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The efficiency of longwall systems in the case of using different cutting technologies in the LW Bogdanka

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Abstract
The authors concentrated on some issues related to the sustainable development of the mining industry, i.e. on the management of fossil fuels deposits to achieve economic efficiency, environmental, as well as social acceptance. It should be borne in mind that Poland still belongs to the countries in which electric energy production and thermal energy production are based on hard coal and lignite. The research work results described in the article present efficiency assessment aspects in the case of different longwall technological systems in the LW Bogdanka. Advantages and disadvantages resulting from using shearer and plow systems are given. An impact of dilution in the run-of-mine on the coal quality is analyzed, and some recommendations emerging from this analysis are suggested. On the basis of the conducted in situ experiments, technical possibilities of reducing dirt are described. As an efficiency assessment is a multi-criterion process, so it requires continuous monitoring of production parameters. The article also contains an analysis of longwall systems in the aspect of dust control. An impact of mining, technical and technological parameters on generated dust amount, in particular in the case of a shearer-equipped longwall face, is discussed. In the conclusions, it is highlighted that an efficient assessment process in the case of longwall systems is complicated as an impact of different factors should be taken into consideration. It is suggested to use the data integration platform based on the Service Oriented Architecture (SOA). Due to the SOA, any mistakes in the scope of the functionality of individual systems can be detected very quickly. Such an approach is fundamental for the realization of the TPM (Total Productive Maintenance), leading to the creation of the so-called Mine of Smart Solutions.

Keywords
hard coal, production, efficiency, longwall system, shearer, plow, safety, dust control

Introduction

At present, it is very popular to use the term 'sustainable development, which includes three main areas:

- environmental protection and rational management of natural resources,
- economic development and a just distribution of advantages resulting from it,
- a social development.

Looking at the above areas from the perspective of the mining sector, it can be stated that sustainable development in mining consists of the management of fossil fuels deposits to achieve the activity which is efficient economically, environment friendly and approved by society. Poland belongs to a relatively small group of countries, where electric energy production and thermal energy production is based on solid fossil fuels such as hard coal and lignite. Due to coal reserves in Poland, this fuel is and will be a guarantee of energy security at present and in the near future. In the seventies of the last century, the Lublin Coal Basin's construction was started in Poland's eastern part. Due to some geological problems at the beginning of the mine construction, the first longwall face started its operation in 1986. A production capacity turn happened in 1988, and since then, the production rates have been increasing. The Mechanical Preparation Plant, enabling beneficiation of coal and an improvement of its quality, started its operation in 1992. In the Bogdanka Mine, the period of recent 40 years is full of problems caused by nature and technical obstacles, but it is also the period of mine modernization, reconstruction and expansion in very difficult mining-and-geological conditions. The restructuring process enabled the Bogdanka Mine to achieve the hard coal branch's leading position – top production capacity, top production concentration, and lowest costs.

It is important to consider a phenomenon of mineral dilution, which results from the mechanization of processes. This phenomenon is one of the key factors having an impact on the economic efficiency of coal winning processes. (Wright, 1983), (Ingler, 1984) and (Knissel, 1955) analyzed the phenomenon of deposits impoverishment. However, (Noppe, 2003) suggested the most popular classification of impoverishment into three main groups:

- primary impoverishment – coal–cutting with a roof layer and with a floor layer made by a shearer or a roadheader,
- secondary impoverishment – cutting of uplifted floor or collecting rock from the roof-fall,
- third-rate impoverishment – including coal impurities during roof supports cleaning or mixing of dirt generated during driving stone roadways with the coal run-of-mine from longwalls.

Sources of dilutions in a longwall face are presented in Fig. 1.

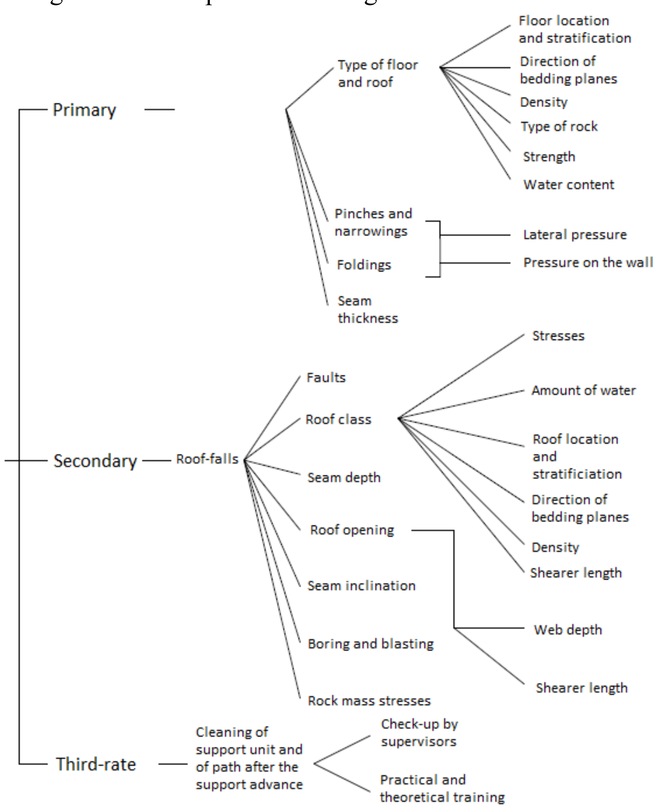


Fig. 1. Sources of dilutions in a longwall face (Noppe, 2003)

The first publications on dilutions appeared in 1971 (Popov, 1971). However, (Agoshkov, 1974) determined relationships among parameters and dilutions.

