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A MULTIFACETED METHOD OF ANALYZING THE AMOUNT OF EXPENDITURES ON MINE LIQUIDATION PROCESSES IN SRK S.A.

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Abstract:
The liquidation of the mine is the last and natural stage of mining activity. The activities related to the revitalization and restructuring of hard coal mines are carried out by Spółka Restrukturyzacji Kopalń S.A. (SRK S.A.), as the legal successor of previous mining operations. The implementation of the mine liquidation process has not been the subject of scientific research so far aimed at rationalization and minimization of the costs incurred. Activities leading to the liquidation of the mining plants are the procedural nature, however, the mine liquidation is always a single case which has a result in diversifying the size of outlays. The support for the implementation of the process approach in the issue of mine liquidation in terms of rationalization and minimization of the costs incurred in SRK S.A. was to develop a method of managing the costs of liquidation processes with the software for evaluation of its size. The proposed method signals to the designer that the estimated cost of the process of liquidation of another mining plant deviates from the average values previously worked out by SRK S.A. The range of acceptable values results from the assumed coefficient of data variation.

Key words: *process management, restructuring of mining enterprises, liquidation of a hard coal mine*

INTRODUCTION

In the Polish hard coal mine industry restructuring activities are being realized adjusting the sector to the functioning in the conditions of the market economy. The most rational way to reduce the costs of this industry is to liquidate mines where coal has been depleted or considered to be permanently unprofitable due to the exploitation in particularly unfavorable mining and geological conditions [1, 2, 3, 4, 5, 6].

The process of the liquidation of mines is financed by the state budget. It is assumed that the amount of subsidy for this purpose in the period from 2015 to 2023 will amount approximately to 5 billion PLN. In the following years, the processes of restructuring and revitalization of mining plants will be led only with the companies' own fund.

LITERATURE REVIEW

Spółka Restrukturyzacji Kopalń S.A. was founded in 2000 (www.srk.com.pl) and since then has been conducting restructuring, revitalization and liquidation activities in the Polish hard coal mining plants. SRK S.A. deals with the liquidation of excavations, construction facilities, machinery and equipment, the performance of security works and prevention of hazards connected with the liquidation of mining plants. These activities are carried out by 8 branches liquidating 9 mines. The management of the industrial property of liquidated mines, the removal of effects of mining damage and reclamation of post-mining areas is the responsibility of the branch of SRK S.A. called Coal Mines in Total Liquidation. Moreover, the Housing Resource Administration is responsible for the management of non-industrial property, mainly housing substance. The protection of neighboring mines against flooding due to the pumping out water is carried out by the Central Department of the Mine Dewatering Plant [6, 7, 8, 9, 10, 11].

The liquidation of the mine has been carrying out by Spółka Restrukturyzacji Kopalń S.A. according to several models depending on the scope of the liquidation and the target model of the liquidation of the mining plant. SRK S.A. may completely liquidate the mine or its ineffective part. Due to the target model, the liquidation is carried out in two ways. First way is to leave the pumping station so as to protect the neighboring operating mining plants. The second way is to complete liquidation when the protection of neighboring mines is not required (Figure 1). In the case of leaving the pumping station, parts of the shafts and excavations, that are being transferred to the Central

Mine Dewatering Plant are not liquidated because they will protect the neighboring mines and the land surface against water hazards.

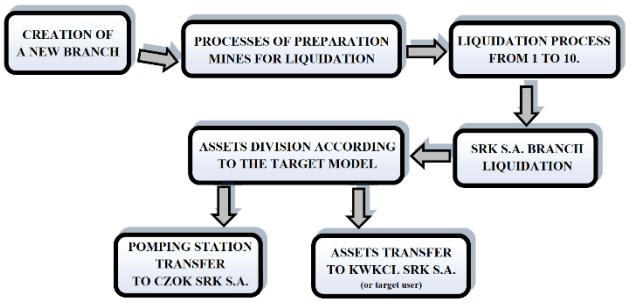

Fig. 1 A map of the mine liquidation process
Source: An own study [5].

