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Increase in the production capacity of a hard coal mining plant

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Abstract:

During the current war in Europe and the restriction of hydrocarbon imports to the EU, there was a need to temporarily increase the production capacity of hard coal mining plants in order to ensure continuity of supply. This requires an increase in the number of longwall excavations (which is time-consuming and requires additional financial resources) or an increase in the efficiency of already operated longwall excavations. The article presents how the organization of the longwall ancestor's work would be shaped with ad hoc production work 24 hours a day, assuming a five-day working week, i.e. from Monday to Friday.

Keywords: hard coal mining plant, production, effectiveness, economic effects

1. Introduction

Socio-political changes initiated in Poland due to EU membership require ensuring profitability in the energy sector and in the entire hard coal mining industry. The sector should be adapted to the requirements of the concept of sustainable development and the so-called "Green Deal" of the EU, while maintaining competitiveness in the market of energy resources. The adaptation of the Polish hard coal mining industry to the realities of the market economy is a process that affects the entire Polish economy. This entails the necessity of radical technical and organizational changes, and consequently leads to reduction of employment in the Polish mining industry, the liquidation of unprofitable mines and mining regions, and the restructuring the unnecessary non-productive assets. Moreover, Poland is currently facing the challenge of decarbonising its economy [1-8].

In these circumstances and legal requirements, the mining sector faces the challenge of a "state-of-the-art enterprise" characterized by: technology, economy, market and management. TECHNIQUE and technology is the modernization of technologies, introduction of new devices, adaptation to ecological requirements. ECONOMY is a comprehensive and continuous cost-effectiveness account, confrontation of economic results and expenditure, cost-effect ratio, optimization of decisions according to efficiency criteria, collection and use of broadly understood capital. MARKET is liberalism, a freely operating demand-supply market mechanism and marketing as activities adjusting the enterprise to external conditions. MANAGEMENT orientation on the effective use of resources: devices, people, financial resources. Therefore, modern tools should be used and people's behaviour should be effectively managed [9,10,11].

The issue of the effectiveness of the organization's functioning is one of the most important subjects of interest for both management theorists and practitioners [12].

Effectiveness of the enterprises functioning can be considered in organizational or economic terms. Zięb icki defines organizational effectiveness as: "*a broad category relating to the positive results and attributes of an organization*" [13]. "*Most often it is expressed in general terms as the ability of an organization to achieve its operational goals*" [13]. On the other hand, economic efficiency is a narrower concept. It is examined as the relation of results to expenditures incurred to achieve them. "*Efficiency defined in this way is widely used in research projects in the field of economic theory and business economics* (...)" [14, 15]. In the literature on the subject, attention is drawn to the need to take into account the specificity of enterprises, when measuring their operational efficiency and selecting proper indicators.

Taking into account the requirements of the so-called the EU "green deal" [16], adjusting management to the requirements of modern economic reality, the need to reduce production costs, improve operational efficiency, are today the main determinants of the activities of hard coal mining entities [5, 6, 10].

An additional impulse during the war in Europe and the blockade of hydrocarbon imports is the need for a possible immediate increase in the production capacity of hard coal mining plants to ensure the demand for energy carriers. In the case of mines or the entire hard coal mining sector, which is currently in the process of shutting down – restoring the mining capacity takes months or even years. In many places it is no longer possible due to the changed directions of mining, the commenced process of liquidation of mining regions and entire mining plants. As for the constant increase in mining capacity, it is possible with a large amount of financial investment and legal changes, but it is an investment process for many years.

2. Materials and Methods

With regard to technical restructuring the mines, the main objectives are the rules that enforce the so-called concentration of mining, consisting in extending longwall panels to about 2,000 meters and increasing the length of longwall faces to about 250-300 meters. Output from the longwall face is planned to reach 5000-8000 Mg/d. Achievement of such a goal is possible with drawing the special attention to the following issues:

- high reliability of the technical equipment of the longwall faces and run-of-mine transport,
- increasing the efficiency of the machines used, along with increasing the power of the machines,

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- ensuring an appropriate advance of preparation work, adapted to the required advance of the longwall face,
- improvement of efficiency by reducing the amount of coal fines, and thus increasing the volume of bigger size of coal in run-of-mine,
- improved quality of run-of-mine, in particular with regard to thin seams, which reduces the costs of mechanical processing of coal and transport,
- improving the methane drainage systems of the deposit to obtain the required daily output,
- deposit management achieve of the technical goal.

