UDC 622

ISSN 2334-8836 (Štampano izdanje)
ISSN 2406-1395 (Online)

Mining and Metallurgy Engineering Bor

4/2016

Published by: Mining and Metallurgy Institute Bor

MINING AND METALLURGY ENGINEERING BOR is a journal based on the rich tradition of expert and scientific work from the field of mining, underground and open-pit mining, mineral processing, geology, mineralogy, petrology, geomechanics, metallurgy, materials, technology, as well as related fields of science. Since 2001, published twice a year, and since 2011 four times a year.

Editor-in-chief

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

Editor

Vesna Marjanović, B.Eng.

English Translation

Nevenka Vukašinović, prof.

Technical Editor

Suzana Cvetković

Preprinting

Vesna Simić

Printed in: Grafomedtrade Bor

Circulation: 200 copies

Web site

www.irmbor.co.rs

Journal is financially supported by

The Ministry of Education, Science and Technological Development of the Republic Serbia
Mining and Metallurgy Institute Bor

ISSN 2334-8836 (Printed edition)

ISSN 2406-1395 (Online)

Journal indexing in SCIndex and ISI.

Published by

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

Scientific – Technical Cooperation with the Engineering Academy of Serbia

JOURNAL OF INTERNATIONAL IMPORTANCE, VERIFIED BY A SPECIAL DECISION OF THE MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGICAL DEVELOPMENT OF THE REPUBLIC SERBIA - M24

CONTENS

SADRŽAJ

MINING AND METALLURGY INSTITUTE BOR ISSN: 2334-8836 (Štampano izdanje)
UDK: 622 ISSN: 2406-1395 (Online)

UDK: 622.271(045)=111 doi:10.5937/mmeb1604001S

Nikola Stanić, Saša Stepanović*, Aleksandar Doderović*, Miljan Gomilanović**

DETERMINING THE STRUCTURAL PARAMETERS OF SLOPES AT THE OPEN PIT POTRLICA IN THE ZONE OF SEPARATION DOGANJE

Abstract

Due to the coal mining in the Northwest part of the Open Pit Potrlica, in the zone of separation "Doganje", there were considerable engineering-geological processes that have resulted in deformations - landslides. For continuation of mining, it is necessary to carry out a rehabilitation of endangered zone within which there are the final slopes of the surface facility Separation. Rehabilitation of endangered slopes is intended to secure the facility of Separation, but also enables maximum utilization of coal reserves in the respective zone. Therefore, it is necessary to harmonize the rehabilitation works on the endangered slope in a structural and dynamic sense of the future works on coal mining with maximum use of available reserves. Simultaneously with defining the measures and facilities of rehabilitation the endangered zone, a limitation and determination the quantity of coal were carried out that can be safely and economically mined in the rehabilitated zone. Optimal mining limits are determined in the zone between the sections 8 and 10 on the east side in the zone of Administrative building, and on the west side in the zone of separation "Doganje".

Keywords: *coal mining, slope stability, rehabilitation*

INTRODUCTION

At the Open Pit "Potrlica", the coal and overburden mining are carried out by discontinuous technology of two parts of the open pit - the Northwest and Central parts. In 2016, there was a physical bonding of these two parts of the open pit, but the mining system is further divided into the Northwest and Central part of the Open Pit Potrlica. [1]

In the Northwest part of the deposit (the site "Cementara") Open Pit Potrlica, near the main coal seam, there is also the first overburden coal seam thickness of 0.05 m (drillhole Bc-3) to 2.0 m (drillholes Bc-36 and B- 99), the average thickness of 0.72 m. It is separated from the main coal seam by the interlayer waste, thickness of 0.5 m (drillhole B-296) to 3.5 m (drillholes Bc-37 and Bc-38), on average of 2.29 m.

The first coal seam overburden consists of marl (^{3}M2). In general, two levels within the marl overburden can be distinguished in the area of "Cementara", as follows:

1. the level of light gray and yellowish marls, and
2. the level of striped dark brown marls, with a significant content of fossil shell conchs and snails in the laminated surfaces inside the dark-belt zones.

* *Mining and Metallurgy Institute Bor – Department Coal Engineering Belgrade, nikola.stanic@irmbor.co.rs, sasa.stepanovic@irmbor.co.rs, aleksandar.doderovic@irmbor.co.rs, miljan.gomilanovic@irmbor.co.rs*

According to the data of all drillholes drilled in the area of "Cementara", the marl overburden thickness is from 1.5 m to 62.0 m (drillhole Bc-1), and the average thickness is 25.54 m.

The marl overburden zone, closer to the ground surface, consists of decomposed marls at the top significantly clayey and transformed into marly clays.

Excavation is carried out with the prior blasting of overburden and coal, except in the Northwest part of the open pit where, due to the proximity of the town Pljevlja, direct excavation and loading are carried out.

Excavation and loading at the open pit Potrlica - Pljevlja are carried out by discontinuous systems. Transport of overburden consists of continuous and discontinuous parts. Discontinuous part of the transport system consists of a fleet of trucks with the capacity of 100 tons.

Continuous part of the transport system consists of 6 belt conveyor with designed capacity of 2000 m^3/h or 3664 t/h.

The excavated coal is transported by the existing truck fleet to the plateau for coal disposal, except the quantities of 100,000 t annually from the Northwest part of the OP Potrlica which are directly transported from the work site to the plant for coal preparation and separation. The other quantities of coal, with transshipment on the plateau, are further transported to the plant for coal crushing and disposal of the Thermal Power Plant Pljevlja.

STRUCTURE OF THE FINAL SLOPE OF THE OPEN PIT IN THE ZONE FROM SECTION 8 TO SECTION 10

The works at the open pit Potrlica of the Coal Mine Pljevlja are carried out according to the Supplementary Mining Project on Coal Mining at the OP "Potrlica" - Pljevlja for the Period 2015 - 2019 (Mining and Metallurgy Institute Bor, 2015). This project documentation has defined a web and dynamics of overburden excavation and coal mining in the Northwest part of the deposit (the site Cementara). Figure 1 presents a structure of the final slope in a part that is the subject of this paper.

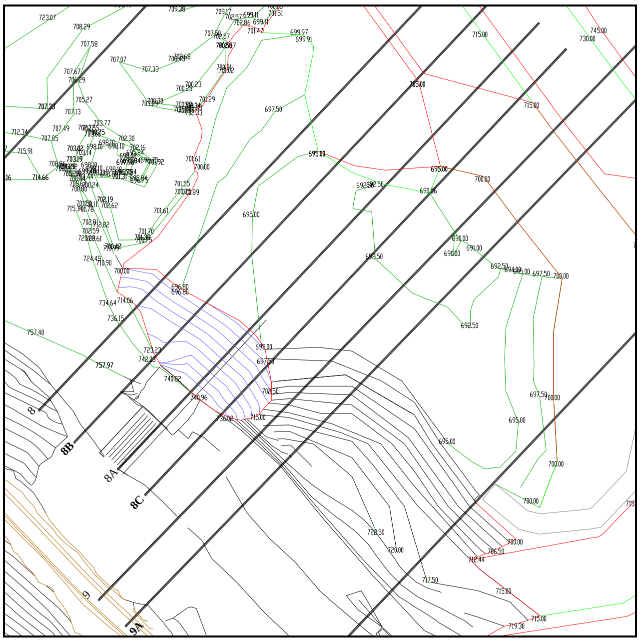


Figure 1 *Final slope of the open pit in the zone of Separation facility*

Verification the Slope Stability on the Northwest Part of the Open Pit Potrlica in the Zone of Section 8 to Section 10

Verification the eastern slope stability of the open pit at the site Cementara was done on sections 8a, 9 and 9a. [2]

Calculation the safety factor was derived using the software package SLIDE v6.0 of the company ROCSCIENCE.

The stability calculation is done using the program SLIDE in the conditions of limit equilibrium according to the criteria that have been also verified in the most common application. The applied methods in calculation are:

- Bishop,
- Janbu,
- Morgenstern-Price

The parameters of rock materials used in calculation the safety coefficient of slopes at the open pit mine on the eastern side of the site Cementara are given in Table 1. These parameters are adopted on the basis of test results the geomechanical characteristics of the work environment and they are also applied to the site Cementara, and they are verified in the current study and project documentation, as well as geological and thematic engineering-geological elaborates.

Table 1 *Parameters of rock material for calculation the safety coefficient*

Material	Color	Bulk density (MN/m^3)	Angle of internal friction (^{o})	Cohesion (MPa)
Coal		0.0135	32	0.21
Clay		0.021	16	0.072
Marls		0.02	39	0.32
Dike		0.016	22	0.034

Engineering - geological sections for calculation the slope stability factors are formed on the basis of reinterpretation the structural characteristics, made on the basis of the results of exploration drillings, speci-fically carried out for the needs of rehabilitation. As an illustration of derived calculations, the appearance of geomechanical models is given on characteristic sections, with the values of safety factor for one of the used methods. Typical geomechanical sections are shown in Figures 2, 3 and 4.

Structural parameters of designed open pit slopes of the subject zone, first of all, had to fulfill the condition that the minimum allowed safety coefficients should be above the levels allowed by the Regulations on Technical Standards for the Open Pit Mining of Mineral Deposits ("Official Gazette SFRY", Nos. 4/86 and 62/87) in Table 3 of the Regulations, relating to the stability of individual slopes, system of slopes and final slopes in soft rocks.

During coal mining at the site Cementara and in a part between sections 8-8' and 10-10', it is necessary, due to the existence of objects on the site surface, geological and engineering - geological characteristics of the work environment and constructive characteristics of the work and general slopes, the works shall be carried out with the increased attention, with strict adherence to the prescribed safety measures and to the eastern boundary of the open pit which provides minimum safety factor of 1.1.

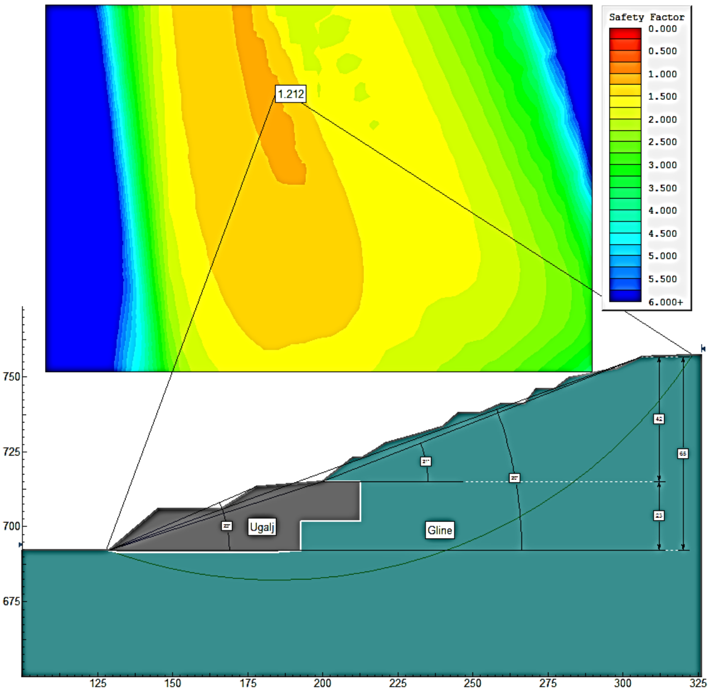


Figure 2 *Model and calculated slope stability factor on section 8a*

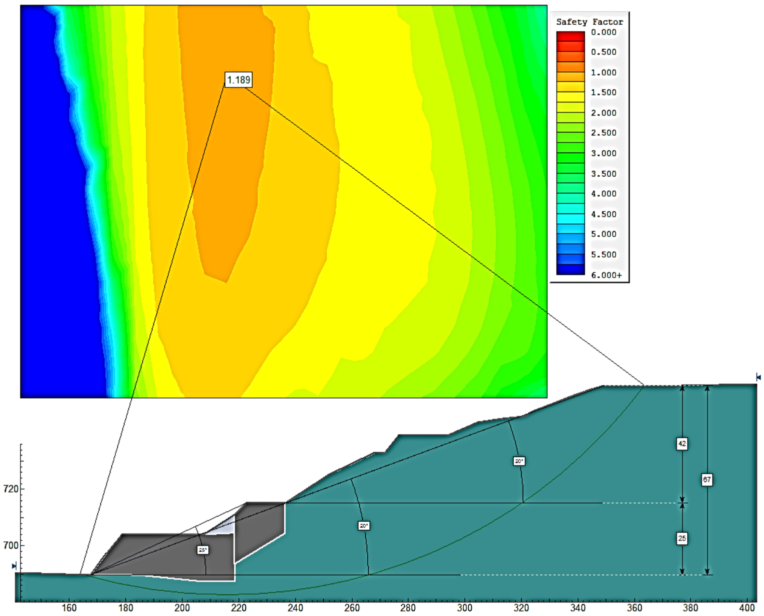


Figure 3 *Model and calculated slope stability factor on section 9*

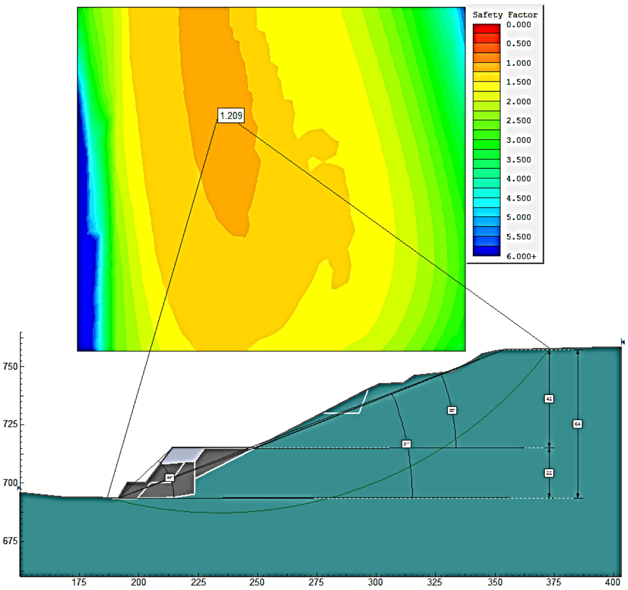


Figure 4 *Model and calculated slope stability factor on section 9a*

Table 2 *Safety factors of slopes on the characteristic sections for the existing condition and deepening work to the coal seam roof*

Section	Case	Method		
		Bishop	Janbu	Morgenstern - Price
8a	Existing condition	1.554	1.367	1.557
	Condition with excavation to the coal seam roof (existing)	1.554	1.367	1.557
9	Existing condition	1.889	1.729	1.889
	Condition with excavation to the coal seam roof	1.565	1.409	1.572
9a	Existing condition	2.084	1.865	2.092
	Condition with excavation to the coal seam roof	1.436	1.315	1.434

Table 3 *Structural parameters of analyzed slopes and calculated safety factors*

Section	Fs min ≈	Partial slope on coal		Partial slope on overburden		General slope		Method		
		Height (m)	Angle (°)	Height (m)	Angle (°)	Height (m)	Angle (°)	Bishop	Janbu	Morgenstern-Price
8a	1,1	23	23.3	42	21.5	65	20	1.212	1.103	1.211
9	1,1	25	24.7	42	20.2	67	20.2	1.189	1.108	1.186
9a	1,1	22	43.7	42	21.8	64	21.3	1.209	1.104	1.208

Verification the Stability of the Western Slope

Verification the stability of the western slope was done successively with the progress of works on stabilization the separation plant (classification plant) Doganje. Verification of stability was carried out on profiles 8a, 9 and 9a. [2]

Calculations were done in the program Phase 2 V8 using the finite element method. The analysis was carried out in phases:

- The first phase with completion the first horizontal beam and excavation of overburden and coal according to a given slope;
- The second phase with completion the second horizontal beam and excavation of overburden and coal according to a given slope;
- The third phase with completion the third horizontal beam and excavation of overburden and coal according to a given slope;
- The fourth phase by lowering of the open pit to the designed depth.

Calculation results are given in the following figures:

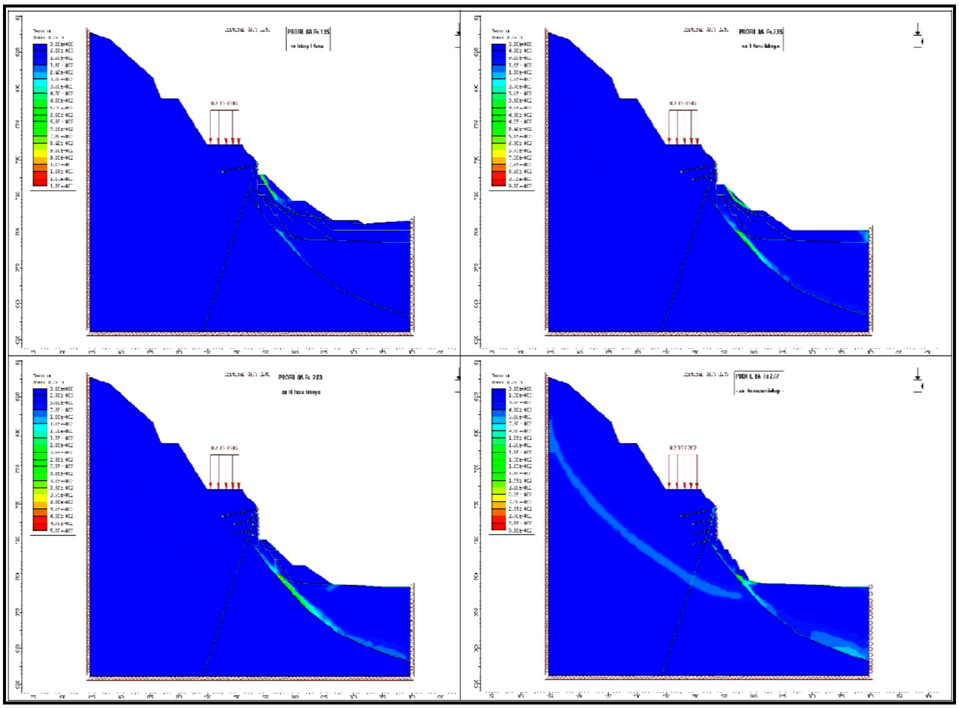


Figure 5 *Calculation the slope stability in section 8a (four phases of stabilization the separation plant Doganje)*

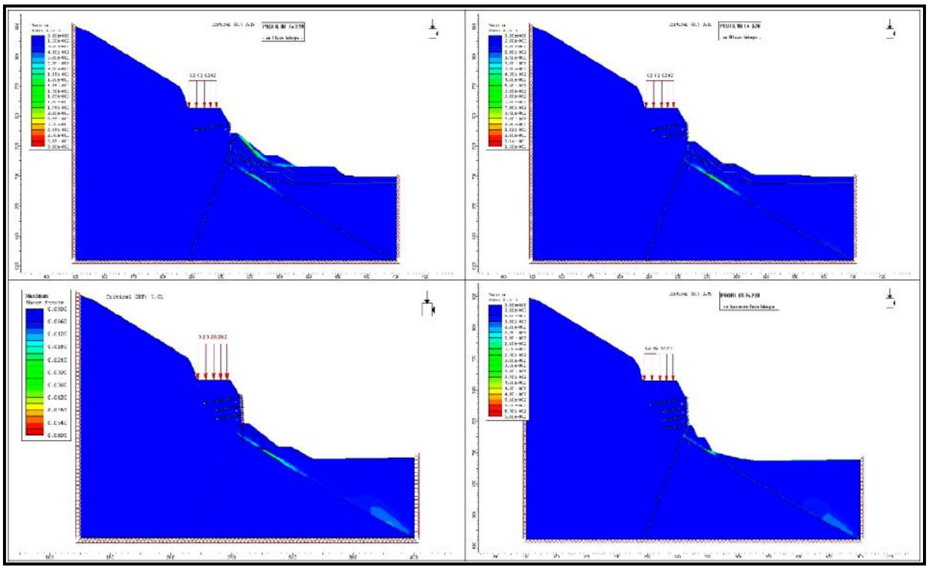


Figure 6 *Calculation the slope stability in section 9 (four phases of stabilization the separation plant Doganje)*

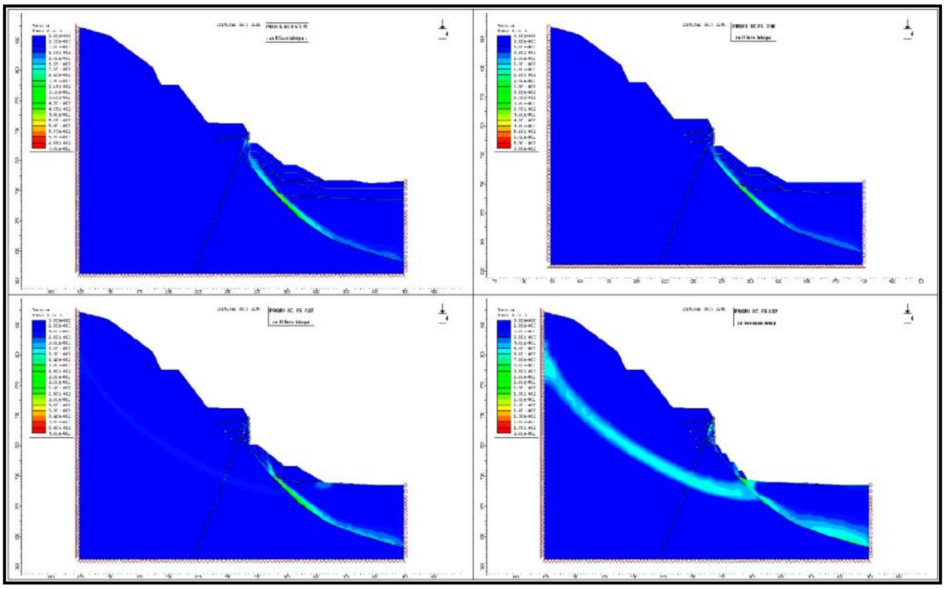


Figure 7 *Calculation the slope stability in section 9 (four phases of stabilization the separation plant Doganje)*

The values of calculated safety factors for all phases of excavation, in all sections, as shown in Table 4 are satisfactory for stability of temporary slopes.

Table 4 *Safety factors for excavation phases*

Section	Fs safety factors for excavation phases			
	I phase of excavation	II phase of excavation	III phase of excavation	IV phase of excavation
8a	1.95	2.95	2.83	2.77
9	3.19	3.16	3.01	2.98
9a	3.11	2.98	2.87	2.82

The adopted constructive parameters of slopes of considered part of the open pit at the site Cementara and for which the shown calculation of safety factor was done, i.e. their verification, are the result of the analysis of more variants of technical solutions. The process of defining the rehabilitation measures of the western slope and facilities of the final coal separation of coal and facilities, has implied the analysis of application of several methods and involved the boundary in the plan and depth.

The western slope of the open pit in the zone, where it was necessary to implement the stabilization measures, is characterized by the complex structural-geological and tectonic structure. The deposit conditions affect both the technical-technological solutions of overburden excavation and coal exploitation as well as the efficiency degree of reserves. The same is applied to the eastern final slope in the observed zone of the site Cementara, i.e. it is the environment with complex geological structure and the present engineering-geological processes have resulted to the instability of the slope itself and structures in a function of the open pit, which are located adjacent to the edge of slope.

Due to the presence of these structures out of which the foremost is the Administrative building with wardrobe, the works were carried out on their stabilization. For the safety of work development and importance of structures, a constant monitoring is carried out on the condition of slopes and structures.

Coal mining in maximum possible volume is directly conditioned by the volume and type of works to stabilize the western slope in the conditions of the eastern slope stability conditions and structures on the site surface with the permanent present requirement to safety of mining works. Therefore, the designed solution represented a compromise between the costs of stabilization the structures of Separation and western final slope and volume of coal reserves to be mined. Also, it was necessary to define the construction parameters of the eastern slope, which will ensure the stability of slope and present structures on one side with reliability degree that requires the importance of these structures, and thereby to maximize the quantitys of coal affected the concerned zone.

In all of this, an important factor is a dynamics of works on slope stability, excavation of overburden, coal mining and development of the internal landfill. Shortening the period, in which the space between the eastern and western slope is opened to the floor of excavated coal, will be enabled by the construction of slopes with lower safety factors, i.e. with larger angles of inclination, and consequently the excavation of large coal quantities. The earlier filling the excavated area by disposed overburden and waste, or as quick formation of internal landfill benches, will significantly reduce the risks of instability of slopes and accidents during realization of works. Due to all reasons listed above, the designed slopes took into consideration the necessary dimensions of working plateaus, berms and transport routes of internal transport of overburden and waste.

Calculation the Cubic Volumes of Coal Masses in the Zone of Section 8 to Section 10

Calculation the cubic volumes of coal that remains unexcavated in the zone of western slope of the open pit on the site Cementara was carried out using the method of vertical parallel sections.

Calculation the reserves of solid mineral raw materials by the method of vertical cross-sections is used most often in cases where deposits (ore bodies) of complex shape were explored by works set on vertical sections.

Calculation the coal quantity that will not be excavated on the site Cementara, in the area of the western slope, was made for a part between section 8 and section 10, or slightly wider area affected by works on the stabilization of the structure Separation. It should be borne in mind that coal in the section 8-8' was, for the most part, excavated and the works on coal mining in cross section will not developed.

Table 5 *Calculation the coal quantity that could be excavated in the zone od section 8-8' to 10-10' with construction of the eastern slope with Fs=1.1*

Section	Area (m^2)	Mean area (m^2)	Distance (m)	Volume (m^3)	Weight (t)
8	0	598	19	11,362	15770
8b	1,196	1,146	20	22,910	31799
8a	1,095	1,205	15	18,075	25,088
8c	1,315	1,301	16	20,808	28,882
9	1,286	1,370	15	20,543	28,513
9a	1,453	2,233	67	149,611	207,660
Σ				**243,309**	**337,712**

CONCLUSION

Realization of works on coal mining is developed on the site Cementara of the open pit Potrlica by very complex structural-geological and engineering - geological conditions. Complex condition of the working environment and occurrence of the open pit slope instability and structures that are located in the immediate environment, and which are of capital importance for development the mining operations and functioning of the open pit as a whole, have caused the necessity to perform the extensive and expensive works to stabilize the slopes and structures.

These works are in constructive, dynamic and economic terms consistent with the requirements of the technological system of coal mining in the monitored zone, ensuring the safe working conditions for their implementation with maximizing the coal quantities that can be mined. Design solutions of restrictions the open pit, in the zone of section 8 to section 10 of the site Cementara, were created in terms of restrictions the mentioned influential factors, and as a compromise solution conditioned by the necessary investments into structures for stabilization of slopes and structures and profit realized by coal mining.

In further period, it is necessary to give an appropriate technological solution of mining that would allow a as soon as possible rapid formation and advancement the internal landfill in the excavated area of the open pit, which would reduce the risk of implementation the mining works and gradually increase the stability of open pit slopes and structures. During the execution of works, the constant monitoring is required for the condition of slopes and structures to the phase when the permanent stability of the open pit slopes is reached by formation the internal landfill.