The mission of the Management Board of SRK S.A. is rational spending of the obtained budget subsidy. The existing scientific research aimed at improving the rationalization and effectiveness of revitalization and restructuring processes in mining plants is very scarce [6, 11, 12, 13, 14, 15, 16, 21]. Spending the obtained budget subsidy on the restructuring of post-mining areas in terms of the rationalization and effectiveness of revitalization and restructuring processes of mining plants has been so far the subject of scientific research only in the field of general issues. The available literature in terms of mine liquidation refers only to general issues [6, 11, 17, 18, 19, 20]. Improving the efficiency of revitalization or mine liquidation processes should be based on instruments supporting cost management. Presented publication with the software is a continuation of the research on the management of liquidation processes costs support tools. The proposed method of the assessment of the correctness of estimated costs in the summary and annual system may improve the efficiency of a mining company that is dealing with the liquidation of mines [11, 21, 22, 23, 24, 25].

RESEARCH METHODS

The aim of the research was to develop and propose a multifaceted tool for the assessment of the liquidation processes. This tool will assess global costs of liquidation processes and the structure of incurred costs during the implementation of these processes. The research plan was implemented on the basis of updated programs of 17 examples of liquidated mining plants or their separate parts. The analysis refers to the period from 2015 to 2023, in which the period from 2015 to 2021 presents incurred costs and the period from 2022 to 2023 presents planned costs.

During the research the available literature referring to the process management was analyzed and compared with the experience of SRK S.A. in the field of restructuring post-mining assets. The results of the analysis made it possible to propose the idea of the method of the cost management of land release processes from unnecessary mining infrastructure.

Table 1
Research methods and the results of their use in particular stages of research

Research methods	Results of the use of research methods
– Study of literature – Analysis – Synthesis – Panel studies – Direct interview	– A statistical analysis of the researched liquidation processes – A preparation of data form – A proposal of the evaluation method – An identification of research areas and problems – A verification of the correctness of the method operation – A modification of the evaluation method of the course of liquidation processes – An indication of further research areas and problems that need to be solved

Source: An own study [5].

During the research, direct interviews with experts were conducted referring to technical problems related to the correct course of individual liquidation processes in the subsequent years of their implementation. Main causes of deviations from the average values were clarified. Moreover, basic statistical analysis of the processes of restructuring, revitalization and liquidation of mining plants in SRK S.A. was carried out divided into years of their course. The analyzed branches were divided due to their size by analyzing the structure of liquidation costs and due to the length of conducted process of mining plant liquidation. Any ambiguities were consulted with experts that directly manage the branches of SRK S.A. The correctness of operation of proposed multifaceted tool for assessing the cost structure of liquidation processes was carried out on the basis of the hypothetical new branches of SRK S.A. According to expectations, the research revealed new areas and problems that need to be solved. The process is shown in Figure 2.

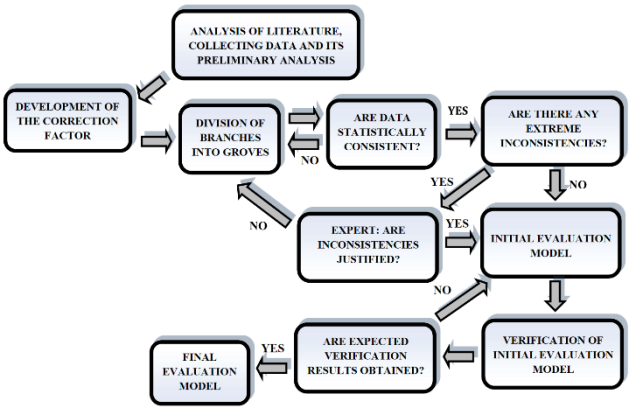

Fig. 2 A map of the research method
Source: An own study [6].

RESULTS OF RESEARCH

The liquidated mines by Spółka Restrukturyzacji Kopalń S.A. are a very heterogeneous group. Each liquidated mine is different and each of them is an individual case,

that results in a significant variation in the costs that incurred. Nevertheless, some regularities can be found with a holistic view. The research plan was carried out on the basis of data on the completed and ongoing mine liquidation processes included in the Updated Mining Plant Closure Programs in the period from 2015 to 2023. In the analyzed period, 8 mining plants were completely liquidated. In order to increase the credibility of the research results, also the currently operating branches of SRK S.A. that liquidate mines were analyzed (www.srk.com.pl). Finally, 17 cases of the liquidation of mining plants were statistically analyzed. The amount of costs in subsequent years were converted into the realities of the fourth quarter of 2021. The current liquidation processes in accordance with the updated liquidation programs should be completed by the end of 2023. However, it should be take into account that due to the pandemic of COVID-19, the liquidation processes may be disrupted.