Thus, the effectiveness of a properly designed mechanization system depends to a large extent on the so-called concentration of mining production and cost reduction. Overall costs can be divided into two groups:

- operational costs which are only slightly changing,
- costs related to the organization of production.

Costs are a part of the company's strategy that must be constantly adapted to the rules of the market. The costs of implementing a specific project (longwall mining) consist with the following costs:

- human (e.g. longwall personnel),
- material (e.g. cost of purchase or lease of machines and equipment, costs of their operation, including the daily use of the machine),
- financial (e.g. expenditures),
- information (e.g. expert opinions, documentation).

The materials are part of the costs that have the greatest impact on the profitability of the mining plant and therefore should be minimized as much as possible. This can be achieved through a better organization of work to maximize the effective daily use of the working time of machines and equipment. This will lead to an increase in the profitability and thus will enable the company more dynamic development [1,3 6,9,10,18].

Advance of the longwall face may be limited by external conditions (natural geological constraints, e.g. CH_4, water, rock bursts), on which we have a limited impact as well as organizational conditions. Just, the organizational conditions are the biggest obstacle to increase efficiency, which we may modify. The maximum daily working time of machines and equipment will significantly improve the efficiency of the longwall face production. Organizational conditions that disturb increasing the effectiveness and efficiency of the longwall face can be divided into four basic groups: machine, electrical, ventilation and mining. By extending the daily effective working time of machines, we increase (with the same employment) the unit profit on the mined coal per one employee. This will lead to cost reduction, i.e. the theoretical possibilities of a given longwall face [1,3 6,9,10,18].

3. Assumed results

With the current technical and organizational knowledge, the longwall face can operate 24 hours a day, assuming work from Monday to Friday. The improvement of the work organization should consist in designing the longwall panel in such a way to achieve the goal. Limitations in the continuous operation of the longwall, can be eliminated by using machines and devices that meet the criterion of continuous operation. If the planned longwall face does not show significant signs of geological limitations, then the only criterion limiting continuous operation is the proper selection of machinery and equipment as well as work organization. The basic limitations of the continuous advancement of the longwall face can be conventionally divided into:

- Mining limitations – the longwall panels should be previously secured as not to affect the advance of the longwall face. On the other hand, components necessary for mining should the transported on an ongoing basis.

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- Machine limitations – this is delivery of a medium necessary to supply powered roof supports, process water and compressed air (pipelines should be shortened on a day off, e.g. Saturday). Another problem is shifting of the stage loader, on an ongoing basis as the longwall face advances. However, shortening the route of the belt conveyor should take place on Saturdays.
- Electrical limitations – design the power supply to machinery and equipment to allow the advance of the longwall face for five days of the week. The power supply conversion will take place as in the previous restrictions on a day off, e.g. Saturday.
- Ventilation limitations – preparation of a proper technology for methane drainage of the longwall face as well as power supply and reinstallation of fans allowing for smooth operation of the longwall.

Maintenance should take place on Saturday. Currently, most of the maintenance operations is done on Saturday, so the operation does not disturb the mining process. The only break in the mining machine operation - the longwall shearer - should result from technological reasons (e.g. general inspection, methane measurements, replacement of cutting bits) [1,3-6,9,10,18].

Further part of the article presents averaged, real data in the mining plant production and its unused possibilities. Three longwalls of the mining plant were analysed for one month. Then, it was analysed to what extent the longwall shearers were used in longwall panels on the example of the whole plant within one year. Degree of the shearer utilization is the time of shearer activity during the day. The analysis covered 4 longwall panels mined for one year. The average degree of use over the entire analysed period is a percentage of operating time that takes into account only the shearer activity during working days, excluding Saturdays, Sundays and holidays.

For analyses, it was necessary to get information on working time, machine failure frequency, based on the ZEFIR dispatching system and daily dispatcher's reports for 1 year. The presented mining plant operated 4 longwall panels (those that ended or started their use in the analysed year were neglected), and the degree of shearers availability was from 0 to 83.33%. The daily production ranged from 0 to 7,920 Mg/d [5,17].

The mining plant output per month

Mining in longwall faces differed in number of shifts. One had 2 shifts, the other had 3 shifts, and the third one 4 shifts. All longwall faces had one maintenance shift. The longwall faces also differed in the effective working time (Table 1) [17].

