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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

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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

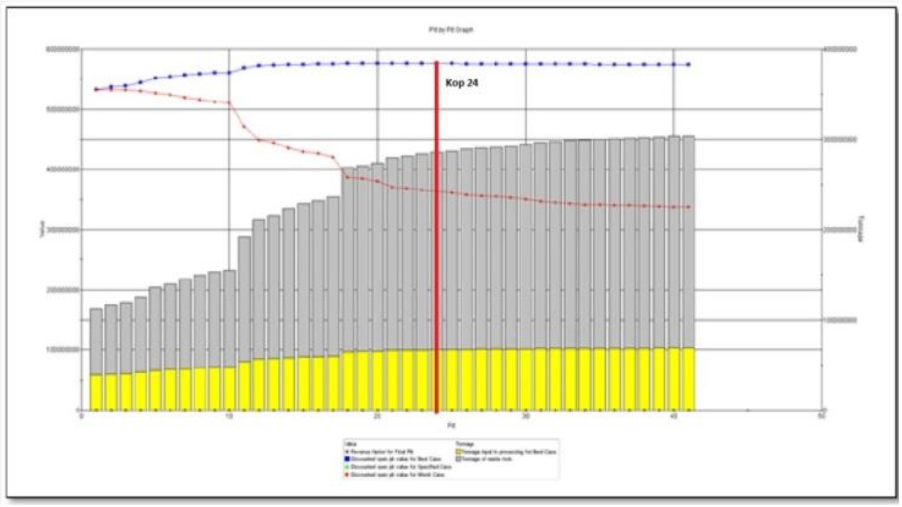

Figure 1 *Graph of the economic analysis of the open pits obtained by optimization for the roof coal seam*

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.

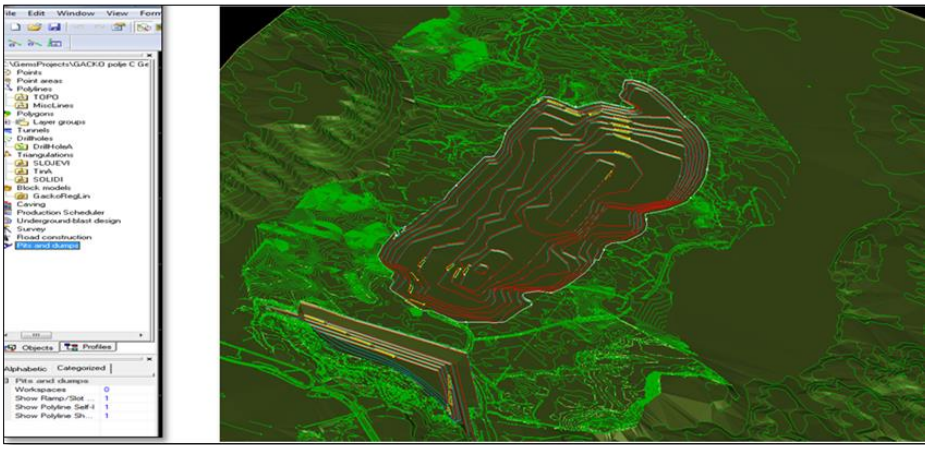

Figure 2 *The open pit constructed in Gemcom Gems in module pit design*

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.