Other tests were conducted in the Stillwater Mine in Montana by (Annels, 1996). He concluded that impoverishment increases when the seam thickness decreases. Soviet scientists Kaplunov, Mielnikov, Agoshkov i Bajkov studied these issues as regards ore deposits (Agoshkov, 1974; Agoshkov, et al., 1973; Agoshkov at al., 1967; Bajkov, 1973; Bajkov, 1978; Bajkov & Kuchko, 1974; Kaplunov, 1938; Kaplunov, 1948; Mielnikov, 1973; Mielnikov, 1974). The results of their research work and tests were used for developing similar methods for the hard coal mining industry.

Management of hard coal seams in the Lublin Coal Basin revealed new mining and geological conditions, unrepeatable in other Polish coal basins. Additionally, a necessity of adapting to the requirements of coal purchasers made the coal producers from the Bogdanka Mine use more efficient cutting technologies and innovative management of seams characterized by changeable quality parameters.

Research objectives

Several methods, techniques and tools were used for an assessment of longwall systems in the Bogdanka Mine. They included as follows:
- an expert assessment of Polish and foreign literature,
- mathematical modelling,
- probabilistic modelling,
- analysis of agglomerations,
- assessment of economic efficiency.

The research methods presented above were used for confirming the fact that it is possible to achieve economic results of rationalizing the coal winning process consisting of extracting less dirt, where it is geologically and technically justified. Technical and economic analysis should present and justify basic elements which are decisive in the management of mineral resources, in particular:
- a selection of deposit opening method and of deposit exploitation system, determining forecasted losses in geological resources,
- a determination of basic mining-and-geological parameters, determining criteria of qualifying the reserves to commercial reserves,
- a determination of costs of exploitation and beneficiation,
- a determination of economic indicators, which decide about exploitation efficiency of the deposit.

A simplified classification of technologies for coal seams extraction is shown in Fig. 2.

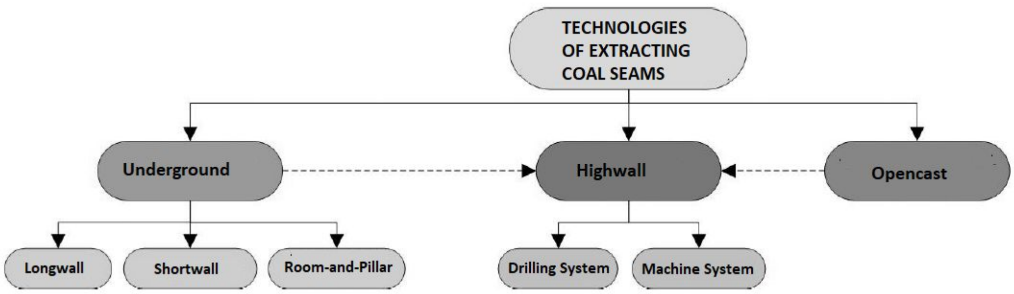


Fig. 2. Classification of technologies for coal seams extraction (Dyczko, 2018)

Technical and economic criteria of selecting a technology of a deposit extraction require a determination of the following issues:
- cutting system of a deposit,
- roof control (roof fall, filling, retarded caving),
- geometry of workings and pillars,
- type of support,
- machines and equipment,
- quantitative and qualitative losses of useful minerals.

An implementation of a correct mining system and of correctly selected machinery reduces losses and impoverishment significantly.

For years, the basic system of exploitation used in the Polish mining industry has been a longwall system. It consists of extracting a part of a seam in a rectangular shape, limited by road-heading workings. Shield support monitoring system plays a vital role as regards roof control and operational safety (Jasiulek, 2019). This part of the longwall process is conducted with the use of a full or partial roof fall or filling in with stowing material. A schematic diagram of a longwall system is shown in Fig. 3

