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# EVALUATION AND PERSPECTIVES OF UNDERGROUND COAL MINES IN SERBIA

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**Summary:** This paper provides analysis of mines operating in Public Company for Underground Coal Exploitation (PCUCE), which is in restructuring process in excess of 10 years. Evaluation of these mines included analysis of performance and development potential of eight mines. Evaluation took into account a wide range of factors, considered to be most appropriate in relation to whether output and productivity could be increased and whether there are enough resources to justify the necessary investment. Based on AHP method and scores allocated for each factor, the mines were ranked according to technical potential.

***Key words:*** *Underground mining, Potential, Restructuring, Evaluation*

## Introduction

Serbia is one of the major coal producers in Europe, with over 38 Mt of coal per year. But most of this production is achieved in lignite open cast mines, which in 2016 produced 37.6 million tonnes [1]. On the other hand, combined production of all underground coal mines in Public Company for Underground Coal Exploitation (PCUCE) is just around 0.6 Mtpa, making their contribution to the energy sector quite insignificant. It should be noted that PCUCE operates 8 mines (with 11 pits) and one non-producing mine whose workers are hired as contractors in other mines. These mines are dispersed throughout Serbia, and they are producing various types of coal, as given in Table 1.

***Table 1.*** *Mines, location, type of coal produced and number of workers (as of March, 2017)*

| Mine | Town / Municipality | Type of coal | Number of workers |
|---|---|---|---|
| Vrška Čuka | Vrška Čuka, Zaječar | Anthracite | 145 |
| Ibarski rudnici | Baljevac, Raška | Hard coal | 479 |
| REMBAS | Resavica, Despotovac | Brown coal | 1161 |
| Soko | Soko Banja, Soko Banja | Brown coal | 535 |
| Bogovina | Bogovina, Boljevac | Brown coal | 247 |
| Jasenovac | Krepoljin, Žagubica | Brown coal | 254 |
| Štavalj | Štavalj, Sjenica | Brown coal | 449 |
| Lubnica | Lubnica, Zaječar | Lignite | 329 |
| Aleksinački rudnici | Aleksinac, Aleksinac | Contractor | 4050 [1)] |

[1)] Including 122 employees in management (Headquarters in Resavica).

Operation and performances of PCUCE were evaluated and analyzed on several occasions in previous years. Most notable analysis were [2], during which PCUCE was a part of JP EPS, and [3], study financed by European Agency for Reconstruction whose beneficiary was Ministry of Mining and Energy, RoS. These studies identified the need for investment in some of the mines to improve their technical performance and also limiting potential of the

other mines, mainly due to lack of coal reserves, market and difficult conditions. However, restructuring process of PCUCE is in standstill, meaning that little changes have been made in previous years. Finally, it should be noted that PCUCE is has direct annual subsidies from the Budget of RoS.

The purpose of this paper is to apply more recent decision-making tools, such as Analytical Hierarchy Process (AHP), for the purpose of evaluating and ranking of the mines operated by PCUCE.

## Criteria for evaluation

Initial step for evaluation of mines operated by PCUCE is to select criteria which will be used in AHP. For this purpose following criteria are selected:

- Reserves, score is given in relation to existing A and B amounts of reserves (criteria C1);
- Geological conditions, such as faulting, seam inclination, block size, seam variation, roof and floor conditions, rock pressure and geo-mechanic conditions (criteria C2);
- Mining hazards, such as gas, water, dust and potential for gas outbursts and spontaneous combustion (criteria C3);
- Potential for mechanization, such as seam inclination, seam thickness, floor and roof conditions, block size, coal clearance facilities and supply facilities (criteria C4);
- Quality of coal and products, such as coal type, sulphur content, ash content, moisture content, calorific value and amount of fines (criteria C5);
- Market and delivery possibilities, such as current markets served, the distance to the market and transport options available (criteria C6);
- Investment potential, possibility to attract an investor (criteria C7).

Score for each criterion ranged from 1 to 5 in relation to actual value of parameter or parameters. Due to restricted number of pages, scores of selected criteria required for AHP are given in Table 2. To provide more complete picture, coal productions achieved in period 2010-2015 in these mines are given in Table 3.

