensors and/or IoT [6,10,18, 19,21,24] for more automation of data capture and real-time reporting, as well as the application of various methods and artificial intelligence techniques [8,24,34], such as, for example, machine learning. Overcoming mentioned restrictions can significantly accelerate this process.

4.2 The challenges of DT in the mining enterprise

This section presents the results of qualitative and thematic analysis to get the answer to the *RQ2: What are the challenges of DT in the mining enterprise?*

Identified challenges are grouped into four categories: operationalization of business strategy, change management, effective application of technologies and external constraints (Table 1).

Discussion

Implementation of changes in such a complex environment, such as mining, carries with it significant challenges. While Nahrkhalaji et al. [14] identify challenges, in terms of vision and strategy for the non-profit sector, the results of the research indicate that the most important challenges in implementing the DT initiative in mining are related to the effective operationalization of the business strategy. In this regard, the key challenges are not only related to ambiguous goals, as Gao et al. [6] claim, because even when there are clearly defined goals, a particular challenge is linking goals with essential information and data, their interdependence and prioritization, because "*the greatest challenge is to decide what data and information are essential and important, and what are not, and prioritize*" (Technical Manager). This challenge can be linked to the challenge of defining business requirements for the improvement of operations, identified by Berman [3].

Challenges related to change management were identified, of which the most important are employee participation and the need to improve their competencies, as well as good cooperation between different organizational units. It is in line with the results Gao et al. [6], who notice that even where there is a clear will to launch DT, organizations have a problem managing the changes, or Deloitte [24], who notice the lack of digital competence in the mining industry. According to the general classification given by Westerman et al. [11], these challenges can be categorized into the challenges of execution and governance.

Although the technological challenges are noticed and analyzed by several authors [6,8,11,22], the results of the research in particular point to the challenges related to the effective application of technology in the context of 1) increasing the demand for automation in all phases of data gathering, controlling, processing, reporting), 2) increasing the complexity of the process and, in particular, 3) preserving security through increased availability and rising cyber-threats. The importance of cyber threats in mining is also highlighted by Ernst & Young [25] and Gao et al. [6].

Finally, there are the challenges related to external constraints. Gao et al. [6] also saw the challenges caused by the complex operating environment and legal regulations. In addition, the un-covertness of all micro-locations with the signal of mobile telephony reduces the possibilities of networking and access to data in real time. Significant challenges are the limitations of business partners, especially considering the limitation of access to data on machines and vendor lock-in.

4.3 The success factors of DT in the mining enterprise

This section presents the results of qualitative data analysis in order to get the answer to the question of *RQ3: What are the success factors of the DT in the mining enterprise?*

The identified success factors are grouped into four categories: people, organizational culture, technological framework and institutional framework (Table 2).

Discussion

The results of the research indicate several different factors that have a significant impact on the success of the DT initiative in mining. The human factor is crucial, especially the key people from business and IT part who, with knowledge, persistence and dedication, must show agility, leadership and a clear vision, because *"there must be leadership from both sides, someone from the business side who knows what he wants to get, and someone from the IT side who knows how to achieve it"* (Technical Manager).

Results further support the assertion of many authors that, regardless of the type of activity, leadership skills are a key factor in the success of DT [17,22,26], and in that sense, Ernst & Young [25] and Deloitte [24] especially emphasize the importance of leadership in the mining industry.

Table 1 *The challenges of digital transformation in the mining enterprise*

Codes	Themes	Categories
- Increasing agility and flexibility at the operational level - Increasing demands for information and analysis - Identifying key information and data	Link business objectives with information and data	Operationalization of business strategy
- Interdependence of information and data - Prioritizing information by relevance	Interdependence and prioritization	
- Difficulties in coordination between the various business OU because of various objectives and priorities - Elimination of inefficiency in the work of other OU	Cooperation across organizational units borders	Change management
- Increasing demands for quality and timeliness of data from existing systems - Up-to-date gathering and recording of data on a daily basis - Accuracy and completeness of data - Lack of employee competence - Difficulties to find and hire good IT staff	Participation, competencies and experience of employees	
- Efficient control of the validity and quality of data - Integration of data from existing systems - Collect data from operational activities, including data from machines	Effective automation	Effective application of technologies
- Effective and efficient data entry - Effective reporting - Integration of existing and external data sources	Complexity of the process	
- Restrict access to data and information - Availability of information - anytime, anywhere	Security and availability	
- Duplication of data due to paper and electronic records	Legal constraints	External constraints
- Restricted access to data on the machines by the manufacturer - Vendor lock-in - Influence of subcontractors' short-term interests on the process	Business partners' constraints	
- Extreme working conditions (temperature, humidity, dust, mud) - Inaccessibility of the terrain	Environmental constraints	
- Non-coverage of all micro-locations by the signal of mobile telephony	Communication constraints	

Table 2 *The success factors of digital transformation in the mining enterprise*

Codes	Themes	Categories
- Engagement of key people from business and IT - Leadership from the business and IT side - Setting clear and achievable goals aligned with the business strategy	Leadership and a clear vision	People
- Knowledge, persistence and commitment of key people from business and IT - Fast delivery of functionality by IT and quick feedback from business users	Competence, commitment and agility	
- Timeliness in the recording of data on a daily basis - Intensive, direct communication and quick resolution of data discrepancies	Discipline and professionalism	Organizational culture
- Excellent communication between business and IT - Excellent coordination between business units	Communication and coordination	
- Good network infrastructure (LAN, WAN) - Private cloud	IT infrastructure	Technological framework
- Simplicity and speed of software usage - High degree of personalization and parameterization	User-tailored software solution	
- Availability and accessibility - Possibility of using mobile devices	Mobile-first, cloud-first approach	
- Gathering data as close to the source as possible - The early detection and elimination of data errors - Increasing the level of automation in the collection, recording and control of data	Speed and quality of data coverage	
- Eliminate the need for duplication of records - Application of digital technologies in order to increase safety and security	Legislation	Institutional framework

In direct relation with leadership is the organizational culture, which must support discipline and professionalism when it comes to tasks, with better communication and cooperation in all parts of the organization, especially between business and IT. These results are consistent with the prevailing attitudes, because Erjavec et al. [8], Pflaum & Gölzer [10] and Osmundsen et al. [15] emphasize the importance of organizational culture for success DT, while Ernst & Young [24] emphasize its importance in the mining companies. Thereby, it is necessary to have in mind complex inter-relationship between the organizational structure and culture in mining enterprises [35].