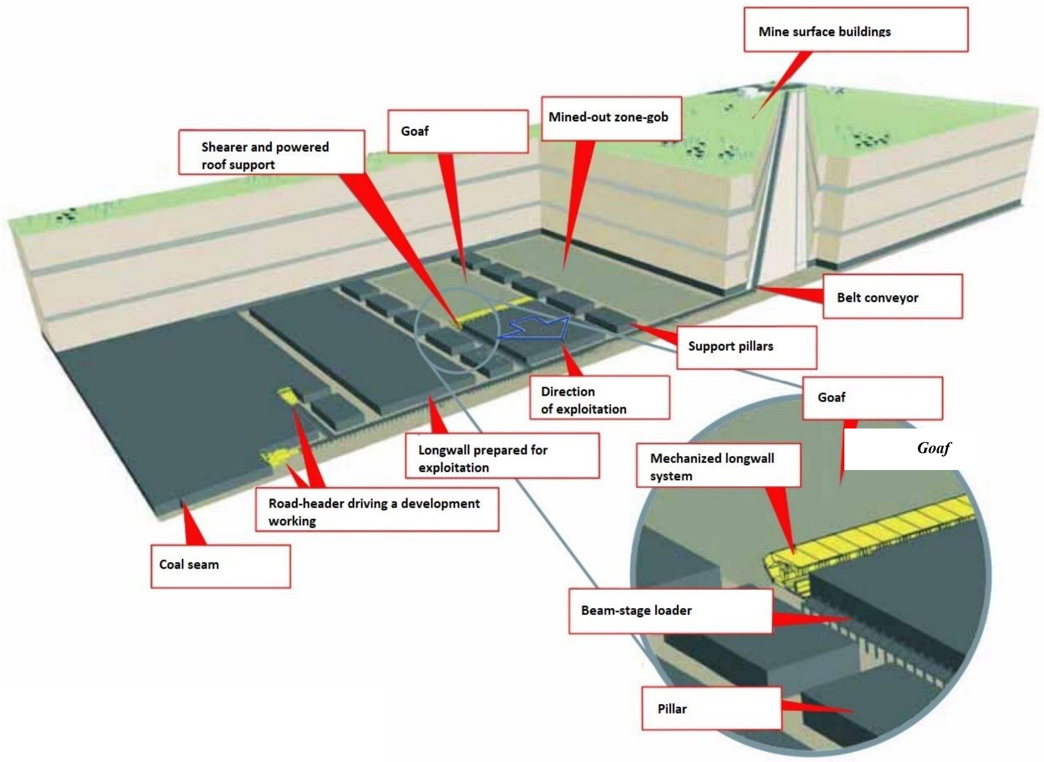


Fig. 3. 3D schematic diagram of a longwall system (Dyczko, 2018)

An operation of longwall faces of lengths from 250 to 300 m enables to obtain advantageous economic and technical results. (Korski, 2019) investigated and analyzed the longwall complex efficient time and reasons for its decreasing. The advantages of longwall systems include a small number of development activities, low exploitation losses, big production concentration, easy roof control and a possibility of implementing fully mechanized systems. In recent years efficient exploitation of thin seams below 1.5 m became a real success. Aiming at rational and economic mining of coal deposits in thin seams, the Jastrzębska Coal Company and LW Bogdanka started exploitation with the use of plow systems.

Characteristics of coal seam No. 385/2 in the Bogdanka Mine

Mining-and-geological conditions, as well as technical-and-organizational factors, have a decisive impact on the development of hard coal exploitation technology such as:

- depth of a deposit bedding,
- thickness of a deposit,
- deposit inclination,
- geological disturbances,
- occurrence of natural hazards.

As regards cutting technologies, the following parameters play a key role:

- conditions of a seam bedding, in particular seam thickness,
- parameters of a longwall face, in particular its height,
- properties of coal expressed by a cuttability index and an angle of lateral crushing,
- required daily production rates.

In the case of coal seam No. 385/2, the mining-and-geological conditions were as follows:

- deposit thickness: 1.2-1.6 m,
- seam drift bands thickness: 0.1-0.16 m,
- primary temperature of rocks: up to 32°C,

- methane hazard: I category, workings with “c” degree,
- compressive strength of coal seam: 8-19 MPa,
- type of roof rocks/compressive strength,
  - moderately compact mudstone and aleuralit/4.5-38 MPa,
- type of floor rocks/compressive strength – mudstone
  - weakly compact mudstone and aleuralit/2.5-20 MPa,
- seam cuttability (acc. to Protodiakonow): 0.75÷1.20.

The maps of seam 385/2 are shown in Fig. 4.

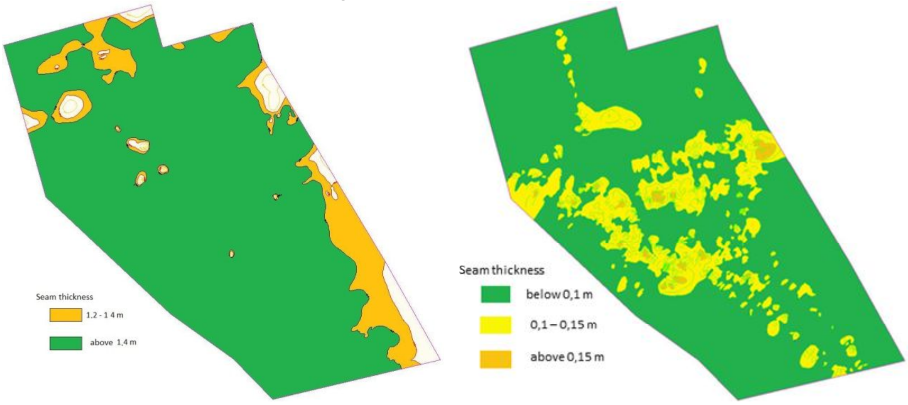


Fig. 4. Map of 385/2 seam thickness and map of 385/2 seam dirt bands thickness (Dyczko, 2018)

Seam No. 385/2, at a depth of 950 m, is one of the richest and most regular hard coal seams in the Lublin Coal Basin.

