THE METHOD FOR THE ASSESSMENT OF THE IMPACT OF THE HARD COAL USERS' VARIABLE DEMAND ON THE PROFITABILITY OF MINES

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Summary: The article presents the method for the assessment of the variable demand of hard coal users on the effectiveness of operation of a multi-facility mining enterprise. Due to the extensive nature of the subject, the focus was on the assessment of the profitability of mines under analysis in the cross-section of the multi-variant nature of the changes in the qualitative and quantitative demand of coal users. What is more, attention has been drawn to situations that can be detected thanks to the proposed method and namely the achievement of worse financial results by mines in the event of the increase in demand which is a result of the changes in the mine-client relationship.

Keywords: The sensitivity analysis, the profitability, the SIMPLEX algorithm, the Monte Carlo method.

1. Introduction

One of the key factors determining the effectiveness of the operation of a mining enterprise is the variable level of demand for coal. The present market conditions, which Polish coal mining has come to function under, imply the necessity to carry out multi-variant analyses allowing to assess the impact of the variable demand of end users on the effectiveness of operation of a multi-facility mining enterprise as well as to isolate the factors determining this effectiveness such as, e.g. profit, profitability, production capacity utilisation rate, etc. in relation to their planned level under the conditions of the variable demand on the part of Polish hard coal users.

The method presented in this paper facilitates the assessment of the effectiveness of the operation of a multi-facility mining enterprise and mines being a part thereof on the basis of the analysis of selected technical and economic indicators in the cross section of the multi-variant nature of the changes in the coal user demand. To create the most probable coal user demand scenarios, the author applied the Monte Carlo method. On the basis of the results obtained by means of the proposed method (histograms), one obtains the probability of incidence of the planned values of the indicators subject to analysis. This provides the basis for the potential corrections of the optimum plan, in turn creating a useful decision-aiding tool, in particular in the scope of the rational coal production and sale programmes at the mining enterprise management level.

The proposed method allows for situations occurring precisely within the multi-facility mining enterprise, such as e.g. the loss of clients of one mine in favour of the remaining ones which results in achievement of worse financial results with the increase of the coal user demand to be revealed.

In his research the author uses the developed software package which represents an important element supporting the management of the group of mines. This method makes production decisions more rational as it combines methods of optimization programs of production and sales of carbon (using the SIMPLEX algorithm) with an extensive, multiaspect, post-optimal analysis results optimization programs of formal production and sales of coal in the coal company conditions (own software algorithms).

2. The essence of the profitability

Making profits for the mines does not guarantee a healthy financial condition. Oftentimes productivity is identified with profitability, which is the achievement of positive financial results.

Many literature sources often state that just profits alone are not the best measure of financial situation of an enterprise in a given period [2, 11]. Profit achieved in a given time period is an arithmetic value and it does not agree with level of generated operating cash. Enterprise can show profits on their books and at the same time not generate cash. Profits along with amortization can be a source of operational financing (increase in inventory, amounts due, repayment of short term obligations). Enterprise can show losses and at the same time generate operating cash which enables them to pay off debts, for example, a company with a structure of high level of fixed assets and intangibles which it amortizes. Next to net profits, it is the „backbone" of operating cash. In reality different circumstances influence the fact that financially healthy companies do not always have enough resources to stay profitable in the short term. At the same time companies that show weak financial results are able to generate short term profits. The time period between cash generation and the financial outcome can be significant.

The subjective portion of profits is the consideration of costs that are non-cash related (such as amortization, reserves, in-between period costs). These costs depend on accounting methods in the current period. That is why it is necessary to use profitability as a measure of financial situation of a company. It reflects in the most synthetic form the productivity of an enterprise. Profitability indicators show in the most general way the relationship between profits and capital. Both the numerator and the denominator of this equation could be quantified differently. Significant outcomes can be attained using larger number of numerator and denominator values. In practice, the profitability value is based on a large scale of indicators that are necessary to manage a company. Generally, it is possible to distinguish three types of profitability [11]:

- sales profitability (trade),
- property profitability (economic),
- invested capital profitability (financial).

In the presented method of analysis the author used profit before tax margin as indicators using the following formula:

$$GPM = \frac{gross\ profit}{sales\ netto} \cdot 100\ [\%] \quad (1)$$

The gross profit margin shows the percentage of profits generated with a given level of sales for a company. In other words it shows how well an enterprise is doing in the product market that it offers to its customers [11].

Therefore it shows:

- quantity of sold products,
- assortment of products with different units of profitability,
- policy of prices,
- level of unit costs for company's sales.