Although Raab [7] in the DT process gives primacy to business transformation in relation to technology, bearing in mind the increasing importance of data as a strategic resource [23], the adoption of new, innovative technologies and their adequate application is one of the key success factors of the DT initiative. Research results point to the growing importance of IT infrastructure and technology that from the beginning supports the development and implementation of user-tailor-made software systems designed to work in cloud-based production environments and the use of mobile devices, supporting the so-called *mobile-first, cloud-first* approach [36].

In this regard, the role of technology for effective, automated data capture, quality control, storage and data processing is very important in order to receive important, useful information in a timely manner. Accordingly, the obtained results are somewhat in contradiction with Deloitte's position, because the success of DT in the mining industry may not depend on the adoption of the latest applications and technologies [24], but largely depends on the adequate application of technologies that have reached a sufficient maturity level.

Finally, in order to exploit the full potential of digital technology in the mining industry, it is necessary for the competent institutions to support the process of digitalization in mining in order to identify the possibilities for increasing the safety of employees, more efficient collection and storage of data related to the realization of the operational activities of mining companies.

5 RESEARCH LIMITATIONS

Three limitations of the research should be taken into account. First, the research is based on the case of the realization of the DT initiative in the context of the development of business software in one mining enterprise. For this reason, a descriptive case study was first realized, with the aim of better understanding the observed phenomenon in its natural environment by examining the context, motivation, initiators, purpose, goals, results, advantages and disadvantages of the DT initiative, followed by an explorative case study, in order to identify the challenges and success factors of the DT initiative in a given context and identify the possibilities for further research. Secondly, one of the authors has played a significant role in the implementation of the DT initiative at various positions in the Company Boksit. For this reason, more researchers are involved in planning and implementing research to reduce the risk of bias. Third, the research is based on qualitative data, so different qualitative data sources, including documents, realized analytical business software system, instructions, and semi-structured interviews were used for qualitative analysis.

CONCLUSIONS AND FUTURE WORK

Digital transformation in the mining industry is an irreversible process due to great opportunities, from increasing productivity to cost reduction [19]. However, regardless of the great potential for growth in the future [24], the current state of digital transformation in mining is at a rather low level [37].

This paper presents the results of an empirical research that describe and discuss key aspects related to the initiation and effective realization of the DT initiative in the mining enterprise, in the context of the development and implementation of the analytical business software system for the improvement of operations, as well as the identified challenges and success factors in a given context. The results of the conducted empirical research point to the inevitability of digitization and the significance of the DT initiative in the mining industry, whereby the effective realization of the DT initiative, such as the development and implementation of an analytical software system based on cloud and mobile technologies, can significantly contribute to the improvement of the operational model in the mining enterprise.

The results confirm that in the realization of the DT initiative mining enterprise faces significant challenges, which are clearly defined and classified. These challenges are not only *technology* related, given the complexity of processes, automation, and security, but also for the *operationalization of a business strategy*, in particular in linking goals with interdependent information and data. In addition, significant challenges are related with *change management*, especially when it comes to competencies and employee cooperation across organizational boundaries, and *external constraints* regarding relationships with business partners, extreme working environment, legal regulations, and communication issues.

In order to meet the challenges, success factors of the DT initiative in the mining enterprise have been identified. The identified success factors, above all, include *leadership capabilities and vision* of key people from business and IT, as a prerequisite for initiating and implementing the DT initiative, as well as participation, competence, commitment and agility of employees. However, success factors are not only related to people, but also to an *organizational culture* that, on the one hand, should promote professionalism and discipline, and on the other, good communication, cooperation and solidarity. In addition, an adequate *technology framework* based on the high-quality IT infrastructure, user-defined software solutions that are intrinsically linked to mobile and cloud technologies must be built to support fast and high-quality data coverage, processing and reporting. On the other hand, in order to exploit the full potential of digital technologies in the mining companies, an appropriate *institutional framework* is needed, which, with amendments to the legislation in the direction of greater support for the digitization process in mining, could become a catalyst for the digitization process in the mining industry.

Research contributions are a better understanding of the DT phenomenon, in general, and in particular in the context of the possibility of initiating and implementing the DT initiative in the mining industry, as well as identifying significant challenges and success factors of the DT initiative in mining companies. The results of the research will contribute to the discussion about the importance and necessity of DT, especially in the mining industry, in order to increase the efficiency of the process, reduce costs, and increase productivity and employees safety. Also, research results can help management and IT personnel in mining companies to more easily initiate and more effectively implement DT initiatives, specifically related to the improvement of the operational model.

Bearing in mind the small number of research on the subject of DT in mining, in order to overcome the gap of digital disconnection [25], additional empirical research is needed on examples of successful and unsuccessful implementations of the DT initiatives in the mining industry under conditions of surface and/or underground exploitation. Starting from the identified challenges and success factors, the possibilities of using digital technologies should be further explored in order to increase the level of automation in the coverage, control and archiving of data, as well as the possibilities for acquiring new knowledge by applying methods and techniques of AI for processing large amounts of data collected from operations.

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Bojan S. Đorđević[*], Gabrijela Popović[*], Dragan Milanović[**]

THE EFFECT OF MACROECONOMIC DETERMINANTS OF THE CHINESE ECONOMY ON THE COPPER PRICE MOVEMENTS[***]

Abstract

The main goal of this work is to identify and analyze the impact of the Chinese economy key determinants on the global market copper price movements. Our research is based on a multilinear regression analysis of the historical data of the time period from 2003 until 2017. The presented multilinear regression model constitutes the 4 (four) statistically most significant macroeconomic variables, that is, determinants of the Chinese economy, which are used for clarifying current trends and can predict the future movements of prices on the global copper market. Statistically significant determinants are the inflation in China, the Chinese export of goods and services, Chinese import of copper, and consumption of refined copper in China. Obtained results of the research show a dominant role of the demand factor and significant influence of the Chinese economy on the movements of the global copper price. At the same time, the results imply that movements of the copper price on the global market can be an indicator of the economic activities slowing down or speeding up, in the countries which are the major traders of this metal.