Table 1. Daily output, price per Mg, economic result on sales [17]

Item	Day of month	Net output Mg per day	Coal price PLN/Mg	Profit from sale PLN
1	2	8190	247.65	2028253.5
2	3	8010	277.21	2220452.1
3	4	9210	266.33	2452899.3
4	5	10010	274.76	2750347.6
5	6	10380	264.82	2748831.6
6	9	11050	261.16	2885818
7	10	9460	245.01	2317794.6
8	12	10170	263.35	2678269.5
9	13	10500	265.49	2787645

10	16	9720	280.58	2727237.6
11	17	9540	246.28	2349511.2
12	18	9000	266.46	2398140
13	19	9210	275.26	2535144.6
14	20	8560	276.06	2363073.6
15	23	10000	280.7	2807000
16	24	9000	239.97	2159730
17	25	10170	255.15	2594875.5
18	26	8820	268.35	2366847
19	27	10040	247.44	2484297.6
20	30	8010	233.9	1873539
Total per month		**189 050**	**5 235.93**	**49 529 707.30**
Average per day		**9 452.50**	**261.79**	**2 476 485.36**

Table 1 shows that over the one month analysis, i.e. 20 workdays, and the daily coal output varied each day, averaging 9452.5 Mg. The average coal price was 261.79 PLN/Mg, and the daily sale reached 2,476,485.36 PLN.

During analysis, the average daily breaks caused by failures and the effective operation of shearers were different depending on the failure rate and geological conditions (Table 2).

Table 2. Real breakdowns caused by failures per day, effective daily operation of the shearer as well as possible shearer operation during a day without failures [5,17]

Item	Day of a month	Breakdowns caused by failures per day		Effective daily operation of the shearer		Possible shearer operation during a day without failures	
		min.	[%]	min.	[%]	min.	[%]
1	2	1180.00	27.31	1399.68	32.40	2579.68	59.71
2	3	1140.00	26.39	1291.68	29.90	2431.68	56.29
3	4	700.00	16.20	1715.04	39.70	2415.04	55.90
4	5	340.00	7.87	2077.92	48.10	2417.92	55.97
5	6	390.00	9.03	2077.92	48.10	2467.92	57.13
6	9	210.00	4.86	2125.44	49.20	2335.44	54.06
7	10	385.00	8.91	2039.04	47.20	2424.04	56.11
8	12	195.00	4.51	2190.24	50.70	2385.24	55.21
9	13	30.00	0.69	2302.56	53.30	2332.56	53.99
10	16	145.00	3.36	2142.72	49.60	2287.72	52.96
11	17	275.00	6.37	2043.36	47.30	2318.36	53.67

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12	18	240.00	5.56	1935.36	44.80	2175.36	50.36
13	19	415.00	9.61	1995.84	46.20	2410.84	55.81
14	20	365.00	8.45	1995.84	46.20	2360.84	54.65
15	23	370.00	8.56	2125.44	49.20	2495.44	57.76
16	24	560.00	12.96	1710.72	39.60	2270.72	52.56
17	25	390.00	9.03	2095.20	48.50	2485.20	57.53
18	26	775.00	17.94	1844.64	42.70	2619.64	60.64
19	27	270.00	6.25	2013.12	46.60	2283.12	52.85
20	30	690.00	15.97	1913.76	44.30	2603.76	60.27
Total		**9 065.00**	**209.84**	**39 035.52**	**903.60**	**48 100.52**	**1 113.44**
Average		**453.25**	**10.49**	**1 951.78**	**45.18**	**2 405.03**	**55.67**

Table 2 presents average possible shearer operation during a day without failures, which is 55.67% of a day, effective operation 45.18% as well as breakdowns caused by failures, which consume 10.49% of time.

Coal production and potential output of the mining plant

The results are presented in Tables 3÷5 and Figures 1÷4.

Analysis of Table 3 and Fig. 1, shows that during the time covered by the analysis, the average breaks caused by failures, due to the additional mining shift increased by 3.50%. On the other hand, the effective working time of the shearer increased to 15.06% per day. The table also shows the possible operation of a shearer without failure, which will increase to18.56%. The effective average available working time of a mining plant due to an additional mining shift would be 74.23% of the day.