The level of profitability of sales depends on the type of business that a given company and a given branch are in.

3. Characteristics of the proposed method

The method of the assessment of the impact of the variable hard coal consumer demand on the profitability of the mine subject to the analysis is based on the set of the optimal solutions of the task of optimising production and sale of coals for a coal company. The set of optimal solutions is created on the way of multiple determination of the optimal coal production and sale for mines, in the cross section of the multi-variant random demand scenario. The most probable scenarios of demand of individual hard coal consumers are obtained through the application of the Monte Carlo method [4, 10, 12]. The algorithm facilitating the generation of the optimal coal production and sale programmes runs in two stages.

In the first step, a demand vector is selected at random. The vector constitutes a sub-vector of right sides of the optimization model equation (3) [5]:

Objective function:

$$\sum_{i=1}^{r_j}\sum_{j=1}^{p}\sum_{k=1}^{m_{ij}}(c_{ijk} - kz_{ijk})\cdot x_{ijk} - \sum_{j=1}^{p} Ks_j \to \max \tag{2}$$

Sales restrictions:

$$\sum_{i=1}^{r_j}\sum_{j=1}^{p}\sum_{k=1}^{mij} x_{ijk} \le Z_k \quad \text{for all k} \tag{3}$$

where:

x_{ijk} - net amount of extracted coal of *ij* type accepted by consumers in group *k*, [netto tone],

Z_k – consumer demand for group *k*, [ton],

i - index of coal type, i =1, 2, 3, ...$r_{j,}$

j – index of mine, j =1,2,3,...p,

k_n – index of consumer groups, k =1,2,3,...,m_{ij}, where m_{ij} marks numerousness miscellany k_n for coal of *ij* type.

The remaining restrictions in the model relate to the structure of production and the capacity of individual mines [5]. The reality of the solutions obtained is assured by allowing the possibility of storing coal.

The normal distribution was adopted for the random fluctuations of demand, whereas the analysis variants presented include:

1) expected value and dispersion according to historic (retrospective) data,
2) expected value according to prediction formulas, whereas the dispersion represents the most probable (standard) error of the forecast,
3) expected value with the consideration of correlated demand changes and dispersion as in point 2,
4) adopted increase or decrease in the expected value and dispersion as in point 2.

Next, the drawn coal consumer demand vector is transposed onto the primary solution and appropriate weakening variables are modified. The smallest weakening variable with the negative value (the most inadmissible one) is selected and reduced to zero in order not to diminish the other negative weakening limits. The manner of proceedings above always leads to an admissible solution thanks to the allowing for the possibility of storing the coal.

The second stage is the optimisation of the admissible solution, consisting in the search for non-base variables with no-zero value which negative dual prices correspond with. Further, their values are modified so as to increase the quality index by applying the *SIMPLEX* for this purpose. The analysis is performed for a sufficiently numerous set of random demand datasets, thus obtaining new optimal solutions. The analysis results are presented as histograms of analyzed economic and technical parameters for the entire company and for individual mining plants. This allows the probability of obtaining an adopted level of analyzed parameters for the company and the mining plants it owns to be determined.

4. Example of calculations and evaluation of results

The calculations were conducted for a real hard coal mines. The mines at issue are a part of the coal company banding four mines within its organisational structure. The production capacity along with the technical and economic indicators of the mines under analysis are presented in table 1 whereas table 2 presents the optimal plans of production and sales for mines „A”-„D”

Tab. 1. Technical and economic coefficients for mines „A”–„D”

Specification	**Unit**	**Kopalnie**			
		„A”	**„B”**	**„C”**	**„D”**
Average Extraction	ton/day	6,200	10,500	19,500	10,200
Max. Extraction	netto ton	1,600,000	2,700,000	5,100,000	2,600,000
Unit cost	PLN/ton	136.9	159.02	153.75	192.53
Fixed cost	%	76.6	86.96	85.71	81.2