The efficiency of longwall systems at the Bogdanka Mine

The mining operations conducted at the Bogdanka Mine for over 30 years have been based on shearers. However, such systems' overall dimensions cause that they can be effectively used in the longwall faces of the height exceeding 1.6 m. In the case of mining the seams of 2.0÷2.5 m in thickness, the daily production rates from one longwall face reached up to 20 000 Mg/day of the coal run-of-mine, and for the longwall faces of the height 1.6-2.0 m – 15 000 Mg/day.

In Fig. 5 longwall systems, used in the Bogdanka Mine, are presented.

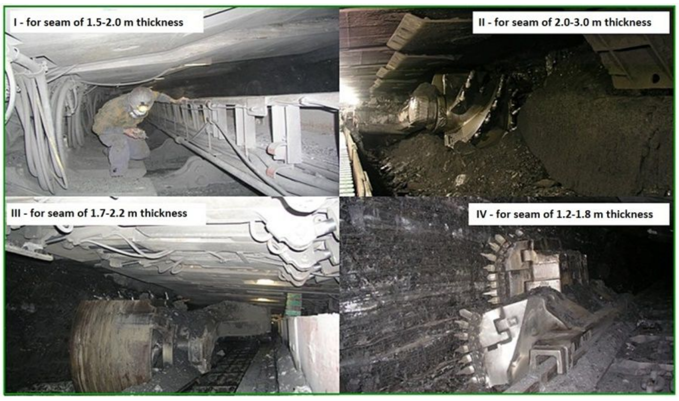


Fig. 5. Longwall systems operated in the Bogdanka Mine (Dyczko, 2018)

As it has already been mentioned before, for low shearer longwall faces, there is a necessity of increasing the longwall height by cutting the roof and the floor layers, causing a generation of dilutions and thus a deterioration of the run-of-mine quality. In 2010, a plow system was implemented in the Bogdanka Mine to eliminate this disadvantage. Due to it, exploitation of seams of the thickness below 1.6 m became more efficient as it was possible to improve the quality of the run-of-mine by reducing the amount of cut roof and floor rock layers, so-called "clean extraction". A 1% reduction of dirt in the run-of-mine often resulted in a two-digit improvement of the production profitability, which has been presented on the example of American mines (Kryj et al., 2011).

An improvement of the run-of-mine quality is confirmed by two longwalls' production rates in seam No. 385. The first longwall 7/V/385, where a longwall system with a shearer was operated, obtained 68% of coal in the run-of-mine. The second longwall 1/VI/385 obtained the result of 75% of coal in the run-of-mine. Over the years 2008-2019, the Bogdanka Mine purchased four plow systems. The first one, purchased in 2009, enabled to achieve the daily production rate on the level of 10 000 Mg/day in seam No. 385/2, whose thickness was about 1.55 m. The average daily longwall advance reached 10.0 m, the average monthly advance – 247.4 m, the average time of plow operation – 5h 23 min, the average daily gross production rate – 8200 Mg and the total production rate over the period: April-October was 1382 thousand Mg.

The world record of the daily production rate from low seams, obtained at the LW Bogdanka, was 22400 Mg. However, this record was broken by the miners from the Pinnacle Mine (USA) in August 2019. Using an automatic plow system, Cat Gleit Hobel GH1600 in the longwall of the height 1.42 m and the length of 294 m; the daily production rate reached 29420 Mg (Cat® Longwall Plow System Helps Set Low-Sean Production Record). Not long afterwards, Bogdanka increased the level of daily production reached 33612 Mg in October 2019.

Another challenge, as regards the implementation of the plow technology, was the longwall 7/VII/385 of the 305 m length and of the panel length of 5 km in the seam of the thickness 1.25÷1.60 m. It was equipped with the plow system, which used to be operated in the longwall 1/VI/385. In 2014 two more plow systems were purchased by the Bogdanka Mine. At present, four plow systems seem to be sufficient to keep the production rates on the required level for several years to come. Both cutting technologies, i.e. shearer systems and plow systems, will be used in the case of four longwall faces to be mined. Six mechanization systems should be at the disposal of the Mine, for example, 3 plow systems and 3 shearer systems or 4 plow systems and 2 shearer systems. The most important factors having an impact on choosing a shearer or a plow technology are listed in Table 1.

Table 1. The most important factors having an impact on choosing a shearer or a plow technology (Dyczko, 2018)

Factor			Plow	Shearer
Geological	Seam thickness		from 0.6 m to 2.3 m	from 1.5 m to 6.0 m
	Coal hardness		comparable properties	
	Inclination	longitudinal	up to 45 deg	up to 20 deg
		transverse	gradient 45 deg, dip 20 deg	gradient up to 20 deg, dip 20 deg
	Passing of faults		average	good
	Seam corrugation		a plow passes in an easier way due to a smaller length	
Technical	Roof conditions		a smaller web depth facilitates a roof control	frequent downfalls
	Floor conditions		comparable properties (bases of powered roof support units adapted to difficult conditions)	
	Granulation of run-of-mine		a larger amount of thick coal sizing	strongly disintegrated run-of-mine
	Overall dimensions of workings		requires wider workings	most often, the return drive situated in the longwall face
	Automation		partly automated operation	a significantly smaller degree of automation

Fully automated plow longwall systems enable to mine very thin seams. This operation is extremely difficult in the case of shearers because shearers operators must follow an advancing machine. However, both in the plow and shearer longwalls, there are roof supports operators who operate the roof supports or supervise their operation in the case of an automated system. The longwall height of 1.5 m seems to be the limit for operators' work in the longwall face (Fig. 6).