Table 3. Breakdowns during a day, effective daily operation of the shearers and possible daily operation of the shearer without breakdowns depending on the number of mining shifts [5,17]

Number of shifts	Time of breakdowns a day		Effective operation of a shearer a day		Possible time of operation of shearers without failure a day	
	hour	[%]	hour	[%]	hour	[%]
3	2.52	10.49	10.84	45.18	13.36	55.67
4	3.36	13.99	14.46	60.24	17.82	74.23
Difference	**0.84**	**3.50**	**3.62**	**15.06**	**4.46**	**18.56**

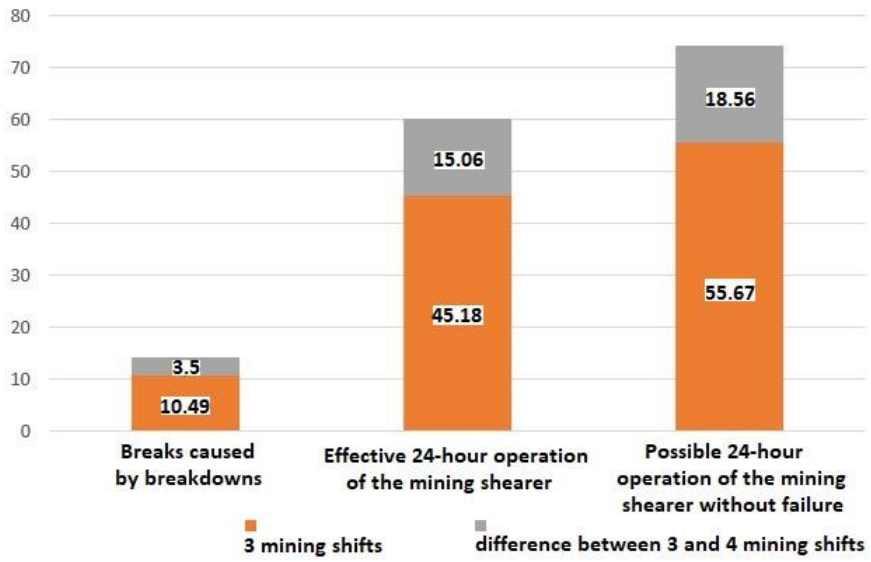

Fig. 1. Time of breakdowns during a day, effective operation of the shearers per a day and possible operation of the shearer per a day without breakdowns depending on the number of mining shifts [%] [18]

Table 4 and Fig. 2 and 3 show that comparison of the daily output for three and four shifts shows increase of the mining plant output to 3,150.8 in the case of four shifts [Mg] and difference in the economic result on sales was 822,941.2 PLN/24h.

Table 4. Daily output and economic result on sales for three and four mining shifts – additional profit of the mining plant [17]

Number of shifts	Additional output Mg/24h	Additional sale profit in PLN/24h
3	9 452.50	2 476 485.40
4	12 603.30	3 299 426.60
Potential capacity	**3 150.80**	**822 941.20**

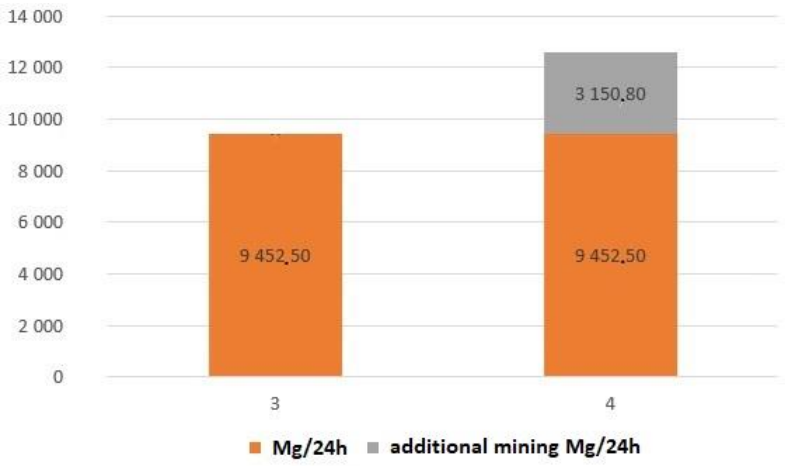

Fig. 2. Additional mining Mg/day depending on number of shifts [17]

Fig. 3. Additional profit from sale in PLN depending on number of shifts per day [18]

Analysis of Table 5 and Fig. 4, shows that during the analysis, the difference (average) in monthly output by increasing the number of shifts from three to four total output would increase to 63,016 Mg and monthly sales profit would amount to PLN 16,458,824.