***Table 2**. Scores of criteria for AHP*

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| Vrška Čuka | 1 | 2 | 3 | 1 | 4 | 2 | 2 |
| Ibarski mines | | | | | | | |
| - Jarando | 1 | 2 | 2 | 1 | 4 | 2 | 1 |
| - Tadenje | 1 | 1 | 4 | 2 | 3 | 2 | 1 |
| REMBAS | | | | | | | |
| - Strmosten | 3 | 3 | 2 | 3 | 3 | 4 | 4 |
| - Block IV | 2 | 2 | 2 | 3 | 4 | 4 | 2 |
| - Senjski rudnik | 1 | 2 | 2 | 2 | 3 | 4 | 1 |
| Soko | 5 | 2 | 1 | 3 | 3 | 4 | 4 |
| Bogovina | 2 | 3 | 4 | 1 | 2 | 2 | 1 |
| Jasenovac | 2 | 2 | 3 | 2 | 3 | 2 | 2 |
| Lubnica | 4 | 4 | 2 | 3 | 2 | 2 | 2 |
| Štavalj | 5 | 3 | 3 | 3 | 3 | 1 | 1 |

***Table 3**. Production from PCUCE mines, in period 2010-2015*

| Year | Coal production (t) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Vrška Čuka | Ibarski rudnici | REMBAS | Soko | Bogovina | Jasenovac | Lubnica | Štavalj | JP PEU |
| 2010 | 7,061 | 101,200 | 113,000 | 121,317 | 4,160 | 62,000 | 67,330 | 76,118 | 552,186 |
| 2011 | 7,034 | 134,474 | 133,001 | 121,317 | 9,684 | 65,230 | 78,150 | 82,665 | 631,555 |
| 2012 | 6,807 | 140,993 | 126,751 | 122,330 | 18,758 | 62,240 | 58,770 | 46,960 | 583,609 |
| 2013 | 5,121 | 155,299 | 138,092 | 119,006 | 1,441 | 40,390 | 60,015 | 82,075 | 601,439 |
| 2014 | 5,115 | 120,939 | 147,902 | 117,028 | 5,270 | 36,530 | 48,140 | 84,305 | 565,229 |
| 2015 | 6,016 | 123,318 | 150,521 | 101,200 | 13,490 | 38,960 | 42,966 | 84,180 | 560,651 |

These scores are used for evaluation of PCUCE coal mines by using the Analytic Hierarchy Process method, as described in following chapter.

## AHP evaluation of underground coal mines in Serbia

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach introduced by Saaty [4]. The AHP method enables users to determine the weights of the parameters in the solution of a multi-criteria problem. In the AHP method, a hierarchical model consisting of objectives, criteria, sub-criteria and alternatives is used for every problem [5].

Solving a problem using AHP is carried out using the weights or priorities of the criteria subjected to pairwise comparison (Table 4). Weights or priorities are determined by normalizing the pairwise comparison matrix (Table 5). While performing pairwise comparisons of criteria in the AHP method, a certain level of inconsistency may occur. Therefore, the logical consistency of pairwise comparisons must be checked [6]. To measure the consistency of pairwise comparison judgments, the consistency ratio proposed by Saaty [7] is used. A consistency ratio is calculated for the pairwise comparison matrix. The upper limit proposed by Saaty for this ratio is 0.10. In a case where the consistency ratio calculated for the judgments is below 0.10, it is considered that the judgments exhibit a sufficient degree of consistency and that the assessment can be continued. If the consistency ratio is above 0.10, then the judgments are considered inconsistent. For each level in the hierarchy it is necessary to know whether the pair-wise comparison has been consistent in order to accept the results of the weighting. The parameter that is used to check this is called the Consistency Ratio. The consistency ratio is a measure of how much variation is allowed and must be less than 10%. Finally, random index (RI) is given in Table 6.