The task of liquidation of the mine in SRK S.A. lasts from 2 to 8 years (5 years on average). The liquidation cost also varies considerably. It is caused by the scope of work necessary to be performed during the duration of the task. Usually, higher outlays on liquidation processes are related to the broadly understood size of the task. They depend on the amount of objects taken over for restructuring (liquidated and maintained). The time of completion of each liquidation processes as well as their costs usually result from the amount, size and type of liquidated objects. The time of liquidation is a derivative of the logical sequence of the mining plant facilities liquidation, the length of the tender procedures and the demolition and reclamation technology itself.

In SRK S.A. the restructuring of mining plants that are put into liquidation is carried out with the division of 10 component processes [1]. Table 2 shows the names of individual processes that are taking place in the branches of SRK S.A. Each of the components of the liquidation processes is a complex process and depends on many factors. Table 3 presents the liquidation costs divided into individual component processes. The largest group of costs, amounting to 35.5%, are the costs that incurred in preventing hazards while liquidation (process 7). The second largest cost group is the maintenance of facilities for liquidation (process 6), which consumes almost 19% of outlays. The third group is the overhead costs of liquidation (process 10), to which approximately 16% of the total expenditures is spent. In each of the presented liquidation component processes, potential saving can be found.

The analysis of all branches as one group gave average values that are very distant from the reality. In order to increase the consistency of costs, it was proposed to divide the liquidated mines into 5 groups according to the amount of liquidation costs (Table 3) and into 7 groups according to the length of their liquidation processes (Table 4).

Table 2

A percentage of the liquidation processes cost in the total liquidation cost

Liquidation process		Cost
Process 1	Liquidation and securing of excavation gates	1.32%
Process 2	Liquidation and securing of shafts and pits	4.61%
Process 3	Protection of neighboring mines against water, gas and fire hazards	7.59%
Process 4	Liquidation of the mine's infrastructure	5.16%
Process 5	Land reclamation	2.75%
Process 6	Maintaining the facilities for liquidation in sequence ensuring safe liquidation of the mining plant	18.65%
Process 7	Carrying out security works and measures to prevent hazards in connection with the liquidated mining plant	35.49%
Process 8	Development of the required projects, documentation, opinions, expertise and analyses related to the closure of the mine	0.86%
Process 9	Repair of damage caused by mining plant operations	7.66%
Process 10	General management of the tasks performed during the mine closure	15.91%

Source: An own study [6].

Table 3

The cost of liquidated mines calculated in a multi-criteria way [dimensionless].

Branches		Average cost	Maximum cost	Minimum cost	Total cost	The range of values
Large	LB	5.87	6.33	5.38	17.61	above 5
Medium Larger	MLB	3.28	3.76	2.66	19.68	from 2.5 to 5
Medium Smaller	MSB	1.64	1.88	1.32	4.92	from 1.25 to 2.5
Small	SB	0.91	1.07	0.76	3.63	from 0.5 to 1.25
Micro	MicroB	0.18	0.18	0.18	0.18	to 0.5

Source: An own study [11].

Table 4

The example (random) of fulfillment of panel 1 for 6 – years mine liquidation processes [in thous. PLN]

Panel 1	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	SUM	COV
Process 1	1814	2668	1460	1584	1353	2246			11125	20%
Process 2	0	8525	6580	2900	112	0			18117	20%
Process 3	0	0	0	6900	14491	5176			26567	20%
Process 4	1816	2385	4962	29493	15563	1934			56153	20%
Process 5	0	0	0	0	1220	4004			5224	20%
Process 6	36119	23688	4241	1025	585	560			66218	20%
Process 7	32989	23692	62981	50742	51564	51416			273384	20%
Process 8	1151	1037	501	2798	2064	1606			9157	20%
Process 9	2112	5746	22340	19752	9661	4883			64494	20%
Process 10	33955	16684	18074	15375	13587	12458			110133	20%
SUM	109956	84425	121139	130569	110200	84283	0	0	640572	20%

Source: An own study [25].

When dividing branches according to the amount of liquidation costs, their broadly understood size was assumed.

The division factor was the structure of their liquidation costs. This value was calculated in a multi-criteria way using the quotient transformation:

$$FC_{j\,max} = \sum_{i=1}^{10} \frac{h_{ij}}{h_{i\,max}}, \quad (1)$$

where:

$FC_{j\,max}$ is the liquidation cost of the branch "*j*" in a multi-criteria approach,

i is the number of the mine liquidation component process,

j is the number of analyzed branch,

$h_{i\,max}$ the highest cost value in the process "*i*",

hij is the liquidation cost in the process "i" for the branch "*j*".