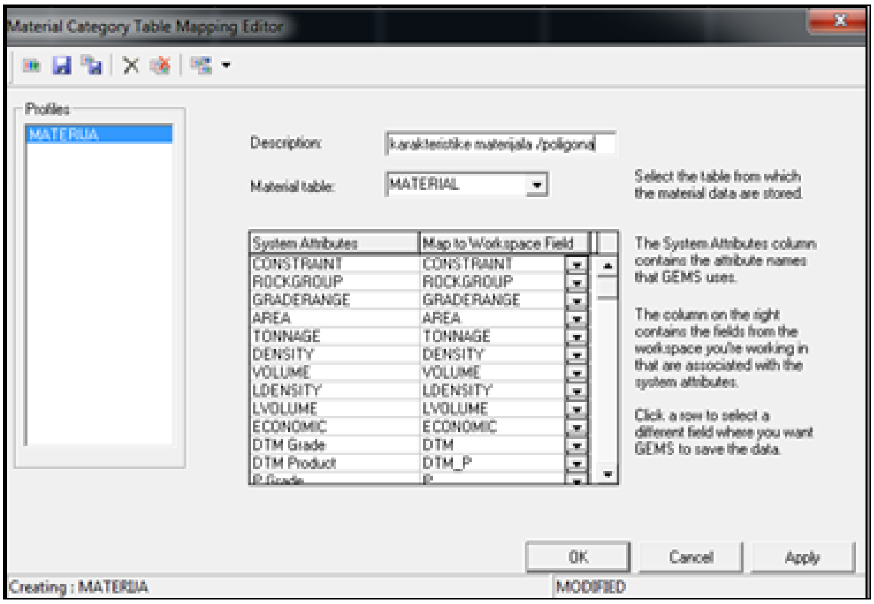

Figure 3 *Category Table Mapping Editor – Mapping the characteristics of polygons that will be considered*

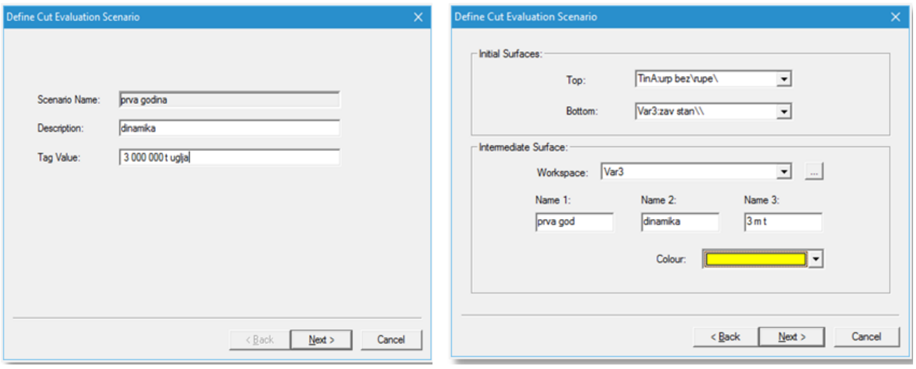

Figure 4 *Determining the boundary of mining dynamics*

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

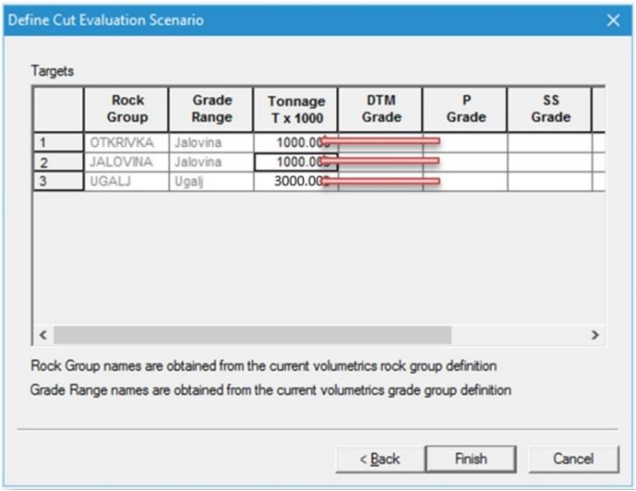

Figure 5 *Masses to be contoured*

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.