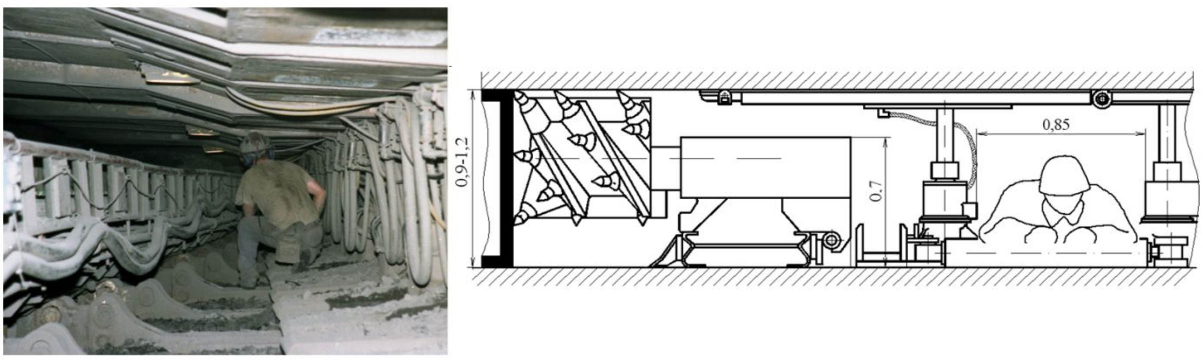


Fig. 6. A difficult position of the operator in the shearer longwall face (Dyczko, 2018)

In the publications of such researchers as (Biały, 2014; 2015; 2016; 2017; Karbownik, 1987; Lewińska & Dyczko, 2016; Lewińska, Matuła & Dyczko, 2017; Lisowski, 2001; Magda et al., 2002; Lorenz et al., 2002; Przybyła & Chmiela, 2002; Rajwa, 2007; Dyczko & Kopacz, 2008; Lubosik 2009; Sobczyk, 2009; Brzychczy, 2012; Wodarski & Bijańska, 2014; Grudziński, 2009, 2012; Turek, 2013; Kopacz, 2015 relationships among geological and mining parameters and their impact on the mine model, mining technology, costs of processes, quality of commercial products and economic efficiency of mines are presented.

Parameters of longwall faces equipped with shearers over the years 2010-2019 are shown in Table 2.

Table 2. Parameters of longwall faces equipped with shearers (Dyczko, 2018).

Longwall No	Period of face exploitation	Panel length	Length	Average coal seam thickness	Average face height	% of ripping	Average daily advance	Average daily advance (net)	Average daily advance (gross)	Total coal production rate	Total run-of-mine production rate	Average coal output (net)
13/II (p.382)	12	2 564	310	2.25	2.53	12%	8.84	9 489.00	12 155.00	2 751 872.00	3 525 037.00	78.10%
3/II (p.382)	8.2	2 160	289	2.4	2.92	22%	10.3	10 975.20	15 938.00	2 304 846.00	3 347 046.00	68.90%
6/IV/385	7.2	1 363	297	1.78	2.17	22%	7.7	6 321.00	9 284.00	1 112 440.00	1 634 006.00	68.10%
9/IV/385	4.0	1 077	296	1.9	2.28	20%	10.6	8 972.40	12 743.00	915 163.00	1 299 758.00	70.40%
4/IV/385	16.0	3 096	294.5	1.8	2.16	20%	7.9	6 372.00	9 691.00	2 510 499.00	3 818 404.00	65.70%
7/IV/385	6	1 110	296	1.7	2.14	27%	7.2	6 522.24	9 467.88	887 024.70	1 287 631.90	68.89%
8/IV/385	6	1 070	296	1.65	2.09	29%	5.8	4 766.39	7 895.97	800 753.32	1 326 522.69	60.36%
2/I/385	11	1 640	313	1.4	2.01	39%	5.9	4 444.33	8 274.06	1 177 747.90	2 192 625.10	53.71%
3/I/385	10	1 601	313	1.43	1.97	35%	6.0	4 488.78	8 356.80	1 151 489.02	1 995 964.68	57.94%
8N	7	1 053	322	3.01	3.35	34%	6.0	7 626.15	12 870.99	1 441 342.15	2 432 617.77	59.25%
4/IV/389	9	2 240	296	2.07	2.52	18%	8.8	9 922.14	12 441.74	2 411 080.40	3 023 342.70	79.75%
3/IV/389	9	2 411	296	2.07	2.49	19%	9.0	9 822.92	12 317.32	2 551 587.47	3 401 372.27	75.10%
1/V/391	12	2450	310.5	2.42	2.79	18%	8.7	11 098.67	14 022.19	2 974 443.10	3 757 948.14	79.15%
2/V/391	11	2 450	310.5	2.37	2.63	17%	8.8	10 550.68	13 292.41	2 911 986.40	3 668 706.10	79.37%
3/V/391	13	2 472	310.5	2.36	2.5	23%	7.1	8 716.96	11 504.42	2 902 746.70	3 830 970.40	75.77%
4/V/391	9	1 827	310.5	2.37	2.68	20%	7.5	9 152.80	11 849.55	2 170 112.27	2 919 918.58	74.42%

Parameters of longwall faces equipped with plows over the years 2010-2019 are presented in Table 3.