Keywords: *copper spot price, Chinese economy, macroeconomic factors, multiple linear regression*

INTRODUCTION

Copper, one of the most important industrial metals, is the third in use (after iron and aluminum) in many industrial sectors. Its use is mostly found in the electrical and electronics industry, construction, energy, machinery and transport industry. It is unavoidable in the production of components for transmission systems of electrical energy and telecommunications, heating and cooling systems, automobile and truck systems. For example, the average car contains 1.5 km of copper wires, or 20-45 kg of copper in hybrid and electric vehicles (EV) vehicles [4]. Although copper has been exploited and used for more than 10,000 years, the new uses are being discovered every day due to increasing urbanization and demands of the global community for the use of renewable resources and environmental protection (reduction of the GHG emissions) [5,6].

Copper is now found in every built object, primarily because of its use in the electro and hydro-installations. The demand for this metal is increasingly dependent on the stability of the construction industry, the realization of infrastructure projects and the state of the real estate market. According to the latest data, the construction industry accounts for more than 35% of the total

[*] *Faculty of Management Zaječar, Park šuma Kraljevica, Zaječar, e-mail: bojan.djordjevic@fmz.edu.rs*
[**] *Mining and Metallurgy Institute Bor*
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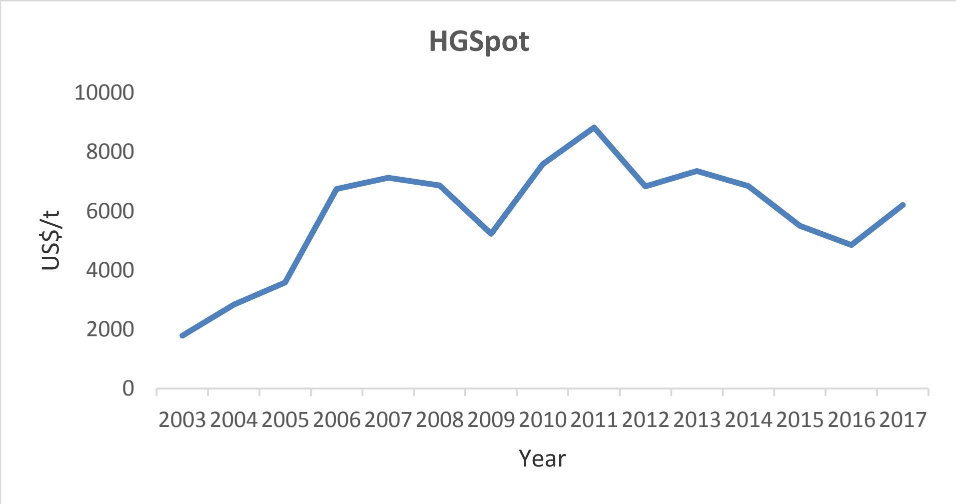
copper consumption world wide. Namely, the copper prices dropped drastically at the end of 2008, at the height of the financial crisis and collapse of the real estate market (at least US $ 1.26/lb on the Chicago Mercantile Exchange - CME and $ 2.777/t on the London Stock Exchange - LME). This connection with construction and real estate sales showed that the price of copper during the recession during the period 2008-2009 had a high level of volatility, unlike the prices of other metals, gold and silver. Copper prices at the end of 2010 and at the beginning of 2011 were growing significantly, where in 2011 they reached their historical maximum of US $ 4.62/lb and US $ 10,182/t (see Figure 1).



Source: Calculation of the authors on the basis of data from LME

Figure 1 *Movement of the average annual spot price of copper on LME in the period 2003-2017 (US $/t)*

The issue that for decades has attracted the attention of all participants in the stock markets is how and in what way to predict the movement of prices of stock exchange goods. In theory and practice, there are different approaches for analyzing the market factors and predicting the prices of marketable materials and stock exchanges. The most common are the two approaches - fundamental and technical analysis, which today are the basic methods of many analysts and investors. Fundamental analysts (the so-called fundamentalists) try to explain and predict the movement of prices analyzing the economic, political and social factors of the environment and their impact on supply and demand [4,5,6,7].

The basic principle of the fundamentalist is that any fundamental factor that leads to a reduction in supply, or increase in demand for a certain product, contributes to the rise in prices, and contrary [8,9]. According to Milenko Dželetović and Marko Milošević, the fundamental analysis starts from the macroeconomic factors, followed by the analysis of the economic environment, competitive groups and ultimately the company's performance analysis ("top to bottom" approach) [10]. As the forward prices (forwards, futures) are the future spot or prompt price, there is an increasing number of analyzes and models based on the movement of futures prices of stock markets [11,12,13].

The basic macrofundamental factors of the copper market can be divided into two basic groups: the factors on a demand side and factors on a supply side. On a demand side, it would be necessary to analyze the macroeconomic and financial performance of the economies of the largest copper consumers, as well as the consumption of copper (eg. in the US, China, India). On a supply side, the significant determinants should be sought in the economies of the largest producers and manufacturers of metal and copper ore (Chile, Peru, Australia, China), world copper reserves, metal stock exchanges, import and export of metal ore, production, trade and prices of substitute metal (such as aluminum),

Our commitment in this paper is to investigate the effect of the Chinese economy on the movement of copper prices. China today takes a significant part in the supply side, i.e. production and export of concentrates, as well as on the side of consumption and imports of refined copper in the world. The aim of this paper is to empirically identify and evaluate the key Chinese macroeconomic determinants of copper prices, and thus to provide a scientific contribution to the analysis of movement the copper prices on the world market. The subject of research is the connection between the global copper market and macroeconomic performance of the Chinese economy, the largest copper consumer in the world, in the period from 2003 to 2017. The research hypothesis, which we will try to prove, is: There is a significant statistical link and effect of the Chinese economy's determinants on movement the copper prices in the global market.

According to the above given, the work is structured in the following way: Section 2 presents the basic characteristics of the Chinese economy in the context of supply and consumption of copper; Section 3 presents the most significant results of the study on effect the macroeconomic factors on commodity prices, with a focus on metal prices (copper) and vice versa; Section 4 presents the methodology and design of our research; Section 5 presents the obtained results of a regression model with an estimate of the reliability and impartiality test of the obtained model; Section 6 gives a discussion of the research results, and Section 7 presents the conclusions.