Source: Own preparation

Tab. 2. The optimal plans of production and sales for mines „A”-„D” for 2011

Consumers	**Assortments**	**Quantity**	**Calorific value**	**Contents**		
				ashes	**water**	**sulphur**
		[ton]	[kJ/kg]	[%]	[%]	[%]
Mine „A”						
Offer: 1,600,000 ton Sold: 438,968 ton			Profits: -16,698,662 PLN Mine reserves: 734,180 ton			
Indv. consumers 4	nut coal	69,265	25,000	15.8	7.0	0.76
Indv. consumers 4	pea coal	64,936	24,650	15.8	7.0	0.77
Indv. consumers 3	fine coal I	304,767	24,904	18.0	7.0	1.10
Dumping ground	fine coal II	401,738	19,089	28.0	12.0	1.00
Dumping ground	slurry	25,109	19,089	30.0	20.0	1.00
Mine „B”						
Offer: 2,700,000 ton Sold: 1,776,600 ton			Profits: 62,938,398 PLN Mine reserves: 0 ton			
Indv. consumers 4	nut coal	328,143	27,000	7.0	9.0	0.8
Export 8	nut coal	14,857	27,000	7.0	9.0	0.8
Indv. consumers 1	nut coal	143,000	27,000	7.0	9.0	0.8
Indv. consumers 3	fine coal IA	237,000	27,000	8.0	10.0	0.8
Dust kettles	fine coal IA	330,000	27,000	8.0	10.0	0.8
Dust kettles	fine coal II	380,700	21,000	23.0	10.0	0.8
Export 9	fine coal II	342,900	23,000	17.0	10.0	0.8
Dumping ground	fine coal II	923,400	19,000	30.0	10.0	0.8
Mine „C”						
Offer: 5,100,000 ton Sold: 3,825,000 ton			Profits: 118,161,928 PLN Mine reserves: 0 ton			
Indv. consumers 4	cobble	23,235	25,000	9.0	13.4	1.1
Chamber grates 1	cobble	282,765	25,000	9.0	13.4	1.1
Indv. consumers 1	nut coal	193,060	25,000	9.0	13.4	1.1
Grates 2	nut coal	265,940	25,000	9.0	13.4	1.1
Indv. consumers 3	fine coal I	1,275,000	25,000	10.0	14.5	1.0
Indv. consumers 3	fine coal II A	1,020,000	23,000	12.0	15.5	1.0
Grates 3	fine coal II	765,000	19,000	23.0	16.4	1.4
Dumping ground	fine coal II	1,275,000	19,000	25.0	16.4	1.2
Mine „D”						
Offer: 2,600,000 ton Sold: 2,600,000 ton			Profits: 89,892,157 PLN Mine reserves: 0 ton			
Chamber grates 1	cobble	143 000	30,283	9.0	6.5	0.8
Export 8	nut coal	286,000	29,934	9.0	6.5	0.8
Export 9	fine coal IA	76,547	29,746	9.0	6.5	0.8
Indv. consumers 3	fine coal IA	21,432	29,746	9.0	6.5	0.8
Indv. consumers 4	fine coal IA	68,421	29,746	9.0	6.5	0.8
Dust kettles	fine coal IIA	1,674,600	23,720	22.0	13.0	0.8
Grates 3	fine coal IIA	330,000	23,720	22.0	13.0	0.8

Source: Own preparation

In the first stage of the analysis, the demand values of individual recipient groups were selected at random in accordance with the normal distribution with expected (nominal) value equal to the forecasted demand (sales) value in the year 2011. The adopted standard deviation (dispersion) value results from the analyses of demand changes among individual groups of recipients (see table 3) [1, 3, 6, 7, 8, 9]:

$$\sigma_r^2 = \frac{\sum_{n=1}^{N} \left(y_n - y_{\text{mod}}\right)^2}{N - L} \tag{4}$$

where:

y_n - actual value of endogenous factor, [ton],

y_{mod} - model-based value of endogenous factor, [ton],

N - number of observations,

L - number of estimating parameters for model structure.

In the second stage, the analysis of effects of random demand changes was carried out in accordance with the most probable forecast error. To determine the forecast error for each case, the stochastic structure parameter estimation (i.e. parameters of the distribution of random factor) was performed, which allows to conclude on the goodness-of-fit of a given model to empiric data at hand, by determining [1, 3, 6, 7, 8, 9]:

– matrix of variance and covariance:

$$K = \left[X^T \cdot X\right]^{-1} \cdot \sigma_r^2 \tag{5}$$

whereby:

$$X = \begin{bmatrix} 1 & x_1 \\ 1 & x_2 \\ 1 & x_3 \\ --- & -- \\ 1 & x_N \end{bmatrix}, \qquad X^T X = \begin{bmatrix} N & \sum_{n=1}^{N} x_n \\ \sum_{n=1}^{N} x_n & \sum_{n=1}^{N} x_n^2 \end{bmatrix} \tag{6}$$