Table 3. Parameters of longwall faces equipped with plows (Dyczko, 2018).

Longwall No	Period of face exploitation	Panel length	Length	Average coal seam thickness	Average face height	% of ripping	Average daily advance	Average daily advance (net)	Average daily advance (gross)	Total coal production rate	Total run-of-mine production rate	Average coal output (net)
1/VI/385	III.2010-XI.2010	1 744	250	1.54	1.77	20%	7.5	6 016.31	7 988.08	1 040 820.83	1 381 937.80	75.32%
7/VII/385	X.2011-III.2013	5 022	300	1.43	1.68	25%	11.5	7 807.36	11 326.37	3 333 741.80	4 836 360.30	68.93%
1/VIII/385	VII.2013-II.2015	5 024	300	1.4	1.7	26%	10.3	6 901.72	10 075.42	3 264 511.60	4 765 674.20	68.50%
2/VIII/385	VII.2015-II.2017	5 021	300	1.36	1.72	30%	9.8	6 443.57	10 139.24	3 335 178.20	4 910 071.80	67.93%
2/VI/385	X.2012-VII.2013	2 310	250	1.54	1.93	28%	10.2	6 392.90	9 592.00	1 374 473.00	2 062 275.80	66.65%
6/VII/385	XI.2013-VII.2015	4 850	300	1.47	1.78	26%	10.2	6 937.23	10 096.19	3 315 996.30	4 825 979.20	68.71%
5/VII/385	XII.2015-IV.2017	4 685	300	1.58	1.9	26%	11.1	7 939.58	11 683.62	3 335 178.20	4 910 071.80	67.93%
3/VIII/385	IX.2017-XII.2018	3 460	300	1.39	1.73	30%	8.9	5 936.90	9 364.57	2 293 709.51	3 621 062.78	63.34%
3/VI/385	XI.2014-X.2015	2 295	250	1.48	1.97	34%	10.5	6 051.96	9 552.95	1 270 912.34	2 006 120.52	63.35%
4/VI/385	II.2017-X.2017	2 320	220	1.44	1.77	31%	10.6	5 033.71	8 011.47	1 082 248.70	1 722 465.10	62.83%

5/VI/385	I.2018-VIII.2018	1 844	300	1.32	1.73	33%	8.5	6 629.01	10 369.71	1 186 592.98	1 856 178.41	63.93%
6/VI/385	XI.2018-VI.2019	1 600	300	1.35	1.68	30%	8.5	6 297.56	9 851.23	1 023 683.70	1 635 488.47	62.59%
1/I/385	V.2015-VII.2016	2 043	318	1.36	1.57	32%	6.4	4 454.80	6 975.00	1 505 716.47	2 357 556.57	63.87%
2/II/385	II.2017-XI.2017	1 640	318	1.35	1.72	30%	7.6	5 143.88	8 087.50	1 075 071.90	1 690 287.70	63.60%
3/II/385	VII.2018-IV.2019	1 640	318	1.17	1.55	34%	6.0	4 783.81	7 521.38	925 928.40	1 605 895.03	57.66%

According to the above tables' data, the average daily advance of plow longwalls is 9.2 m per day, while the daily net advance of shearer longwalls is 7.9 m per day. However, the daily net production in the case of plow longwalls is about 2,000 tons lower than that of the longwall mining (6,185 tons per day vs 8,078 tons per day). This is due to the fact that the thickness of the excavated coal for plow longwalls was almost 30% lower in the period under consideration than it is in the case of shearer longwalls. At the same time, both the plow and shearer longwalls had a similar abundance, on average about 1.95 million tons per longwall.

Due to the specificity of available data, the analysis was conducted for the whole life cycle of a longwall face. The assessment process is presented in Fig. 7.