CHINESE ECONOMY AND THE WORLD MARKET OF COPPER

Most of the world's copper supplies come from South America, especially from Peru and Chile (38.18% of the world's total production and 31.7% of world copper reserves in 2017). On the other hand, we have the US and China, two countries that are very large copper consumers. The stability of these two largest economies has a strong impact on supply and demand for almost all goods/products. Table 1 shows the countries of the largest copper producers in 2017.

The growth of global demand for copper, as one of the main factors (in addition to the production volume and reserves) continues to play a significant role in the formation of copper prices. Based on trends in copper demand, it is assumed that it is possible to draw the conclusions about the situation in the world economy, where the reduction in demand for copper indicates a decline in the industrial activity, and therefore a weakening of the global economy, which is currently taking place with the economy of China that has been recorded in recent years stagnation of economic growth and industrial production. Namely, in this context, the movement of the gross domestic product (GDP) of the countries of the largest producers and consumers of copper in the world - China, USA, Chile, India and Australia - which in the period of 2003-2015 recorded a significant growth in its GDP, industrial production, but also consumption. The United States and China, the world's largest copper consumers, each year have a combined US $ 32 trillion total of $ 32 trillion, accounting for 39.66% of the total global GDP. It should also be noted that the industrial sectors that use copper most are growing within their national and within global GDP (construction, electrical and electronic industries, telecommunications and transport).

Table 1 *World copper production and reserves in 2017 [4]**

Country	Production (Metric Tons)	Rank	Reserves	Rank
Australia	920,000	5	88,000	2
Canada	620,000	10	11,000	10
Chile	5,330,000	1	170,000	1
China	**1,860,000**	**3**	**27,000**	**6**
Congo	850,000	6	20,000	8
Indonesia	650,000	9	26,000	7
Mexico	750,000	8	46,000	4
Peru	2,390,000	2	81,000	3
USA	1,270,000	4	45,000	5
Zambia	755,000	7	20,000	9
Other countries	4,300,000		260,000	
Total	**19,700,000**		**790,000**	

Significant growth in China is seen as an importer of copper concentrates, where the refined copper dominates on the import and consumption side with over 35% of the world's total imports, with a consumption of 3.2 million tons in 2003 to 11 million tons in 2017. Lately, due to the need for sustainable business and development, as well as growing demands for decarbonisation, China appears as a significant consumer and importer of waste copper [5]. The basic Chinese sources of waste copper imports are concentrated in highly industrialized countries and regions that include the United States, Australia, Japan and the Netherlands. Total exports from these countries exceed 2 million tons of copper. The growth of import of waste copper is shown in Figure 2. The Chinese import areas for the treatment of waste copper are located in the megalithic region of Pearl River Delta in the Guangdong district, the Yangtze River delta and Tianjin, where over 88% of copper is processed in China.

The Chinese economy should be perceived as one of the three economic powers today, affecting not only the global economic trends with its policies (eg Eurasian Economic Union with Russia and the New Road of Silk), but also daily movements in prices of commodities, interest rates, currencies. In recent years, after remarkable growth, there has been a noticeable decline in Chinese investments in regions rich in energy products and ore. First of all, this refers to the investments in the countries of Africa (Libya, Nigeria, Angola, Zambia, Congo, Ethiopia, Kenya, Cameroon, etc.), which amount to about 60 billion US$. In African countries, the share of Chinese investment in energy products is 33% and in metals 11% of the total amount of investments. The largest volume of Chinese investments in Africa relates to the transport

* *Data from USGS Mineral Commodity Summaries (2018) Data from USGS Mineral Commodity Summaries (2018), USGS, USA*

sectors (33%) and energy (33%) [7]. On the other hand, China's policy limits the foreign investment in its country, especially when it comes to energy and mining enacting the legal acts (eg. Mineral Resources Policy, Foreign Investments Guidance Catalog) [8].

Figure 2 *Chinese import of waste copper in the period from 2003 to 2017 [5]*

In addition to the significant growth of traditional copper-based industries in China (construction, energy, telecommunications, electrical and electronics), an accelerated growth of the industry of transport vehicles, primarily electric vehicles (EV), has been evident in recent years. Namely, the vehicle industry (commercial and transport) in China is registering steady growth, where since 2003, when 4.5 million units of vehicles were produced, reached 29 million units in 2017, which makes up over 43% of the world's EV production [5]. In 2011, when the rapid evolution of the EV market in China began, vehicle sales rose from 8,159 units to 798,000 in 2017 [6]. According to many forecasts, the accelerated growth of the EV market is yet to come, with projected growth above 4% per year due to acelerated urbanization and requires decarbonisation, which in many cases can be a signal of rise in the price of copper and other metals in the global market, given limited resources.

REVIEW OF LITERATURE

There is a large number of research papers dealing with analyzes of the prices of copper prices, as well as long-term forecasts of future trends in the global market. We have highlighted the most important for us in the context of our research.

Franklin Fisher, Paul Kutner, and Martin Bailey represent the econometric model of the world copper market taking the period of research 1949-1966. The basic variables of their research are grouped on the supply side of primary and secondary copper (copper production in the US and Chile, world reserves) and on the demand side for copper (world consumption, consumption in the US) [5]. Jeffrey Hill and Michael Barrou examine the linkages and the impact of interest rates on the movement of 3M forward prices of non-ferrous metals at LME in the period 1965-1977, where interest rates were taken from 91 UK Treasury Bill and growth rate based on the OECD Index of Industrial Production [6]. Chu Suan Tan represents the supply and demand structure and forms the econometric model of the copper market of Western countries, taking into account macro and microeconomic factors analysis. The most important macroeconomic determinants are related to the countries of the largest producers and consumers of copper: GDP, industrial production, primary and secondary copper production, exports and imports of metal ore and refined copper, copper and stocks [7]. Volter Labis and Alfred Mezels examine the impact of changes in prices of the agricultural products, mineral resources and energy products on the basic macroeconomic indicators of selected developed countries (GDP, industrial product, exchange rate, employment, and balance of payments) for the period 1957-1986. They conclude that the price fluctuations have more than expected impact on economic stability and the performance of developed economies [8]. Xun Luo, using a fundamental analysis, is a model of the futures of the crude oil market. Analyzing spot and futures prices, balance of supply and demand, interest rates, geopolitical conditions and market expectations in the period 2003-2006, it can be concluded that on the basis of the application of the fundamental analysis, a model of forecasting the future prices on the energy market can be formed [9].