REFERENCES

[1] Supplementary Mining Design on Coal Mining at the Open Pit "Potrlica" - Pljevlja for the Period 2015 – 2019 (in Serbian)

[2] Main Design on Ensuring the Stability of Doganje Separation Structures and Defining the Coal Mining Limit in this Zone (in Serbian)

[3] Simplified Mining Project for Coal and Overburden Mining from the Northwest Part of the Open Pit “Potrlica” (Cementara) (in Serbian)

MINING AND METALLURGY INSTITUTE BOR | ISSN: 2334-8836 (Štampano izdanje)
UDK: 622 | ISSN: 2406-1395 (Online)

UDK: 628.512:662.966:622.33(045)=111 doi:10.5937/mmeb1604011L

Milenko Ljubojev[*]*, Dana Stanković*[*]*, Zlatko Ječmenica*[**]*, Milorad Ćirković*[*]

WASTE FLUE GAS DESULPHURIZATION IN COAL COMBUSTION FROM UGLJEVIK BY THE WET PROCESS[***]

Abstract

This paper describes the process of waste flue gas desulphurization (FGD) formed in combustion [1] of brown coal from Ugljevik. For the purposes of development the technology of waste flue gas desulphurization (W) in coal combustion from Ugljevik, the experimental development of technology was approached in the laboratory conditions. For experimental work, an apparatus was designed for combustion the coal samples in a closed system with projected measuring points for measuring the composition of waste flue gases. The wet method was used for desulphurization FGD, i.e. the absorption of sulfur dioxide (SO_2) in the limestone suspension. The advantage of this desulphurization method is as follows:

- *possession a large amount of raw material for S absorption,*
- *relative small investments to prepare the absorption suspension,*
- *very simple method of S absorption of EDC,*
- *verified in operation [2],*
- *high efficiency,*
- *obtaining a potentially useful by-product,*
- *possibility of application in large plants.*

Keywords: *coal, sulfur dioxide, desulphurization, technological method*

INTRODUCTION

Due to the increased pollution of atmosphere with waste gas and various vapors from the industrial plants that are a great threat to the flora and fauna, it is necessary to find a possibility to reduce pollutants. One of the atmospheric pollutants is also SO_2 gas that is one of the constituents of waste gas from coal combustion and whose maximum allowed value in the waste gas is up to 200 mg/m^3 [3].

Description the Technological Process of Waste Flue Gas Desulphurization in Coal Combustion

Waste flue gas desulphurization in the process of coal combustion is a technological method of chemical bonding a free SO_2 gas for components by which a new compound is formed that does not pollute the external environment. Sulfur dioxide is a component of the gas mixture or the coal combustion products that is directly discharged into atmosphere and thus polluting

[*] *Mining and Metallurgy Institute Bor, Zeleni bulevar 35*
[**] *Mine and Thermal Power Plant Ugljevik*
[***] *This paper is the result of the Project No. TR 33021 "Research and Monitoring the Changes of the Stress Strain State in the Rock Mass "In-Situ" around the Underground Rooms with Development of Models with Special Reference to the Tunnel of the Krivelj River and Pit Bor", funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia*

the environment. By the presence of SO_2 gas in the exhaust gas and moisture from the air, sulfuric acid is formed which causes some damages to the flora and fauna. Due to this type of pollution the external environment as well as the consequences of pollution that can be produced by SO_2 gas in the external environment, the plants for complete absorption of [3] resulting SO_2 gas are required or to reduce it to the allowed values. The presence of SO_2 gas in the waste exhaust gas is regulated by the EU regulations and maximum allowable amount of SO_2 gas at the outlet of the plant which produces 200 mg/m^3 of gas. To comply with the prescribed amount of SO_2 gas in the outlet gas from plants that rely on fuels containing S, it is necessary to construct a desulphurization plant of waste flue gases.

Desulphurization process can be made in several ways depending on whether [2] desulphurization is done before the fuel combustion containing sulfur or after the combustion of the same.

Methods of desulphurization before fuel combustion:

1. Techniques in the combustion zone
   - Addition of sorbent in a fixed layer
   - Addition of limestone or dolomite into burning layer
   - The simplest method of emission reduction,
   - Low efficiency (15-20%)
   - Efficiency can be increased by water injection into burning layer (0.1 kg water per kg of coal)
2. Combustion in a fluidized bed
3. Additive method

If there is no possibility of desulphurization before fuel combustion, it is necessary to do the FGD desulphurization after combustion in order to reduce the sulfur dioxide emissions to the statutory prescribed value.

Purification methods of waste flue gases after combustion [2]:

- Dry systems: injection of dry sorbent with dry residue.
- Semi-dry systems: sorbent is injected as slime and solid residue is obtained.
- Wet system: both sorbent and residue are wet, non-regenerative and regenerative systems.

EXPERIMENTAL TESTS

Laboratory experimental tests of the flue gas desulphurization process were carried out after the coal combustion process. Due to this reason, the only acceptable method of the proposed 3 is the wet system method where both sorbent and residue are wet [2]. The advantage of using the wet non-regenerative system method is as follows:

- SO_2 is bound into a chemical compound that is used as a by-product or is disposed (waste)
- Sorbent: suspension of limestone or lime
- Sorbent comes into contact with the flue gas, producing a mixture of calcium sulfite and sulfate (gypsum)

For the experimental investigations of waste flue gas desulphurization in coal combustion, a large number of experiments were done at different temperatures of combustion in the range of 500^{o}C to 900^{o}C [1] with introduction of oxygen in the combustion process.

The absorption of flue gas was conducted into 20% suspension of limestone of the known chemical composition, granulation and specific reactivity. The principle of desulphurization FGD is based on the absorption of FGD going through the limestone suspension, whereby a chemical reaction is developed between SO_2 gas and $CaCO_3$ from suspension and $CaSO_4$ and CO_2 are obtained. Reaction between SO_2 and $CaCO_3$ from suspension results to decrease of SO_2 gas [3] in FGD and hence reduce SO_2 gas in the exhaust gases into the atmosphere.

Coal was firstly ground, sampled to determine the physical characteristics and technical analysis of coal, then the experiments were planned, and samples were measured for FGD desulphurization.

For the experiments of waste flue gas desulphurization in coal combustion from Ugljevik, an apparatus was used for combustion the coal samples in a closed system with projected measuring points for measuring the composition of exhaust gases.

Apparatus is shown in Figure 1.

Figure 1 *Apparatus for coal combustion and waste flue gas desulphurization in combustion*

Parts of apparatus for coal combustion and waste flue gas desulphurization (FGD): 1. Mars tubular oven with corresponding tube of Al_2O_3 and associated transformer station for power supply. 2. Connecting gas pipelines with compensators with the measuring point 1 for measuring the composition of gas mixture FGD at the outlet of oven. 3. Two absorption units with 20% suspension of limestone with the known reactivity. 4. Pump for extraction of FDG from oven, which allows the passage of gas mixture through columns with suspension of lime for desulphurization. 5. A part of gas pipeline behind the pumps and absorption units with the measuring point 2 provided for measuring the composition of gas mixture at the outlet of system for gas absorption (desulphurization). 6. Ventilation system for gas extraction from the working space

Coal sample with the known technical analysis and certain physical characteristics is measured in a boat of rotosyl and put in a preheated Mars tubular oven at the pre-set temperature. The tube of oven for combustion of coal samples is made of Al_2O_3. The coal samples are burnt at temperature of 500^{o}C, 900^{o}C. The process of coal combustion flows with continuous introduction of oxygen into oven as long as the separation of SO_2 gas. During the combustion process of coal, the composition of waste flue gases is measures at the outlet of oven MM-1, before entering the absorption column and at the outlet of the absorption columns MM-2.

Physical Characteristics and Technical Analysis of Coal from Ugljevik

Physical characteristics of coal were carried out after coal grinding. Determination the physical characteristics of coal were done from two coal samples from Ugljevik 1 and 2.

The results of physical characteristics of coal samples from Ugljevik are given in Table 1.

Table 1 *Results of physical characteristic of coal samples from Ugljevik*

Sample designation	Humidity w(%)	Bulk density [g/cm^3]	Specific weight [g/cm^3]
Sample 1	15.54	1.367	1.611
Sample 2	18.96	1.279	1.579

After determining the physical characteristics of coal, the technical analysis of coal was carried out.

Technical analysis of coal from Ugljevik Bogutovo Selo is given in Table 2.

Table 2 *Technical analysis of coal*

With total moisture			With rough moisture			With hygroscopic moisture		
495 (hg)	Intervals		-495(hg)	Intervals		-495(hg)	Intervals	
Elements	5.70-10.70	10.70-14.70	Elements	5.70-10.70	10.70-14.70	% ash	5.70-10.70	10.70-14.70
% ash	14.42	16.07	% ash	17.22	18.30	% combustible	21.12	23.11
% combustible	45.91	47.33	% combustible	54.78	53.90	% volatile	67.21	68.09
% volatile	24.19	25.07	% volatile	28.87	28.55	% coke	35.42	36.06
% coke	36.14	38.33	% coke	43.13	43.65	% C-fix	52.91	55.14
% C-fix	21.71	22.27	% C-fix	25.91	25.36	% S-total	31.79	32.03
% S-total	4.71	4.36	% S-total	5.62	4.97	% S-bound	6.90	6.27
% S-bound	1.22	1.08	% S-linked	1.46	1.23	% S-combustible	1.79	1.56
% S-combustible	3.49	3.28	% S-combustible	4.16	3.73	KJ/kgGTM	5.11	4.71
KJ/kgGTM	12794	13364	KJ/kgGTM	15268	15219	KJ/kgDTM	18731	19224
KJ/kgDTM	12385	12934	KJ/kgDTM	14780	14730	% ash	18132	18606

Technical analysis of coal from Ugljevik shows that content of combustible sulphur in it is 3.49%.

Measuring the Composition of Gas Mixture of the Waste Flue Gases from Coal Combustion

Series of samples in each of 5 samples were formed from prepared and analyzed coal for experimental tests of desulphurization FGD at different temperatures of combustion.

In the process of coal combustion at particular temperature, the measurement was firstly performed for composition of the gas mixture of waste gases so that the amount of SO_2 gas was clearly seen in the gas mixture which has to be absorbed in the limestone suspension.

Temperature of Coal Combustion at 800°C

Under the same conditions of coal combustion as it was done at temperatures of 500°C to 700°C, series of combustion the coal samples of 1-5 at temperature of 800°C were also done, and measurements of waste flue gases were done as well as the absorption of waste flue gases during the combustion process. The absorption of the waste flue gases was done in 20% suspension of limestone Spasine Brdjani, granulation 5.6 - 16.0 μm. The oxygen flow in the combustion of coal samples is 2 l/min.

Time of measurement the composition of waste flue gases will flow from the moment when the loaded coal sample in the oven starts to burn. Measurement the composition of gas mixture of waste flue gases is at the measurement point 1 (MM-1) immediately after the outlet of FGD from oven tube in which the coal combustion takes place at particular temperature.

The obtained test results of measurement the waste flue gases on MM-1 from coal combustion at 800°C with the introduction of oxygen are given in Table 3.

Table 3 *Results of measurement the waste flue gases at 800°C on MM-1*

Measurement time (s)	T-gas, °C	CO_2-gas, %	CO-gas, ppm	SO_2-gas, ppm	SO_2-gas, mg/m^3
27	19	0.7	346	2864	8188
44	18.6	1.1	458	3581	10238
255	18.9	0.0	8	1299	3714
263	18.7	0.0	11	1588	4540
275	19.0	0.0	13	1731	4948
613	20.2	0.0	22	415	1187
623	20.2	0.0	22	422	1207
697	20.3	0.0	25	493	1410
782	20.3	0.0	30	516	1474
1073	20.4	0.0	41	597	1706
1085	20.5	0.0	43	603	1723
1375	21.5	0.0	65	635	1814
1380	21.4	0.0	65	657	1877
1476	21.7	0.0	70	746	2133
1537	22.3	0.0	77	819	2343
2144	20.7	0.0	240	1041	2976
2274	20.7	0.0	42	514	1470
2333	20.8	0.0	30	247	707
2491	20.8	0.0	3	73	210
2628	20.6	0.0	2	46	132
3052	20.1	0.0	1	5	14
3121	19.9	0.0	1	1	3
3152	19.8	0.0	1	0	0

It is seen from the measurement results at the combustion temperature of 800°C with the introduction of O_2 that the obtained values for SO_2 gas 8188 and 10238 mg/m^3 are very large in regard to the allowed value of SO_2 gas for discharging intothe atmosphere. For this reason it is necessary FGD desulphurization, thus reducing the SO_2 gas allowed to 200 mg/m^3.

Figure 2 shows the curve of selected CO, SO_2 gases from the composition of the gas mixture FGD during the coal combustion at temperature of 800°C.

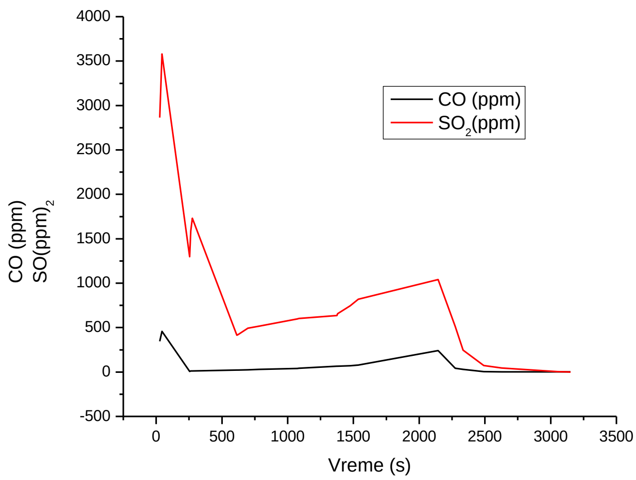


Figure 2 *Diagram of gases on MM-1 at 800°C, (CO, SO_2)*

Diagram in Figure 2 presents the contents of CO and SO_2 in the gas mixture beside the oven for coal combustion on MM-1.

FGD Desulphurization Using 20% Aqueous Suspension of Limestone at the Combustion Temperature of 800°C

The indicated amounts of separated SO_2 gas from combustion of coal at 800°C are very high so it is necessary to reduce them from FDG that would prevent pollution of the environment. Reduction of SO_2 gas from FDG was performed by absorption the same from FDG in the limestone suspension of known granulation, chemical composition and reactivity [4].

For desulphurization the flue gases for samples with combustion at 800°C, the 20% suspension of limestone SP-BRDJANI was used with granulation 5.6 - 16.0 µm and reactivity of 89.89%.

After completion of the FGD desulphurization of a series of 5 samples of coal (100 g), the absorption suspension was filtered, and the content of S in the solid and liquid part of suspension was determined.

The S Absorption in the Solid Part of Suspension (Absorbent)

By analyzing the hard part of adsorbent on the S absorbed from the flue gases in coal combustion at 800°C, the obtained results are shown in Table 4.

Table 4 *Results of the S content in the solid part of absorbent according to the Report on testing No. 195130-688/2016*

Elements	**U_{ap}-3**	**U_{ap}-4**	**Method**	**Standard**
S (%)	3.98	0.079	ACS	*BMK E.3.1

Based on the obtained results of chemical analysis of sulfur content in the solid absorbent, the balance of S absorption was made from the waste flue gases from coal combustion at 800°C; the obtained results are given in Table 5.

Table 5 *Results of S absorption balance in the solid part of absorbent*

Elements	**Amount of solid absorbent U_{ap}-3 (g)**	**Amount of absorbed S in U_{ap}-3(g)**	**Amount of solid absorbent U_{ap}-4(g)**	**Amount of absorbed S in U_{ap}-4(g)**	**% total of absorbed S**
	62.8	2.5	58.1	0.046	73

Based on the balance of S absorption in the solid absorbent, the obtained results show that 73% of S is absorbed from the waste flue gases.

The S Absorption in the Liquid Part of Suspension (Absorbent)

By analyzing the liquid adsorbent on the S content in the form of SO_4^{2-}, the obtained results are shown in Table 6.

Table 6 *Results of the chemical analysis of SO_4^{2-} content in the liquid part of absorbent for combustion of coal from Ugljevik at 800°C*

Sample designation	**SO_4^{2-} mg/l**	**Volume of liquid absorbent (ml)**	**Amount of absorbed S (g)**	**% Amount of absorbed S**
V-3	1550.0	850	0.43	12.5
V-4	875.0	800	0.233	6.7
			∑0.669	19.2

Based on the obtained results of adsorbed S in combustion of coal of 100g from Ugljevik in solid and liquid absorbents, the amount of 3.22 g S was obtained, what is the total absorbed S of 92.2%.

Such high degree of S absorption in the solid and liquid part of the absorption suspension can be also confirmed by measurement the content of SO_2 gas at the measuring point 2 (MM-2) behind the absorption columns at the same time when it is measured on MM-1. The process of absorption is not interrupted; it is clear from the measurement results that the total amount of separated SO_2 in coal combustion was absorbed in the limestone suspension.

The results of measurement the waste flue gases at the outlet of desulphurization system (MM-2) at 800°C are given in Table 7.

Table 7 *Results of measurement the content of the waste flue gases on MM-2*

Measurement time (s)	**T-gas, °C**	**CO_2-gas, %**	**CO-gas, ppm**	**SO_2-gas, ppm**
496	20.9	0.0	33	0
504	20.9	0.0	35	0

The obtained results of measuring the composition of waste flue gases on MM-2 show that all released SO_2 gas is absorbed in the absorption suspension of the mounted system for absorption.

Notice

In desulphurization of FGD at the coal combustion temperature of 900^{o}C, a separation of H_2S gas is developed that is highly toxic and whose separation in chemical processes should be strictly controlled within the allowed limits. The elimination of separated H_2S gas requires a special system for waste gas treatment as well as a gauge for H_2S gas concentration at the outlet of treatment system so that the overdraft of MDK for H_2S would not be developed. The procedure and equipment for waste gas treatment with the present H_2S is very expensive, so whenever it is possible in the chemical process to avoid its formation. Due to the separation of H_2S, it is necessary that the coal combustion process takes place at lower temperature of 900^{o}C.

CONCLUSION

Based on the experimental testing in the laboratory conditions of coal combustion from Ugljevik and desulphurization of the waste flue gases, formed during combustion, the following could be concluded:

- in coal combustion, it is necessary to introduce oxygen into the process, a flow rate of 2 l/min.
- the highest amount of the obtained SO_2 gas in the waste flue gases is at the combustion temperature of 800^{o}C.
- the highest degree of SO_2 gas absorption of the waste flue gases (desulfurization) is at the combustion temperature of 800^{o}C, 92.2%, that is 73% in the solid part of adsorbent, and 19.2% in the liquid part of absorbent,
- for FGD absorption, the suspension of 20% was used, made of composite limestone SP BRDJANI, 5.6-16.0 μm, with reactivity of 89.89%.

REFERENCES

[1] Coal Combustion - Internet presentation (in Serbian)

[2] Reduction of Emissions, Desulphurization (in Serbian)

[3] Z. Malović, Project of Desulphurization the Flue Gases in the Thermal Power Plant Ugljevik, Evalustion the Production Costs and Maintenance Costs for the Systems with Lime and Limestone (in Serbian)

[4] N. Z. Čolić, Conceptual Design of the Plant for Flue Gas Desulphurization in the Thermal Power Plant Nikola Tesla B by the Wet - Limestone Method, Faculty of Mechanical Engineering, University of Belgrade (in Serbian)

[5] V. Jovanović, V. Jovanović, M. Jovanović, Flue Gas Desulphurisation in Serbia, Legal and Economic Aspects, Mining and Metallurgy Engineering Bor, 3/2013, pp. 175-182 (in Serbian)

[6] V. M. Marjanović, A. T. Ivanović, V. Cvetković Stamenković, Soot Participation in Total Air Pollution in the Municipality of Bor with Statistical Data Processing, Mining and Metallurgy Engineering Bor, 3/2014, pp. 61-72 (in Serbian)

[7] V. Ljubojev, V. Marjanović, D. Milanović, S. Stanković, Mineralogical Characteristics of Slag (From the Flotation Plant of RTB BOR) Granulated in the Laboratory Conditions, Mining and Metallurgy Engineering Bor, 2/2015, pp. 1-6 (in Serbian)

MINING AND METALLURGY INSTITUTE BOR ISSN: 2334-8836 (Štampano izdanje)
UDK: 622 ISSN: 2406-1395 (Online)

UDK: 622.271(045)=111 doi:10.5937/mmeb1604019D

Aleksandar Doderović, Nikola Stanić*, Miljan Gomilanović**

PROTECTION SYSTEM AGAINST WATER AT THE OPEN PIT GACKO WITH COLLECTIVE WATER COLLECTOR AS THE CAPITAL STRUCTURE

Abstract

Protection of the open pit against water is very important, especially if the open pit is located in the complex conditions regarding protection of the open pit against water. To reduce the investments, it is proposed to define the protection system of the open pit against water for a longer period. In the specific case, the technological system of protection against water was considered at the open pit Gacko with construction the canal system with a The Cumulative water collector. The aim of developing such system is the water directing water the river Musnica riverbed and effective protection of the open pit.

Keywords: *water collector, canal, protection against water, open pit Gacko*

INTRODUCTION

Gatačko field (karst field) is the intermountain depression filled with Neogene sediments formed in the relaxation phase of the field after cessation the directed tectonic pressures (Oligocene - Miocene). Gatačko polje and coal bearing Neogene sediments are located in the extreme southeast of the Republic of Srpska on the border with Montenegro. Three quarters of the field are covered with the Quaternary sediments beneath which are the Neogene formations in the area of about 40 km^2. Gatačko polje is mildly ruffled plateau that greatly changed its shape with construction of the open pit.

The river Musnica is the largest water flow that passes across the field. It enters into Gatačko polje in the east of Avtovac, and leaves it at Srđević where gradually sinks. Right tributary of the river Musnica are the river Gračanica and Gojković stream (with its tributaries) flowing directly through the productive part of the coal bearing Gatacki basin, and but flows and amounts of water in them have a major impact on the open pit mining of coal and system of the open pit protection against water. Flows in all three surface flows are a direct consequence of climate conditions in the region, and rainfall in certain seasons.

From late fall to early spring, the lowest, southern and southwestern parts of the field are often flooded by a pillar of water, depth of up to 0.6 m, which (by a steep gradient) decreases immediately after cessation of heavy rainfall. Flooding arise due to the formation of natural pre-abyss retention, as the common abyss zone does not exist (due to the existing geological situation) in the lowest southwestern part of the field, so the gorge near Srdjevici cannot, in a short term, to miss the great storm water collected by the river Musnica.

The open pit Gračanica - Gacko was opened in 1978 in the western part of Ga

* *Mining and Metallurgy Institute Bor – Department Coal Engineering Belgrade, aleksandar.doderovic@irmbor.co.rs, nikola.stanic@irmbor.co.rs, miljan.gomilanovic@irmbor.co.rs*

tacko polje. Mining at the open pit Gračanica took place in the Field A, Field B and part of the Field C.

To enable the undisturbed coal mining, it was necessary to relocate the said watercourses. The reason for relocation is too great proximity of the riverbeds of watercourses to the open pit contour, or the watercourse is on the site where the planned progress of works was planned on deposit mining.

On two occasions, the mining was terminated due to the reason of water penetration from nearby watercourses into the open pit, more precisely into the Field B of the open pit Gračanica, as follows:

- in 1998 when, when the open pit contour was broken by the water from the stream Gojković,
- in 2013, when the open pit contour was broken by the water from the river Musnica (with Gračanica).

In the previous period due to the needs to develop the open pit Gacko, the regulation of the river Gracanica and relocation a part of the Gojković stream were done, as well as relocation the riverbed of the river Musnica (phase I). Currently the river leaves Gatačko polje through the regulated flow of the river in the zone of the road Gacko - Kula ("Bypass"). Due to the development of mining operations, no later than 2024, it is necessary to complete the relocation of the river Musnica and implement the second phase of relocation.

By development the mining activities and mining in the south-east section of the excavation front, the old riverbed of Musnica is cut and loses the natural recipient for water drainage from the open pit Gacko-Central Field. The solution to this problem is a condition for further mining.

Coal mining of the deposit Gacko takes place in complex hydrological and hydrogeological conditions and therefore a considerable attention and time should be given and to invest the financial assets for protection the open pit against water.

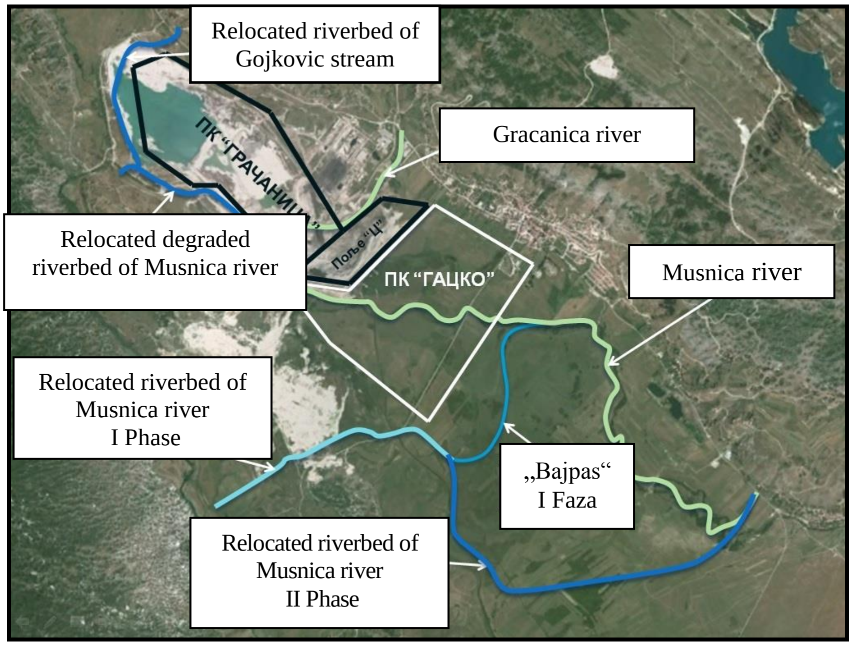


Figure 1 *Position of mine and major watercourses in Gatacko polje*

The protection system of the open pit against water among other facilities also includes development of the Collective water collector as the capital facility. Within work described in detail those parts of the drainage system that are related to Collective water collector.

The theme of this work is to construct a drainage system with the Collective water collector as the capital facility.

Analysis of the sizing factors of facility

In order to define the drainage system, it is essential to know the baseline of hydrogeological, geological, hydrological, geomechanical and mining technological parameters, then to realize a quality selection and sizing drainage the facilities for drainage the surface water and groundwater.

For selection the technical measures for protection the open pit on surface water, it is necessary to know the size and characteristics of catchment areas. The area from which water runs into the zone of the open pit represents a catchment area that is designated by the watersheds. Contours of the catchment area of surface and ground water as a rule do not have to match. Characteristics that affect the regime of surface water inflow from the catchment area of the open pit are: the geometrical shape of the catchment area, geological and pedological cover, high-altitude conditions, climatic conditions, density of watercourse streams in the catchment area, etc. In the planning process, an analysis of the size and basic elements of catchment areas that have a direct impact on the flow of surface water in the zone of the open pit Gacko-Central field. Figure 2 presents the position of catchment areas that gravitate towards the area of the open pit Gacko, and Table 1 presents the size of catchment areas of the open pit and their characteristics.