Ultimately, the branches were divided into Large Branches (LB), Medium Larger Branches (MLB), Medium Smaller Branches (MSB) and Small Branches (SB). It was also assumed that one of the branch differs from the rest of the group of Small Branches (SB) by more than 3 standard deviations. Therefore, it was proposed to create an additional fifth group called Micro Branches (MicroB).

Table 4 presents the parameters of the adopted groups of branches, recalculated into dimensionless values. These values were the basis for dividing the branches into reference groups in terms of the amount of costs.

The easiest way to reduce expenses could be to intensify the liquidation processes. Nevertheless, only a part of the costs depends on the passage of time. Because of technological reasons, the correct technique and sequence of liquidated objects should be followed. For this reason, the analysis of branches is carried out in 7 groups designated in accordance with the length of the liquidation process.

In order to supervise the amount and structure of costs of planned and current liquidation of mining plants, it is necessary to have tools to compare the planned capital expenditures with SRK S.A. experience. The "proprietary" method of investment expenditures is the answer to this need. The proposed method indicates deviations of the mine liquidation cost from the average value generated by SRK S.A.

Figure 3 presents the idea of the method against the entire group of analyzed liquidation examples. In most cases, the cost incurred by the branch is significantly different from the average. On the left side, the total costs of liquidation processes from 1 to 10 are presented, and on the right side, as an example, the amount of expenditures incurred for the implementation of process 1 in subsequent years of its implementation is presented. The method signals the deviations of analyzed costs from the average value in the appropriate reference group. Due to the large diversity of the results, it was proposed to adopt a zone of acceptable values. The statistical analysis of such a diverse research group outlines a significant differentiation of the size of the costs incurred (Figure 3). Consistency of data was analyzed using the coefficient of variation according to the formula:

$$V = \frac{s}{\bar{x}}\tau \cdot 100\% \quad (2)$$

where:

V – compliance coefficient,

s – standard deviation,

$\bar{x}$ – arithmetic average.

The range of acceptable values results from the coefficient of variation assumed by the user or designer, for which the standard deviation is calculated. Most of the costs are out of the acceptable value zone. The lower limit of acceptable values is determined by the average value decreased by the calculated standard deviation, and the upper limit by the average value increased by the same value. In the proposed method, the potential user assumes the value of the coefficient of variation for each of the processes and for the total cost of liquidation.