Antonio Gargano and Alan Timerman analyze the movement of the spot price index and the impact of macroeconomic and financial factors as a predictor. They conclude that in a long run, the industrial production and investment ratios considerably determine the price of commodity prices. Joe Victor Isler, Klaudia Rodriguez and Rafael Burdzak give understanding the future movements in metal prices, highlighting the synchronization of metal price movements with industrial cycles and industrial production [6]. Algita Miečinskiene and Indre Lapinskaite, using the multi-line regression model, represent a significant influence on the price of commodity prices on inflation (CPI) in Lithuania. Statistically significant determinants of inflation are the prices of cocoa, aluminum, copper, natural gas, coal and oil [7]. Ronald Rati and Hoakin Vespinians represent the interdependence of the M2 liquidity of the G3 and BRIC countries with the liquidity of commodity prices [8]. Eugi Kabwe and Wang Jiming analyze the world copper markets and point out the significant contribution to development the economies of China and India, increasing the world copper consumption, and thus increasing the price of this metal [9]. Tom van Gerve in his research identifies the six key fundamental indicators that determine the global copper market: warfare, technological development, economic boom, supply and demand, financial market and investment environment [10]. Jainbo Yang, Xin Li, and Kuini Liu use the ARIMA method to develop a dynamic model of predicting the copper consumption in China. Key determinants are the economic growth, consumption, urbanization, construction and transport [11].

METHODOLOGY OF RESEARCH

Our task is to form a multi-line regression model of effect the determinants of the Chinese economy on the movement of copper price, which can be represented by the following expression:

$$Y(HGSpot) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_n x_n + \varepsilon \qquad (1)$$

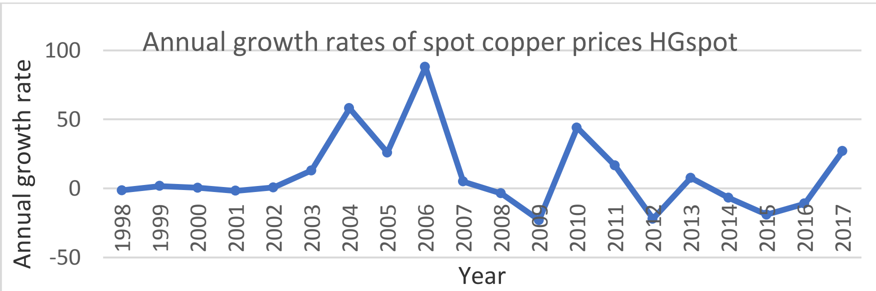
where:

- Y - market copper price (annual increase of copper spot prices) (HGSpot)
- α – model constant
- $\beta_1 \ldots . \beta_n$ – regression coefficient with independent model variables $(x_1 \ldots x_n)$
- $x_1 \ldots x_n$ – regressors, independent variables (annual rate of increase the Chinese economy determinants)
- ε – residuals of model

10 independent variables (macroeconomic determinants of the Chinese econo-

my) were selected in a time series of 20 years (observation), for which it is first necessary to assess the condition of a normal distribution of residuals. In the absence of a normal distribution of residuals, for all variables the logarithmic transformation will be applied. The next step is the formation of a multi-line regression model using the stepwise method, and then evaluation the standard model assumptions, i.e. reliability and impartiality of the model. The assessment of the reliability and impartiality of the model involves checking the model's standard assumptions using the following tests: multicolonarities (VIF, TOL), normal distribution of residuals (Shapiro-Wilk and Jarque-Bera test), homoskedasticity (Breusch-Pagan and White test) and autocorrelation (Durbin-Watson test). If it is determined that there is a pronounced autocorrelation of residuals, a Cohraine-Orcutt model for autocorrelation will be applied [5]. The statistical software SPSS 20 and XLStata Premium will be used for the analysis.

The research is based on an analysis of the annual increase in spot copper price (HGSpot) as the dependent variable *Y*, and the selected annual growth values of the determinant of the Chinese economy as independent variables *x*. The period taken for research is a time series of 20 years, i.e. from 1998 to 2017. Historical data are of the secondary character and are obtained from the official stock exchanges, global institutions and associations of producers and traders of metals (LME, CME - COMEX, WTO, US Geological Survey, World Bank ...), as well as from the specialized economics portals (Trading Economics, Macrotrends etc). The annual rates of growth the spot copper prices as dependent variables are shown in Figure 3, while a description of the independent variables of the Chinese economy is given in Table 2.



Source: Calculation of the authors on the basis of data from LME

Figure 3 *Movement of the annual growth rates (%) HGSpot (1998-2017)*

Table 2 *Variables of Chinese economy (X_1 -X_{10})*

	Variable	Unit
X1 CHNGDP	BDP of China	Annual growth%
X2 INFCHN	Inflation rate in China (measured CPI)	Annual growth%
X3 INDCHN	Industrial production of China	Annual growth%
X4 EXGSCHN	Chinese exports of goods and services	Annual growth%
X5 IMGSCHN	Chinese imports of goods and services	Annual growth%
X6 URBCHN	Urbanization rate of China	Annual growth%
X7 IMCOCHN	Chinese copper imports *	Annual growth%
X8 EXCOCHN	Chinese copper exports *	Annual growth%
X9 CRafCOCHN	Consumption of refined copper in China	Annual growth%
X10 CNY/USD	Exchange rate Juan / US dollar	Annual growth%

**Include concentrate, refined and waste copper*

CHECKING THE STANDARD MODELS AND RESULTS

There are two important empirical issues that need to be considered before we begin to build models, which are the issues of structural interruptions and exogenous shocks in the observed period, i.e. time series. First, as shown in Figure 3, there is a clear structural breakdown in the price range of copper in 2003/2004, when China became the largest net importer of copper. The basic dynamics in the copper market has changed at that point, the spot price increases dramatically and becomes much more unstable. Therefore, it may be necessary to focus on the next period for model design, as in order to generate reliable properties, it is necessary that models are based on the prevailing dynamics of the structural market. Secondly, there were major changes in the spot price of copper from mid-2008 to mid-2009, when the price fell sharply and then recovered rapidly. The collapse was caused by the global financial crisis, which resulted in a massive distribution of funds, as well as a decline in global trade. Then the demand for copper recovered after the stimulus package of the Chinese government, which significantly increased spending by investment in the infrastructure development and construction. Thus, we come up with three approaches to integrating variables and stationary testing. First, to include variables for the entire period 2003-2017; second, to exclude the period 2003-2004 with the included period from 2008 to 2009, in order to take into account the extraordinary event of the financial crisis, and the third, the period of the sample could be reduced to begin only in 2010. We have opted for another approach, i.e. time series for the period 2005-2017 (13 annual observations).