***Table 4.** Pairwise comparison matrix of criteria*

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|---|---|---|---|---|---|---|---|
| C1 | 1 | 2 | 3 | 1 | 1 | 2 | 4 |
| C2 | 0.5 | 1 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| C3 | 0.33 | 2 | 1 | 0.33 | 0.33 | 0.5 | 2 |
| C4 | 1 | 2 | 3 | 1 | 1 | 3 | 2 |
| C5 | 1 | 2 | 3 | 1 | 1 | 2 | 2 |
| C6 | 0.5 | 2 | 2 | 0.33 | 0.5 | 1 | 1 |
| C7 | 0.25 | 2 | 0.5 | 0.5 | 0.5 | 1 | 1 |

***Table 5.*** *Normalized pairwise comparison matrix*

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | |
|---|---|---|---|---|---|---|---|---|
| C1 | 0.2182 | 0.1538 | 0.2308 | 0.2143 | 0.2069 | 0.2000 | 0.3200 | 0.2206 |
| C2 | 0.1091 | 0.0769 | 0.0385 | 0.1071 | 0.1034 | 0.0500 | 0.0400 | 0.0750 |
| C3 | 0.0727 | 0.1538 | 0.0769 | 0.0714 | 0.0690 | 0.0500 | 0.1600 | 0.0934 |
| C4 | 0.2182 | 0.1538 | 0.2308 | 0.2143 | 0.2069 | 0.3000 | 0.1600 | 0.2120 |
| C5 | 0.2182 | 0.1538 | 0.2308 | 0.2143 | 0.2069 | 0.2000 | 0.1600 | 0.1977 |
| C6 | 0.1091 | 0.1538 | 0.1538 | 0.0714 | 0.1034 | 0.1000 | 0.0800 | 0.1102 |
| C7 | 0.0545 | 0.1538 | 0.0385 | 0.1071 | 0.1034 | 0.1000 | 0.0800 | 0.0911 |
| Sum | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Lambda ( $\lambda$) = 7.355393; CI = 0.059232; RI = 1.32; CR = 0.044873;

***Table 6.*** *Random index*

| n | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|
| RI | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.49 | 1.51 |

Rank of the underground coal mines operated by PCUCE obtained after completion of the calculation according to the AHP method is given in the Table 7. It can be seen that Soko has the best ranking, while the Jarando pit of Ibarski mines has the worst ranking. This result is mainly because Soko has significant coal reserves, stable market and potential for improvement (mechanization and investment), while these criteria are completely opposite in case of Jarando pit in Ibarski mines.

However, it is more important to highlight perspective or potential of all the mines. In this context, ranking of the mines provides reasoning for supporting some of the mines which are having potential for improving their operation (Soko, Strmosten pit in REMBAS mine, Lubnica and Štavalj) and for closure of those mines without potential (Tadenje and Jarando pits of Ibarski mines, Senjski rudnik pit of REMBAS, Bogovina and Vrška Čuka).

This approach leaves Jasenovac mine and Block IV pit of REMBAS mine in between these two groups, meaning that these two mines should probably continue operation until depletion of reserves or in relation to other non-technical criteria (such as social importance).

***Table 7.*** *Rank of the PCUCE mines*

| Rank | Mine | Value |
|---|---|---|
| 1 | Soko | 0.1296 |
| 2 | Strmosten | 0.1203 |
| 3 | Lubnica | 0.1191 |
| 4 | Štavalj | 0.1179 |
| 5 | Block IV | 0.0987 |
| 6 | Jasenovac | 0.0738 |
| 7 | Tadenje | 0.0715 |
| 8 | Senjski rudnik | 0.0699 |
| 9 | Bogovina | 0.0687 |
| 10 | Vrška Čuka | 0.0682 |
| 11 | Jarando | 0.0624 |

## Conclusion

Public Company for Underground Coal Exploitation operates 8 mines and one company working as a contractor at other mines. AHP analysis, based on technical criteria, identified two groups of mines, one with potential for further development (Soko, Strmosten pit-REMBAS, Lubnica and Štavalj) and the other group of mines which should be closed in near future (Tadenje and Jarando pits-Ibarski mines, Senjski rudnik-REMBAS, Bogovina and Vrška Čuka).

Results of this analysis are in accordance to findings of study [3], completed some 10 ago, meaning that any changes are not likely and decision on closure of above mentioned mines should be made soon. This approach would enable proper support to mines with potential for development. Finally, two mines (Jasenovac and Block IV-REMBAS) are in between these two groups, and decision on their future should include other aspects, such as social management.

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