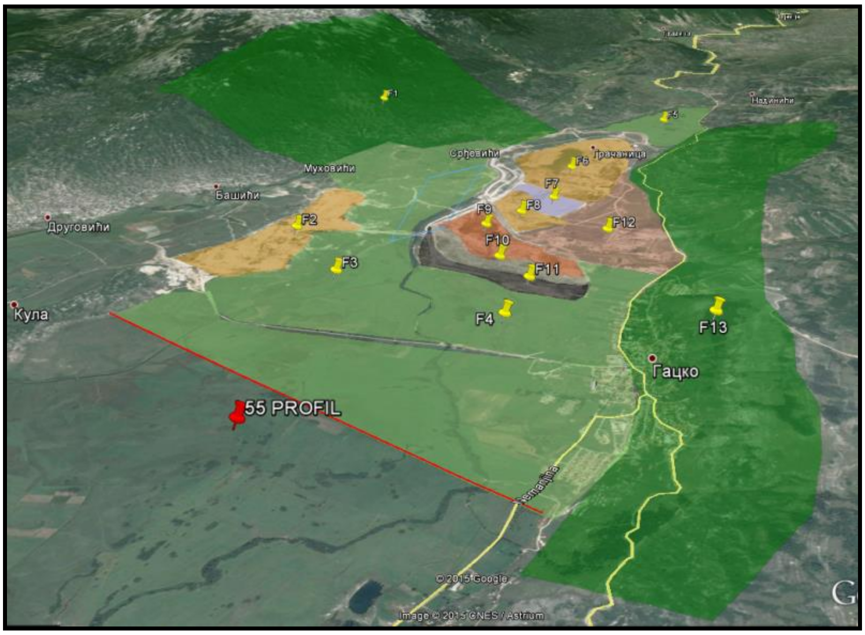


Figure 2 *Catchment areas of the open pit Gacko*

Table 1 *Size of catchment areas at the open pit Gacko*

Name of catchment area	F (km^2)	Volume (km)	VH (m)	VL (m)
F1 – Catchment area of southern mountains	11.70	14.70	500	2,700
F2 – External landfill	1.00	5.30	15	900
F3 – South part of plane	4.75	13.00	5	2,000
F4 – North part of plane	1.61	6.74	5	2,000
F5 – West part of plane	0.98	5.65	15	3,000
F6 – Internal landfill Field B	1.49	4.97	30	1,700
F7 – Ash landfill Field A	0.26	2.27	10	800
F8 – Internal landfill Field A	0.32	2.72	30	1,800
F9 – Current internal landfill	0.59	4.26		
F10 – Excavated area	0.34	3.83		
F11 - Mining front	0.34	4.29		
F12 – Industrial circle	1.44	6.32	5	3,000
F13 – Catchment area of norther mountains	7.80	18.00	100	1,800
F14 – Eastern flat part behind the road Gacko – profile 55	3.00	9.00	5	3,000
TOTAL:	**35.62**			

In the previous period all surface and groundwater, collected within the protection system of the open pit of water, were evacuated into the riverbeds of the rivers Musnica and Gracanica. All water from the area of the basin swell by the flows of these rivers to the west beyond the borders of coal basin. Despite the fact that the river Musnica was relocated, the old riverbed was so far used for the water evacuation. By designed development works at the open, the old flow of this river was cut, and it is necessary todirect all water in the area of the existing open pit and east of the front of works carried out in the new riverbed of the river Musnica. Based on the present situation in Figure 2, the catchment areas are seen with pouring water into this zone of the open pit:

- F2 – External landfill
- F3 – South part of plane
- F4 – North part of plane
- F9 – Current internal landfill
- F10 – Excavated area
- F11 – Mining front

Considering data from Table 1, the position of front works and facilities of drainage system, it is shown that out of total 35.62 km^2 actually is around 3.0 km^2 of the area from which the water inflows into the zone of drainage facilities that are directed towards Collective water collector.

For sizing the protection facilities of the coal open pits against surface water and groundwater, it is necessary to determine the so-called computational rain. They are determined by the analysis of probability the rain occurrence with certain intensity of duration. Computational rain or the amount of precipitation is calculated by the methods of mathematical statistics.

This processing is usually done by the specialized institutions (Hydrometeorological Institute, and similar), which determine the mentioned precipitation on the basis of pluviographic data. In the present case those are data of the Meteorological Service of the mine Gacko referring to the sixty-year return period and that meets the prescribed requirements for design the protection facilities of the open pit against water, and these values are:

- Maximum sixty-year 60-minute rainfall: 56.0 mm (lit/m^2)
- Maximum sixty-year 24-hour rainfall: 198.4 mm (lit/m^2)
- Maximum sixty-year monthly rainfall: 636.0 mm (lit/m^2)

- Average sixty-year annual rainfall: 1,615 mm (lit/m^2)
- Maximum sixty-year annual rainfall: 3012.5 mm (lit/m^2)

Protection system of the open pit against water

The previous drainage method is based on the fact that water that inflow into contour of the open pit has to be collected in two water collectors VS-C1 and VS-C2, where they are pumped by the system of pumps and pipeline into the river Gracanica. Evacuation of water, collected in the water collector VS-PZ1 (water collector within the Zone of roof coal), is carried out by pumping into the old riverbed of the river Musnica.

The new system requires that all water received at both limbs of the open pit (Central Zone and Zoneof roof coal) has to be evacuated into the river Musnica. To enable this, it is necessary to create a system of circumferential canals and Cumulative water collector (CWC).

System of circumferential channel is intended to prevent the additional water inflow from the catchment areas in the contour of the open pit. Water collected in canals are directed towards a common recipient Collective water collector. Some channels, in addition to the function of protecting the open pit from water inflow from catchment areas in the open pit contour, have the task to accept water that is pumped from the open pit contour and direct them towards a common recipient Collective water collector, where it will continue to send the collected water into the river Mušnica.

Circumferential canals, intended to prevent the inflow of water in the open pit contour, are:

- East Canal 1 (EC-1)
- East Canal 2 (EC-2)
- East Canal 3 (EC-3)
- East Canal 3’ (EC-3’)
- South Canal 1 (SC-1)
- South Canal 2 (SC-2)
- Austrian Canal (AC)
- North Canal (NC)

The North Canal has a function to accept all water flowing towards the open pit on the north side (Figure 2 - catchment area F13). It directs the collected water to the North water-collector (NWC), and from there into the river Gracanica.

The East Canal 1 is the main canal of the group of eastern canals. Its task is to take water from the catchment area, to receive water from the East Canals 3 and 3' collected in the Auxiliary water collector (AWC) (where it is transferred using the pumps and pipeline transferred to the East Channel 1) and directs them to a new riverbed of the river Musnica, more specifically to the "Bypass".

All water that has entered the Central Zone of the open pit are collected in a water collector (MWC-CP) and using the pump station with an installed pumps and piping system (required equipment is shown in Table 2) are evacuated into the South Channel 1. The pumped water, with water in canal from catchment areas, is directed towards the Austrian Canal. The Austrian Canal, besides water arrived from the South Canal 1, also has the water coming from the South Canal 2 (which is designed to accept water from the eastern part of the catchment area of the landfill) as well as water from the catchment area of the Austrian Canal. All water that gets into the Austrian Canal are directed to the Cumulative water collector.

Unlike the Central zone, water that are received at the Zone of roof coal are significantly simpler to evacuate to the Cumulative water collector. From the Zone of roof coal, the water that was collected in the water collector MWC-KS is evacuated directly into the Austrian Canal using a pumping station with the installed pumps and pipeline. The planned equipment is shown in Table 2.

The East Canal 2 is located directly in front of the front works in the Zone of roof coal, with the purpose to prevent the inflow of water in the open pit from the east side. In addition to the collected water, this canal is sized to accept, if necessary, the water that was collected in the water collector in the Zone of roof coal. All received water in canal is transported in the Cumulative water collector.

Table 2 *Pumping facilities of water collectors connected to the system of circumferential canal and Collective water collector*

Water collector	Pumps	No. of pumps	Power [kW]	Power of facility [kW]	Calculating - required capacity [l/s]	Installed capacity [l/s]	Pipeline Ø [mm]	Length of pipeline [m]	Total length [m]
CWC	DH 86-50	2	500	1000	950	1000	350	430	860
	BS 2250MT	2	54	108		260	250	430	430
GVS-CP	CS 3240	3	275	825	470	558	300	810	2430
	BS 2400HT	2	90	180		102	250	810	810
GVS-KS	BS 2250HT	2	54	108	90	180	250	400	800

The backbone of this system is the Austrian Canal; it is sized to accept all water from the south side, i.e. water from the South Canal 1, South Canal 2 South, water that inflows from the catchment area around canal and collected water in both limbs of the open pit. Its original intention was to irrigate the agricultural land, while it is currently used as a canal for drainage.

This method drainage is anticipated to begin operations in 2017, so that in 2016 the drainage of the open pit is carried out on the current mode. The reason for this is the required time to construct the drainage facilities and purchasing the necessary equipment. All facilities that make up the drainage system are stationary. Figures 3, 4 and 5 show the designed status of works in 2017, 2020 and 2037 (the end of mining) and the position of drainage system with the Cumulative water collector.

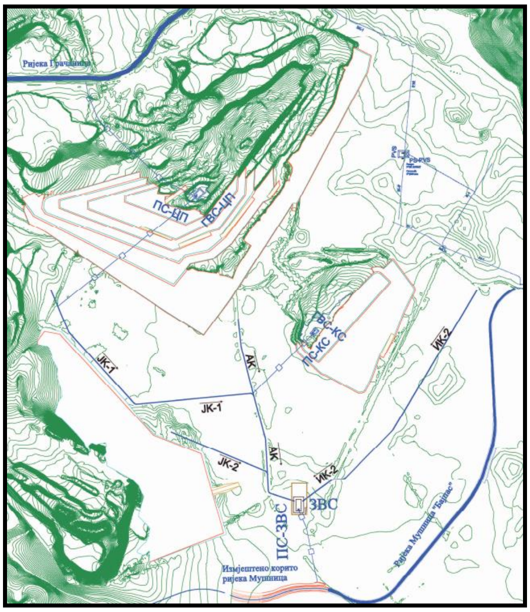


Figure 3 *Position of drainage facilities and system of circumferential canals and the Cumulative water collector in 2017*

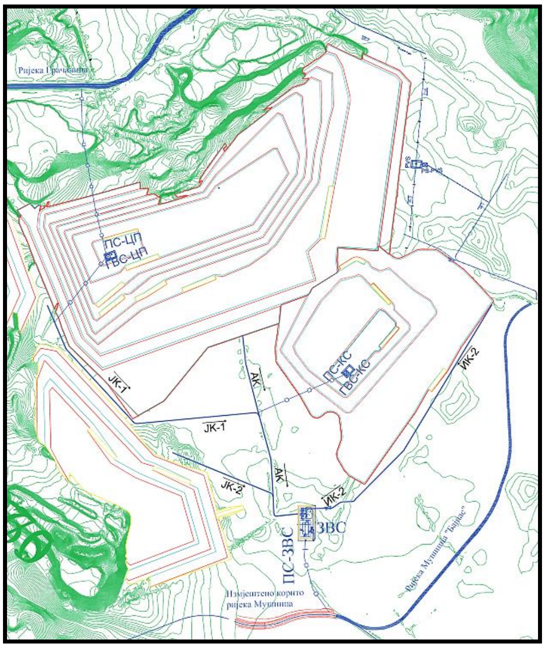


Figure 4 *Position of drainage facilities and system of circumferential canals and the Cumulative water collector in 2020*

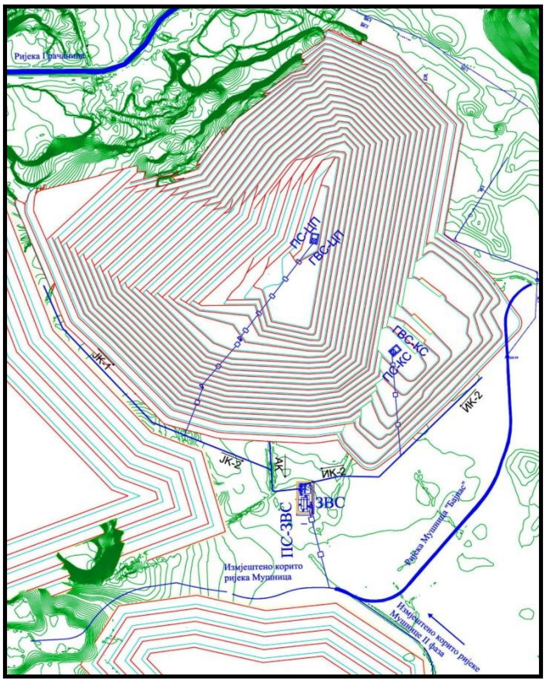


Figure 5 *Position of drainage facilities and system of circumferential canals and the Cumulative water collector in 2037*

The Cumulative water collector (CWC)

Due to the changes in direction of water evacuation in the Gacko basin, the gravitational connecting of predicted canals cannot be predicted in a new riverbed of the river Musnica, but it must be carried out by force. The main facility that allows this is the Cumulative water collector.

The Cumulative water collector is designed to accept water that inflow from the canal:

- East canal 2 (EC-2)
- South canal 1 (SC-1)
- South canal 2 (SC-2)
- Austrian canal (AC)

The surface from which The Cumulative water collector collects water is about 3.0 km^2. In addition to the water that inflows from the catchments areas, the water evacuated from the open pit is also collected in water collector. Maximum inflow of water into water collector is about 11 m^3/s.

Table 3 *Inflow of water into canals that flow into the the Cumulative water collector*

Canals	F Catchment (km^2)	Hourly intensity of rainfall (mm)	α drainage coefficient	Additional inflow (m^3/s)	Water inflow into canal	
					(l/h/m^2)	(m^3/s)
JK-1	0.50	56.00	0.40	0.47	11.20	3.58
JK-2	0.30	56.00	0.40	0.00	6.72	1.87
IK-2	0.60	56.00	0.40	0.00	13.44	3.73
AK	0.20	56.00	0.40	0.09	4.48	1.33
					Total:	**10.52**

Construction of water collector is planned to take place in two phases. The first phase of construction the Cumulative water collector includes excavation the Quaternary series and body of water collector. Works on the first phase of construction the water collector are foreseen for 2016. The second phase of the Cumulative water collector involves construction a settlement tank with overflow. The body of water collector and settling tank with overflow is necessary to coat to prevent water drainage from the water collector. Works on the completion of the water collector (II second phase) are foreseen for 2017.

Total volume of water collector is 36,700 m^3, although the quantity of excavated material would be much higher. For the reasons why the water collector is constructed, it was necessary to lower the water collector to 5m below the ground level, i.e. below the level of +940. In order to provide a sufficient maneuvering space for equipment that will work on maintaining the water collector, a space for installation the emergency pumps and other ancillary works at the level +935, a plateau is formed with a descending ramp. Dimensions of excavated area at the level +940 are 156.3·70.6 m, and the slopes at angle of 65º. From the level +935, the construction of a part of water collector is foreseen that should receive water from the canal and its volume is 36,700 m^3, out of which the volume of settling tank is 5,700 m^3, and a body of water collector 31,000 m^3. Dimensions water of collector are shown in Figure 6.

The area between the plateau at the level of +935 and the surface are predicted to be a reserve area for flooding, namely that in the event of heavy rainfall they can receive water that the pump cannot evacuate. Volume of this area is about 58,000 m^3. In order to enable the sinking of the area above the level of +935, the condition is that the plateau has no installed equipment that can be jeopar-dized by its immersion. The additional equipment will be stationed at the level +940.

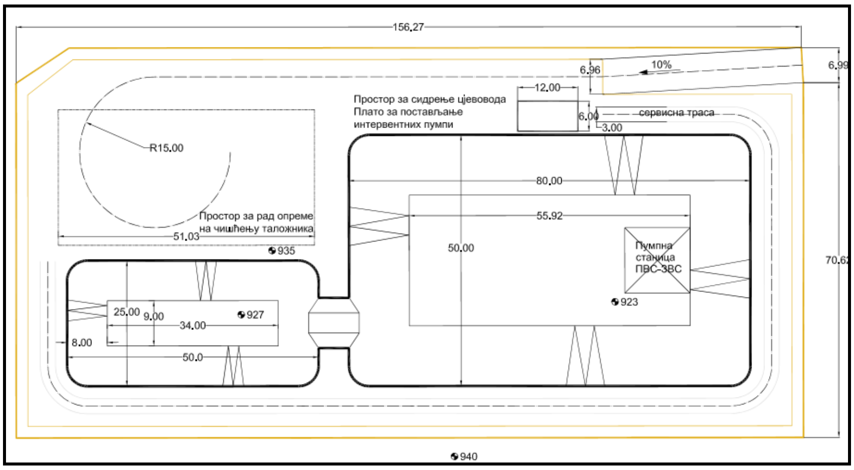


Figure 6 *Construction and dimensions of the Cumulative water collector*

Position, at which the construction of the Cumulative water collector was planned, by its geological characteristics meet the requirements for its development. Perhaps the most important thing about the choice for water collector site is that the water collector is constructed in homogeneous material, marl. After examining the geological base, it was found that a layer of limestone, developed in depth, in a given area is deeper than the anticipated depth of the water collector that can affect the functioning of water collector. It is also important to note that in the immediate vicinity of the water collector site, there is a current riverbed of the Austrian Canal that will be used and in the future.

It is anticipated that the drain of water collector is 13 hours. To make the drain of water collector in a given period, it is necessary to install a pumping station with capacity of 950 l/s. The pumping station on the Cumulative water collector consists of two pumps type DH 86-50 (after the planned revitalization) of the individual capacity of 500 l/s with a lifting height up to 20 m of water, and the necessary reserve in capacity will be provided by installation another two pumps BS 2250 with capacity of 129.5 l/s and lifting height of 25 m. Elements of the pumping station are shown in Table 2.

Economic view of investment for construction the water drainage system with the Cumulative water collector

In order for this system to function successfully, it is necessary in addition to construct the Cumulative water collector, also to construct a circumferential canal and supply the all necessary equipment for operation of this system. Of all these canals, there is currently only the Austrian canal, although it requires a small reconstruction and regulation of the riverbed. The bill of quantities that have to be realized is shown in Table 4.

Table 4 *Bill of quantities on circumferential canals*

Canals	Length [m]	General incline [‰]	Inflow level	Excavation volume [m^3]
JK-1	1,288.0	3.0	934.2	41,099.0
JK-2	523.0	15.9	937.0	17,936.0
IK-2	1,380.0	0.6	934.0	20,000.0
AK	852.0	3.2	933.5	24,857.0

Total costs of construction the drainage system with the Cumulative water collector are shown in Table 5.

Table 5 *Costs of construction the drainage facilities*

Circumferential canals			Water collector		
Canals	**Excavation volume [m³]**	**Costs of excavation [KM]**	**Part of water collector**	**Excavation volume [m³]**	**Costs of excavation [KM]**
JK-1	41,099.00	82,198	Quaternary	58,000.00	116,000
JK-2	17,936.00	35,872	Water collector	31,000.00	124,000
IK-2	20,000.00	40,000	Precipitator	5,700.00	22,800
AK	24,857.00	49,714			
Total		207,784	Total		262,800
				Total:	470,584

CONCLUSION

In order to conduct the effective and sustained mining, it is necessary to provide the required conditions for smooth operation. In the specific example, the oopen pit Gacko has complex requirements in terms of protection the open pit on water. It is necessary to pay attention to development the drainage system that will prevent the inflow of water into the open pit contour and to protect effectively the open pit alone. The efficient solution of the problem means a solution that will solve that problem, to cost a little and take a long time.

The present drainage system will completely replace the current one, and improve the protection of the open pit on water, whereby:

- to direct all collected water on the east side to the river Musnica,
- the circumferential canals will reduce the amount of water that inflows into the open pit,
- the surface water will be controlled and at a safe distance from the open pit contour,
- the main recipient will be the river Musnica whose riverbed is outside the zone of mining.

From the economic point of view, such a system is cost effective provided that a longer period would have no changes on the structures that comprise it.

From the standpoint of the efficiency, this system is intended to operate until the end-of-life of the open pit. All facilities are placed so that they can freely perform their function of drainage. It is required that the canals are regularly maintained and extended, if necessary.

REFERENCES

[1] Strategy Mining - Technological Opening, Development, Optimization and Maintenance the Continuity of Coal Production with Introduction the Process of Enrichment of Dry Separation Coal at the Open Pit gecko, Book 1, MMI Bor, Bor, 2015 (in Serbian)

[2] Additional Mining Desing on Mining a Part of the Field C at the Open Pit Gracanica – Gacko Center for Open Pit Mining, Belgrade, 2010

[3] Additional Mining Desing on Mining a Part of the Field C at the Open Pit Gracanica - Gacko, Simplified Mining Desing on Mining a part of the Field C with Englargement the Current Front Works in the South Part and Part of Roof Coal at the Open Pit Gracanica + Gacko, MMI Bor, Bor, 2014 (in Serbian)

[4] Main Mining Design of the Open Pit Gacko – Central Field for the Capacity of $2.3 \cdot 10^6$ t/year of Run-of-Mine Coal, Project on Defense against Water, MMI Bor, Bor, 2016 (in Serbian)

MINING AND METALLURGY INSTITUTE BOR ISSN: 2334-8836 (Štampano izdanje)
UDK: 622 ISSN: 2406-1395 (Online)

UDK: 622:669:621.3(045)=111 doi:10.5937/mmeb1604029P

Marijana Pavlov-Kagadejev, Radojle Radetić**, Vladimir Despotović****

IMPACT OF ADMINISTRATIVE MEASURES ON ELECTRICAL ENERGY COSTS IN COPPER PRODUCTION****

Abstract

The Mining and Smelting Complex Bor (RTB) is one of the biggest electrical energy consumers in Serbia, with costs that exceed 3 million USD per month, or between 30 and 40 million USD per year. A complex technological process of copper production comprises mining, concentrate production (flotation), smelting and electrolytic refining. In all these stages a large amount of energy is consumed. The electricity is supplied from the power plants using 5 substations: two of them located in Bor, and the remaining three in Majdanpek. The conditions for delivery and billing of the electrical energy were defined by the contract with the supplier. The methods of billing (calculation) the electrical energy costs were changed several times in the previous 25 years. Although the consumed energy is the largest part of the overall costs, there were also some indirect costs affecting the final monthly price. It is clear that even a minor percentage decrease of costs can lead to substantial savings in the total amount. Hence, different technological and organizational activities were undertaken to reduce these costs. The paper presents primarily the effects of administrative measures on the amount of total electrical energy costs in copper production.

Keywords: *Mining and metallurgy, electrical energy, active energy, reactive energy, peak load*

INTRODUCTION

Copper production in RTB includes various technological and organizational activities in a wider geographical area [1]. In these activities, the large amounts of electrical energy are consumed [2]. For the security of power supply, the five primary transformer substations (TS) (110 kV/6 kV*) were built; two located in Bor, and three located in Majdanpek. The total installed capacity of all power stations in RTB is close to 500 MVA. All costs (including energy and power) are calculated and billed by the electrical energy supplier at the level of consumer substations, not the individual plants that are the part of RTB. Allocation of costs within RTB organizational units - plants and factories, is carried out based on the internal measurements. Measures to reduce these costs have always been undertaken, but until late 80s and early 90s there was no systematic monitoring and control of power and energy consumption, so these measures

* *Mining and Metallurgy Institute Bor, ZeleniBulevar 35, 19210 Bor, Serbia, e-mail:marijana.pavlov@irmbor.co.rs*
** *Serbian Transmission System, Nade Dimić 40, 19210 Bor, Serbia; e-mail: radojle.radetic@ems.rs*
*** *Technical Faculty Bor, University of Belgrade, V.J. 12, 19210 Bor, Serbia, e-mail: vdespotovic@tfbor.bg.ac.rs*
**** *This research was supported in part by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Grant Nos. TR33037 and TR34005, within the framework of Technological Development Program*

were not always effective. In fact, at that time, design, construction and application of supervisory and control systems in transformer substations started, at the beginning only in TS Bor3 [3]. Later, the other transformer substations were included, as well as the individual plants in RTB. As the supervisory system enabled real-time and continuous monitoring of consumption, with the option of creating technical and financial reports with objective presentation and distribution of costs, an opportunity for reduction and optimization of these costs appeared [5]. Many concrete actions were undertaken in this period that can be classified into two main categories: technological and organizational; or combination of both. Very often they give the significant results [4, 6, 7, 8, 9, and 10].

The aim of this paper is not to present measures and activities to reduce the electrical energy costs, nor the effects, but the impact of numerous changes in the methods of calculation the costs in last 25 years. These changes were initiated by the electrical energy supplier and demanded different measures and strategies to reduce the costs, which will be denoted by administrative measures in further text.

The analysis provided in the paper covers the period 1991-2015. As a proof of concept, only the substation Bor 3 will be analyzed, as it was the first one with the installed monitoring and control system and provides continual data acquisition since 1990 (with the exception of 1999, when it was ruined in bombing of Serbia and Montenegro). Also, all the metallurgical and some of the mining plants are electrically supplied from this transformer substation (see Table 1), hence the results can be easily generalized for other substations.

Table 1 *The plants electrically supplied from TS Bor 3*

	Plant	**TS Bor 3 cell**
1	Smelting Plant 100	K9+K10
2	Smelting Plant 456	K42+K43+K44
3	Electrolytic Refinery	K45+K46
4	Foundry	K17+K18
5	Old Air Separation Unit	K19
6	Power Plant	K40+K47
9	New Smelting Plant	K6+K21
10	Sulphuric Acid Plant	K15
11	Filtration	K30
12	Old Concentrator	K2
13	New Concentrator	K31+K32
14	Export pit	K33+K34
15	FOD	K27
16	New Sulphuric Acid Plant	K5+K20
17	Power Plant for the Smelting Plant	K14
18	Fibre-Reinforced Plastic (FRP) Unit	K3

OVERVIEW OF CALCULATION METHODS

It has already been noted that in the reporting period (1990 - 2015) RTB Bor purchased the electrical energy from the supliers according to the contracts that were signed each year. The contracts contained regulation the method of delivery, quantities and prices of electrical energy and power. Each of the contracts contained a price list with the specification of energy and power unit price, and some additional costs. Those additional costs were small both in absolute and in relative terms, and will not be further discussed in this paper. The electrical energy, active and reactive, as well as the tariff system, have the greatest influence on the overall costs. However, these costs will not be discussed in detail, because it would be necessary to take into account the productivity norms, which is beyond the scope of this paper. Hence, the focus of the article will be on power costs, as the second most significant factor influencing the overall costs, or to be more specific the peak load costs [7, 8]. The peak load is the maximum average power load over a designated interval of time (15 minutes) during one month (Figure 1). It is clear that, under certain circumstances, 15 minutes of unusually high energy import, resulting from the concurrent start-up of power consumers, may drastically increase the power costs for an entire month. This can be often avoided with only a minimal technical effort, by just a few short, targeted interventions at the right point in time. The calculation of peak load costs has changed over the years, and the company had to adapt to these changes in order to reduce the costs. Each of these methods of calculation is discussed in details in further subsections.