First, it is necessary to evaluate the normal distribution of dependent and explanatory variables, as a precondition for applying the least squares method and fitting the initial model using the Jarque-Bera test. In the absence of a normal distribution, a logarithmic transformation will be applied in order to stabilize the variance. The next step is to form a multi-line regression model using the stepwise method of multilinear regression, and then assess the reliability and impartiality of the model parameter estimates that involve checking standard assumptions by the following tests: multicolonarities (VIF, TOL), normal distribution of residuals (Shapiro-Wilk and Jarque-Bera test), homoskedasticity (Breusch-Pagan and White test) and autocorrelation (Durbin-Watson test). If it is determined that there is a pronounced autocorrelation of the residual, a Cohraine-Orcutt model for the removal of autocorrelation will be applied. For statistical analysis and final model formation, the statistical software SPSS 20 and XLStata Premium will be used.

Since the initial model variables did not satisfy the condition of the normal distribution of residuals, the logarithmic transformation was applied. After that, the distribution normalization was again performed where the results obtained are shown in Table 3.

After testing the normal values of the input variables, the stepwise method of multilinear regression was applied. The statistical parameters shown in Table 4 are obtained. We note that out of 10 input independent variables of the method, only 4 variables with a statistical significance of 0.05 (95%) were singled out. Parameters of the determination coefficient indicate that the model explains 86% (adj. R2 = 71.6%) of variation the spot copper price, which is extremely high. The information criteria of AIC and SBC, as well as the F statistics, tell us that the chosen model has the good prognostic properties, i.e. that it is good for predicting ($F (9.8) = 5.754$, $p<0.05$).

Table 3 *Results of normal distribution using the Jarque-Bera test*

Test of normal distribution (Jarque-Bera)						
JB (Critical value - $\chi 2$)	5.991465		*H0- Residuals have normal distribution*			
DF	2		*Ha – Residuals have not normal distribution*			
p-value(α)	> 0.05					
Variable	**DF**	**JB**	**p -value**			
logHGSPOT	2	1.885582	0.389539	*α>0.05*	*JB<χ2*	*H0*
logCHNGDP	2	2.226438	0.328501	*α>0.05*	*JB<χ2*	*H0*
logINFCHN	2	1.057531	0.589332	*α>0.05*	*JB<χ2*	*H0*
logINDCHN	2	1.978232	0.371905	*α>0.05*	*JB<χ2*	*H0*
logEXGSCHN	2	2.133446	0.344134	*α>0.05*	*JB<χ2*	*H0*
logIMGSCHN	2	2.037289	0.361084	*α>0.05*	*JB<χ2*	*H0*
logURBCHN	2	2.399320	0.301297	*α>0.05*	*JB<χ2*	*H0*
logIMCOCHN	2	1.480275	0.477048	*α>0.05*	*JB<χ2*	*H0*
logEXCOCHN	2	2.605396	0.271798	*α>0.05*	*JB<χ2*	*H0*
logCRafCOCHN	2	2.569074	0.134278	*α>0.05*	*JB<χ2*	*H0*
logCNY/USD	2	1.123698	0.354802	*α>0.05*	*JB<χ2*	*H0*
ALL RESIDUALS HAVE NORMAL DISTRIBUTION						

Table 4 *The obtained parameters of a multilinear regression model*

Fit model results		
Statistic	**Training set**	**Validation set**
DF	8.000	-9.000
R2	**0.862**	65535.000
Adjusted R^2	**0.716**	
MSE	0.115	
RMSE	0.351	
MAPE	361.460	0.000
DW	**2.112**	
Cp	10.000	
AIC	**-31.960**	
SBC	**-23.045**	
PC	0.461	

ANOVA					
Source	**DF**	**Sum of squares**	**Mean squares**	**F**	**Pr > F**
Model	9	6.496	0.722	**5.754**	**0,011**
Error	8	1.004	0.125		
Corrected Total	17	7.500		**F(9.8)=5.754. p<0.05**	

Parameters of model (α=0,05)				
Source	**Value**	**Standard error**	**t**	**Pr > |t|**
Intercept	-0.129	0.136	-0.954	0.368
logINFCHN	**-0.798**	**0.321**	**-2.485**	**0.038**
logEXGSCHN	**1.165**	**0.420**	**-2.776**	**0.024**
logIMCOCHN	**-0.906**	**0.215**	**-4.414**	**0.003**
logCRafCOCHN	**0.887**	**0.280**	**-3.173**	**0.013**

The assessment of the reliability and impartiality of the obtained model depends on the fulfillment the model's standard assumptions [5]. The first standard assumption is to examine the absence of multicolorarity. In this test, we use two indicators: Variance Inflation Factor (VIF) and Tolerance Factor (TOL). The VIF indicator gives us an estimate of how much the variance of regression coefficient will increase due to a linear dependence with the other independent variables.

There are divided opinions which are the limits for VIF, or TOL, when testing the model. As a rule, the problem of multicolorarity does not exist when the values of VIF are < 5 and 10 (R2 < 0.8 (0.9)), while the values of the indicator TOL < 0.2 (0.1). The variables whose VIF values exceed 10 should not be in the model, although it is emphasized that the values of VIF 2.5 and TOL 0.5 indicate the problem of multicolinearity [6]. The values of VIF and TOL are given in Table 5 below.