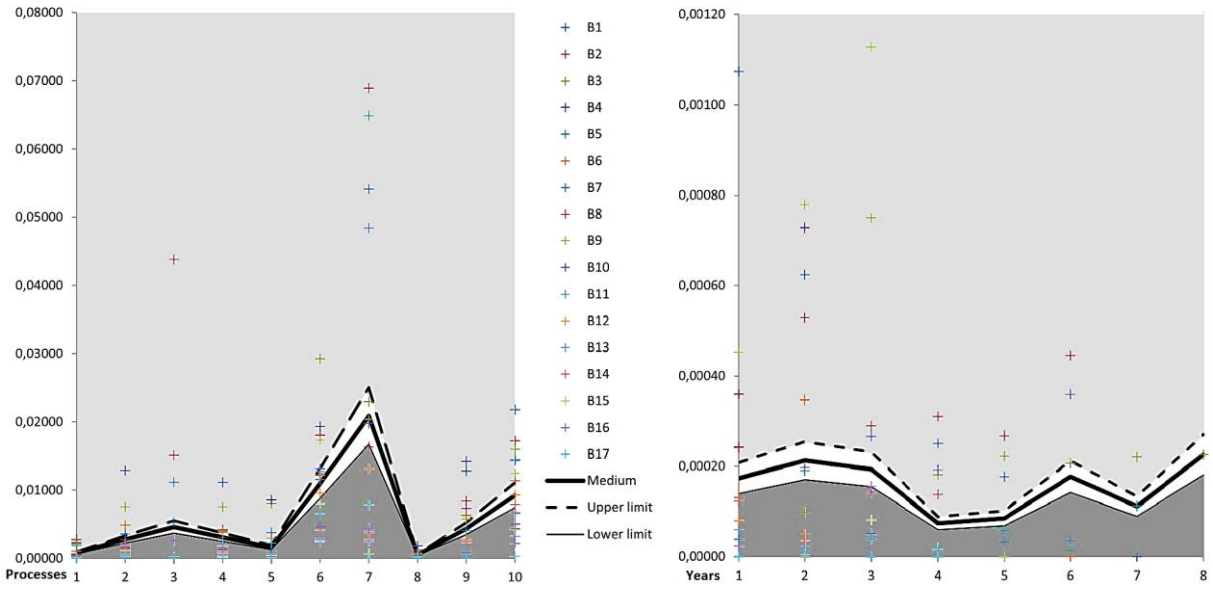

Fig. 3 The idea of the evaluation method of the correctness of the cost estimation of mine liquidation processes in SRK S.A.
Source: An own study [25].

Four panels that were based on a proprietary method, were used in the proposed software. The first panel gives the opportunity only to enter data. In the first panel, the user or designer enters the estimated liquidation costs (Table 5) and the size of the coefficient of variation (COV column), extending or narrowing the width of the zone of acceptable values. In columns in accordance with the annual distribution, the user enters the amount of the incurred expenditures (expressed in thousand PLN) with a division into the individual liquidation components. So as to avoid mistakes, the software color into brightly gray fields with "0" values and fields that have not been filled yet. In the column and in the line entitled SUM, the software sums the values of the costs. As in the analyzed example, the process of liquidation of the shaft (process 2) is carried out only in 2, 3, 4 and 5 years of liquidation. For securing neighboring mines against hazards (process 3) resources are spent only in the last three years. Referring to reclamation (process 5) is carried out only in 5 and 6 years. For other liquidation processes, expenditures are incurred for 6 years, so throughout the whole period of conducting the task of liquidation of the mine.

The second panel (Table 5) and the third panel (Table 6) of the method of the assessment of liquidation costs evaluate the absolute value of the estimated liquidation costs expressed in money.

Table 5

The response of panel 2 to sample data entered in the Table 5 [in thous. PLN]

Panel 2	ALL	L	ML	MS	S	Micro
Process 1	11124	11124	11124	11124	11124	11124
Process 2	18116	18116	18116	18116	18116	18116
Process 3	26567	26567	26567	26567	26567	26567
Process 4	56154	56154	56154	56154	56154	56154
Process 5	5224	5224	5224	5224	5224	5224
Process 6	66218	66218	66218	66218	66218	66218
Process 7	273383	273383	273383	273383	273383	273383
Process 8	9157	9157	9157	9157	9157	9157
Process 9	64493	64493	64493	64493	64493	64493
Process 10	110134	110134	110134	110134	110134	110134
Sum	640570	640570	640570	640570	640570	640570

Source: An own study [6].

Table 6

The response of panel 3 to sample data entered in the Table 5 [in thous. PLN]

Panel 3	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Process 1	1814	2668	1460	1584	1353	2246		
Process 2		8525	6580	2900	112			
Process 3				6900	14491	5176		
Process 4	1816	2385	4962	29493	15563	1934		
Process 5					1220	4004		
Process 6	36119	23688	4241	1025	585	560		
Process 7	32989	23692	62981	50742	51564	51416		
Process 8	1151	1037	501	2798	2064	1606		
Process 9	2112	5746	22340	19752	9661	4883		
Process 10	33955	16684	18074	15375	13587	12458		
SUM	109956	84425	121139	130569	110200	84283		

Source: An own study [25].

The second panel of the tool analyzes the total costs allocated to the implementation of processes from 1 to 10 in all reference groups. In the second panel the same summary costs of liquidation component processes are analyzed in all reference groups determined due to the total system of costs of the component processes. In all columns, the obtained costs are compared to the average for each process and for the total liquidation cost in this reference group. The same amount of the cost may be too high, too low or compatible with the average depending on which the reference group is analyzed. The method on the black field in a row called the second panel (Table 5) assigns the analyzed task of mine liquidation to the appropriate reference group. The assessment contained in this column is the base of the second panel. The comparison in other columns refers only to comparative purposes. For comparison, the costs entered by the user are analyzed in the same way in other groups and for the entire group of liquidated mining plants, which may additionally reassure the designer to the correctness of the estimated liquidation costs. At this point, there is an opportunity for a possible larger correction of the estimated costs.