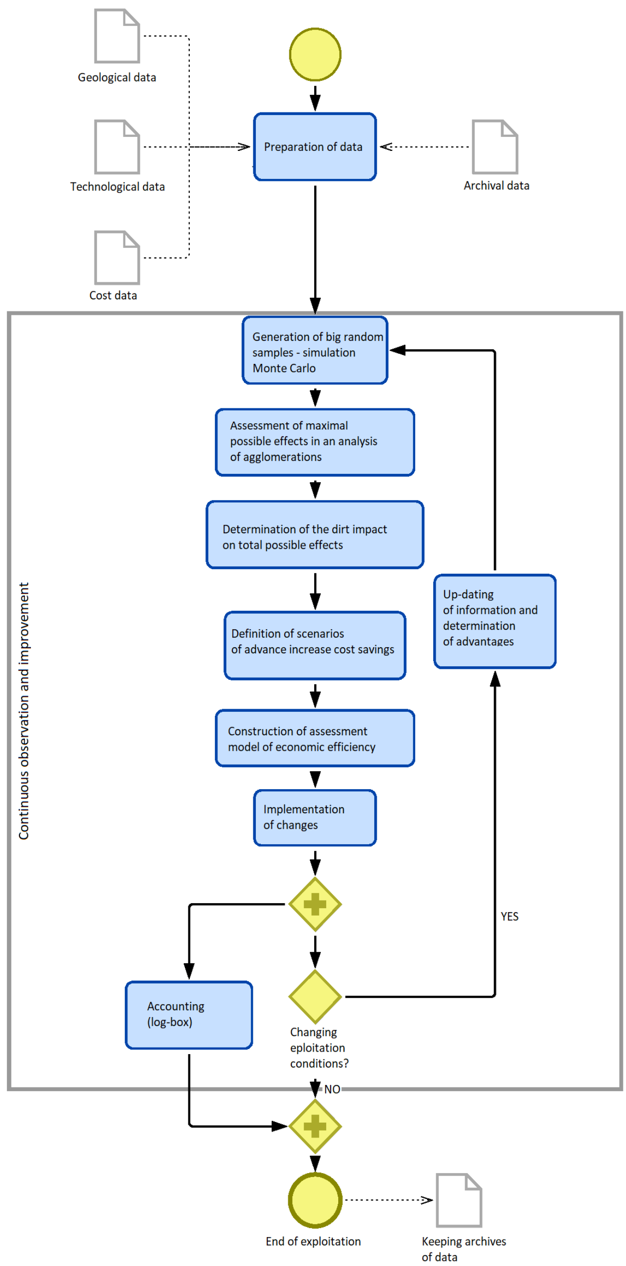


Fig. 7. Procedure and analytical assessment process of coal extraction economic efficiency (Dyczko, 2018)

This analysis includes several key stages: preparation of data, a generation of big random samples, construction of an economic efficiency model.

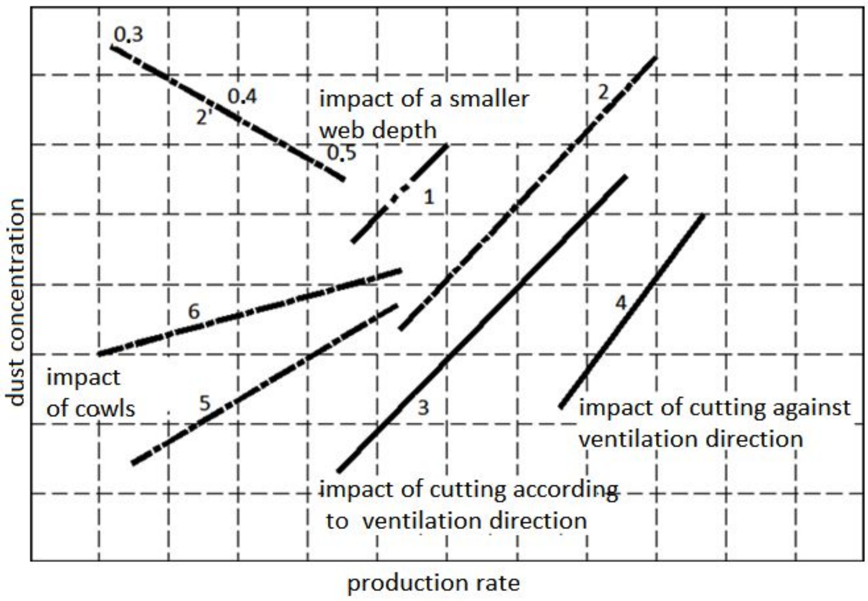
The thematic scope includes geological data (ash content, calorific value, humidity, weight of run-of-mine), cost data, data analysis and construction of an economic efficiency model, an analysis of agglomerations, verification of results and finally, a generation of assessment results in the form of scenarios. This approach combines qualitative features of the run-of-mine with the features of the mining system and exploitation costs.

A model of economic efficiency assessment is also based on the data from empirical samples and the samples generated using the Monte Carlo method and grouped into 11 clusters implemented in the RapidMiner Studio 5 Software.

Analysis of longwall systems in the aspect of dust control

The necessity of reducing rock-dust concentration in the mine atmosphere is justified by the requirements relating to workplace safety. Excessive dust content has a negative impact on the health conditions of the personnel working in the longwall face and the technical condition of machines, particularly their control systems (Myszkowski & Paschedag, 2013; Cernecky et al., 2015).

During an operation of a shearer, a lot of small-size coal dust concentrated on a relatively small area is generated as well. This kind of dust causes an explosion hazard. Particles of generated dust are ejected into the environment by a rotating cutting drum. Sizes and properties of the dust depend on the type of the coal being cut and on several parameters of the shearer, such as, for example: cutting drum diameter, number and arrangement of cutting picks, drum rotational speed, shearer haulage speed. An impact of selected parameters characterizing the cutting technology in a shearer-equipped longwall face is shown in Fig. 8.



Mine A: cutting without cowls against ventilation direction (1), cutting without cowls according to ventilation direction (2), Mine B: cutting with cowls against ventilation direction (3), cutting with cowls according to ventilation direction (4), Mine C: cutting with cowls according to ventilation direction (5), cutting without cowls according to ventilation direction (6).