Table 5. Monthly production and economic result on sales for three and four mining shifts and potential profits of the mining plant [17]

Number of shifts	Net production Mg/month	Profit from sale PLN/month
3	189 050	49 529 708
4	252 066	65 988 532
Potential profits	**63 016**	**16 458 824**

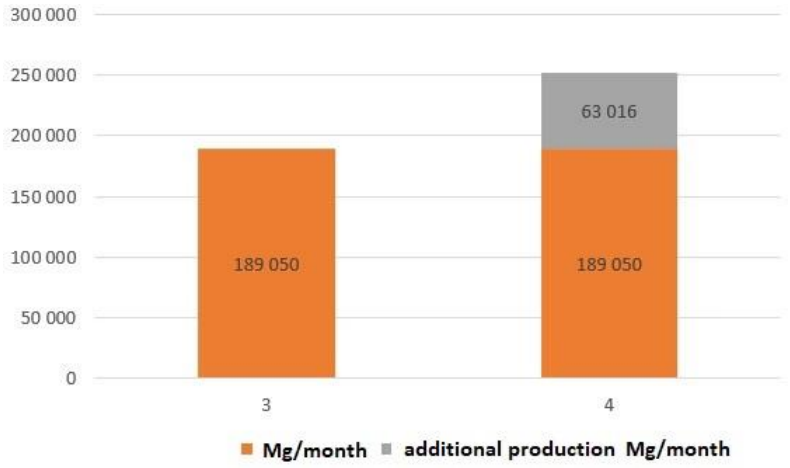

Fig. 4. Net production in Mg/month depending on the number of shifts [18]

Over the time of analysis, the average shearer availability was 43.725%, while the potential shearer operational capacity increased by 14.58% (Table 6). The average daily production during one year was 11,470 Mg/d, while the loss (potential profit) was 3,820 Mg/d. The average economic result on sales amounted to 3,002,731 PLN/day, while the potential profits of the mining plant amounted to 1,000,910 PLN/day. For the purposes of the analysis, the average unit price of coal was assumed as 261.79 PLN/Mg.

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Table 6. Actual average availability of shearers 24-h production and economic result from sales [18]

Item	Shearer type	Average availability for the entire period of longwall mining %	Average daily production for the entire longwall mining Mg/day	Average economic result on sales in PLN/24-h (unit coal price 261.79 PLN/Mg)
1	Joy 4LS20	34.5	2164	566 513.6
2	Electra 1000/A	39.4	2724	713 116
3	Electra 1000	56	4808	1 258 686
4	Eickhoff SL-300	45	1774	464 415.5
Total		**43.73**	**11470**	**3 002 731**
Potential capability		**14.58**	**3823**	**1 000 910**
Total possible		**58.3**	**15293**	**4 003 641**

The analysis based on the "Zefir" dispatcher system, gives some idea of the shearer's availability but it is not accurate enough. The data from this system show only the shearer's on/off status, not indicating whether the shearer's active operation is the result of mining, idle operation or the shearer maneuvering. A more detailed analysis is possible if the load to the shearer's driving motors is also analyzed. This would enable excluding the idle operation or the shearer maneuvering.

4. Conclusions

The article presents a comparative analysis of a mining plant output, profits from sales, possible capacity, failure breaks, shearer's effective operation time and possible shearer's operation time without failure and its dependence on the number of shifts. As a result of introduction of the fourth shift, production capacity of the mining plant will significantly increase, positively affecting the potential profits of the plant. Consequently, it will contribute to the improvement of the economic results. The four-shift work system enables extending the working time of the mining plant during the year, an increase of the annual output by about 25%, with the employment system of unchanged. The assumption of continuous operation of the mining plant from Monday to Friday will not increase the number of underground personnel and the costs of remuneration, and costs linked with remuneration, as longwall faces still work in a four-shift system. The fourth maintenance shift employs a comparable number of employees and therefore these changes were not included in the calculation.

However, to implement continuous mine operation, it is necessary to implement prediction of mining machines and equipment condition. Prediction allows to determine the future condition of objects due to continuous measurement, constant monitoring (also in real time), analysis of the current and historical states and estimation of future parameters. As a result, it is possible to plan optimal maintenance, repair, replacement and other work that minimize failures and allow to extend time between failures. Taking preventive measures at the best possible time enables more effective prevention, but also removes failures.

Thus, the financial effect for the mining plant, resulting from the introduction of the continuous work system, including the remuneration costs of the staff working in this system and costs related to remuneration, is positive. Higher concentration of production in the face, also by increasing the number of shifts reduces costs [5, 6]. However, use of continuous operation of the mining plant leads to faster exploitation of the mining front (longwall), which requires opening the subsequent operating fronts in due time.

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