In panel 2, 3 and 4 when entered cost exceeds the upper limit of the acceptable value, the field turns into light gray, while when the cost is below the lower limit of the acceptable value, the field turns into dark gray. It was also proposed to leave the field blank so as to signal the fact that costs are not incurred in a given process, which is a warning and a question to the designer whether any expenditures will not be incurred in this area (Table 4, 6, 7 and 8). Additionally, in panel 2 (Table 5), when entered cost exceeds the lower or upper limit greater than the value of 3 standard deviations, the adjacent field turns into black. This case occurs when the cost differs from the average value by more than three standard deviations. According to the described principle, the entered task costs are compared with the average value for the appropriate reference group. In the third evaluation panel (Table 6), the method similarly assesses the absolute amount of planned outlays in individual years of advancement of the mine liquidation task.

The second panel (Table 5) showed the analysis of the example of the costs introduced in Table 4. It turns out that the analyzed branch should belong to large branches (LB), which indicated coloring the field "L" into black in the first row of the second panel. In this column a detailed analysis of the total costs of the liquidation processes of this mining plant should be carried out. The total expenditures on carrying out the liquidation task is within the values acceptable for this group of branches. A similar situation is in the case of process 1 (liquidation and securing of excavation gates), process 7 (carrying out security works and measures to prevent hazards in connection with the liquidated mining plant) and process 10 (general management). The other processes showed an overestimation (shown in light gray) or underestimation (shown in dark gray). In any case, for these processes, there was no black field indicating that the upper or lower limit of the acceptable values was exceeded by more than 3 times the standard deviation. At this point, there is an opportunity to make major adjustments to the planned outlays for carrying out the task of liquidation this mine. The analysis of the same inputs of the remaining reference groups can be helpful. As expected, the analyzed branch that was qualified to large branches, indicating its component costs showed an overestimation for smaller groups. The method additionally indicated that the same inputs for

processes 4, 8 and 9, analyzed for the group of smaller medium branches, already exceed the upper limit of acceptable values by more than 3 times of the standard deviation. This suggests paying special attention to the correctness of the estimation of these three components of the liquidation processes.

The third panel of the method, unlike the second panel, compares the entered liquidation cost values with their average value for a group of mines liquidated for the same period (according to the planned time interval entered by the user). Table 7 shows the response of the panel 3 of the method to the sample data entered in Table 4. At first glance, a detailed analysis of the results may give the impression that there are inconsistencies with the panel 2 analysis. Processes 1, 7, 10 and the total cost of the panel 2 were complied with the range of acceptable values. In the panel 3, the analysis of the amount of expenditures incurred on these processes indicates their overestimation. This is due to the fact that this size of the mine is usually liquidated over a period longer than 6 years. The method suggests extending the liquidation processes with the total unchanged expenditures for these 3 processes and the correction of the amount of expenditures for the remaining processes according to the coloring of the fields in the panel (reduce the costs colored into light gray and possibly correct up the dark gray ones). In addition, the method indirectly indicates that in the process 2 (liquidation of shafts), it should be considered to conduct this process also in the first and/or last year of liquidation, and that process 5 (reclamation) should be extended by another year.

Absolute average liquidation costs cannot be applied to all mining plant cases. The division into groups related to the length of restructuring processes solves the problem only partially. In the fourth panel of the method, an analysis of the structure of incurred costs was proposed (Table 8). Independently from the actual amount of expenditures, it was assumed that the total cost incurred by the branch is 100% and all component costs are given as a fraction of this cost. This will mainly lead to compare the costs incurred by branches with extreme costs. For example, the total cost of liquidating the "most expensive" branch is 40 times higher than the cost of the "cheapest" branch. The panel 4 is an auxiliary tool indicating to the designer the places most appropriate for correction. The costs colored into light gray should be reduced, and in the case of costs colored into dark gray, they should be increased.

Table 7 presents the reaction of the panel 4, for data entered in Table 4. In the analyzed case, the corrections proposed by the panel 4 should be introduced only after considering extending the length of the mine liquidation task. Extending the time of conducting liquidation processes will result in case studies in a different group of branches. If such an extension will not take place, the panel 4, similarly like the panel 3, suggests that process 2 (liquidation of shafts) should be carried out additionally in the first or last year of liquidation, and possibly for the entire time of mine liquidation.

In panel 4, the proposed method (Table 7) only analyzes the structure of outlays for conducting a specific component process of the branch liquidation.