Fig. 8. Impact of mining, technical and technological parameters on dust amount in a shearer-equipped longwall face (Prostański, 2017)

Longwall shearers are equipped with dedicated spraying systems to control dust. Spraying nozzles are usually installed on the cutting drum directly behind cutting picks. As the result of multi-year tests (Prostański, 2017), a system of air-and-water spraying devices was implemented. The essential idea of the air-and-water spraying installation consists in delivering water and compressed air to spraying nozzles; these are produced by the cutting technologies (for example, Peterka et al., 2008). Due to atomization, its aerosol is ejected (Prostański, 2012). Streams of air-and-water aerosol, ejected from nozzles installed around the cutting drum and on the top edge of the ranging arm, generate a curtain separating the cutting zone (Prostański, 2013).

Despite a continuous operation of the spraying installation on the shearer, it is also indispensable to reduce dust in the case of other sources in a longwall face, for example, generated by the articulated face conveyor and advancing powered roof support units. A significant reduction of dust in a longwall face was achieved as the result of using the "KOMAG" system, equipped with assemblies of spraying nozzles installed on the canopies of powered roof support units. The system starts when the cutting operation begins. An operational control of the spraying installation was developed due to the use of empirical models presented in the project (Prostański, 2015). An issue of modelling the zone protecting against a coal dust explosion propagation is presented in (Prostański, 2017).

In the case of cutting with a plow technology, bigger coal blocks are obtained in comparison to cutting with shearer technology. The plow technology generates smaller amounts of suspended dust, but an increase in the web depth causes a reduction of suspended dust amount and an increase in big coal blocks' contribution in the run-of-mine (Myszkowski&Padchedag, 2013). A more uniform distribution of generated dust along the face length is an advantageous phenomenon.

While cutting, the plow body always pushes a heap of the run-of-mine in front of it. Due to that, the plow picks cut the solid under the shield of the coal, which has already been mined, which suppresses an ejection of dust to the environment (Myszkwoski, 2004). In plow-equipped longwalls spraying systems are usually installed on the canopies of shield support units (for example, Prostański et al., 2017) or along the scraper conveyor.

The plow control system starts spraying nozzles only a few seconds before the plow passage and switches them off a few seconds after the plow body passes the nozzles. Due to tests relating to identifying the dust source in plow-equipped longwalls and assessing the applied dust control technology conducted in three plow-equipped longwalls, it was stated that the spraying system installed on the canopies of the shield units effectively eliminates dust generated during the cutting process. From the tests discussed in (McClland & Jankowski, 1998), it can be concluded that in comparison to the weight of the dust generated during a plow operation, the dust generated during the powered roof support advance has a bigger impact on the dust level in the longwall face. The biggest amount of dust (60%) is generated by a stationary crusher installed at the longwall inlet. Control of this dust is obtained due to an installation of a complex system of spraying nozzles presented in (McClland & Jankowski, 1998) on the crusher and discharge points. An efficient dust control of discharge points is possible due to an application of air-and-water spraying installations of BRYZA or VIRGA types (Prostański & Vargova, 2018).

Summary and final conclusions

The research work results presented in the article concern the efficiency assessment of longwall systems using shearers and plows in the LW Bogdanka. Measurements were taken for several longwall faces using different extraction technologies in similar mining and geological conditions. An analysis of dilutions in the run-of-mine enabled to determine quality losses and their impact on underground mining systems' economic efficiency on the example of the Bogdanka Mine. On the basis of conducted in situ experiments, technical possibilities of reducing dirt are described. An optimation of the cutting machine operational trajectory reduces dilution as it enables to avoid cutting floor or roof layers containing small quantities of coal. The dirt has a negative impact on the quality of the run-of-mine, causing an increase of the ash content and thus a reduction of the feed calorific values directed to the preparation plant. It should be highlighted that an efficient assessment process is complicated, so it requires continuous monitoring of production processes. It is suggested to take advantage of the data integration platform using the SOA – Service Oriented Architecture. It is important that due to the SOA, any mistakes, as regards the functionality of individual systems, can be detected very quickly. In terms of underground mining conditions and transported loads, safe and optimal transport organization plays an important role in hard coal production processes. Researchers (Tokarczyk & Dudek 2020) have developed the Safe Trans Design system for computer aiding the configuration and assessment of auxiliary mine transportation means, which facilitates complex activities, minimizing the possibility of errors due to a human factor. Mechanization and automation of mining processes require a connection of management systems and keeping production archives with the maintenance of machines and equipment. Such an approach is fundamental for the realization of the TPM (Total Productive Maintenance) recommendations. This system is one of the LW Bogdanka strategic objectives oriented onto so-called Mine of Smart Solutions, taking advantage of innovative technical ideas to increase production efficiency at a simultaneous guarantee of miners' work safety and a minimalization of the negative environmental impact. An analysis of longwall systems in the aspect of dust control is important from the point of view of miners' health. Some recommendations concerning air-and-water spraying systems for longwall faces and the run-of-mine haulage routes contribute to effective dust control in underground workings.

The research results presented in the article contain practical recommendations concerning the efficient management of longwall systems. From the conducted analyses, it can be concluded that various barriers must be overcome. They are of technical, legislative, financial, organizational and institutional character (Malec, Stańczak & Ricketts 2020). The research processes conducted at the LW Bogdanka confirm the orientation of the authors on an industrial implementation of innovative solutions, being the result of collaboration between science and industry.

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