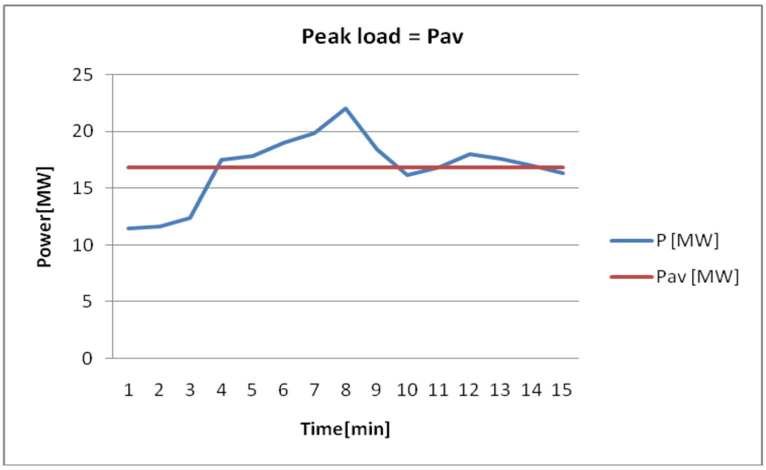


Figure 1 *Peak load definition*

Principle of "regional peak load"

The period 1991-2003 was characterized by the significant share of peak load costs in the total electrical energy costs, which went up to 46%. Clearly, potential savings in these costs were significant, having in mind the absolute amounts of costs.

This was also the period when a special attention was paid to development of systems, actions and algorithms for its reduction [3, 6, and 9]. However, the method of calculation the peak load costs was rather interesting. The electrical energy supplier (Elektroprivreda Srbije – EPS at that time) measured the peak load in all 110/6 kV transformer substations in the Zajecar administrative district (municipalities of Zajecar, Bor, Majdanpek, Negotin, Kladovo, Knja-ževac and Boljevac) during each month. Hence, the substations that had nothing to do with RTB were also included in the calculation of peak load costs. These data were then merged to find maximum 15-minute peak load values over all substations in the administrative district. The time when the maximum peak load in the whole district occurred, was further used to read the peak load in substations that supplied RTB.

This method of calculation of peak load costs was neither logical, nor fair, from the point of view of the consumer, but the supplier insisted that it was the only way to guarantee the continual supply of electrical energy to all consumers in the district. It was very difficult to optimize or reduce the costs, as the time of occurrence of peak load was not always related to production activities in RTB. It should be insisted on as less as possible engaged electrical power, and thereby the peak power was lower, anyway measured. In this way, RTB Bor achieved significant savings in 1991 [11]

The year 1991 was used as an example, as this was the year with extremely large production of cathode copper.

Table 2 *Costs distribution in 1991*

Costs	
Energy (active) [USD]	6 850 000
Peakload [USD]	5 800 000
Total [USD]	12 650 000

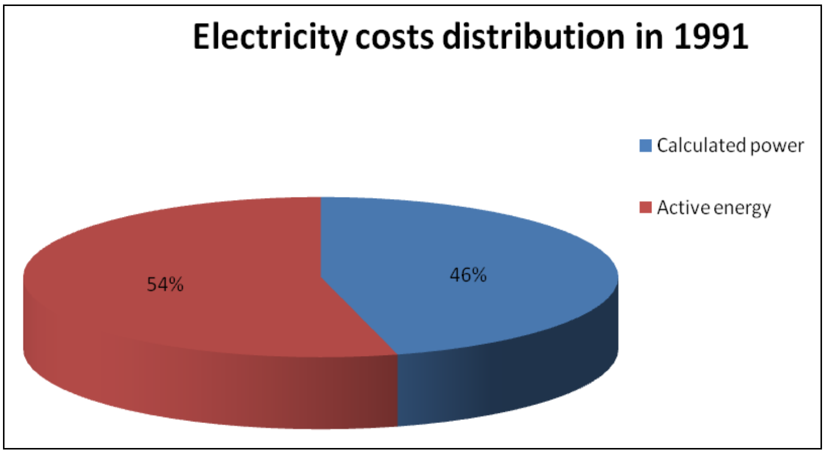


Figure 2 *Costs distribution in 1991*

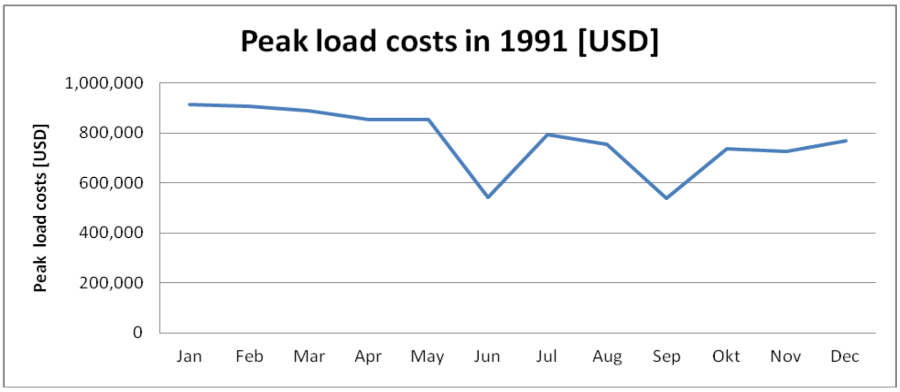


Figure 3 *Measured (engaged) power in 1991*

The principle of "common peak load"

From 2003 to 2008, the electrical energy supplier (Elektromreža Srbije - EMS), introduces a new method of calculation and billing the electrical energy costs. The peak load was now determined as the maximum average 15-minute sum of loads in all 5 substations that supplied RTB with electrical energy. This was a fundamental change as it included only the substations that suplied RTB. Although the RTB plants are distri-buted and very often technologically independent, it was possible, for the first time, to make organizational and procedural algorithms that would enable the optimization of power costs [11, 12]. The dynamic plan for activation of large consumers was made, to avoid its concurrent start-up whenever it was possible, without disturbing the technological process.

In order to enable the realization of such dynamic plan, all five substations were monitored in real-time using the installed monitoring systems. Although the most optimal results would be obtained by making a centralized system that would merge the data from all substations, this was not realized due to very complex technological processes and organizational structure in RTB, so only the individual impact of every substation on reducing the peak load was assessed. However, even not optimal, these measures yielded positive results. The impact of peak load in the total costs decreased to approximately 30% (Figure 5). A typical example of annual costs for this period is shown in 2004.

Table 3 *Costs distribution in 2004*

Costs	
Energy (active) [USD]	2 358 705
Peak load [USD]	1 050 343
Other costs [USD]	251 452
Total [USD]	3 660 501

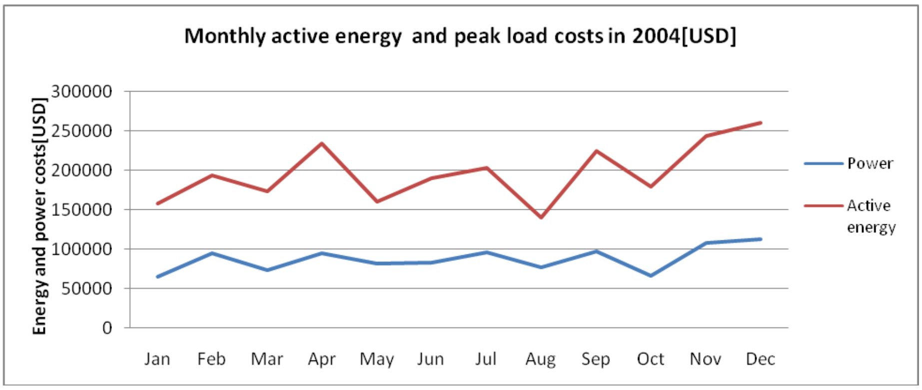


Figure 4 *Consumed electrical energy and measured (engaged) power in 2004*

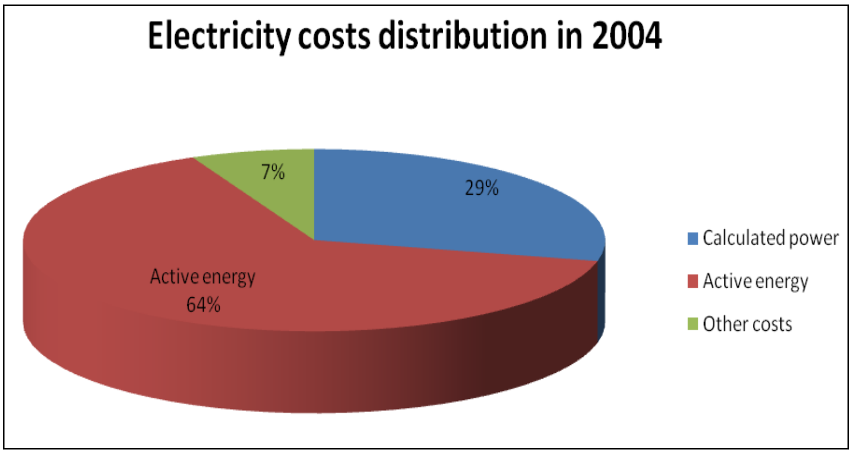


Figure 5 *Costs distribution in 2004*

The principle of "individual peak load"

In the period 2008-2014, the method for calculation and billing the electrical energy costs changed again. The peak load was determined at the level of each individual substation, as its maximum average 15-minute load during one month. This was not beneficial for consumers, as the sum of maximum peak load values is always higher (or equal in the best case) then the maximal sum ("common peak load" principle). Hence, all the actions to reduce the power costs were transferred to a lower level, a level of the single substation and plants that were supplied by this substation [14]. Technologically speaking, it was a simpler procedure, but the possibilities of savings were limited [13]. Nevertheless, the impact of power costs decreased in this way to approximately 20%, as shown in Figure 6.

Table 4 *Costs distribution in 2012*

Costs	
Energy (active) [USD]	5 841 673
Peak load [USD]	1 505 505
Other costs [USD]	23 450
Total [USD]	7 370 488

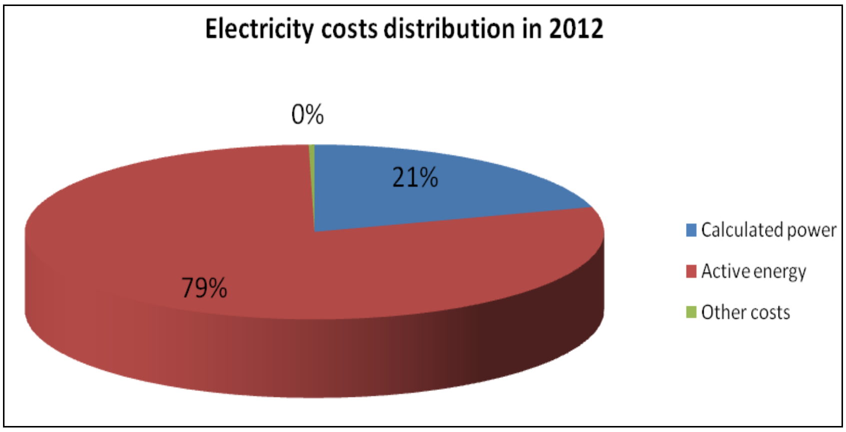


Figure 6 *Costs distribution in 2012*

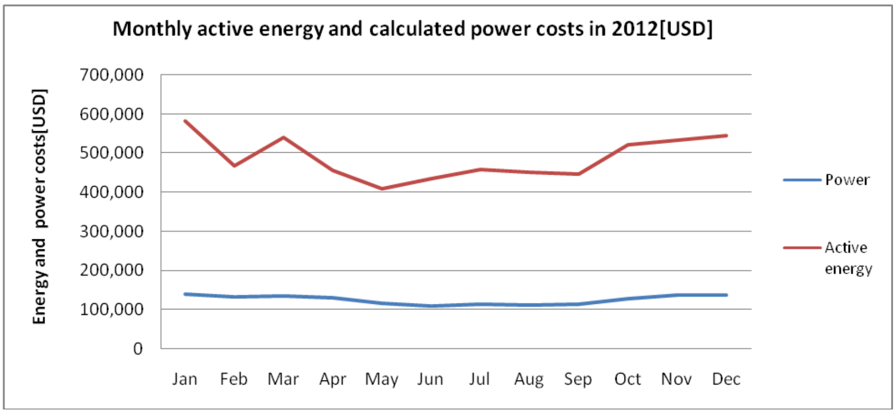


Figure 7 *Costs for electrical energy and measured (engaged) power in 2012*

The principle of "approved peak load"

Changing the laws and government regulations in 2014, the electrical energy market was liberalized, and EPS was no more the exclusive supplier. Also the terms of calculation and billing the electrical energy costs were negotiated with the supplier. Hence, the method of calculation has changed once more.

Jugoistok (the part of EPS) was chosen as the supplier. The structure of costs consists of the consumed electrical energy, the approved electrical power and monthly dynamic for the whole year. Based on consumption in recent years, and production plans in the future, RTB needs to provide the plan to the supplier, which in turn defines the approved power, as the new term in the bill. Power was still measured as maximum average 15-minute load during the month. As long as this peak load is less than, or equal to the approved power, the user only pays the amount of approved power. Any excess over the approved value is called the *excessive power*, and it is billed at four times higher prices. This method of calculation requires a thorough analysis of electrical behavior in previous years and good planning and prediction of production in the year for which the agreement is to be made [16,17]. So, in addition to energy experts, it is necessary to involve the technical stuff in the individual organizational and technological units [18]. This method of calculation may be illustrated by the case of 2015, where it is clear that the share of the power costs decreased significantly using the new principle of cost calculation (only 3%).

Table 5 *Costs distribution in 2015*

Costs	
Energy (active) [USD]	9 533 933
Peak load [USD]	369 809
Other costs [USD]	2 033 869
Total [USD]	11 937 611

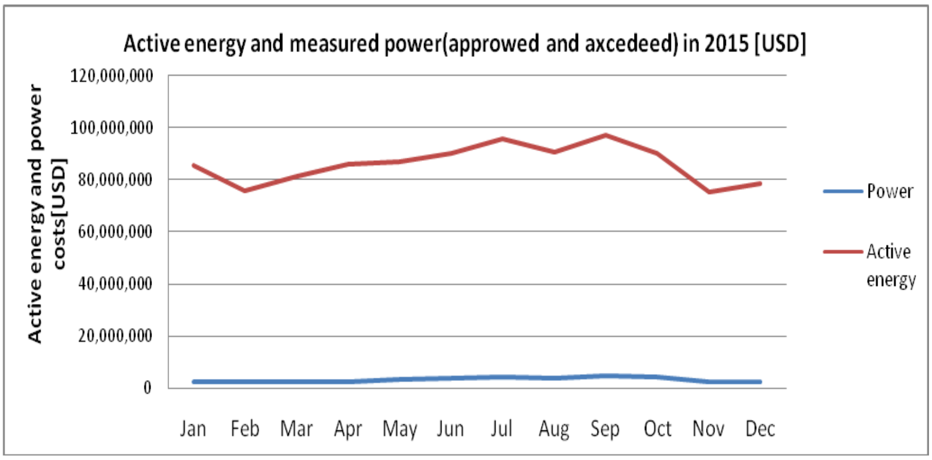


Figure 8 *Monthly costs for electrical energy and measured (approved and exceeded) power in 2015*

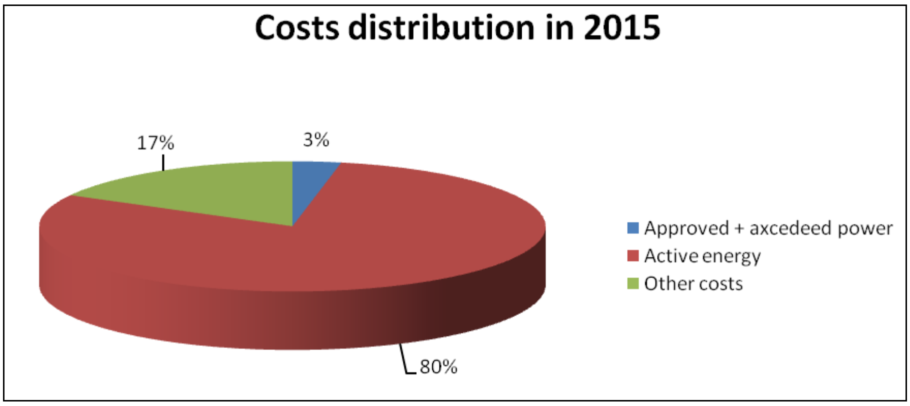


Figure 9 *Costs distribution in 2012*

DISCUSSION

To make a fair comparison of impacts and effects of changes in methods of calculation and billing of electrical energy, the objective measures should be used, such as: active and reactive energy, electrical power, or some administratively defined quantities, such as: excessive energy, peak load, approved power, excessive power, and the like. Active energy was the most dominant part of electrical energy costs in the whole analyzed period. Reactive energy, on the other hand, in some periods was not billed, sometimes not even measured .Note that Bor3 substation had the capacitor batteries installed (with the power of 14 MVAr); thereby the satisfactory compensation of reactive energy was achieved. However, after it was destroyed in bombing in 1999, the new one was built, but without a section for reactive power compensation. Only after years the capacitor batteries were installed, and the reactive energy was compensated.

Copper production in the observed 25-year period varied from more than 100.000 tons per year in the early 1990s to 30.000 tons in recent years. Several factors influenced the reduced production, including technological factors (smaller percentage of copper in the ore), political (economic sanctions during the 1990s), economic factors (drastic changes in prices on the stock market, from 1.500 USD/t in 2002 to 10.000 USD/t in 2011) etc. In order to make an objective comparison, a new quantity is defined denoted as the "average price of active energy per annum" C_{Ea}:

$$C_{Ea} = \frac{P_{Ea}[USD]}{Ea[kWh]} \qquad (1)$$

where E_a is the total active electrical energy spent over a year, and P_{Ea} is the total annual price of this active energy denominated in USD.

In addition to active the energy, a significant part of costs was the electrical power. These costs were calculated in different ways over the analyzed period (regional peak load, common peak load, individual peak load, or the approved power and excessive power). Therefore, the concept of "average monthly price of power per annum" C_P is introduced:

$$C_P = \frac{PMC\,[USD]}{AMP\,[kW]} \qquad (2)$$

Where *PMC* represents the average monthly cost for the power over the year and *AMP* is the average monthly power over the year (determined as the peak load or the approved peak load, depending on the analyzed period). In this way the parameters C_{Ea} and C_P were introduced, that represent the unit price of energy and power, irrespective of the way of calculation. These are the two key parameters for comparison because they are dominant in the total amount of costs for each of the listed methods of calculation.

Figure 10 presents C_{Ea} and C_P calculated for TS Bor 3 for all described methods of calculation

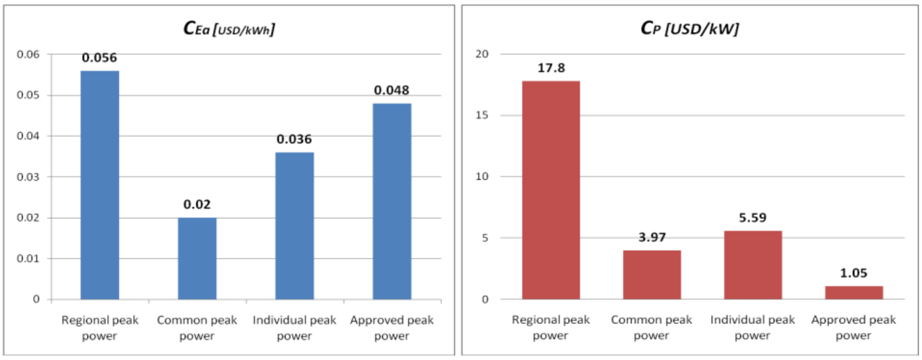


Figure 10 *Energy and power unit prices for different methods*

Comparison of described methods of calculation and billing the electricity costs shows that only the spent active energy represents a significant (dominant) part, independently of the used method. The other costs are allocated or categorized differently. Therefore, reducing the total consumption of active energy still has a significant effect in reducing the cost and impact on other elements (peak power, reactive power,) does not always provide equivalent savings for each of the methods. Given that the costs of reactive power are becoming bigger, it should be accessed by installing the compensation batteries in all consumer substations.

CONCLUSION

The all results presented in this paper are given for one substation (TS Bor 3) out of five that are used to supply electri-city in RTB, which has the share in the total electrical energy costs ranging from 24% to 45% over the analyzed period. The total costs of electrical energy are approximately 3.000.000 USD per month. It is clear that savings of only 1% amounts 360.000 USD per annum. To reduce the cost of electricity various activities were undertaken in the analyzed period. In the period when 'regional' and 'common' peak load method was used, the main objective was to reduce the peak load, as the share of the peak load in the total costs was very high (up to 46%).

The reduction and optimization of electrical energy consumption is a permanent task. This is achieved by installing the appropriate aggregates and their optimum operating regime. The current method of calculation the electrical energy costs particularly insists on careful planning the consumption, as the approved peak load is determined annually, based on the previous consumption and productivity plans. Any excess of approved power can lead to significantly increased total costs.

REFERENCES

[1] Mitovski M., Mitovski A., Efficiency of Rational Management in Electricity Copper Metallurgy, Copper 36(2011)1, pp. 4-16 (in Serbian)

[2] Schlesinger M. E., King M .J., Sole K. C., Davenport W. G. (2011) Extractive Metallurgy of Copper. Amsterdam: Elsevier, pp. 427-439

[3] D. R. Milivojević, M. Radojković, G. Jojić Blagojevic, Dj.Šimon, S.Lalović, Distributed Microcomputer System for Monitoring and Control of Electricity Consumption in RTB Bor, Praksa No. 11-12, 1991 (ISSN 0351'675X)

[4] J. Petrović, D. Grubišić, D. R. Milivojević, M. Radojković, G. Jojić Blagojević, Dj. Šimon, S. Lalović, Effects of Operation System for Control the Consumption of Electricity in the Basin Bor in 1991, XVIII International Conference on Mining and Metallurgy, D.Milanovac, 1992

[5] G. Jojić, D. Milivojević, M. Radojković, V. Tasić, S. Lalović, Microcomputer System for Control the Consumption of Electricity in the Substations, Paper announced at the Conference ENYU99, Zlatibor, 9 - 13 March, 1999 (in Serbian)

[6] Milivojevic D. R., Jojic Blagojevic G., Radojkovic M., Lalovic S., Tasic V., (1999), Application the System for Impact on Reducing the Peak Power and Spent Electricity in RTB Bor (Possibilities and Some of Defects Realized in Practice), Energy, Economy, Ecology, 4(I), 199 (in Serbian)

[7] V. Tasić, D. Karabašević, G. Jojić, D. Milivojević: Monitoring the Consumption of Electrical Energy in TS Bor 3, Symposium YUINFO′2004, Kopaonik 9 - 13 March, 2004 (in Serbian)

[8] V. Tasić, D. R. Milivojević, D. Karabašević, V. Despotović, Z. Eskić, Monitoring - Control System in the Power Plant TIR Bor, Conference ETRAN 2005, Budva, 6-10 June, 2005 (in Serbian)

[9] D. R. Milivojević, V. Tasić, V. Despotović, A. Ignjatović, An Example of Influence on Reduction of Electrical Energy Costs, Proceedings of XLI International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST 2006, 29 June - 1 July, 2006, Sofia, Bulgaria

[10] V. Despotović, V. Tasić, D. R. Milivojević, A. Ignjatović, Power Consumption Control System in Copper Tubes Factory - Majdanpek, Proceedings of the XLI International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST 2006, 29 June – 1 July 7, 2006, Sofia, Bulgaria

[11] M. Pavlov, D. R. Milivojević, V. Tasić, V. Despotović, Distributed Control System Applied in Copper Metallurgy, Proceedings of 41. International October Conference on Mining and Metallurgy, 2009, Kladovo, Serbia

[12] D. R. Milivojevic: Experience in Reduction the Electricity Costs for Large Consumers (RTB Bor), Bakar No. 2, Vol.27 (2002), YU ISSN 0351-0212 [UDC 669.3] (in Serbian)

[13] V. Tasić, D. R. Milivojević, M. Pavlov, V. Despotović, Reducing the Costs of Electricity in the Copper Mining and Smelting Complex RTB Bor (Serbia) by Using of the Distributed Control System, 33rd International Convention on Information and Communication Techology, Electro-

nics and Microelectronics MIPRO 2010, Opatija, May 2010, Proceedings (ISBN: 978-1-4244-7763-0)

[14] M. Pavlov, V. Despotovic, D. R. Milivojevic, V. Tasic, D. Brodic, Overview of Electrical Energy Costs in Metallurgical Plants of Copper Mining and Smelting Complex Bor, 43rd International October Conference, Kladovo, Octobar 12-15, 2011, Proceedings (ISBN: 978-86-80987-87-3), COBISS. (SR-ID 186644236)

[15] Methodology of Determining the Price to the Access System of Electric Energy Distribution, Chapte XIII, Official Gazette of RS Nos. 105/12 ... 65/15), (in Serbian)

[16] V. Tasic. D. R. Milivojevic, M. Pavlov, V. Despotovic, D. Brodic, Microcontroller Based Systems for Peak Load Reduction, Proceedings of Jubilee 35rd International Convention on Information and Communication Technology, Electronics and Microelectronics MIPRO 2012, Opatija 2012, (ISSN: 1847-3946)

[17] V. Tasić, V. Despotović, D. Brodić, M. Pavlov, D. R. Milivojević, Twenty Years of Monitoring and Control of Electricity Consumption in RTB Bor, Serbia, Proceedings of 36rd International Convention on Information and Communication Techology, Electronics and Microelectronics MIPRO 2013, Opatija 2013, (ISSN: 1847-3946)

[18] M. Pavlov Kagadejev, V. Tasić, D. Brodić, D. R. Milivojević, The Analysis of Electro-Energetic System Elements in Majdanpek Copper Mine, 45rd International October Conference, Bor Lake, October 16-19, 2013.

MINING AND METALLURGY INSTITUTE BOR ISSN: 2334-8836 (Štampano izdanje)
UDK: 622 ISSN: 2406-1395 (Online)

UDK: 622.33/271:681.51(045)=111 doi:10.5937/mmeb1604041S

Nikola Stanić[*]*, Aleksandar Doderović*[*]*, Saša Stepanović*[*]*, Miljan Gomilanović*[*]

DYNAMICS OF DEVELOPMENT THE WORKS OF ROOF COAL SERIES OF THE OPEN PIT GACKO BY THE SOFTWARE GEMCOM GEMS - MODULE CUT EVALUATION

Abstract

This work presents a method of determining the dynamics of development the open pit Gacko in the zone roof coal series with the annual capacity $3{\cdot}10^6$ t/year of run-of-mine coal using the module cut evaluation of the software package Gemcom Gems.

Defining the dynamics was preceded by optimization of the open pit that is done in the software Whittle. By optimization, the optimum boundary of mining (final contour) was obtained which includes $66{\cdot}10^6$ t of run-of-mine coal. The contour of the open, obtained in the process of optimization, was used as the final contour of dynamics of the open pit development.

Dynamics was developed for the period from 2016 to 2036 (until the end of service life). In the first 5 years, a detailed dynamics was made for the annual period, and after the fifth year, the dynamics was made for a five-year period.

Keywords: *open pit mining, dynamics of works, cut evaluation, optimization*

INTRODUCTION

The Coal Basin Gacko is divided into four exploitation fields: the Western, Central, Eastern mining field and Roof coal series.

The first works on coal mining began in 1954, when the open pit Vrbica was opened on the main coal seam outcrops in the Eastern mining field, and in 1982 the open pit Gračanica was put into operation in the area pf the Western mining field, with the annual capacity of 1,800,000 tons of coal and 3.2 million m^3 of overburden. After the overhaul of the Thermal Power Plant Gacko, the coal requirement has increased, so that the current capacity is 2,300,000 tons of coal.