Table 5 *Test results of multicolinearity*

	logINFCHN)	**logEXGSCHN)**	**logIMCOCHN)**	**logCRafCOCHN)**
TOL	0.690	0.194	0.334	0,599
VIF	1.450	5.153	2.998	1,669
TOL average			0.8975	
VIF average			2.817	

The other standard model assumption is the normal residue distribution, which was tested by Shapiro Wilk and Jarque-Bera test (H0 = residuals have a normal distribution). The third standard assumption of the model relates to checking the homoscedasticity/heteroscedasticity of random errors. It is necessary that the random errors show the same degree of scattering around their mean value. In case the variances of random errors differ significantly from one another, this is heteroskedasticity. Residual testing was checked using the Breusch-Pagan and White test. In the case of time series, autocorrelation of the residual is a common occurrence, which is the fourth standard assumption. Durbin-Watson test (DW) was used to detect autocorrelation. The values of DW < 2 and DW 2, in consultation with tables d_l and d_u, may indicate the presence of a pronounced autocorrelation of residuals. In this case, the Cohraine-Orcutt model for autocorrelation (DW transformed) is necessary. The results of all model tests are shown in Table 6.

Finally, a model of the effect of determinants of the Chinese economy on the movement of copper prices has been obtained, which has the following form:

$$Y(HGSpot) = -0{,}798(INFCHN) + 1{,}165(EXGSCHN) - 0{,}906(IMCOCHN) + 0{,}887(CRafCOCHN)$$

On the basis of the obtained estimates of the regression coefficients, a detailed analysis the effect of the observed determinants of movement the copper prices on the global market was carried out.

Table 6 *Results of tests of normality, homoscedasticity and autocorrelation*

<table>
<tr><th colspan="4">Test of normality</th></tr>
<tr><td colspan="2">Shapiro-Wilk test</td><td colspan="2">Jarque-Bera test</td></tr>
<tr><td>W</td><td>0.925</td><td>JB (Observed value)</td><td>1.396</td></tr>
<tr><td>P-value (2-tailed)</td><td>0.231</td><td>JB (Critical value)</td><td>5.991</td></tr>
<tr><td>Alpha</td><td>0.05</td><td>DF</td><td>2</td></tr>
<tr><td colspan="2" rowspan="3">W= 0.925; Sig. = 0.231>0.05 = H_0
Residuals have normal distribution</td><td>P-value (2-tailed)</td><td>0.498</td></tr>
<tr><td>Alpha</td><td>0.05</td></tr>
<tr><td colspan="2">JB= 1.396; Sig.= 0.498 >0.05 = H_0
Residuals have normal distribution</td></tr>
<tr><th colspan="4">Test of homoscedasticity</th></tr>
<tr><td colspan="2">Breusch-Pagan test</td><td colspan="2">White test</td></tr>
<tr><td>LM (Observed value)</td><td>0.085</td><td>LM (Observed value)</td><td>2.436</td></tr>
<tr><td>LM (Critical value)</td><td>3.841</td><td>LM (Critical value)</td><td>5.991</td></tr>
<tr><td>DF</td><td>1</td><td>DF</td><td>2</td></tr>
<tr><td>P-value (2-tailed)</td><td>0.771</td><td>P-value (2-tailed)</td><td>0.296</td></tr>
<tr><td>Alpha</td><td>0.05</td><td>Alpha</td><td>0.05</td></tr>
<tr><td colspan="2">LM= 0.085; Sig. = 0.771>0.05 = H_0
There is no pronounced heteroscedasticity</td><td colspan="2">LM= 2.436; Sig.= 0.296>0.05 = H_0
There is no pronounced heteroscedasticity</td></tr>
<tr><th colspan="4">Test of autocorrelation</th></tr>
<tr><td colspan="2">Durbin-Watson test</td><td colspan="2">Cohraine-Orcutt model</td></tr>
<tr><td colspan="2">DW(Original) = 2.112</td><td colspan="2"></td></tr>
<tr><td colspan="2">Autocorrelation is within tolerance limits on the basis of the table values du and dl</td><td colspan="2"></td></tr>
</table>

DISCUSSION

Based on the obtained F test results (F (9.8) = 5.754, $p<0.05$), we estimate that the model is adequate for analyzing the relationship between the observed variables (see Table 4). The value of the custom determination coefficient leads us to conclude that 71.6% of the variation in the spot copper price is explained by the variations of observed independent variables, the regressors (Adjusted R Square = 0.716). The quality of the proposed model obtained by the stepwise regression is confirmed by the lowest values of information criteria (AIC = - 31.960; SBC = - 23.045). Regressors of the model that at a statistically significant level (p = 0.05 (95%) determine the movement of copper prices are: inflation in China (INFCHN), Chinese exports of goods and services (EXGSCHN), Chinese imports of copper (IMCOCHN) and consumption of refined copper in China (CRafCOCHN). It should be noted that at the statistical level of significance p = 0.1 (90%) there were several significant variables (GDP in China, imports of goods and services and Chinese copper exports), but they will not be taken into discussion.

Based on theoretical grounding and our expectations, the model has shown very interesting results. Namely, our expectations were higher in terms of strength the correlation of dependent (HGSpot) and in dependent variables (the variables of the Chinese economy). Also, from the equation of the regression model and coefficients we see the inverse functions, i.e. the inverse regression coefficients for the variables INFCHN and IMCOCHN, which has somewhat its theoretical and practical foundation.

The fluctuations in the price of goods, primarily energy products and agricultural products (foods), significantly contribute to the growth of consumer prices and the rise in inflation. High inflation is in the focus of all central banks, both in developed and developing economies, where sharper monetary policy measures occur during the period of growth. In this regard, the question is how much and how the state can influence the stabilization of consumer prices with its monetary policy, and thus to inflation in order to preserve social security and population standards. The characteristic of today's China, in addition to the industrialization, has accelerated the urbanization and migration of the rural population to large cities. With that, a large number of Chinese residents, due to the improvement of their living standards, are changing their lifestyle habits. According to data from the Chinese customs authorities, in 2017 food was imported in the amount of 58 billion. US $, which is 25% more than the previous year, which indicates that the population of China is changing its eating habits. On the other hand, China is the world's largest buyer and consumer of oil, estimated at 10% of global energy consumption. The fluctuations in oil prices WTI and Brent do not affect demand, as China buys all available quantities. Currently, China does not import oil and gas from the United States due to a trade war and is facing other sources of supply, which can lead to volatility in prices and inflation, as the United States was China's significant supplier of these energy products. Analyzing the commodity correlation coefficients of crude oil and wheat, as the most important agricultural product (range 0.30-0.65), and the possibility of rising prices for these commodities, it is evident that prices and inflation are followed in China. As the copper is correlated with these goods at the intermediate level of bond strength, the impact of inflation in China measured CPI at the price of copper can be partially explained. The rest is in the domain of macroeconomic and monetary measures and unforeseen events on the market. Currently, the latest recorded inflation in China is 1.92% in 2018 (growth of 0.06% compared to 2017).