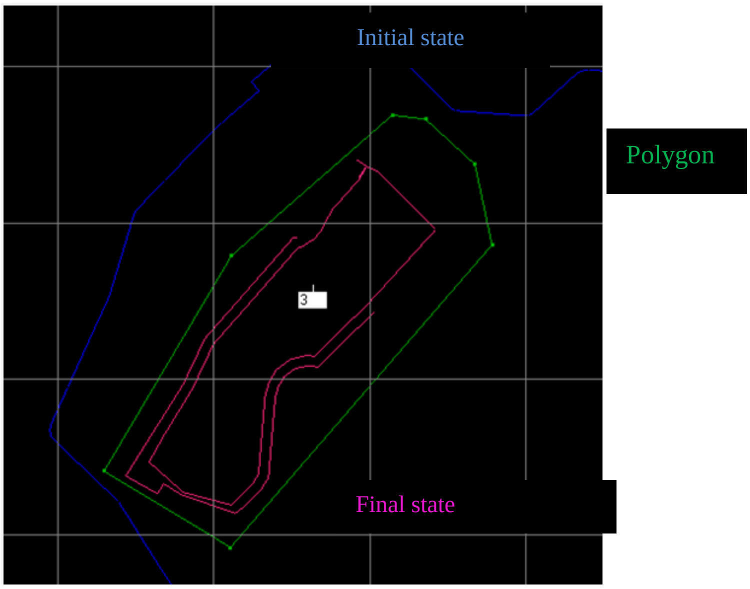

Figure 6 *Defining the mining boundaries*

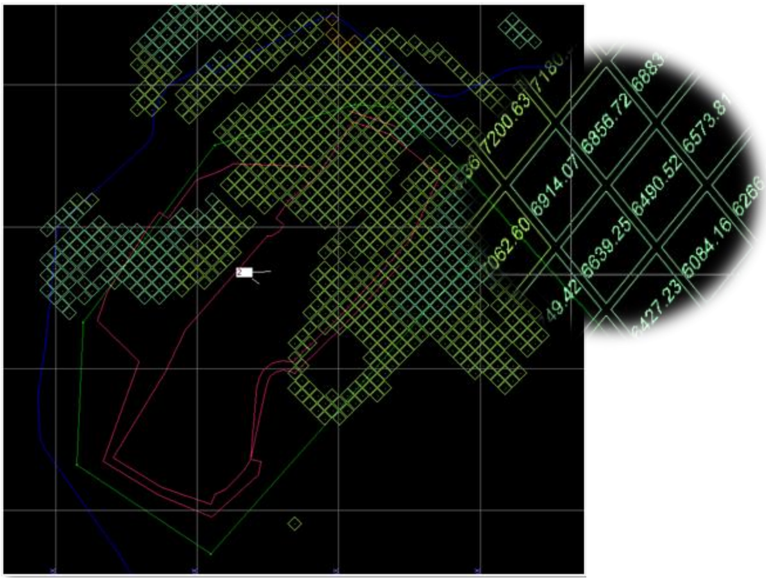

Figure 7 *View of the block model*

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

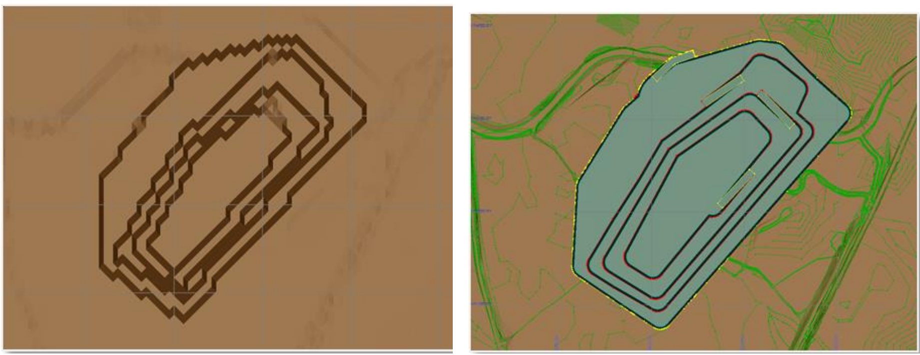

Figure 11 *a) Contour obtained in "Cut evaluation" b) Contour constructed in module "Pit design"*

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

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