Table 7

The response of panel 4 to sample data entered in the Table 5

Panel 4	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Process 1	16,31%	23,98%	13,12%	14,24%	12,16%	20,19%		
Process 2		47,06%	36,32%	16,01%	0,62%			
Process 3				25,97%	54,55%	19,48%		
Process 4	3,23%	4,25%	8,84%	52,52%	27,72%	3,44%		
Process 5					23,35%	76,65%		
Process 6	54,55%	35,77%	6,40%	1,55%	0,88%	0,85%		
Process 7	12,07%	8,67%	23,04%	18,56%	18,86%	18,81%		
Process 8	12,57%	11,32%	5,47%	30,56%	22,54%	17,54%		
Process 9	3,27%	8,91%	34,64%	30,63%	14,98%	7,57%		
Process 10	30,83%	15,15%	16,41%	13,96%	12,34%	11,31%		
SUM	17,17%	13,18%	18,91%	20,38%	17,20%	13,16%		

Source: An own study [25].

The analysis of the structure of costs incurred in relation to the total expenditures on the liquidation of mines requires further research. The researched cost can be entered in any unit, but constant for a specific analysis. The introduction of a monetary unit other than PLN will cause correct operation of only panel 4, and the activation of panels 2 and 3 would require the software to be scaled.

In this method, the signaling of a deviation from the average value does not have to mean an error, and any deviation may result from the specific nature of the liquidated branch. The decision whether the signaled deviation is justified is left to the designer, and the method is only a tool supporting the designer's work.

The correct operation of the method was checked by putting it into practice. The verification of the method and the tool itself was carried out in two stages. In the first stage, the correctness of the method was tested on the basis of four hypothetical branches called: ALPHA, BETA, GAMMA, DELTA. In the second stage, experts were asked to evaluate these branches.

ALPHA branch is a branch liquidated for 4 years and belongs to the most numerous and at the same time the most diversified reference group. The liquidation costs of ALPHA Branch are equal to the average value for the group of Small Branches (SB).

The analysis of ALPHA Branch was as expected (Table 8).

Table 8

***The analysis of the hypothetical branch called* ALPHA**

Panel 2	ALL	L	ML	MS	S	Micro		
Process 1	952,6	952,6	952,6	952,6	952,6	952,6		
Process 2	8464	8464	8464	8464	8464	8464		
Process 3								
Process 4	5983,5	5983,5	5983,5	5983,5	5983,5	5983,5		
Process 5								
Process 6	37437	37437	37437	37437	37437	37437		
Process 7	15250,2	15250,2	15250,2	15250,2	15250,2	15250,2		
Process 8	1099,7	1099,7	1099,7	1099,7	1099,7	1099,7		
Process 9	4085,3	4085,3	4085,3	4085,3	4085,3	4085,3		
Process 10	22151,6	22151,6	22151,6	22151,6	22151,6	22151,6		
Sum	95423,9	95423,9	95423,9	95423,9	95423,9	95423,9		
Panel 3	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Process 1	212,8	295,9	368,4	75,5				
Process 2	91,3	2159,4	883,4	5329,9				
Process 3								
Process 4	584	903,2	1205,8	3290,5				
Process 5								
Process 6	11892,8	15608	8032,9	1903,3				
Process 7	3432,1	4758,1	4117,6	2942,4				
Process 8	348,8	440,4	209,9	100,6				
Process 9	424,3	1254,2	790,1	1616,7				
Process 10	6235,4	6341	5147,7	4427,5				
SUM	23221,5	31760,2	20755,8	19686,4				
Panel 4	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Process 1	22,34%	31,06%	38,67%	7,93%				
Process 2	1,08%	25,51%	10,44%	62,97%				
Process 3								
Process 4	9,76%	15,09%	20,15%	54,99%				
Process 5								
Process 6	31,77%	41,69%	21,46%	5,08%				
Process 7	22,51%	31,20%	27,00%	19,29%				
Process 8	31,72%	40,05%	19,09%	9,15%				
Process 9	10,39%	30,70%	19,34%	39,57%				
Process 10	28,15%	28,63%	23,24%	19,99%				
SUM	24,34%	33,28%	21,75%	20,63%				

Source: An own study [6, 25].