The determinant of Chinese copper imports (IMCOCHN) explains 19.3% of the variability of spot price movement of copper. We see that this is an inverse function, so that the decline in copper imports in China by 1% per annum affects the annual growth of copper prices by 0.90%, and vice versa. Although China is the largest importer and consumer of refined copper in the world, this can be explained by the fact that it is at the same time the world's largest importer of ore and copper concentrates (43% of world imports), and is increasingly reliant on the processing of secondary copper and recycling. Also, the Chinese economy receives more and more copper from its own sources and from the mines and plants they own, which makes them competitive in the world market, strengthens their bargaining power and can effect the prices through lowering demand in foreign markets.

Based on the data in Table 7, we see that the determinant of Chinese refined copper consumption (CRafCOCHN) explains 35.1% of the annual growth rate of copper spot prices (HGSpot), where the growth of refined copper consumption in China has a 1% impact on the annual increase in spot copper prices by 0.88%. Due to the slowing down of the Chinese economy, in recent years there has been a decline in annual consumption of refined copper to around 3%. At the same time, China has been reducing imports of refined copper in recent years due to accumulated supplies. The issue of copper stocks in China distorts the picture of consumption, according to analysts of Bloomberg and several other important financial portals. Namely, there are allegations that about 70% of refined copper imported into China is used to obtain credit, not for production. Chinese banks have approved the loans based on copper, as it has a certain market price and is traded on markets such as the London Metal Exchange (LME) and the Shanghai Futures Exchange (SHFE). According to the Goldman Sachs estimates, the total value of such credit arrangements reaches as much as $ 160 billion. US $, or about 31% of all short-term foreign currency loans in China. The last significant determinant - export of goods and services (EXGSCHN) stands on the theoretical and practical bases, with the low prediction coefficients in our model, so we will not explain it in more detail.

Table 7 *Values of the coefficients of correlation and determination the model variables*

Pearson R	logINFCHN	logEXGSCHN	logIMCOCHN	logCRafCOCHN	logHGSpot
logINFCHN	1	0.370	-0.117	0.068	-0.117
logEXGSCHN	0.370	1	0.100	-0.143	0.194
logIMCOCHN	-0.117	0.100	1	-0.388	**-0.440**
logCRafCOCHN	0.068	-0.143	-0.388	1	**0.593**
logHGSpot	-0.117	0.194	**-0.440**	**0.593**	1

R^2	logINFCHN	logEXGSCHN	logIMCOCHN	logCRafCOCHN	logHGSpot
logINFCHN	1	0.136	0.013	0.0046	0.0136
logEXGSCHN	0.136	1	0.010	0.020	0.037
logIMCOCHN	0.013	0.010	1	0.150	**0.193**
logCRafCOCHN	0.0046	0.020	0.150	1	**0.351**
logHGSpot	0.0136	0.037	**0.193**	**0.351**	1

CONCLUSION

Correlations of copper prices with the world variables and Chinese economy are of particular importance. In recent years, the increasing influence of unclear (undetermined) factors on the price of copper, such as the investor mood, speculations and use of copper in solving the geopolitical and geoeconomic issues, is evident. These factors can further lead to the significant fluctuations in the copper price, even if basically there is no reason for such volatility. This situation on the market can be illustrated by the data from the period from 2012 to 2017, when there was an intensive increase in production and consumption of refined copper in the world, while the copper prices recorded an intense stagnation. In 2017, owing to the slowdown in the economic growth of the world's largest economies (China and the US), the production and consumption of refined copper declined, while the average price of spot and copper fuels increased by 30%. Certainly, these data tell us about the high price volatility and the extremely high level of speculative jobs on the market, which can be explained by various motives of producers and investors, from making profits to solving the geopolitical and geoeconomic issues among the strongest economies in the world (USA, EU, Russia, China).

Our research confirms effect of the Chinese economy on the movement of copper prices, which is evident and should not be ignored. The preliminary analysis revealed several significant features of annual series of data on the movement of copper prices: 1. Copper copper prices had a structural break in 2003-2004, which coincides with China's entry as the largest net importer of copper to the global market, where the price series showed much higher volatility and higher average price than before; 2. The global financial crisis in 2008 had a major impact on copper prices, as well as on other considerations. Bearing in mind the identified structural breakdown, it was decided that the period of the series should be limited to the period from 2005 to 2017. What is somewhat surprising for the authors are the statistical insignificance and the weakness of the connections of some of the selected determi-nants to the movement of the price of copper (eg rates of GDP growth and urbanization of China). Expectations were met with the variable import of copper and the consump-tion of refined copper in China. The fact that the Chinese inflation rate is statistically significant points to the next research of economic factors, which should include other financial factors of the Chinese economy (exchange rate, interest rates, Shanghai Stock Exchange indices), as well as the impact of significant price movements - oil, steel and aluminum as the main copper substitute). Also, the analysis of trading of ETF funds on metals can be of great importance, which may explain us somewhat the influence of speculation on the price of copper.

In the end, we can conclude that we have confirmed our research hypothesis: the determinants of the Chinese economy have a statistically significant impact on the movement of prices in the global copper market. However, in order to better understand the movement of prices in the copper market, a comprehensive funda-mental analysis is needed, which, in addition to macroeconomic factors, would include microeconomic as well as factors of a political and social environment that could have an impact on the price of copper. Previously, this is confirmed by the sudden events of July 2018 on US-China relations and beginning of a trade war that continues.

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