– estimation of variance in prognosis model:

$$\sigma_{\hat{y}}^2 = u \cdot K \cdot u^T \tag{7}$$

whereby:

$$u = \begin{bmatrix} 1 & x_{N+2} \end{bmatrix} \tag{8}$$

where:

x_{N+2} – the time for which the prognosis is prepared,

– dispersion (standard deviation) of the forecast upon the assumption of (4) and (7) in accordance with the following formula (see table 3):

$$\sigma_{yprog} = \sqrt{\sigma_r^2 + \sigma_{\hat{y}}^2} \tag{9}$$

Tab. 3. Nominal value and dispersion σ_r, σ_{yprog} for every group of consumers [ton]

Name of consumer group	Nominal prognosis values	Dispersion σr	Dispersion σ_{yprog}
Export 8	300,857	95,728	70,205.89
Export 9	419,447	133,461	116,913.60
Indv. consumers 1	336,060	13,035	10,565.02
Indv. consumers 3	5,475,600	212,387	140,552.80
Indv. consumers 4	1,391,200	53,962	35,710.60
Dust kettles	2,385,300	92,521	61,228.09
Grates 2	265,940	10,315	6,826.40
Grates 3	1,095,000	42,472	28,107.22
Grates 4	567,619	22,017	14,570.20
Chamber grates 1	425,765	16,514	10,928.80

In the third stage, the impact of correlated demand value changes on the value of the profitability was determined. In order to do this, the nominal forecasted demand value for each recipient was decreased in first case (P_1) and increased in the second case (P_2) by the model error value (tab. 4).

In the fourth stage, the nominal forecasted demand value for each recipient was decreased in first case (P_3) and increased in the second case (P_4) by 10% (tab. 4). The number of samplings was adopted at 1,000 which allows to obtain a sufficiently large set of production tasks for individual mining plants as well as it allows to calculate the profitability in the cross-section of the analyzed variability of coal recipients.

Tab. 4. Nominal value of prognosis P_1, P_2, P_3 and P_4 for every group of consumers [ton]

Name of consumer group	Nominal value of prognosis P_1	Nominal value of prognosis P_2	Nominal value of prognosis P_3	Nominal value of prognosis P_4
Export 8	230,651.11	371,062.89	270,771.3	330,942.7
Export 9	302,533.40	536,360.60	377,502.3	461,391.7
Indv. consumers 1	325,494.98	346,625.02	302,454.0	369,666.0
Indv. consumers 3	5,335,046.20	5,616,151.80	4,928,039.1	6,023,159.0
Indv. consumers 4	1,355,489.40	1,426,910.60	1,252,080.0	1,530,320.0
Dust kettles	2,324,071.91	2,446,528.10	2,146,770.0	2,623,830.0
Grates 2	259,113.60	272,766.40	239,346.0	292,534.0
Grates 3	1,066,892.78	1,123,107.20	985,500.0	1,204,500.0
Grates 4	553,048.80	582,189.20	510,857.1	624,380.9
Chamber grates 1	414,836.20	436,693.80	383,188.5	468,341.5

The author based the analysis of profitability of the analyzed mining plant, with reference to adopted variants of demand changes of coal recipient, on the formula 1.

The results of the profitability for thus calculation are listed in table 5 and illustrated in Figs. 1-3.

Tab. 5. The list of the nominal, minimal, maximum and average values of the forecasted level of profitability of mines and the probability of the results at dispersion σ_r, σ_{yprog} , and levels P_1, P_2, P_3 and P_4