The analysis of the current situation in TPP Gacko clearly indicates that there are a number of problems in realization the strategic goals of the company so the expected results are not achieved. Due to the complex geological, technical - technological and economic conditions of mining, a continuous and stable coal supply of power plant was brought into question, what required consideration the overall problems and finding the optimal solution based on the available resources and production capacities. Coal mining, exclusively from the roof coal series, is imposed as one of the possible solutions.

DETERMINING THE MINING BORDER

Optimization of the open pits is a process of defining and selecting the contours

[*] *Mining and Metallurgy Institute Bor – Department Coal Engineering Belgrade, nikola.stanic@irmbor.co.rs, aleksandar.doderovic@irmbor.co.rs, sasa.stepanovic@irmbor.co.rs, miljan.gomilanovic@irmbor.co.rs*

of the best open pit in terms of profits, according to the criterion of optimal discounted profit, and on the basis of input techno-economic parameters. The boundary contour of the optimum open pit is determined using the software for optimization and strategic planning Whittle Fx for a given selling price of coal, operating costs and corresponding technological parameters. The term "optimum pit" means a contour of the open pit where maximum economic results (discounted profit or discounted cash flow) are achieved in mining.

In the particular case - the open pit Gacko, optimization includes the roof coal seams as a whole.

In the process of optimization, based on certain input parameters and described restrictions, the following open pits were obtained:

Table 1 *Optimization results of the roof coal seam series*

Pit	Minimum Rev Ftr	Rock Tonnes t	Wast Tonnes t	Ore Tonnes t	Strip Ratio t/t	DTM Units kJ	DTM Grade kJ/kg
1	0.425	112,215,661	73,286,380	38,929,281	1.88	311.0E+9	7,990
2	0.45	116,162,923	76,302,614	39,860,309	1.91	317.0E+9	7,963.64
3	0.4755	118,648,767	78,254,907	40,393,860	1.94	321.0E+9	7,952.48
4	0.5	125,531,647	83,609,182	41,922,465	1.99	331.0E+9	7,903.97
5	0.525	135,958,519	91,786,144	44,172,375	2.08	346.0E+9	7,828.84
6	0.55	139,803,744	94,886,956	44,916,788	2.11	351.0E+9	7,812.13
7	0.575	144,958,530	99,018,285	45,940,245	2.16	357.0E+9	7,781.41
8	0.6	149,465,552	102,685,832	46,779,720	2.2	363.0E+9	7,758.41
9	0.625	153,191,402	105,720,212	47,471,190	2.23	367.0E+9	7,736.93
10	0.65	154,623,267	106,899,357	47,723,910	2.24	369.0E+9	7,729.45
11	0.675	191,390,184	137,982,999	53,407,185	2.58	408.0E+9	7,644.14
12	0.7	210,994,309	154,727,936	56,266,373	2.75	428.0E+9	7,612.59
13	0.725	215,220,481	158,338,688	56,881,793	2.78	433.0E+9	7,604.16
14	0.75	223,633,078	165,611,120	58,021,958	2.85	441.0E+9	7,593.03
15	0.775	228,951,923	170,195,205	58,756,718	2.9	445.0E+9	7,581.50
16	0.8	231,615,391	172,483,981	59,131,410	2.92	448.0E+9	7,574.05
17	0.825	236,281,720	176,521,142	59,760,578	2.95	452.0E+9	7,562.53
18	0.85	268,494,438	203,952,655	64,541,783	3.16	480.0E+9	7,429.47
19	0.875	270,152,807	205,383,459	64,769,348	3.17	481.0E+9	7,424.63
20	0.9	273,241,781	208,071,416	65,170,365	3.19	483.0E+9	7,416.89
21	0.925	279,662,586	213,669,711	65,992,875	3.24	488.0E+9	7,400.85
22	0.95	281,389,202	215,191,577	66,197,625	3.25	490.0E+9	7,397.71
23	0.975	283,404,510	216,972,592	66,431,918	3.27	491.0E+9	7,393.93
24	**1**	285,299,510	218,651,727	66,647,783	3.28	493.0E+9	7,390.45
25	1.025	286,707,920	219,915,935	66,791,985	3.29	494.0E+9	7,389.22
26	1.05	289,061,443	222,019,663	67,041,780	3.31	495.0E+9	7,385.74
27	1.075	290,298,036	223,117,197	67,180,839	3.32	496.0E+9	7,382.86
28	1.1	290,801,174	223,567,685	67,233,489	3.33	496.0E+9	7,381.98
29	1.125	292,066,371	224,701,842	67,364,529	3.34	497.0E+9	7,379.66

Continuation Table 1

30	1.15	294,344,967	226,726,256	67,618,711	3.35	499.0E+9	7,373.21
31	1.175	296,534,912	228,699,458	67,835,454	3.37	500.0E+9	7,369.45
32	1.2	297,495,575	229,566,521	67,929,054	3.38	500.0E+9	7,367.74
33	1.225	298,512,174	230,485,133	68,027,041	3.39	501.0E+9	7,365.90
34	1.25	299,363,563	231,256,669	68,106,894	3.4	502.0E+9	7,364.47
35	1.275	299,914,713	231,759,849	68,154,864	3.4	502.0E+9	7,363.82
36	1.3	300,541,174	232,334,830	68,206,344	3.41	502.0E+9	7,363.29
37	1.325	301,208,027	232,946,401	68,261,626	3.41	503.0E+9	7,362.61
38	1.35	301,753,536	233,441,307	68,312,229	3.42	503.0E+9	7,361.43
39	1.375	302,494,438	234,121,077	68,373,361	3.42	503.0E+9	7,360.49
40	1.4	303,250,294	234,811,120	68,439,174	3.43	504.0E+9	7,359.07
41	1.425	303,532,721	235,073,072	68,459,649	3.43	504.0E+9	7,358.93

For the resulting contours of the open pits for the corresponding selling price / return factor, the following graph shows the associated economic results - discounted cash flows presented by the corresponding curves.

Table 2 *Optimization results of the roof coal seam series – economic analysis*

Final pit	Revenue factor for final pit	Open pit cash flow best KM disc	Open pit cash flow worst KM disc	Tonne input best	Waste best tonne	Mine life years best	DTM kJ	DTM KJ/KG
1	0.425	532,105,191	532,105,191	38,994,927	73,246,990	13.0	311.0E+9	7,990
2	0.45	536,462,635	532,328,379	39,927,546	76,262,521	13.3	317.0E+9	7,963.64
3	0.4755	538,822,481	532,338,684	40,462,010	78,214,453	13.5	321.0E+9	7,952.48
4	0.5	544,363,979	530,627,164	41,993,228	83,567,731	14.0	331.0E+9	7,903.97
5	0.525	551,535,179	526,764,145	44,244,347	91,745,880	14.7	346.0E+9	7,828.84
6	0.55	553,698,360	523,757,847	44,988,860	94,847,376	15.0	351.0E+9	7,812.13
7	0.575	556,465,930	519,923,024	46,013,188	98,978,992	15.3	357.0E+9	7,781.41
8	0.6	558,450,438	516,379,596	46,854,098	102,646,161	15.6	363.0E+9	7,758.41
9	0.625	559,823,757	512,721,195	47,545,578	105,681,342	15.8	367.0E+9	7,736.93
10	0.65	560,248,795	511,524,306	47,794,335	106,864,761	15.9	369.0E+9	7,729.45
11	0.675	568,521,902	470,541,005	53,482,637	137,951,900	17.8	408.0E+9	7,644.14
12	0.7	571,930,420	449,451,473	56,343,489	154,699,862	18.8	428.0E+9	7,612.59
13	0.725	572,496,556	444,846,346	56,959,375	158,311,143	19.0	433.0E+9	7,604.16
14	0.75	573,617,860	435,807,547	58,101,489	165,583,549	19.4	441.0E+9	7,593.03
15	0.775	574,135,887	429,524,439	58,832,817	170,172,226	19.6	445.0E+9	7,581.50
16	0.8	574,342,613	426,414,122	59,206,392	172,462,705	19.7	448.0E+9	7,574.05
17	0.825	574,612,848	419,904,203	59,834,291	176,502,044	19.9	452.0E+9	7,562.53
18	0.85	575,320,795	386,475,639	64,599,057	203,957,446	21.5	480.0E+9	7,429.47
19	0.875	575,352,584	384,702,942	64,825,253	205,389,980	21.6	481.0E+9	7,424.63
20	0.9	575,368,899	380,458,176	65,226,370	208,078,477	21.7	483.0E+9	7,416.89
21	0.925	575,350,795	370,464,844	66,049,700	213,677,336	22.0	488.0E+9	7,400.85

Continuation Table 2

22	0.95	575,337,729	368,419,616	66,254,214	215,199,818	22.1	490.0E+9	7,397.71
23	0.975	575,299,633	365,616,133	66,488,907	216,980,881	22.2	491.0E+9	7,393.93
24	1	575,244,960	362,895,317	66,703,969	218,661,196	22.2	493.0E+9	7,390.45
25	1.025	575,193,886	361,711,773	66,848,418	219,925,472	22.3	494.0E+9	7,389.22
26	1.05	575,087,809	357,883,306	67,098,347	222,029,570	22.4	495.0E+9	7,385.74
27	1.075	575,020,495	355,921,790	67,236,764	223,128,021	22.4	496.0E+9	7,382.86
28	1.1	574,989,574	355,191,901	67,289,504	223,578,529	22.4	496.0E+9	7,381.98
29	1.125	574,897,331	353,152,131	67,418,717	224,714,789	22.5	497.0E+9	7,379.66
30	1.15	574,706,778	350,620,695	67,666,302	226,746,339	22.6	499.0E+9	7,373.21
31	1.175	574,528,394	346,574,211	67,883,415	228,719,637	22.6	500.0E+9	7,369.45
32	1.2	574,442,037	344,811,577	67,977,175	229,586,740	22.7	500.0E+9	7,367.74
33	1.225	574,339,284	343,090,618	68,072,693	230,508,039	22.7	501.0E+9	7,365.90
34	1.25	574,254,006	341,803,102	68,152,389	231,279,916	22.7	502.0E+9	7,364.47
35	1.275	574,194,727	341,336,540	68,200,148	231,783,436	22.7	502.0E+9	7,363.82
36	1.3	574,124,475	340,734,283	68,251,716	232,358,466	22.8	502.0E+9	7,363.29
37	1.325	574,047,741	340,389,847	68,307,093	232,970,094	22.8	503.0E+9	7,362.61
38	1.35	573,981,420	339,872,727	68,357,782	233,465,039	22.8	503.0E+9	7,361.43
39	1.375	573,888,023	339,128,148	68,419,019	234,144,876	22.8	503.0E+9	7,360.49
40	1.4	573,784,251	338,200,083	68,483,186	234,836,741	22.8	504.0E+9	7,359.07
41	1.425	573,746,227	337,782,485	68,503,696	235,098,722	22.8	504.0E+9	7,358.93

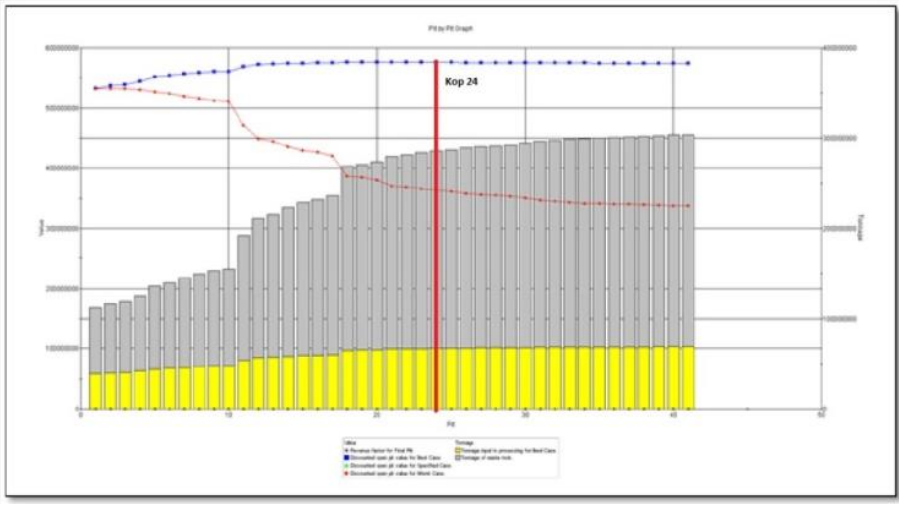


Figure 1 *Graph of the economic analysis of the open pits obtained by optimization for the roof coal seam*

Graph of economic analysis of the open pits (Figure 1) shows the open pits as a result of optimization with corresponding amounts of coal and overburden; the graph of discounted profile for the "worst case" – angle of the working bench system of the open pit equal to 0°/mining only in one phase and the "best case" – mining with maximum angle of the working bench system/or operating in several phases of the open pit (push backs)/.

Based on Table 1, the summary optimization of the open pits in the roof coal seam series and graph in Figure 1, in case the maximum value of discounted profit, the associated open pits was selected (open pit contour number 24) as the optimum.

Based on contours of the open pit No. 24, defined in the software package Whittle, as the final contours in development process of mining, a construction of the open pit was carried out in software Gemcom in module “*Pit design”* (Figure 2). After the detailed construction of the open pit No. 24, which has also considered the technological of characteristics of foreseen equipment, the future routes of transport communications, etc., et al., further procedure for development the dynamics was made in the module "Cut evaluation" of the same software package.

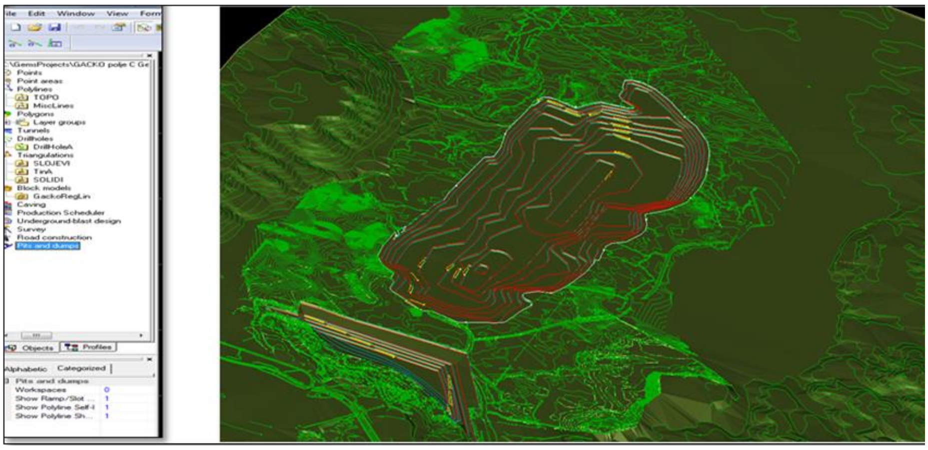


Figure 2 *The open pit constructed in Gemcom Gems in module pit design*

DEFINING THE MINING DYNAMICS

The final mining dynamics is done in software Gemcom as the basic software, in module *"Cut evaluation".* The same is done on the basis of preliminary mining dynamics that is for selected optimum open pit, in this case the open pit No. 24.

Dynamics of mining or development of mining operations at the open pit in the *"Cut evaluation"* is carried out in several steps:

Preparation of input data and elements

Within the preparations of necessary elements for dynamics is creation the TIN* topography and TIN final contour of the open pit. Total volume of excavation is equal to the volume between these surfaces. In module *"Cut evaluation"* is the principle to determine a space in a given spatial limitation in which the amount of material will be excavated in a given period (year).

Defining the input parameters

The amounts (waste and coal, or excavation) are defined in the second step that are planned for excavation per certain periods (years).

Determining the boundaries of mining dynamics in the program Gemcom, in module *"Cut evaluation"* defines a *polygon* line that is created for each slice of materials that is planned for mining. The program,

* *TIN – Triangle irregular network –surface made by the method of triangulation by the network of irregular triangles.*

according to the above limitation, calculates the affected amounts of material. If they are different than planned, the procedure is repeated (polygon is reduced or enlarged, if necessary) until the mining boundary is determined for the set amounts.

Program after each operation warns if less or greater amounts are affected than the set ones and shows the difference. Polygons in the software package Gemcom have certain characteristics, and operations with polygons are mathematical operations with sets (eg. union of two or more polygons, difference of two or more polygons, etc.). Calculations are made according to the laws of mathematical operations with sets.

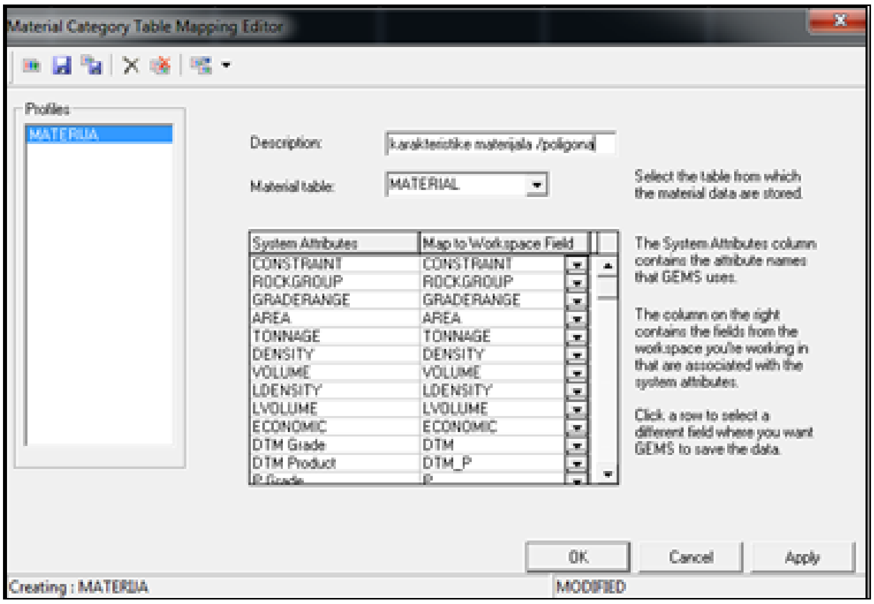


Figure 3 *Category Table Mapping Editor – Mapping the characteristics of polygons that will be considered*

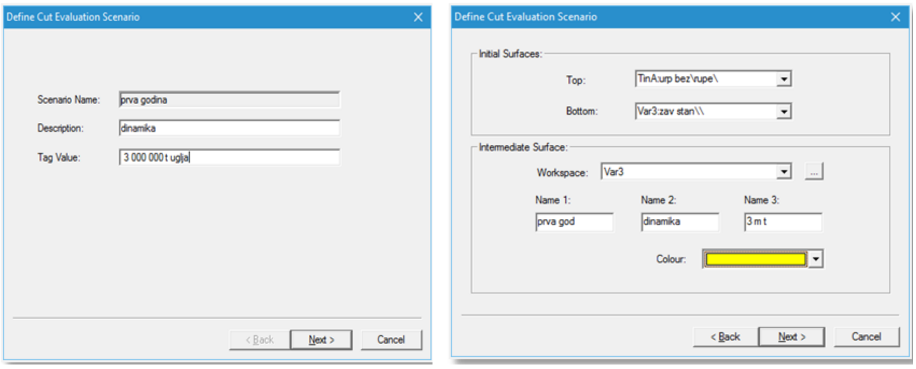


Figure 4 *Determining the boundary of mining dynamics*

Figure 5 shows the input amounts of coal, overburden and waste that need to be contoured for a given period (one year).

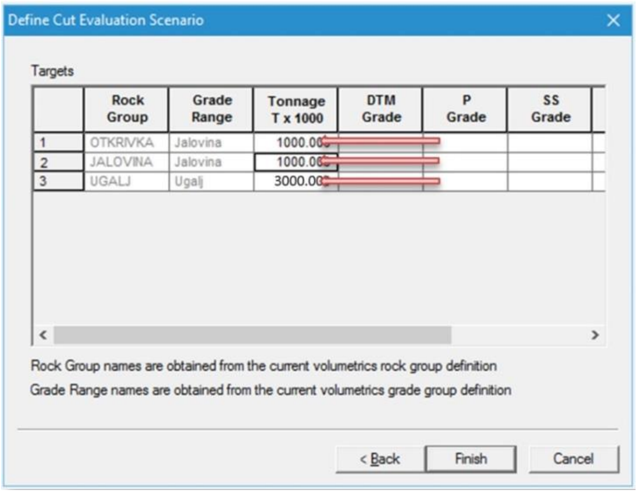


Figure 5 *Masses to be contoured*

Polygon (green line) consists of the area between the two surfaces (beginning and final state), which defines the boundaries of mining (Figure 6). Polygon is defined for each bench plain individually. The included blocks of material have the values determined in the previous formed block model of deposit. Figure 7 shows the lower calorific value of coal in kJ/kg, and the other parameters can be displayed that are defined in the block model of deposit.

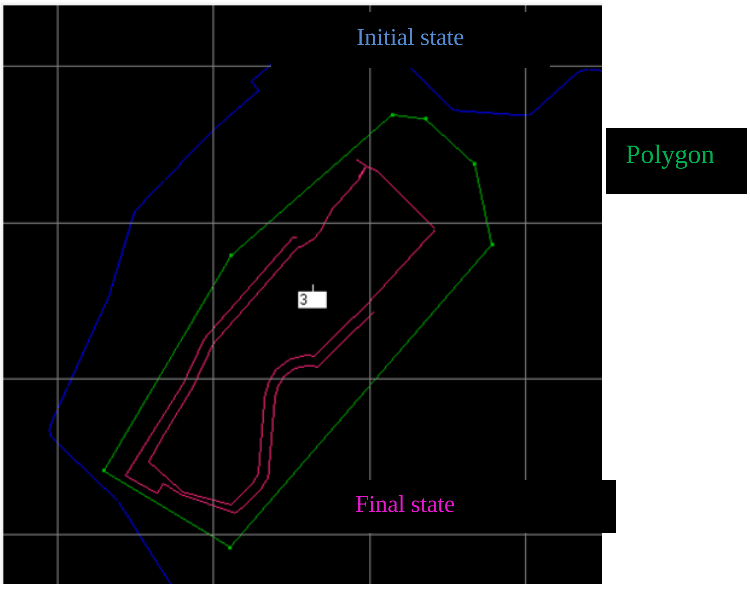


Figure 6 *Defining the mining boundaries*

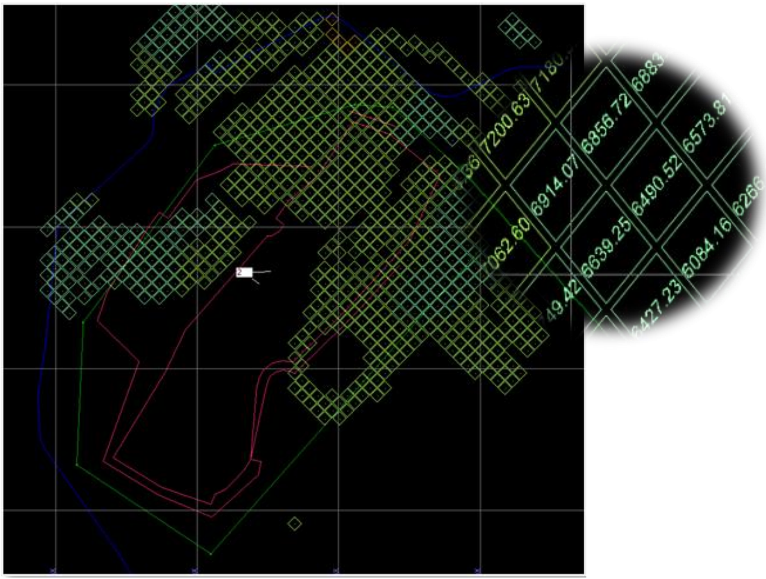


Figure 7 *View of the block model*

After the set limits according to plan and depth, the software forms the reports. The reports give:

"Summary report" - displayed set and contoured amounts (Figure 8).

Summary Report dinamika					
Rock Group : OTKRIVKA ***Grade Range : Jalovina***	***Tonnage T x 1000***	***DTM Grade***	***P Grade***	***SS Grade***	***V Grade***
Total	713.317				
Target	1,000.000				
Remaining	286.683				
Rock Group : JALOVINA ***Grade Range : Jalovina***	***Tonnage T x 1000***	***DTM Grade***	***P Grade***	***SS Grade***	***V Grade***
Total	994.731				
Target	1,000.000				
Remaining	5.269				
Rock Group : UGALJ ***Grade Range : Ugalj***	***Tonnage T x 1000***	***DTM Grade***	***P Grade***	***SS Grade***	***V Grade***
Total	1,756.411	7,464.027	22.972	1.484	37
Target	1,750.000				
Remaining	-6.411				
Grand Total	***Tonnage T x 1000***	***DTM Grade***	***P Grade***	***SS Grade***	***V Grade***
All material	3,464.459				

Figure 8 *Summary report*

“Delivered material report"-contoured masses by benches for the given type of material displayed masses in tons and m^3, and with values of important parameters (e.g. lower heat effect, ash content, combustible sulfur content, moisture content, etc.) (Figure 9).

Detailed Material Report
Rock type JALOVINA, Material type Jalovina
dinamika

Bench	Outline	Packet	Tonnage T x 1000	Volume M**3 x 1000	DTM Grade	P Grade	SS Grade	V Grade
E-940	GRADES	ID1	0.000	0.000	0.000	0.000	0.000	0
E-930	GRADES	ID2	272.806	160.474	0.000	0.000	0.000	0
E-920	GRADES	ID3	289.926	170.545	0.000	0.000	0.000	0
E-910	GRADES	ID4	224.662	132.154	0.000	0.000	0.000	0
E-900	GRADES	ID5	207.337	121.963	0.000	0.000	0.000	0
Total			994.731	585.136	0.000	0.000	0.000	0

Detailed Material Report
Rock type OTKRIVKA, Material type Jalovina
dinamika

Bench	Outline	Packet	Tonnage T x 1000	Volume M**3 x 1000	DTM Grade	P Grade	SS Grade	V Grade
E-940	GRADES	ID1	5.254	2.786	0.000	0.000	0.000	0
E-930	GRADES	ID2	576.196	305.567	0.000	0.000	0.000	0
E-920	GRADES	ID3	0.000	0.000	0.000	0.000	0.000	0
E-910	GRADES	ID4	16.738	9.675	0.000	0.000	0.000	0
E-900	GRADES	ID5	115.129	66.549	0.000	0.000	0.000	0
Total			713.317	384.577	0.000	0.000	0.000	0

Detailed Material Report
Rock type UGALJ, Material type Ugalj
dinamika

Bench	Outline	Packet	Tonnage T x 1000	Volume M**3 x 1000	DTM Grade	P Grade	SS Grade	V Grade
E-940	GRADES	ID1	0.000	0.000	0.000	0.000	0.000	0
E-930	GRADES	ID2	670.503	515.772	7,271.908	22.737	1.479	37
E-920	GRADES	ID3	609.506	468.851	7,578.636	23.625	1.496	37
E-910	GRADES	ID4	313.930	241.485	7,612.518	22.413	1.463	38
E-900	GRADES	ID5	162.472	124.979	7,540.010	22.579	1.500	38
Total			1,756.411	1,351.086	7,464.027	22.972	1.484	37

Figure 9 *Delivered material report (waste, overburden and coal)*

“Detailed Packet Report” - masses of all materials given in detail by benches (Figure 10).