	The profitability [%]				**Probability of achieving profitability [-]**			
	nominal value	**min**	**max**	**average**	**min**	**max**	**above**	**average**
Mine „A”								
σ_r	–15.53	–3,481.91	1,073.39	–31.16	0.003	0.003	0.881	0.881
σ_{yprog}	–15.53	–1,282.30	45.30	–54.70	0.003	0.285	0.705	0.831
P_1	–15.53	–4,242.55	19.81	–195.38	0.003	0.003	0.719	0.802
P_2	–15.53	–82.09	53.49	28.89	0.002	0.021	0.986	0.598
P_3	–15.53	0	0	0	-	-	-	-
P_4	–15.53	19.2	55.7	45.56	0.003	0.164	1.000	0.696
Mine „B”								
σ_r	14.07	14.06	32.45	14.84	0.003	0.003	0.977	0.117
σ_{yprog}	14.07	14.063	24.82	14.41	0.003	0.003	0.977	0.997
P_1	14.07	13.35	25.74	15.09	0.003	0.003	0.814	0.280
P_2	14.07	14.06	33.47	14.89	0.003	0.003	0.997	0.109
P_3	14.07	14.1	22.6	15.15	0.002	0.008	0.998	0.208
P_4	14.07	14.1	37.5	20.25	0.003	0.008	0.997	0.308
Mine „C”								
σ_r	13.17	7.4	13.181	13.04	0.002	0.006	0.938	0.938
σ_{yprog}	13.17	8.9	13.181	13.16	0.002	0.003	0.980	0.983
P_1	13.17	1.28	13.181	11.64	0.002	0.003	0.494	0.672
P_2	13.17	13.17	13.178	13.18	0.003	0.542	1.000	0.003
P_3	13.17	–2.8	13.2	6.58	0.003	0.003	0.691	0.542
P_4	13.17	13.168	13.18	13.175	0.003	0.001	0.992	0.597
Mine „D”								
σ_r	15.66	3.09	15.67	15.46	0.003	0.003	0.121	0.987
σ_{yprog}	15.66	4.12	15.67	15.58	0.003	0.003	0.114	0.983
P_1	15.66	–15.95	15.68	14.27	0.003	0.003	0.120	0.842
P_2	15.66	13.78	15.67	15.65	0.003	0.003	0.121	0.889
P_3	15.66	–56.1	15.7	–1.58	0.003	0.003	0.061	0.595
P_4	15.66	15.646	15.66	15.653	0.003	0.001	0.001	0.624

The application of the profitability indicator makes more sense since it returns the information on what sales percentage falls per profit, e.g.: in the case of mine „B” 14% of the revenues shall constitute the profit. As can be seen, the mines subject to analysis are characterised by small profitability which testifies at the same time to high fixed and unit costs. This is of particular importance in case of a decrease of production below the production capacity. In case of mines characterised by a high BEP, the safety margin (profit margin) shall be small.

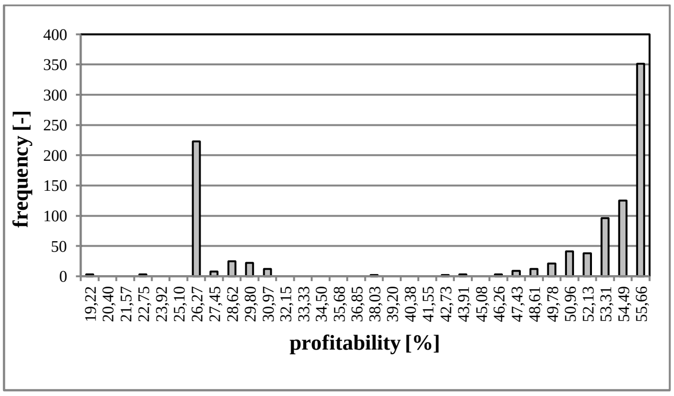

Fig. 1. Histogram of frequency of obtained sales profitability values for mine „A" at the planned value P_2 and dispersion σ_{yprog}. Source: Own preparation

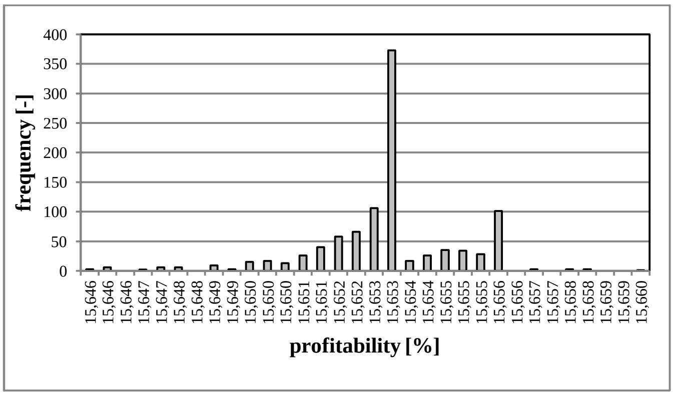

Fig. 2. Histogram of frequency of obtained sales profitability values for mine „D" at the planned value P_2 and dispersion σ_{yprog}. Source: Own preparation

Based on the results (tab. 5) obtained for the selected profitability indicator (formula 1), it can be stated that the planned profitability of sales of mine „A" (resultant from the optimum plan) reaches the level of –15.53% with the probability that such a state shall continue, for dispersion σ_r and σ_{yprog} respectively 0.881 and 0.705. In the event of the decrease in demand to level P_1, the probability shall be 0.719, but with the higher probability – 0.802, said profitability may amount to –195.38% whereas the increase in demand to P_2 guarantees that at least the planned profitability is maintained, with the probability being almost equal. It is highly probable that the mine shall turn profitable – a probability of 0.6. At the increase in demand to level P_4 with a probability of 0.7, the mine shall reach a profitability of 45.56% (fig. 1). The probability of mines „B" and „C" reaching the planned profitability for σ_r, σ_{yprog} and with the increase in demand to P_2 is almost 1. This probability, in the event of the decrease in demand to value P_1, decreases slightly to value 0.814 (mine „B") and 0.494 (mine „C"). Their profitability indicator values can become lower in relation to the planned value by 2 percentage points.