Detailed Packet Report

dinamika

Bench	Outline	Packet	Rock Group	Grade Range	*Tonnage T x 1000*	*Volume M**3 x 1000*	*DTM Grade*	*P Grade*	*SS Grade*	*V Grade*
E-940	GRADES	ID1	OTKRIVKA	Jalovina	5.254	2.786	0.000	0.000	0.000	0
E-940	GRADES	ID1	JALOVINA	Jalovina	0.000	0.000	0.000	0.000	0.000	0
E-940	GRADES	ID1	UGALJ	Ugalj	0.000	0.000	0.000	0.000	0.000	0
E-930	GRADES	ID2	OTKRIVKA	Jalovina	576.196	305.567	0.000	0.000	0.000	0
E-930	GRADES	ID2	JALOVINA	Jalovina	272.806	160.474	0.000	0.000	0.000	0
E-930	GRADES	ID2	UGALJ	Ugalj	670.503	515.772	7,271.908	22.737	1.479	37
E-920	GRADES	ID3	OTKRIVKA	Jalovina	0.000	0.000	0.000	0.000	0.000	0
E-920	GRADES	ID3	JALOVINA	Jalovina	289.926	170.545	0.000	0.000	0.000	0
E-920	GRADES	ID3	UGALJ	Ugalj	609.506	468.851	7,578.636	23.625	1.496	37
E-910	GRADES	ID4	OTKRIVKA	Jalovina	16.738	9.675	0.000	0.000	0.000	0
E-910	GRADES	ID4	JALOVINA	Jalovina	224.662	132.154	0.000	0.000	0.000	0
E-910	GRADES	ID4	UGALJ	Ugalj	313.930	241.485	7,612.518	22.413	1.463	38
E-900	GRADES	ID5	OTKRIVKA	Jalovina	115.129	66.549	0.000	0.000	0.000	0
E-900	GRADES	ID5	JALOVINA	Jalovina	207.337	121.963	0.000	0.000	0.000	0
E-900	GRADES	ID5	UGALJ	Ugalj	162.472	124.979	7,540.010	22.579	1.500	38
Total					3,464.459	2,320.798				

Figure 10 *Detailed Packet Report*

After completion the reports, the program generates surfaces based on defined limits (Figure 6). Following this approach, the construction is done of the corresponding state of works at the open pit in module *"Pit design"*. In this module, the construction parameters of the open pit, angle of operating bench systems and benches in the final position, width of berms and other are given. Based on the given parameters, the state of works at the open pit is constructed at the end of considered period (Figure 11a). The constructed open pit is a phase in mining dynamics (e.g. view of the open the end of the first year or other period)

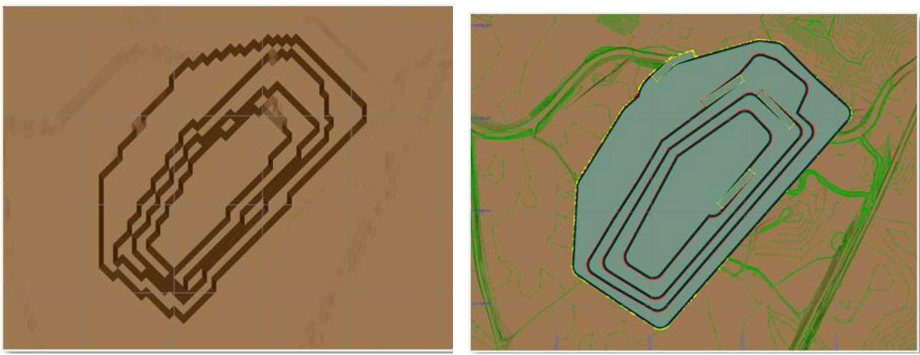


Figure 11 *a) Contour obtained in "Cut evaluation" b) Contour constructed in module "Pit design"*

The same process is repeated for each subsequent year, mining period. Table 3 gives the dynamics of coal mining in the roof coal series of the deposit Gacko. The amounts of waste and coal are given, as well as the lower calorific value of coal. Dynamics of 2016-2021 was made for each year respectively, while after 2021 it was made for a five-year period until the end of mining.

Table 3 *Mining dynamics of the roof coal series 2016-2036.*

		Volume	Density	Tonnage	DTM
First year		M**3 x 1000	T per M**3	T x 1000	Grade
COAL	**Total**	2,310.085	1.300	**3,003.110**	7,458.266
WASTE	**Total**	**1,699.653**	1.702	2,891.966	0.000
Second year					
COAL	**Total**	2,314.541	1.300	**3,008.903**	8,143.455
WASTE	**Total**	**2,326.268**	1.610	3,746.097	0.000
Third year					
COAL	**Total**	2,314.790	1.300	**3,009.226**	7,301.560
WASTE	**Total**	**4,116.671**	1.672	6,882.600	0.405
Fourth year					
COAL	**Total**	2,312.267	1.300	**3,005.947**	7,839.242
WASTE	**Total**	**5,840.520**	1.750	10,221.931	64.164
Fifth year					
COAL	**Total**	2,310.907	1.300	**3,004.179**	7,812.796
WASTE	**Total**	**4,222.648**	1.773	7,484.809	16.264
Tenth year					
COAL	**Total**	11,614.264	1.300	**15,098.542**	8,165.814
WASTE	**Total**	**19,399.805**	1.752	33,978.796	0.168
Fifteenth year					
COAL	**Total**	11,541.723	1.300	**15,004.239**	7,272.084
WASTE	**Total**	**39,776.407**	1.758	69,914.472	34.903
Twentieth year					
COAL	**Total**	13,361.139	1.300	**17,369.481**	6,547.721
WASTE	**Total**	**47,471.922**	1.727	81,990.761	111.509

CONCLUSION

Dynamics of development the open pit Gacko, based on the exclusive coal mining of the roof coal series, was made within a wider analysis of the possibilities for development the open pit mining mining in the area of the Gacko coal basin. This analysis was formally given within the Strategy of Mining - technological Opening, Development, Optimization and Maintenance the Continuity of Coal Production with Introduction the Coal Enrichment Process of Dry Coal Separation at the Open Pit Gacko (MMI Bor, 2015) and it is its integral part. The schedule of operations within the framework of the Strategy was used in module *"Pit design"*.

Since dynamics of work development is a necessary element of overall economic assessment the coal mining, and is also the most complex part of technical - technological part of assessment, the presented method allows to define precisely the dynamics of works in terms of spatial distribution of works, amounts, and taking into account the other qualitative parameters. Using the software packages Whittle and Gemcom is performed to estimate the optimum mining operations as a whole, but also to optimize the parameters of mining within the certain periods of development. The available tools within these two packages also enable quickly performance of this task.

REFERENCES

[1] Strategy of Mining - technological Opening, Development, Optimization and Maintenance the Continuity of Coal Production with Introduction the Enrichment Process of Dry Coal Separation at the Open Pit Gacko; MMI Bor, 2015 (in Serbian)

[2] Study on Coal Reserves in the Deposit Gacko with the State on 30/06/2012; “GEOING GROUP” doo Belgrade, 2012 (in Serbian)

[3] Simplified Mining Design on Mining a Part of the "C" Field with Expansion the Existing Fron Works in the Southern Part and Part of Roof Coal ("Roof Seam Zone") of the Open Pit "Gračanica" - Gacko; MMI Bor, Zvornik, 2015 (in Serbian)

[4] Whittle FX 4.1, Strategic Mine Planning - Tutorial

[5] Gemcom Gems, Geology and Mine Planning, GEMS Tutorial Cut Evaluation

MINING AND METALLURGY INSTITUTE BOR ISSN: 2334-8836 (Štampano izdanje)
UDK: 622 ISSN: 2406-1395 (Online)

UDK: 622:005(045)=111 doi:10.5937/mmeb1604053V

Danijela Vujić[*], *Dragiša Stanujkić*[*], *Snežana Urošević*[**], *Darjan Karabašević*[***]

AN APPROACH TO LEADER SELECTION IN THE MINING INDUSTRY BASED ON THE USE OF WEIGHTED SUM PREFERRED LEVELS OF THE PERFORMANCES METHOD

Abstract

Today, more attention is paid to the leadership and leaders in the mining industry. Leadership and leaders have a key role in creating a sustainable competitive advantage of enterprises. Leaders initiate changes and create conditions for higher quality products and services and contribute to the improvement of market position of the company. Enterprises in their operations seek to ensure personnel that possess leadership skills due to their belief that such people can provide the additional value to their organizations. Bearing in mind the importance of the leaders for organization, therefore this manuscript is aimed to the selection of leaders in the mining industry based on the use of multiple-criteria decision-making methods (MCDM). The proposed approach for selection of leaders is based on the use of the SWARA method and a weighted sum preferred levels of performances approach (WS PLP). The usability and efficiency of the proposed approach is considered on the conducted empirical example.
Keywords*: leadership; leaders; mining industry; MCDM; SWARA; WS PLP*

1 INTRODUCTION

Proper decision making and adoption of decisions having the function of continuous improvements in the field of work contributes to the success of sustainable business operations of mining companies [8]. Therefore, one of the key decisions that lie on the management of mining companies is the selection of personnel/people. People with their skills, knowledge and personal capabilities are very significant resource of any organization. The achievement of organizational goals in a harsh business environment depends on them and their inventiveness, innovation, information and most important motivation; further, Urošević et al. [14] especially emphasizes importance of moti vation and satisfaction of employees of the organization.

Taking into account that the strategic and organizational solutions become increasingly complex and demanding, there is a need that the top management of the company should replace its traditional focus on strategy and structure towards managing people and processes. Today the critical strategic requirements are related not only to finde the most appropriate structural solutions, but to finde an organizational design that will allow usage of all the potential of employees and to motivate the entire organization, in order to be ready to work in a complex and dynamic environment [1].

[*] *Faculty of Management Zaječar, John Naisbitt University Belgrade, Park Šuma "Kraljevica" bb, 19000 Zaječar, Serbia*
[**] *Technical Faculty in Bor, University of Belgrade, Vojske Jugoslavije 12, 19210 Bor, Serbia*
[***] *Faculty for Applied Management, Economics and Finance, Business Academy University, Jevrejska 24, 11000 Belgrade, Serbia. e-mail: darjankarabasevic@gmail.com*

Therefore, in modern business organizations, increasing attention is given to the very concept of teamwork and leadership. Leadership as a specialized management discipline is becoming an inevitable factor that affects the performance of entire business. Leadership is a phenomenon that in recent decades, with a high degree of intensity is continuously explored. As a result of this research, there are numerous and varied definitions of the concept of leadership. Higgins [3] defines leadership as the "process of making choices about how to act with people in giving orders for influencing on them and then of transformation of those choices into actions". Kotter [6] for leadership says that represents the art of mobilezing others which want to struggle for realization the common aspirations, whereas Chemers [2] leadership define as a process of social influence in which a person can enlist the aid and support of others in the fulfilment of a common goal. Yukl [15] points out that leadership is a process of influence that affect the interpretation of events by the followers, selection of objectives for a group or organization, organization of work activities in order to achieve the objectives, the maintenance of cooperative relations and teamwork, as well as the provision of support and cooperation from people outside the group or organization. Northouse [10] states that leadership is a process whereby an individual influences the members of the group in order to achieve the common objective. As it can be seen from previous definitions, leadership can be viewed as a phenomenon that is bound to change, also, leadership is a process of influence on a group of people / followers in order to achieve a specific goal.

In the literature on leadership, the terms such as leader and manager are often used. Leadership is important for management, but it does not mean that every manager has the ability of a leader i.e. the ability to motivate others in the organization. Kotter [6] states that the essence of the distinction between these two notions is in differentiating of tasks of leaders and managers. Leader is the creator of the mission and leader is a visionary of the organization, by contrast, the task of the manager is to realize this vision in practice.

Multiple - criteria decision - making (MCDM) is often used as a tool for solving a wide range of complex problems. In the simplest sense, MCDM can be defined as the selection of an alternative from the set of available alternatives. Rapid development of the MCDM field has caused a creation of many methods, therefore, a good overview and comparisons of some of them are given by Mardani et al. [7] and Turskis and Zavadskas [13]. It is also important to point out that MCDM methods are applied for personnel selection problems, such as: selection of candidates in the mining industry based on the application of the SWARA and the MULTIMOORA methods [4], and the leadership competency evaluation and selection of leader by integration of fuzzy Shannon's entropy and VIKOR methods [9], and so on.

For all the above-mentioned reasons, the rest of this paper is organized as follows: In Section 1 Introductory considerations are presented. In Section 2, the SWARA method is presented in details. The WS PLP approach is considered in Section 3. In Section 4, a framework for the selection of the alternatives based on the use of the WS PLP and the SWARA methods is given. In Section 5, an empirical illustration of leader selection is considered, with the aim to explain in detail the proposed methodology. Finally, the conclusions are given at the end of the manuscript.

2 SWARA METHOD

The SWARA method was proposed by Kersuliene et al. [5]. Similarly to the well-known AHP method, the SWARA methods can be used to determine the weight of criteria as well as to completely solve MCDM problems. However, compared with the AHP method, the SWARA method requires the significantly lower number of pairwise comparisons.

Based on Kersuliene et al. [5] and Stanujkic et al. [12], the computational procedure of the ordinary SWARA method can be shown through the following steps:

***Step* 1**. Determine the set of the relevant evaluation criteria and sort them in descending order, based on their expected significances.

***Step* 2**. Starting from the second criterion, determine the relative importance s_j of the criterion j in relation to the previous (j-1) criterion, and do so for each particular criterion.

***Step* 3**. Determine the coefficient k_j as follows:

$$k_j = \begin{cases} 1 & j = 1 \\ s_j + 1 & j > 1 \end{cases}. \quad (1)$$

***Step* 4**. Determine the recalculated weight q_j as follows:

$$q_j = \begin{cases} 1 & j = 1 \\ \dfrac{q_{j-1}}{k_j} & j > 1 \end{cases}. \quad (2)$$

***Step* 5**. Determine the relative weights of the evaluation criteria as follows:

$$w_j = \frac{q_j}{\sum_{k=1}^{n} q_k}, \quad (3)$$

where w_j denotes the relative weight of the criterion j.

3 WS PLP APPROACH

Based on the Weighted Sum method, Stanujkic and Zavadskas [11] proposed the WS PLP approach. The basic idea of the WS PLP approach can be shown as follows:

$$S_i' = \sum_{j=1}^{n} w_j \, r_{ij} - \gamma \, c_i, \quad (4)$$

where S_i' denotes the adjusted overall performance rating of the alternative i, c_i is the compensation coefficient; $c_i > 0$, γ is the coefficient, and $\gamma \in [0,1]$.

In this approach, the compensation coefficient is introduced with the aim to provide adequate ratios between the greatest possible value of S_i and better matching with preferred performance ratings given by decision makers. According to Stanujkic and Zavadskas [11], the compensation coefficient should be calculated as follows:

$$c_i = \lambda \, d_i^{\max} + (1-\lambda) \, \bar{S}_i^{*}, \quad (5)$$

with:

$$d_i^{+\max} = \max_i r_{ij} w_j; \quad r_{ij} > 0, \quad (6)$$

$$\bar{S}_i^{+} = \frac{S_i^{+}}{n_i^{+}}, \quad (7)$$

and

$$\bar{S}_i^{*} = \frac{S_i^{+}}{n_i^{*}}, \quad (8)$$

where: $d_i^{\max}$ denotes the maximum weighted normalized distance of alternative i to the preferred performance ratings of all the criteria, so that $r_{ij} > 0$; $\bar{S}_i^{*}$ denotes the average performance ratings achieved on the basis of criteria, so that $r_{ij} \geq 0$; n_i^{+} denotes the number of criteria of alternative i, so that $r_{ij} \geq 0$; λ is coefficient, $\lambda \in [0,1]$ and is usually set at 0.5.

3.1 Computational Procedure of the WS PLP Approach

Based on the above considerations, the computational procedure of the WS PLP approach for a MCDM problem containing m alternatives and n criteria can precisely be expressed by using the following steps [11]:

***Step* 1**. Evaluate the alternatives in relation to the selected set of criteria.

***Step* 2**. Define the preferred performance ratings for each criterion. In this step, the decision maker sets the preferred performance ratings for evaluation criteria, thus forming the virtual alternative $A_0 = \{x_{01}, x_{02}, \ldots, x_{0n}\}$. If the decision maker does not have preferences for any criterion, it should be determined as follows:

$$x_{0j} = \begin{cases} \max\limits_i x_{ij} \mid j \in \Omega_{\max} \\ \min\limits_i x_{ij} \mid j \in \Omega_{\min} \end{cases}, \qquad (9)$$

where x_{0j} denotes the preferred performance rating of criterion *j*.

***Step* 3**. Construct a normalized decision matrix. The normalized performance ratings should be calculated as follows:

$$r_{ij} = \frac{x_{ij} - x_{0j}}{x_j^+ - x_j^-}, \qquad (10)$$

where:

$$x_j^+ = \begin{cases} \max\limits_i x_{ij} \big| \; j \in \Omega_{\max} \\ \min\limits_i x_{ij} \big| \; j \in \Omega_{\min} \end{cases}, \text{ and} \qquad (11)$$

$$x_j^- = \begin{cases} \min\limits_i x_{ij} \big| \; j \in \Omega_{\max} \\ \max\limits_i x_{ij} \big| \; j \in \Omega_{\min} \end{cases}. \qquad (12)$$

***Step* 4**. Calculate the overall performance rating for each alternative, as follows:

$$S_i = \sum_{j=1}^{n} w_j \, r_{ij} \;, \qquad (13)$$

where S_i denotes the overall performance rating of alternative *i*

***Step* 5**. Calculate the compensation coefficient for all the alternatives with $S_i > 0$ by applying Eq. (5).

***Step* 6**. Calculate the adjusted performance rating for all the alternatives with $S_i > 0$, as follows:

$$S_i' = S_i - \gamma \, c_i \,, \qquad (14)$$

where the decision maker can reduce, or even eliminate, the impact of compensation coefficient by varying the values of coefficient γ.

***Step* 7**. Rank the alternatives and select the most efficient one. The considered alternatives are ranked by ascending S_i'.

4 FRAMEWORK BASED ON THE USE OF THE SWARA METHOD AND WS PLP APPROACH

The framework based on the SWARA and WS PLP can accurately be expressed through the following phases and the corresponding steps.

Phase I - *Form a team of experts who will carry out the evaluation, determine the set of available alternatives and form the set of evaluation criteria*.

Phase II - *Determine the relevance and weights of evaluation criteria*. In the proposed approach, the SWARA method is used for determining the weights of evaluation criteria, as shown in Section 2.

Phase III - *Evaluate the alternatives*. The evaluation of alternatives is based on the application of the WS PLP approach, as shown in Section 3.

The five-point Likert Scale, shown in Table 1, is proposed for evaluating the alternatives with respect to the selected evaluation criteria.

Table 1 Ratings for evaluating criteria

Ratings	Meaning
1	Excellent
2	Good
3	Average
4	Fair
5	Poor

In this phase, applying the first part of the WS PLP approach, each expert involved in the evaluation calculates his/her own adjusted overall ratings for the considered alternatives, on which basis the corresponding ranking orders of alternatives is formed.

Phase IV - *Selection of the most appropriate alternative*. As a result of conducting the previous phase, the *K* ranking orders of alternatives are obtained.

Based on the theory of ordinal dominance, the alternative appearing in the first position the largest number of times is potentially the most appropriate one. However, in some cases, when it is not so easy to determine the dominant alternative, the evaluation process should be sent back, usually at the step 6 in phase IV; but, in rare cases, it can be put back to the beginning of phase IV, or even beginning of phase III.

5 AN EMPIRICAL ILLUSTRATION OF THE PROPOSED APPROACH OF LEADER SELECTION

In this section, in order to briefly demonstrate the efficiency and usability of the above considered approach, an example of selection the leaders/candidates in the mining industry is considered. Suppose that the human resources decision makers (HRMs) have evaluated the criteria and competences for the total of five preselected leaders / candidates.

The team of the HRMs have used seven criteria adopted from Moradi *et al*. [9] for further evaluation of leaders, as follows:

- Follower Retention (C_1),
- Follower - Organizational Citizenship Behaviour (OCB) (C_2),
- Productivity/ performance outcomes (C_3),
- Corporate Sustainability (C_4),
- Leader Motivation (C_5),
- Leader Relationship (C_6), and
- Leader Resilience (C_7).

After that, each of three HRMs determines weights of evaluation criteria using the SWARA method. The opinions of HRMs and weights of are shown in Tables 2, 3 and 4.

Table 2 *The opinions of the first of the three HRMs and weights of criteria*

Criteria	s_j	k_j	q_j	w_j
C_1		1	1	0.18
C_2	0.9	1.1	0.91	0.17
C_3	1	1	0.91	0.17
C_4	0.75	1.25	0.73	0.13
C_5	1	1	0.73	0.13
C_6	0.8	1.2	0.61	0.11
C_7	1	1	0.61	0.11
			5.48	1.00

Table 3 *The opinions of the second of the three HRMs and weights of criteria*

Criteria	s_j	k_j	q_j	w_j
C_1		1	1	0.16
C_2	1	1	1.00	0.16
C_3	0.9	1.1	0.91	0.15
C_4	0.85	1.15	0.79	0.13
C_5	1.1	0.9	0.88	0.14
C_6	1	1	0.88	0.14
C_7	0.9	1.1	0.80	0.13
			6.25	1.00

Table 4 *The opinions of the third of the three HRMs and weights of criteria*

Criteria	s_j	k_j	q_j	w_j
C_1		1	1	0.18
C_2	1	1	1.00	0.18
C_3	1	1	1.00	0.18
C_4	0.8	1.2	0.83	0.15
C_5	0.8	1.2	0.69	0.12
C_6	0.7	1.3	0.53	0.10
C_7	1	1	0.53	0.10
			6.25	1.00

In the next Phase III, the HRMs made an evaluation of the preselected leaders in relation to the set of evaluation criteria. The obtained ratings, as well as the weights and preferred ratings, obtained from the three HRMs are given in Tables 5, 6 and 7.

Table 5 *The ratings, weighting and preferred ratings obtained from the first of the three HRMs*

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7
w_j	0.18	0.17	0.17	0.13	0.13	0.11	0.11
A*	4	4	4	4	3	3	3
A_1	4	4	4	4	3	4	4
A_2	4	5	4	4	4	2	2
A_3	5	4	5	3	3	5	4
A_4	4	3	3	3	4	3	3
A_5	4	4	3	3	3	5	5

Table 6 *The ratings, weighting and preferred ratings obtained from the second of the three HRMs*

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7
w_j	0.16	0.16	0.15	0.13	0.14	0.14	0.13
A*	4	4	3	3	3	4	4
A_1	4	3	3	2	2	3	3
A_2	4	4	4	3	3	3	4
A_3	3	3	4	3	2	3	4
A_4	3	3	4	4	2	3	3
A_5	4	4	4	4	4	4	4

Table 7 *The ratings, weighting and preferred ratings obtained from the third of the three HRMs*

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7
w_j	0.18	0.18	0.18	0.15	0.12	0.10	0.10
A*	4	3	4	3	3	3	3
A_1	4	3	4	3	4	2	2
A_2	4	2	3	3	3	3	3
A_3	5	3	3	2	3	3	3
A_4	3	3	3	4	3	4	4
A_5	4	3	4	4	3	3	3

The normalized decision matrix and weighted normalized decision matrix formed on the basis of the responses obtained from first of the three HRMs are presented in Tables 8 and 9.

Table 8 *The normalized decision matrix based on the responses obtained from the first of the three HRMs*

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.00	0.00	0.00	0.00	0.00	0.33	0.33
A_2	0.00	0.50	0.00	0.00	1.00	-0.33	-0.33
A_3	1.00	0.00	0.50	-1.00	0.00	0.67	0.33
A_4	0.00	-0.50	-0.50	-1.00	1.00	0.00	0.00
A_5	0.00	0.00	-0.50	-1.00	0.00	0.67	0.67

Table 9 *The weighted normalized decision matrix based on the responses obtained from the first of the three experts*

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.00	0.00	0.00	0.00	0.00	0.04	0.04
A_2	0.00	0.08	0.00	0.00	0.13	-0.04	-0.04
A_3	0.18	0.00	0.08	-0.13	0.00	0.07	0.04
A_4	0.00	-0.08	-0.08	-0.13	0.13	0.00	0.00
A_5	0.00	0.00	-0.08	-0.13	0.00	0.07	0.07

In the same manner, the normalized decision matrix and the weighted normalized decision matrix for the second and the third experts are calculated. The calculation details obtained by using the WS PLP approach, based on responses three HRMs, are shown in Tables 10, 11, 12 and 13.

Table 10 *The calculation details obtained based on the responses of the first of the three HRMs*

	S_i	Ranks	$d_i^{+\max}$	n_i^*	S_i^*	$S_i^{'}$	Final ranks
A_1	0.07	3	0.04	7	0.07	0.01	5
A_2	0.14	2	0.13	5	0.22	0.04	2
A_3	0.24	1	0.18	6	0.38	0.06	1
A_4	-0.17	5	0.13	4	0.13	0.03	3
A_5	-0.07	4	0.07	5	0.15	0.03	4

Table 11 *The calculation details obtained based on the responses of the second of the three HRMs*

	S_i	Ranks	$d_i^{+\max}$	n_i^*	S_i^*	$S_i^{'}$	Final ranks
A_1	-0.56	5	0.00	2	0.00	0.00	5
A_2	0.00	2	0.15	6	0.15	0.02	4
A_3	-0.39	3	0.15	3	0.15	0.05	2
A_4	-0.45	4	0.15	2	0.21	0.10	1
A_5	0.28	1	0.15	7	0.28	0.04	3

Table 12 *The calculation details obtained based on the responses of the third of the three HRMs*

	S_i	Ranks	$d_i^{+\max}$	n_i^*	S_i^*	$S_i^{'}$	Final ranks
A_1	0.03	2	0.12	5	0.12	0.02	2
A_2	-0.36	5	0.00	5	0.00	0.00	5
A_3	-0.16	4	0.09	5	0.09	0.02	3
A_4	-0.10	3	0.07	5	0.17	0.03	1
A_5	0.07	1	0.07	7	0.07	0.01	4

Table 13 *The ranks obtained from the three HRMs obtained based on the WS PLP approach*

	HRM_1	HRM_2	HRM_3
A_1	3	2	5
A_2	2	4	4
A_3	1	5	3
A_4	5	1	1
A_5	4	3	2

As it can be seen from Table 13, the leader labelled as A_4 ranks in the first position twice, on the basis of the opinions of experts HRM_2 and HRM_3, whereas the leader A_3 ranks in the first position only once, on the basis of the opinion of the expert HRM_1.

Based on the theory of domination, it is evident that the leader labelled as A_4 is the most appropriate leader; and that is why the calculation process does not have to be re-done.

CONCLUSIONS

Human resource management through its core activities seeks to ensure to the organization a quality and dedicated leaders, who can cope with the effects of changes. In the area of leadership, the focus of global companies is put on early detection the candidates with leadership characteristics. Companies invest considerable efforts in organizing various programs in order to further direct and to develop their leadership skills.

The proposed approach for the selection of leader in the mining industry is based on the use of the SWARA method, the WS PLP approach and the theory of dominance.

In the proposed approach, each expert and/or decision maker involved in evaluation, sets the values for his/her preferred performance ratings of the selected evaluation criteria and determines his/her ranking list of the alternatives. After that, the alternative with the largest number of appearances in the first position in the ranking lists is declared the most acceptable alternative, or the most acceptable alternative(s) is (are) determined in the negotiation process if there is no dominant alternative.

Finally, the considered example of selection the leader in the mining industry has confirmed the applicability and usability of the proposed approach.

REFERENCES

[1] Aleksić A., Role and Importance of Leadership in the Conditions of Global Business, Sociology, 49(2) (2007) 145-160 (in Serbian)

[2] Chemers M. M., An integrative Theory of Leadership. Lawrence Elrbaum Associates. Inc., Publishers, Mahwah, 1997 (in Serbian)

[3] Higgins J. M., The management Challenge: An Introduction to Management. Macmillan, New York, 1994.

[4] Karabasevic D., Stanujkic D., Urosevic S., Maksimovic M., Selection of Candidates in the Mining Industry Based on the Application of the SWARA and the MULTIMOORA Methods. Acta Montanistica Slovaca, 20(2) (2015) 116-124

[5] Keršuliene V., Zavadskas E. K., Turskis Z. Selection of Rational Dispute Resolution Method by Applying A New Step-Wise Weight Assessment Ratio Analysis (SWARA). Journal of Business Economics and Management, 11(2) (2010) 243-258

[6] Kotter J. P., Leading change. Harvard Business Press, 1996

[7] Mardani A., Jusoh A., MD Nor K., Khalifah Z., Zakwan N. Valipour A., Multiple Criteria Decision-Making Techniques and Their Applications – A Review of the Literature from 2000 to 2014. Economic Research, 28(1) (2015) 516-571

[8] Miletić S., Paunković D., Bogdanović D., Evaluation of Sustainability Indicators for Decision-Making in Mining the Companies. Megatrend Review, 13(2) (2016) 83-96

[9] Moradi M., Maleki M., Pilehrood H. A., Leadership Competency Evaluation by Integration of Fuzzy Shannon's Entropy and VIKOR Methods. Global Journal of Advanced Research, 2(12) (2015) 1864-1870

[10] Northouse P. G., Introduction to Leadership: Concepts and practice. Sage Publications, 2014

[11] Stanujkic D., Zavadskas E. K., A Modified Weighted Sum Method Based on the Decision-Maker's Preferred Levels Of Performances. Studies in Informatics and Control, 24(4) (2015) 61-470

[12] Stanujkic D., Karabasevic D., Zavadskas E. K., A Framework for the

Selection of a Packaging Design Based on the SWARA method. Engineering Economics 26(2) (2015) 181-187

[13] Turskis Z., Zavadskas E. K., Multiple Criteria Decision Making (MCDM) Methods in Economics: An Overview. Technological and Economic Development of Economy, 2 (2011) 397-427

[14] Urošević S., Milijić N., Đorđević-Maljković N., Karabašević D., Indicators of Motivation and Employee Satisfaction in Public Enterprise: Case Study of PE 'Post of Serbia'. Industry, 44(3) (2016) 77-95

[15] Yukl G., Leadership in Organizations. Upper Saddle River, New Jersey, Prentice-Hall, 1998

MINING AND METALLURGY INSTITUTE BOR ISSN: 2334-8836 (Štampano izdanje)
UDK: 622 ISSN: 2406-1395 (Online)

UDK: 330.1(045)=111 doi:10.5937/mmeb1604063K

Zoran Katanić, Snežana Todosijević - Lazović**, Radmilo Todosijević****

NEW TECHNOLOGIES, BUSINESS CYCLES - CONTROVERSIES AND PARADOXES

Abstract

Debates over the business cycle in the economic theory have been continuously carried out. Some have, but others have not adopted tricyclic, or multicyclic scheme because so far they have not or even have been convinced by the Kondratiev's theoretical analysis and Schumpeter's historical analysis, but numerous statistical analysis of the US National Bureau of Economic Research, so frequently used in this field, and especially in Mitchell, Barnes, Torpa, Hansen and others confirm the thesis of the need for further research continuity. The world economy goes through "a tectonic shift" and through the deluge and booms of transformation. The new technologies and globalization change the world. Technology will (which was considered to be a residual factor by economists for years) rather than the market affect the direction and pace of economic development. The question is: Can the cycles be predicted and planned as such and can their formation be prevented? Who and what are the causes and how to successfully master them while they last?

Keywords: *new technologies, business cycles, innovative activities*

1 INTRODUCTION

Development of economy as a whole system, nowadays, contradicts some elements of developmental strategy, which lean towards corporate economies containing elements of discretion in terms of the goals that are set. Do these shifts reveal the new needs to study questionable theories of modern economy, especially in terms of their importance, function and duration? The very act of creation of crises, which are most often the result of development discontinuity as well as the other disorders in the functioning of economies and their partial complexes, indicates the ways of functioning of certain laws both in terms of stability and from position of devaluation.

Globalization movement, which tends to present the world economy as a single system, is likely to contribute to the globalization cycle in the future as well. Instead of multiple types of cycles, some economic theorists, from the aspect of duration, also define the so-called medium cycle. This type of cycle is the end result of a special operation of the law of capital accumulation, or the result of a certain class of division of national income on accumulation funds and the personal consumption of population, as well as on movement of new investments that aim for maximum profit, and which, as a conseaquence, has a constant disparity of faster increase in the respective composition of capital.None of the existing civil theories of business cycles, taken as a whole, is satisfactory. The solution is not to, from the all existing

* *High School of Economics Peć in Leposavić, Serbia, mobilshopkm@yahoo.com*
** *University of Priština, Faculty of Economics Mitrovica, Serbia, snezana.todosijevic1@hotmail.com*
*** *Emeritus, e-mail: todosijevicr@ef.uns.ac.rs*

theories of business cycles and their happy combination, get a new theory that would tend to have the highest accuracy and complexity, but above all that, starting from a good base, would only take those elements which, involved in the whole, would give a logically linked and elaborate theory of cyclic movements of individual and overall world economy. The question of technical and technological breakthroughs and prosperous future is particularly stressed.

There are, in essence, two approaches. Some theorists approach the problem of cycle and cyclic movement from the position of the capitalist mode of production, contained in the method of its accumulation and expanded reproduction, while the others seek an explanation for particular types of cycles in purely exogenous factors (Todosijević and Lazović, 2010).

Long cycles are explained with large changes in production techniques, which have emerged as a result of epochal discovery (Schumpeter, Spithof), preparing for war and by making wars such as the Napoleonic Wars, the American Civil War, the First and the Second World War, production of gold as money and similar.

Cyclic movement of the world economy has its causes in the economy itself, in its method of accumulation and expanded reproduction, primarily due to the impact of endogenous factors, while external factors can only emphasize and mitigate their effects, but cannot significantly alter economic flow.

The crisis of 2009 was interdependent because when it emerged in one economy (the US) it transferred with an exceptional speed and reflected on the functioning of other developed economies such as the EU, China and Japan economies, but the economic systems of underdeveloped countries were also affected, although to a lesser extent. Countries in transition, being short sighted, were unable to predict the emergence of this crisis, and consequently did not create a defence mechanism for what was coming. By studying long cycles and statistical probability of their appearance we could foresee the crisis and prepare defensive mechanisms to mitigate its effects and consequences.

Time and changes received the proper place in the system of economic thought only after 1990s. Politics, economics and value standards change cyclically and tend to be in a state of equilibrium.

2 CYCLES

Changes that occur in economy arise periodically, have characteristics of a cycle, in economics are treated as a cyclic change and are seen as a fluctuation that is repeated at the same time in many economic series with periodicity ranging from one to 50 years. This movement consists of four phases (Todosijević and Lazović, 2010). The main characteristic of this type of change is its periodicity. Duration of the entire cyclic movement or a cyclic phase is different from cycle to cycle. The entire economy is characterized by cyclic variations and passing through four stages, which, essentially, has the characteristics of cyclic fluctuations. They are characteristic for the development of capitalist economy, but can also be observed in regulatory economies where their nature is different. The cycle in economy is often defined as a period of time from one crisis to another - from one of the lower points to the other, in which there are repetitive changes in the movement and development of economy and its structure. The crisis is a culmination point in the cyclic movement of economy and appears as a culmination of disorder that manifests itself primarily in economy, and then in other spheres of social life. There are certain connections between the trend and the cycle. When the trend becomes an eliminated form of the remaining cyclic fluctuations, it is in fact partly determined by the same forces of the trend. Elimination of trend can be considered as a mechanical method of presenting the influence of trend on the cycle.This relationship between the cycle and trend leads to consideration the long-term aspects of changes that, to a certain extent, give an idea for discussion about cycles. In the behavior of economy, there may occur a model of change that has the characteristic of stable equilibrium position. Its characteristic is in the dynamic expression that has the feature of scientific stability, which can be characterized as a stationary state in which there are changes, but no growth.

If we can present that a cycle exists in the absence of growth, it is acceptable to explore whether further growth can exist without cycles. If it is possible, then we should see economic cycles as a break in the growth process which can be controlled, rather than see a cycle as a necessary precondition for the growth process. Factors such as population growth, changes in technology, changes in consumption habits, and the greater scope of government activity in economy, may alter the model of fundamental cyclic fluctuations. In this way, when summarizing a retrospective of events, a conclusion is drawn that growth occurs as a product of changed cyclic behaviour and consideration of the presence of a cycle in the absence of growth, while growth without a cycle is essentially not possible.

There is no absolute progression without relative regression (Todosijević, 2010). Although this attitude is fundamental, the growth comes through cyclic experience. We can consider models that locate economy in the model of continuous upward movement, which reverses the position. There is a correct model, but the question is how to sustain it. It has been proved that both approaches are directed toward the same goal, although they may be described differently. If the model can achieve growth without cycles, then a tendency to correct any deviations from them is set as a goal, and thus we return to the main track. If the experience is cyclic, the aim is to control the amplitude so as to obtain the net result of growth. In the first situation, growth is observed without the cycle, and in the second, growth is the net result of cycle.

The newer approaches place the macro model on optimizing target function in an electronic environment which is characterized by perfect competition, and in which all markets adapt without causing costs (Joksimović, 1984). Is this the time of digital Darvinism? It is a dynamic economic system in which rational approach enables subjects to act on the basis of established expectations, as if they were fully informed about the structure and economy, which is why the expected values are different from the actual values of variables, only as a result of serial non-correlated random errors. The subjects appear to be fully informed about the structure of the economy, and make mistakes only as a result of random exogenous shocks through policy of surprises, or, as it stands out in the later development of the new classics, due to random fluctuations in the technology which is seen as a "real shock" (Praščević, 2008).

There are three main hypotheses on which the new classical macroeconomics is based and which are particularly important for the explanation of cyclic fluctuations:

1. The hypothesis of rational expectations,
2. The hypothesis of continuous market cleaning,
3. The hypothesis of aggregate supply (Snowdon, 1997).

The hypothesis of rational expectations is integrated into the model which includes market cleaning and the natural rate hypothesis. In the further development of the macroeconomic theory, the key difference between the new classic and Keynesian response, through the new Keynesian economics, was just in the disagreement on the issue of accepting the Walrasian structure frame of economic model, i.e. the existence of simultaneous, continuous balancing of market (The hypothesis on rational expectations has also been accepted by the new

Keynesians). Two analytical bases: the aggregate supply curve and hypothesis of rational expectations define the new classical macroeconomics. The idea of rational expectations attracts more attention, but its use of the version of aggregate supply curve makes the most fundamental innovation of the new classical macro-economics. The Keynesian economics (including its monetarist variant) may include rational expectations, but cannot be complemented with the universal existence of competitive markets that are continuously cleaned with flexible prices, which is the *sine qua non* of the aggregate supply curve (Laider, 1997).

The new classical macroeconomics insists on optimizing behaviour of individuals and coherent microeconomic fundamentals, thereby contributing to establishment the neo-Walrasian research programme in macroeconomics. The characteristics of this program would be the following:

1. existence of economic subjects
2. subjects have preferences regarding the results,
3. subjects independently optimize their target functions,
4. selections are made on the interconnected markets,
5. subjects fully own relative knowledge,
6. observed economic results are coordinated and must be considered in relation to the equilibrium states (Backhouse, 1996).

We come to the fact that the new classical macroeconomics faced the problem of existence the business cycles when they tried to apply the aggregate supply function to the data on real economic criteria (Lucas' function-Changes in policy instruments, will lead to changes in the parameters of the model, either in a soothing effect policy or making its effects unpredictable). This criticism is closely linked to the rational expectations in the neoclassical macroeconomics.

Information indicating the existence of fluctuations relate essentially to the business cycles, and then the important assumption on which the new classic is based, and its conclusions are called into question, because the function of aggregate supply does not correspond to the real economic developments. According to this function, the real product conforms to its natural level, and any deviations from that level are temporary, and result from the surprises of economic subjects.

Disturbances at the level of economic aggregates do not refer to a period, but it is the existence of several successive periods in which the product departs from its natural level both upwards and downwards and therefore unemployment and other economic aggregates are characterized by the same behaviour. This fact raises the question of explaining the problem of stability for the new classics: How to explain the serial correlated movements of economic aggregates? The theory of the new approaches is based on the assumption of current, simultaneous cleaning of all markets in the economy, which is related to Walrasian overall balance as a framework for the analysis of trends in economy (Walras and Schumpeter, 1954). Real economic developments, which had a cyclic character, ask for the explanation and answer to the question of whether the cycles are deviations from equilibrium, or they are just imbalances in economy. New approaches do not accept the explanation of the imbalances that characterize the economy in other periods. This led to a confrontation with the extremely complex task of providing the necessary explanations of cyclic movements as the constituent elements of economic balance, offering a model of equilibrium business cycle.

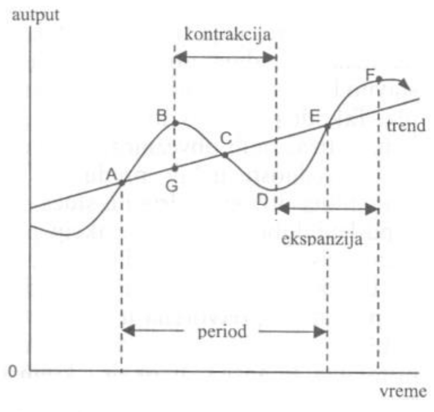
The traditional view of equilibrium includes two approaches: the first approach is operational in character and there balance and imbalance are understood as equality or inequality of two groups of size - economic variables, with no analytical approach to the problem that would enable clarification of the nature of the relationship (income and expenditure budget, import and export, etc.).

Another approach is based on treating the concept of equilibrium as a methodological tool of abstract economic theory. Here the phenomenon of equilibrium is used in conjunction with the models that have mutual relationships between the economic variables. The traditional view of equilibrium in economic theory is generally defined as a relationship of economic variables that are adapted so that there is no inherent tendency for changes in the relationship of the model that they form.The traditional treatment of equilibrium specifies the conditions of equilibrium depending on whether it is a short, medium and long term period of time (Marshall's distinction between the current, short-term and long-term market equilibrium). There are also other distinctions of equilibrium.

Schumpeter talked about partial, aggregate and general equilibrium. Under partial equilibrium, he saw the equilibrium of enterprises or industries, under the aggregate equilibrium between certain aggregate quantities selected depending on the analysis that is preferred to be performed and under general equilibrium – he saw the equilibrium of the national economy. Dynamic understanding of general equilibrium is the subject to constant evolution, and consequently has continuously pursued correction. Starting from the general theory of (economic) system, equilibrium is the lowest form of the system organization in the hierarchy: optimality - stability - equilibrium. The first significant theoretical correction of understanding the general equilibrium emerged with appearance the Keynes's theory of general equilibrium with full employment of the all factors of production. This reformulation of general equilibrium is reflected in the fact that at that time a big step was made towards defining the economic stability as a higher form of organization of the economic system. The equilibrium is no longer interpreted as the ultimate goal of economic system, but as a necessary precondition of its stability.

3 TYPES OF BUSINESS CYCLES

National income is the basis for expressing and analyzing all fluctuations in economic activity, and they can be recognized as an economic, trade or business cycle. The regular model represents an expansion of activities, followed by a contraction and then again by a new expansion (Pierce and MacMillan, 2003). This cycle occurs around a secular or long-term trend of output in the form of a curve that reflects current paths of output, with the peak at point "B" and "F" and the bottom at point "D", presented in the following diagram.



Privredni/trgovinski ciklus

Figure 1 *Economic/Trade cycles*

The time between any two points in the cycle phase represents a cycle period as from "A" to "E" or "B" to "F". The amplitude of the cycle is given between the top and trend line, or between the bottom and trend line (Pierce and MacMillan, 2003). The theory of business cycles is associated with Hicks, Schumpeter, Metzeler, Goodwin, Kondratiev ... Since the mid-19th century, when Zuglar definitively established the existence of wave movements that pervade life within the institutional set of the capitalist economic environment, working on research, networking and measuring relevant facts has constantly been progressing. It was found long ago that there is only one type of business cycles. Some are general, some sectoral, they occur simultaneously and superimpose on each other, which leads to the irregular periodicity of general economic trends. We recognize the Zuglar’s cycle as a trading cycle of economic activity that lasts for a period of nine to ten years (C. Juglar, (1819-1905), a French economist who is said to have claimed to be the first one to recognize "wavy" movements in economic activity). He divided the cycle into three periods of prosperity, crisis and liquidation and emphasized the importance of bank loans to the development of crisis.

Schumpeter proposed the tricyclic scheme: long cycles that last 54 to 60 years; cycles of medium length of 9 - 10 years and short cycles that are 40 months long (Schumpeter, 1939). He named these cycles after the economists who first described them, and whose terminology later entered the literature. He linked them in such a way that the shorter cycles are included in long ones and grow into their phase part. The Long Cycle of Kondratiev contains six medium cycles. The Juglar's cycle contains three short Kiciniev's cycles. Statistical research shows the existence of 20 year long cycles, which are usually associated with long-term conjecture in housing construction. Then, shorter housing, or construction cycles were identified. A whole series of spider web type cycles is determined in agriculture: the pork cycle, the cattle cycle, the cycle of coffee, etc. Nowadays, the understanding that the capitalist economy is immune to the cycles, because the contemporary bourgeois theorists attach extremely a great importance to this issue that is seen as wrong. We have a large number of papers on the theory of business cycles, but also in the field of anti cyclic policy.

The question that arises is whether government intervention succeeds completely in eleminating the cyclic movement or not, and whether under the influence of government intervention may be more correct to speak of a cyclic form of movement, with a clearly expressed periodicity and the existence of all four phases of the cycle, or else the cyclic movement, in large modifications and deformations, is expressed in that regularity? Regardless of the disclaims in terms of regularity of manifestation, there is no denying that, in addition to various types of short-term and long-term fluctuations, movements and disorders in economic life, there are also typical business cycles, which are not a pathological disease, but a characteristic inherent to private enterprises and market economy (Hansen and Schumpeter, 1951). They represent the most typical, and of all possible ones, the most unique form of movement in the capitalist economy.

4 ANALYSIS THE THEORY OF LONG CYCLES

Aleksander Helfand is one of the first authors in the history of industrial capitalism who drew attention to existence of long cycles. Dealing with the problems of the agrarian crisis he thought that the long depression that began in 1873 was soon to be replaced with a new long term verve. In order to conceptually include the long expansive waves that are accompanied by the long wave of economic depression, he used the term "period of Sturm und Drang". He believed that the expansion of the world market is crucial for the explanation of this long-wave movement due to changes taking place in almost all spheres of the capitalist economy: in technology, trade, money market, in the colonies - and they place the total world production on a new and much wider base. He uses statistics, and his periodization of long waves will varied a lot from the one that other long-wave theorists gave later (according to him, the "Sturm und Drang period" began in the seventh decade of the nineteenth century and ended at the beginning of the eighth decade, while it is generally considered that there was a long wave of expansion of the crisis from 1847 to 1873).

After Helfand, in 1913, the Dutch Marxist J. Van Gelderen again raised the issue of long waves. Under the pseudonym J. Feder, he published three articles in which, on the one hand, he tried to provide empirical evidence on the existence of long waves, and on the other hand, to give a theoretical explanation of the same. Unlike Helfand, he attempts to explain the long waves through expansion of production. A precondition for emergence of a strong tide periodis expansion of production of consumer goods, which indirectly creates a new demand for other products, capital goods and raw materials (Van Gelderen, 1913). Such expansion may also be caused by expansion of the world market through colonization or new areas in the world economy, or by sudden creation the new expansive branches of production. In the present circumstances this would mean an expansive appearance on new markets, the so-called. countries in transition. Van Gelderen also discovered, independently of Kautsky (Kautzki, 1913) who formulated something similar on an exclusive wave, that a stage of a long cycle was preceded by extremely increased gold production (Similar views can be found a little later with Duprijez). The end of period of tide occurred because the escalation of production and trade cannot go beyond the point of saturation of the market in which highly developed capitalist countries export. This moment becomes faster through industrialization of importing countries and their overall development. Production of raw materials cannot keep up with the production of finished products. As for the periodization Van Gelderen makes difference between "the period of growth from 1850 to 1873, the period of decline from 1873 to 1895, and the period of growth from 1896 to the present (Van Gelderen, 1913).

The idea of long waves can be found with the Marxists. Kuznec mentions Lescure, Aftalion, Lenoir, Spiethoff, Cassel. It is primarily monetary theorists who emphasized the reduction of money supply in relation to demand from 1873 to 1896. According to Landes "this attitude got its most complete analytical character in the work of Simiad who gave an overview of events in the 19th century, and constructed a model of alternating inflationary and deflationary long trends. The first ones are characterized by a quantitative growth at a relatively stable technology base (analogous to what we call today the expansion of capital), and the second ones by qualitative improvement (capital deepening) and the forced liquidation of inefficient enterprises" (Landes, 1969).

We should add Wicksell to the Kuznec's list, who, before the end of the XIX century, also spoke of secular fluctuations in prices and interest rates, and then Pareto who in 1913 mentioned the long-term fluctuations.

Kondratiev, the former deputy minister for nutrition in the interim government Kerensky, was interested in this issue in 1919, and in 1920 he founded the Institute in Moscow, where he began collecting material for study of long cycles (Note that the Kondratiev probably did not read the Van Gelderen's study when he wrote his articles in the period from 1922 to 1928).

Trotsky, analyzing the postwar development of capitalism in comparison with the development of pre 1914, also entered this complex issue. Simultaneously with Kondratiev, though independently of him, the Dutch Marcsist de Wolff tried, among other things, to statistically improve Van Gelder's analysis by calculating "decycled" numerical sequences (De Wolf, 1924). He follows the dynamics of prices and production of gold, but does not provide a satisfactory explanation of long waves, so his overall analysis is far behind Van Gelderen.

5 INVESTMENT CYCLES AND COMPREHENSIVE CHANGES BASED ON THE NEW TECHNOLOGIES

On the pedestal of power, making a decision to change appears as a dangerous precedent because of the inability to obtain materially confirmed signposts. If the success is maintained for a longer period of time and the bigger it is, the more difficult it would be to make changes because a dominant position can turn into decadent - into complacency. A strategy tracing a new path in conditions of a dominant position is more unknown to those who are in that position than to imitators and followers. Due to the impossibility of an adequate movement into the future, a need for creating a dynamic development strategy for evolutionary changes of the new era necessarily appeared. We found help for adequate response in a modification of the Newton's laws to changes. For analytical purposes, we carried out the minor linguistic modifications without skipping intuition in order to accomplish the process of adaptation to the phenomenon of change in organizations.

1. Law: the behavior of an organization cannot change if it is not affected by an external force.

Very few organizations face the need to make some significant internal changes without a significant degree of influence of external forces that operate in the region and to apply to them. If the success of the company is viewed through output value placement over time, then characteristics and quality of the output are not good. The reasons for their acceptance and active feedback operation can be found in the environment. Under the influence of the environment, there appears an internal response of a company to challenges coming from the outside.

2. Law: the amount of change in behavior will be directly proportional to the amount of effort that is entered into it. "The amount of effort" raises the question of efficiency of different types of effort, and while it is quite clear that a major change in strategy requires major changes in the sources of obligations, such a process is not automatically accompanied by the required changes in behaviour.

3. Law: resistance of an organization to change will be of the same value as the amount of attempts that went into its change but of opposite direction.

This law holds a change maker awake even at night (Davidson, 1995). The more homogeneous, more successful historically and more natural organization in its composition, the less "sleep" a change maker can expect. The stronger the culture, the stronger the thrust. If you cannot find any way to channel external resistance, it results in stalemate. If change makers are few and are the only expression of external forces (Act 1), then their chances of making significant decisions are small. No one owns a winning recipe for the synthesis, but more interaction is needed between functions and not only that it goes with each of them but it also determines the success of the whole system. With a better operation of each function, the process of approaching the success of the whole is greater.

The characteristic thinking of the modern economic thinkers reduces to the following:

1. A few brave ones look forward to a new era of prospects and prosperity, and

2. Majority of them foresee a form of economic final battle.

The world is increasingly concerned about the growing unemployment and stagnant wages. The alleged cause of that are globalization and amazingly the rapid technological changes (The Economist, 1996). Computers and robots, together with management techniques, destroy jobs !? At the same time, free trade and capital flows and enormous progress in telecommunications, increased international competition and made it easier to companies to transfer their production into developing counries with low wages. Many feel that the invisible hand of Adam Smith tries to push them off the cliff. There is a suspicion that the present government policies do not function anymore, because they are not suitable for a new global, digital economy (Lloyd and Thurow, 1980). The question that can generally be asked might be: does technological revolution require economic revolution? Modern processes are characterized by the pace of technological change, which defines the contemporary trends in capital movement, as we are the witnesses of its internationalization. The views of political economy that the owners do not have the real power of equity, but those who manage capital will be confirmed. The quality of output will primarily depend on the quality of decisions and management skills, on the degree of implementation and transformation of inputs, including information. By lowering the cost of communications, technology fuelled the globalization of production and financial markets (Todosijević, 2010). In return, the globalization encourages technology by intensifying competition and accelerating the diffusion of technology through foreign direct investment. Josifidis K. would answer to a multitude of terms with only one question: "Is globalization a process, a trend, a project, a myth, a cultural pattern, a way of organization, a strategy, everyday life, viewed separately or all these at the same time?" (Josifidis, 2008). Together, it will be proved that information technologies and globalization more efficiently overcome time and space. Over the last twenty-five years, a global network of computers, phones, TVs and other electronic devices used for business and fun, increased its capacity to convey information by 1.3 million times. Computer power doubles about every 18 months in accordance with Moore's Law (Gordon Moore, co-founder of the US Intel).

Today's computer is much more powerful than computers in mid-1970. 30 years ago the whole world has about 50,000 computers. Today, the number has increased to about 1.5 billion, but still with unequal distribution. Chips embedded in cars, washing machines, dishwashesr, talking postcards, protective systems, aerospace and others are not included here. A typical car today has more computing power than the first vehicle launched to the moon in 1969 (The Economist, 1996).

Is it possible to compare the level of technical modernity and the quality of output, or should it always be seen in the context of time when changes or some specific techno-economic domination happened? A good number of economies of different countries opened their markets for trade and capital. Is it their way into deeper poverty? The developed progress at a faster pace and with greater intensity, because they can put more scientific, technical and material resources into service. The tendencies in capital movement are feasible as forecasts.

Information technologies today represent the engine of growth and prosperity. Ethan Kapstein in the Foreign Affairs states that "rapid technical change and sharper international competition weaken the labor market of major industrial countries ..."