It is also proper to draw attention to the fact that in the case of unfavourable market conditions, mine „D" may become unprofitable. The probability of reaching the planned profitability for mine „D", for the demand variants σ_r, σ_{yprog}, P_1, P_2, equals c. 0.12. Both the maximum and median profitability values are close to its planned value (an exception for the P_1 prognosis). Slightly lower values: 15.46%, 15.58%, and 15.65%, can occur with the probability of 0.987, 0.983, and 0.889 respectively. It can be concluded that the mine has excessive fixed costs which is suggested by the sales profitability indicator – almost 16% of the sales values generate profit for the company with almost full production capacity utilisation.

The decrease of the demand to level P_1 revealed that in 22 cases per 1,000, the mine may become unprofitable while the decrease to level P_3 only further exacerbates the mine's financial situation – the occurrence of the loss has been recorded in 430 cases per 1,000. In this situation, the mine stands very little chance (probability of 0.061) of maintaining the planned profitability. As can be observed, at the increase in demand to level P_4, said probability equals 0.001 (fig. 2). This results from the fact that clients - *Individual consumers 3* and *Individual consumers 4* - shall decrease the quantities of coal purchased from this mine to the benefit, first and foremost, of mine „A" (tab. 6 and 7). This is impacted by, admittedly, slight fluctuations in the sale of particular assortments, but substantial enough for the mine to draw close to the BEP. The situation to the contrary shall occur in the event of the demand level drop to P_3. The presented method of analysis of the changes in demand on the effectiveness of operation of a multi-facility mining enterprise allows to disclose such situations.

Tab. 6. The specification of the planned, minimal, maximum value of obtained quantity of coal sales to *Individual consumers 4* and the probability of reaching it for the planned value P_4 and dispersion σ_{yprog}

Sales quantity [t]			**Probability of reaching the sales quantity [-]**		
According to the plan	**Min**	**Max**	**Min**	**Max**	**According to the plan**
Mine „A"					
nut coal					
69,265	69,265	128,000	0.001	0.999	1.000
pea coal					
64,936	64,936	120,000	0.001	0.990	1.000
Mine „B"					
nut coal					
328,143	0	424,782	0.062	0.011	0.156
Mine „C"					
cobble					
23,235	0	306,000	0.131	0.072	0.819
Mine „E"					
fine coal IA					
68,421	0	166,400	0.969	0.005	0.020

Tab. 7. The specification of the planned, minimal, maximum value of obtained quantity of coal sales to *Individual consumers 3* and the probability of reaching it for the planned value P_4 and dispersion σ_{yprog}

Sales quantity [t]			**Probability of reaching the sales quantity [-]**		
According to the plan	**Min**	**Max**	**Min**	**Max**	**According to the plan**
Mine „A”					
fine coal I					
304,770	304,770	563,200	0.001	0.999	1.000
Mine „B”					
fine coal IA					
237,000	0	567,000	0.006	0.150	0.874
Mine „E”					
fine coal IA					
21,432	0	166,400	0.484	0.358	0.491

5. Conclusion

On the basis of the developed method for the assessment of the impact of the variable demand of hard coal users on the effectiveness of operation of a multi-facility mining enterprise, the results are obtained to be presented in the form of histograms of fluctuations of selected technical and economic values in the cross-section of the multi-variant character of demand fluctuations. Thus, the managerial staff receives information on the probability of reaching the values of the indicators under analysis, be it in relation to the production plan or other adopted criteria as well as the information on those technical and economic indicators with a decisive impact on coal production and sales plan for a multi-facility mining enterprise.

The obtained results set out the direction of these changes and determine their probability which allows the mines' production plans within the time interval under analysis to be adjusted.

The proposed method allows situations occurring within a multi-facility mining enterprise, e.g. such as the loss of clients of one mine in favour of the remaining ones at the increase of the hard coal users' demand to be revealed.

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