The new technologies certainly suggest a different industrial revolution, but understanding and mastering this revolution does not require a revolution in economic science. However, the scope of both globalization and information technologies has greatly increased. By some measures, the economies at the beginning of this century were as open, and integrated as they are today. Trade of the majority of industrial countries, as a share of GDP, is not much higher now than it was a century ago. While the capital definitely has become much more mobile in recent decades, the net capital flows between countries were, in fact, bigger in relation to GDP at the end of XIX century. At that time Britain invested abroad more than 40% of its savings (The Economist, 1996).

Perhaps the railways, steamships and the first transatlantic submarine telegraph cable in 1860 were far more revolutionary than lasers, satellites, the Internet and other digital magic. What is different is that globalization in the nineteenth century was encouraged by falling transport costs, while globalization is now encouraged by "tumbling" communication costs. Cheap communication networks allow companies to locate different parts of their production process in various countries and also be in close contact with them. It is difficult to measure the influence of globalization and new technologies on the output because conventional economic statistics, being projected for the industrial age, are not up to the information age. We point out that there is no reasoned justification for the apocalyptic prophecy of rising unemployment, because the total information society will, like any other technological revolution before that, create at least as many jobs as it destroys in total. The new jobs would be better paid than the old ones. Many tasks will be executed according to the predefined software, so management and control functions will be increasingly prominent, compared to the immediate execution functions that would be manifested by operations through mechanical approach.

Changes and innovations has lead to fear incitement and uncertainty, due to the fact that changes are always destructive and sudden and that there is always someone who opposes to them. Nevertheless, the change is simply the economic growth under a different name (In 1820, three thirds of American workers cultivated land. Today that share is barely 3%. The others are much more productively employed in other sectors).

Steady growth of income and employment, which is based on the continuous shift of resources from declining industries to industries that are in the process of development, was described by J. Schumpeter as a "creative destruction" (This attitude of Schumpeter clearly confirms the views Gutenberg on dual effect of technical progress, which we pointed out earlier in this paper). Also, if the governments try to protect their companies and jobs from change through import tariffs, subsidies or the protection of employees, they will prevent not only changes but also economic growth.

Rapid technological changes in the long run are the main source of higher social standards for economy as a whole, regardless of the fact that the costs and benefits of technology and globalization are not evenly distributed. The economic theory has proved to be clear, multilateral and adaptable enough to provide answers for digital future and mechanical history.

5.1 New technologies- similarities and differences of earlier innovations

Innovation processes of products, production and organization are the main forces that stimulate economic growth and rise living standards. Economies have access to a limited amount of capital and labour (The first complex elaboration of the theory of limitation was found at Richard, from whom Marx took it and included in his scientific method. The starting point is that the degree of exploitation of certain types of resources can only be less than or equal to total available resources). Technical progress and competition have become the main growth incentives. Growth can only be maintained by finding the new and better ways of using the limited resources. With increasing levels of technologicality (scientific value) in work processes, as a rule, limitation is not abolished, but the process of their permanent use in time is realized. As the process of development of productive forces objectively delimits possible and conditioned productivity, the development of productive forces equally leads to more cost-effective exploitation of available resources.

In the last two centuries, a real GDP per capita in developed countries has increased by about 1.6% per annum. At this rate the income per capita doubles every 44 years. Historically, such growth was the exception rather than the rule. The inability of precision does not inhibit the assessment that until 1800, for 13 centuries the real output per capita in Western Europe had slowly grown, on average by no more than 0.1 to 0.2% per annum (The Economist, 1996). According to that dynamics, living standards do not improve significantly over the life of the individual and real income is only doubled every 500 years. There were changes through the tempo of technological innovation (Todosijević, 2010). In the Middle Ages, several innovations such as windmills and horseshoes appeared, but technological progress was imperceptible in comparison with what happens today. From A. Smith to the present day, the economists have noted that technological change is important for long-term growth, but it has only become the subject of study in the last 35 years.

Labour and capital add knowledge and technological change to the model and eliminate paradoxical qualities. If we did not respect technological progress, the output growth would be condemned to be "zero" because the long-term investment rate has no effect on the growth rate of economy. Technological change is dominant by nature, because labour and capital can hardly contribute 50% to the total increase in output of the 20th century. This participation decreases with development of the nano technology, and there is an increase in knowledge, innovation and technology changes based on them. With his pioneering work in the mid-1980s, the economist Paul Romer of Stanford University (The Economist, 1996), directly incorporated technology into the models of economic growth.

Josifidis K. said: "It is important to note that a new knowledge in the Romero's model is the main determinant of long-term growth generated by the new investments in technology research which shows diminishing income" (Josifidis, 2008). It is not that the models of Harod Domar and Kalecki no longer apply, but they got a qualitative modification. The new ideas about more efficient processes and new products enable continuous growth.

5.2 Technological changes and employment

Throughout history, we have faced a lot of forecasts about the influence of machinery on employment. They are most often pessimistic in character with the statement that technological advancement through increase in level of technical equipment, work and technical modernity of production means will cause unemployment with a tendency to grow . At the beginning of the nineteenth century, the British workers broke machines for fear that they would jeopardize their existence. In 1930s people blamed automation. In 1940's, Norbert Weiner, a pioneer of computeristics, predicted that computers would create unemployment to such an extent that the great depression would look like a picnic (The Economist, 1996). Nowadays, the instigators of doom again predict the future without jobs because computers and robots will take them over. This, however, is not a human response to the human issues. The man is not to face the possibility of his own destruction. In his book “The End of Work”, Jeremy Rifkin, a technophobe, argues that 3 out of 4 jobs in America can be automated (Rifkin, 1998). His prognosis is that in the mid 21st century, hundreds of millions of workers will lose their jobs and be permanently unemployed. We ourselves are the only ones who can confront everything around us, and how well we can do that depends on our abilities, knowledge and skills as well as on effective negentropy, and that is essentially the solution of the puzzle of the past, and the puzzle of the future.

The new technologies create at least as many new jobs, proportionally to the demographics, as they destroy.

5.3 The new waves of innovative activities - prognostic statements

Until the study of Romero, J. Schumpeter was one of a few economists who attempted to explain the growth mainly in terms of technological innovation, and interest in his theories has revived in recent years. In 1930s, he presented a model that assumed a growth through interaction, which consisted of a technological breakthrough and competition among firms. Schumpeter saw the capitalism as movement in long waves: approximately every 50 years technological revolutions cause "a storm of creative destruction" in which the old industries disappear, and are replaced with the new ones (As if there is an analogy with the cycles of nature. eg., every 50 years in the plains of America drought happens as an equal periodic phenomenon; or the Kepler's law according to which every 176 years, there is a lineup of planets in one direct line; or the Halley's Comet flight path...). This attitude is in correspondence with the laws of science development.

It is necessary to point out the modern history: the first long wave from 1780s to 1840s brought the steam energy that drove the industrial revolution; the second wave from 1840s to 1890s introduced the railways; the third wave from 1890s to 1930s produced electricity; the fourth wave of 1930s to 1980s was initiated with cheap oil and cars; the fifth big wave was triggered by information technology. Is a digital Darwinism imminent to the mankind? It is extraordinarily difficult to predict the consequences of the new technology. Pitfalls of the future are always mobile. Nathan Rosenberg in his speech at a conference on technology and growth states: the Western Union in 1876 refused to buy the Bell's telephone patent (Rosenberg, 1996). The company refused to offer an explanation "the appliance is inherently of no benefit to us (The Economist, 1996)."

In 1899, the head of the US Patent Office recommended that this office was abolished because "everything that can be invented has already been found". Thomas Watson in 1944, the then president of IBM, foresaw the world market for maybe five computers; he could not foresee any commercial opportunity for computers.

Information technologies won their anticipated part several times. Twenty years ago, much was said about the office without paper and cashless society to which new technologies would lead. Nevertheless, paper and cash are still used today – and paper is used even more than ever before.

Information technologies vary in type from earlier technologies and will therefore have very different economic consequences.

We are witnesses of vertiginous fall in price of IT equipment, which, in real scale, has fallen by 30% per year on average in recent decades. Will the prices be stabilized, or will the rapid penetration of nano technology lead to a further fall in prices and an increase in performance in terms of universal diffusion of these technologies? (Had cars developed at the same pace as microprocessors over the past two decades, a typical car would now cost less than 5 dollars and would exceed 250,000 miles with a single gallon of fuel). Falling prices are one of the best criteria for assessing speed of technological progress, which confirms the impression that the pace of technological change has accelerated (Todosijević, 2010). A rapid fall in prices leads to incentives to make more people buy computers, which allows the technology to expand much faster. Product cycles tell the same story about fast changes: 70% of the computer industry revenue comes from products that did not even exist two years ago.

Tumbling down the costs of communication and transaction has a special advantage. Viber is free, Skype and VOIP make negligable costs. Thanks to the novelties, decline in costs is likely to accelerate. The massive and mass increase in transmission capacity and increased competition will certainly contribute significantly to this. There are forecasts that the marginal cost of telecommunications will fall somewhere near zero, both for the international and local calls (The question that regularly arises: Did not companies in the field of telecommunications convert fixed costs of technical capacity into variable and thus reach the enormous extra profit? In fact, the cost of telephone, fax or internet to send messages from Belgrade to New York is the same from the aspect of the technical system as between Belgrade and Ćuprija, or even closer, from one to the other destination in Belgrade).

Simon Forge, a member of the Cambridge Strategic Management Group, made a forecast which showed that in 2005 transatlantic video-phone call would cost only a few cents per hour. This forecast ignored the legality in development of science, ie. the tendency of transition from exponential into logistic growth, as well as economic principles of the product life cycle.

Knowledge is an important characteristic of information technologies as more and more knowledge can be codified: information, in the form of numbers, letters, pictures or voice may be reduced to digital form and stored in computers as a series of zeroes and ones. Codification makes it possible to spread knowledge faster, which should enable developing countries to use such knowledge in order to reduce the technological gap and try to catch up with the developed countries in terms of development. Codification of knowledge and low transmission costs also lead to easier sale of services, by eliminating the need for direct contact of producers and consumers, which, in fact, allows companies to locate different parts of their activities in different countries, to different destinations and to connect them with computer networks. The classic rules or laws of economic science in the field of location will be repealed.

6 LOST PARADOXES - OPTIMISM AS A WAKING FALSE HOPE OR PESSIMISM AS A REALISTIC EXPECTATION

Continuity of development cannot be bypassed, nor can it be achieved through sudden and abrupt growth and development, except in certain domains. Scientific progress and technical progress as the key drivers of intensification and increased efficiency are an integral part and the assumption of continuous development. Constant improvement of techniques and technologies and replacement of outdated technique with new productive models make an important direction of technical progress in production, and it is the role of investment and development policies. Development of machine tools production, electrical industry, microelectronics, computer technique, apparatus and instruments, and the entire IT industry is a prerequisite for improvement of machines that are included in technological processes, which will allow complex mechanization and automation of all stages of production. We emphasize this because of the fact that the level of technical modernity of production means, as a rule, is expressed through quality and service properties of a product. These two characteristics with other categories of marketing management, predominantly affect the level of competitiveness of output. In principle, the new technologies will cause huge fundamental changes, because some of the characteristics of progressive technologies are: the small number of operations, continuity, lower consumptions of resources and so on. Creating materials with pre-defined properties, i.e. with progressive, constructive, synthetic, compositional, super pure and other properties will represent the implementation of progressive technologies. Chemization of production becomes an important direction which requires accelerated development of branches of chemical industry. Technical development of energy complex would mean a qualitative advance in energy balance and the quality of production and supply. Radical shifts will happen in the agro-industrial complex, due to the impact of technical progress, on the one hand and, environmental standards, on the other. The new varietes will appear and they will be stimulated with the industrial activities whose characteristics will be enormously high yields and perhaps genetic modification. Productivity in agriculture will gradually approach the industrial productivity and then there will not be any subsidies.

The developing and underdeveloped countries are in a colonial situation as regards productivity, not only in the primary, but also in the secondary and tertiary sector. The driving force of development, business strengthening and innovative breakthrough, as a rule, lies in technological changes, particularly where there is a growing discontinuity. Development and innovative processes are in the function of strengthening competitive power, and are intended to indicate the direction of stocks and dynamics of development. The results of these efforts are manifested in programming development of products, processes and technologies (Todosijević, 2014). We will particularly accentuate branches and businesses with dynamic development where scientific and technical progress is intense. This is due to the fact that the total amount of knowledge, available in one area, is the starting point of innovation and development process. For the forecasts of development process, and a competitive position of products and technologies, and general business conduct of companies, it is essential that in the pool of available knowledge there is a continous inflow of the new knowledge in order not to devalue the current efferts directed at the future.

Why is there no certainty of likely future for the countries in transition? Due to a slow capital turnover? Due to binding of significant resources for investing for a longer period of time? Due to the impossibility of adequate anticipation of technological progress? Due to the danger of premature devaluation in technical and technological sense! Because the concept of investment requires consideration of dominant solutions at the level of world achievements in technics and technology, in order to avoid devaluation, before the period in which it is possible to perform reproduction. The proof: for a power plant you need 32 months, 5 years for a chemical plant, 2 years for a gas plant, from 1 to 3.5 years for manufacturing industry capacities based on reproducing the raw materials of agricultural origin, and so on. The lifetime of production now is from 5 to 7 years in the scientific industries, in young non-traditional branches 10 months to 3 years, while in the information technology every 18 months there is devaluation based on the operation of scientific and technical progress. Due to this or other reasons, the economists and governments of developing countries have become more cautious in their attitude about visible benefits of this strategy of (re)industrialization. The Russian Academy of Sciences is redefining the role of the state in economic development, while the United States have never abandoned that role. Removing territorial obstacles from the circulation of resources is, in fact, a precondition for creation the financial market in general and deciding on investments.

What is possible for developing countries? It is possible to reconstruct the large technical systems with an emphasis on specialization and previously preassumed cooperation. It is possible to rationalize and revitalize the existing industrial capacity. Modernization in relation to technical and technological achievements and behaviour of competition is possible. It is possible to operate innovatively in various ways. The new measures of economic policy and a new policy of regional development are possible (Todosijević and Lazović, 2010). It is possible to identify the comparative advantages of managing certain types of resources, and to have the ability of effort disposition, which together correspond to the structure, quality and goals of development strategy. We need development without determination of location. We need a new approach to location according to which development of capacities is implemented in centres that have a lot of workforce, in centres that are rich in raw materials, in centres of consumption and the communication centres. This approach defines the future aspect of comprehensive development and tends to optimal weight dispersion of industrial and supporting service capacities. This includes, among other things, the overall urban and demographic development. The central problems of economy of the future are identified, and they are focused on the following areas: finding th new and cheaper sources of energy; finding the new and cheaper sources of raw materials; and high-level and economy efficient production of means of labour.

Another paradox shows that despite the investment in IT sector, there has been a lag in labour productivity, after which Robert Solow, a Nobel Prize economist, noted that "you can see computers everywhere except in the productivity statistics" !? The growth can be explained by higher input of labour and capital as well as by the fact that the contribution of technological progress was minimal.

The obvious lack of incentives in the new technologies among economists is known as the paradox of productivity. Paul Krugman, an economist at MIT, argues that the recent technological progress is not in the same league with the progress achieved at the beginning of the 20th century. Investments in a new technology are not necessarily aimed at stimulating productivity. The OECD study "Technology, Productivity and Jobs", emphasizes that an increasing share of costs for research, development and information technology is essentially devoted to product differentiation and marketing in the battle for market share, and not to making the existing production more efficient.

A historical explanation of this paradox is possible in a sense that there is a delay of several decades before the technological breakthrough can bring productive benefits (Todosijević, R., in "Prognostics", Savremena administracija, Belgrade 1983 states "The reseracrh of Giffilan confirms this historical analogy starting with a photo for which 112 years had to pass since the discovery, to the mass application from radio, television, the atomic bomb, up until Mazer, the mass application of which took only a week. However, the time from an idea to the mass use is getting increasingly shorter, but the legality of the rules in the form of equity neither exists nor is possible. The level of knowledge in one field and level of complexity of research outputs confirm this beyond doubt "). The wide spread of the new technology, not its discovery, is what brings the highest profit (Todosijević, 2010).

Paul David explained in his study (David, 1990) that in early 1880s introduction of the electric dynamo was manifested through productivity.

Another paradox is that three thirds of all investments in information technology were invested in service sectors such as telecommunications and financial services. However, owing to falling prices, computers are faster spread in economy than it was the case with other innovations throughout history. Some studies show that only when the diffusion rate is over 50% the productivity gain is possible. Research at the company level carried out by Erik Brynjolfsson and Lorin Hitt from the MIT in one study (Brynjolfsson and Hitt, 1994) that examined 367 major US manufacturing and service companies between 1988 and 1992 found that the investment in computers gave an average gain of more than 50% annually.

It is hard to conceive, but no improvement will be found in the official statistics. Replaceable steel production technologies are an example of this. The method, volume of production and degree of alloying, i.e. the degree of quality depend on them. Coking, blowing oxygen or electrical methods, provide different quality of output. Whether we express that quality by natural or value indicators, although the price may have a declining tendency, the synthetic expression does not show that.

According to Zvi Griliches the measurement problem is a twofold: Firstly, economies move towards services that are always difficult to measure and secondly, the nature of the gain from modern technologies is difficult to quantify (Zvi Griliches, 1994) It is possible to conclude that the increase is under the influence of the new technologies, and that it is in essence respectable.

7 CONCLUSIONS AND MESSAGES

Man's greatness lies in his liberation from fate. He himself is the only one who can confront the whole entropy of his psyche and how well he can do that depends on his knowledge, skills as well as effective negentropy, and that is essentially the solution of the puzzle of the past and the puzzle of the future. During the last two centuries the enormous technological progress, employment and real income in rich industrial countries, and in those where the investment activity was carried out, continuously grew. The number of jobs and living standard has increased due to technological change, and not in spite of it. The unscientific approach of technophobes has no basis in relation to the future. The following questions may be asked: more or less science? more or less technology? The answer is very clear: more science and more technology, because it is the only way for humanity to get rid of fate, through control, and to be an autonomous creator of its own values that will last continuously.

Increasing levels of technologicality leads to the opening space for filling gaps and detection of new jobs in the sphere of management (planning, organizing, leadership, motivation), preparation and control as a corrective action in company management instead of in direct production. Technology will lead to changes in types of jobs and types of occupation. The lesser the resistance to change, the lesser are disorders in functioning of tangible systems; cycles and crises will last shorter, new jobs will be created and perhaps the relevant long term continuity can be preserved.

Opponents of new technologies have misconceptions, because, ad acta, there is an idea of a fixed amount of output. The technology will encourage both outputs and new demand. Theoretical items prove to be right, because the US and Japanese economies as the biggest users of computer technologies in production are exactly the best on jobs market. There is no room for futurephobia and dark apocalyptic looking toward the future. Here is the proof. From 1980 to 2000, the total employment level in the US grew by 24% in Japan by 17% in the EU by less than 2%. It shows that the new technology is good, not bad, at least in terms of new jobs. It is more difficult to assess the impact of information technology on services, but the OECD found that in the 1980s the fastest growth of jobs was seen in the countries that invested most in the Information Technology. All social and economic processes are far from being automatic, nor can they be spontaneous. They can be programmed but must be controlled. With this philosophical approach we can annul the possible time distance, and duration of the performance cycle. The speed of developmental and technological response is likely to decrease the potential discontinuities, and reduce them to a permissable extent.

REFERENCES

[1] Backhouse, R. E. (1996), Interpreting Macroeconomics, Routledge: London.

[2] Brynjolfsson, E. and Hitt L. (1994), Information Technology as a Factor of Production: The Role of Risk Among Companies, Economic Innovation and New Technology, Notebook 3.

[3] David, P. (1990), The Dynamo and the Computer: A Historical Perspective a Contemporary Production Paradox, Ameriacan Economic Review, 355-361.

[4] Davidson, M. (1995), The Transformation of Management, MacMillan Business, London - New York.

[5] De Wolf, S., (1929), Het Economisch Getij, *Amsterdam*: J. Emmering.

[6] Griliches, Z. (1994), Productivity, IR and Limitation of Data, American Economic Review. Volume ISBN: 0-226-30886-3, University of Chicago Press.

[7] Hansen, A. H. and Schumpeter, J., (1951), Social Scientist, Cambridge Mass. Harvard University Press, IX-X. Jap. trans. in SE. Harris (Ed.).

[8] Josifidis, K. (2008), Macroecnomics, Priniciple of Political Theory, Second Supplemented and Altered Edition, Futura publications, pp. 337-432.

[9] Kautzki, R., (1913), Neurochirurgische Abteilung der Neurologischen Universitats-Klinik, Hamburg, pp. 20.

[10] Kondratiev, N. D. (1922). The World Economy and its Conjunctures During and After the War (in Russian). Dynamics of Industrial and Agricultural Prices (Contribution to the Theory of Relative Dynamics and Conjuncture) (1928), Main Problems of Economic Statics and Dynamics (in Russian), Moscow, 1934. All translated and published by Lloyds Bank Review 129 (July 1978).

[11] Kondratijev, N. D. (1923), Spornie voprosi mirovoga kozjajstva i ego krizisa, Socialističkoe kozjajstvo, No 4-5.

[12] Kondratiev, N. D. 1924. "On the Notion of Economic Statics, Dynamics and Fluctuations". Moscow. Translated and published in Problems of Economic Fluctuations (1936). Institute for Business Cycle

[13] Kondratijev, N. D. (1925), Boljšie Cikli konjunkturi, Voprosi konjuinkturi, vol. 1.

[14] Kondratijev, N. D. (1928), Die Preisdynamik der industrielen und landwirschaftlichen Waren (Zur Problem der relativen Dynamik und Konjunktur), Archiv fur Socialwisenschaft und Socialpolitik, no. 60.

[15] Kondratijev, N. D. (1928), Voprosi konjunkturi, No. 4.

[16] Landes, D. (1969), The Unbound Prometheus, Cambridge University Press.

[17] Laider, D. (1990), "New - Classical Contribution to Macroeconomics", originally published in Banca Nazionale Del Lavoro, Quarterly Review 39 (1), 336.

[18] Lloyd. B., and Thurow. L., (1997), "The future of Capitalism", Leadership & Organization Development Journal, MCB books, 18 (2), pp. 93 – 98.

[19] Malaia Sovjetskaja Enciklopedija 1929.

[20] Pierce, D. V. and MacMillan., (2003), Dictionary of Modern Economics, Palgrave Macmillan; 4th edition.

[21] Praščević, A. (2008), Business Cycles in Macroeconomic Theory and Policy, Publishing Center of the Faculty of Economics in Belgrade.

[22] Rifkin, J. (1998), The End of Work, The Decline of the Global Labor Force and the Dawn of the Post-market Era, New York, G.P. Putnam's Sons.

[23] Rosenberg, N. (1996), Uncertianty and Technological Changes, Boston.

[24] Snowdon, B. and Vane, H. R. (1997), A Macroeconomic Reader, Routledge, London.

[25] Schumpeter, J. (1912), A. Theory of Economic Development, English translation published in 1934, Cambridge, MA: Harvard University Press.

[26] Schumpeter, J. (1939), Business Cycles, I - II, New York, McGraw-Hill Book Company.

[27] Todosijević, R. (2010), Strategic Management, Faculty of Economics, Vol. 1, pp. 494-533.

[28] Todosijević, R. and Lazović S. (2010), New Production Programs, Growth of Production Capacity and Economic Efficiency of Enterprises, Doctoral dissertation, Faculty of Economics, Subotica.

[29] Todosijević, R. (2014), Evaluation of Investment Performances, The International Congress of the Association of Accountants and Auditors of the Republic of Serbia, Banja Vrucica September 18–20, p. 374

[30] The Economist, (1996), London, No. 52, pp. 8-10.

[31] The Economist, (1996), A Survey of the World Economy, September 28, pp. 8-19.

[32] Van Gelderen, Ch., (1913), Springvloed Boeschouwingen over Industriele Outwikkeling en Prijesbewegung, Die Niuewe Tijd, Vol. 18, pp. 268-449.

INSTRUCTIONS FOR THE AUTHORS

Journal **MINING AND METALLURGY ENGINEERING BOR** is published four times per a year and publishes the scientific, technical and review paper works. Only original works, not previously published and not simultaneously submitted for publication elsewhere, are accepted for publication in the journal. The papers should be submitted in both, Serbian and English language. The papers are anonymously reviewed by the reviewers after that the editors decided to publish. The submitted work for publication should be prepared according to the instructions below as to be included in the procedure of reviewing. Inadequate prepared manuscripts will be returned to the author for finishing.

Volume and Font size. The work needs to be written on A4 paper (210x297 mm), margins (left, right, upper and bottom) with each 25 mm, in the Microsoft Word later version, font Times New Roman, size 12, with 1.5 line spacing, justified to the left and right margins. It is recommended that the entire manuscript cannot be less than 5 pages and not exceed 10 pages.

Title of Work should be written in capital letters, bold, in Serbian and English. Under the title, the names of authors and institutions where they work are written under the title. The author of work, responsible for correspondence with the editorial staff, must provide his/her e-mail address for contact in a footnote.

Abstract is at the beginning of work and should be up to 200 words, include the aim of the work, the applied methods, the main results and conclusions. The font size is 10, italic.

Key words are listed below abstract. They should be minimum 3 and maximum of 6. The font size is 10, italic.

Basic text. The papers should be written concisely, in understandable style and logical order that, as a rule, including the introductory section with a definition of the aim or problem, a description of the methodology, presentation of the results as well as a discussion of the results with conclusions and implications.

Main titles should be done with the font size 12, bold, all capital letters and aligned with the left margin.

Subtitles are written with the font size 12, bold, aligned to the left margin, large and small letters.

Figure and Tables. Each figure and table must be understandable without reading the text, i.e., must have a serial number, title and legend (explanation of marks, codes, abbreviations, etc.). The text is stated below the figure and above the table. Serial numbers of figures and tables are given in Arabic numbers.

References in the text are referred to in angle brackets, exp. [1, 3]. References are enclosed at the end in the following way:

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

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

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

Specifying the unpublished works is not desirable and, if it is necessary, as much as possible data on the source should be listed.

Acknowledgement is given where appropriate, at the end of the work and should include the name of institution that funded the given results in the work, with the name and number of project, or if the work is derived from the master theses or doctoral dissertation, it should give the name of thesis / dissertation, place, year and faculty where it was defended. Font size is 10, italic.

The paper works are primarily sent by e-mail or in other electronic form.

Editorial address : Journal MINING AND METALLURGY ENGINEERING BOR
Mining and Metallurgy Institute
35 Zeleni bulevar, 19210 Bor
E-mail: nti@irmbor.co.rs; milenko.ljubojev@irmbor.co.rs
Telephone: +381 (0) 30/435-164; +381 (0) 30/454-110

We are thankful for all authors on cooperation

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

622

MINING and Metallurgy Engineering Bor / editor-in-chief Milenko Ljubojev. - 2013, no. 2- . - Bor : Mining and Metallurgy Institute Bor, 2013- (Bor : Grafomedtrade). - 24 cm

Tromesečno. - Je nastavak: Rudarski radovi = ISSN 1451-0162
ISSN 2334-8836 = Mining and Metallurgy Engineering Bor
COBISS.SR-ID 201387788