Because of the fact that the analyzed example was a verification of the method and a software response to the benchmark element evaluation, none of the field evaluating in this example from panel 2 to 4 became stained. As expected, panel 2 showed that the data came from the group of Small Branches (SB). When analyzing this panel, it can be noticed that the values for the process 1, 2 and 6 in the group of Medium Smaller Branches (MSB) turned into light gray. It is not an error that inconsistently with expectations, the average values for these processes in the group of Small Branches (SB) are higher than in the group of Medium Smaller Branches (MSB). The remaining fields in all groups of branches larger than smaller turned into dark gray, signaling their underestimation, and in one case, for Large Branches, a significant (gross) underestimation of costs was signaled. The situation was different in the group of Micro Branches (MicroB). All fields turned into light gray, indicating an overestimation (Table 8). The method and software also signaled a significant excess of the average values for the Micro group by the set values (difference greater than the value of 3 standard deviations). This case proves the rightness of the decision to create an additional group of the smallest units called Micro Branches (MicroB).

BETA Branch is a mine that has been liquidated for 7 years, with the average cost of liquidation of Large Branches (LB) multiplied by 1.5 to obtain a particularly costly liquidation process. When analyzing this branch, the reaction of the method was in accordance with the authors' expectations (Table 9).

Table 9

The analysis of the hypothetical branch called BETA

Panel 2	ALL	L	ML	MS	S	Micro		
Process 1	16090,1	16090,1	16090,1	16090,1	16090,1	16090,1		
Process 2	36485,2	36485,2	36485,2	36485,2	36485,2	36485,2		
Process 3	131525,9	131525,9	131525,9	131525,9	131525,9	131525,9		
Process 4	57071,4	57071,4	57071,4	57071,4	57071,4	57071,4		
Process 5	23722,4	23722,4	23722,4	23722,4	23722,4	23722,4		
Process 6	148403,7	148403,7	148403,7	148403,7	148403,7	148403,7		
Process 7	390372,9	390372,9	390372,9	390372,9	390372,9	390372,9		
Process 8	9808,5	9808,5	9808,5	9808,5	9808,5	9808,5		
Process 9	73441	73441	73441	73441	73441	73441		
Process 10	147577,8	147577,8	147577,8	147577,8	147577,8	147577,8		
Sum	1034498,9	1034499	1034499	1034499	1034499	1034499		
Panel 3	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Process 1	5583	4087	1536	1326	1178	1866	514	
Process 2			7924	8129		20048	385	
Process 3			13373	32160	34414	45242	6337	
Process 4	617	320	2449	19851	6616	26836	383	
Process 5					559	4963	18200	
Process 6	55984	29996	21507	14796	13644	12254	224	
Process 7	49886	74340	60581	56049	58513	55423	35582	
Process 8	993	2491	1859	2412	1272	733	48	
Process 9	2018	2195	14950	43212	5767	3391	1908	
Process 10	18558	27309	27881	28600	20666	14179	10386	
SUM	133638	140737	152059	206534	142630	184934	73967	
Panel 4	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Process 1	34,70%	25,40%	9,55%	8,24%	7,32%	11,60%	3,19%	
Process 2			21,72%	22,28%		54,95%	1,05%	
Process 3			10,17%	24,45%	26,17%	34,40%	4,82%	
Process 4	1,08%	0,56%	4,29%	34,78%	11,59%	47,02%	0,67%	
Process 5					2,36%	20,92%	76,72%	
Process 6	37,72%	20,21%	14,49%	9,97%	9,19%	8,26%	0,15%	
Process 7	12,78%	19,04%	15,52%	14,36%	14,99%	14,20%	9,11%	
Process 8	10,12%	25,40%	18,96%	24,59%	12,97%	7,47%	0,49%	
Process 9	2,75%	2,99%	20,36%	58,84%	7,85%	4,62%	2,60%	
Process 10	12,57%	18,50%	18,89%	19,38%	14,00%	9,61%	7,04%	
SUM	12,92%	13,60%	14,70%	19,96%	13,79%	17,88%	7,15%	

Source: An own study [6, 25].

Panel 2 indicated that an example of a mine belonging to the group of Large Branches (LB) was with particularly high liquidation costs exceeding 1 billion PLN, but with the correct structure of expenditures. In panel 2, the software additionally provided information about a significant excess of this limit (by more than 3 standard deviations) in the case of process 10. Additionally, in panel 2, the information about gross exceeding the upper limit of the acceptable cost value was also included in all other reference groups for a larger number of component processes. On the other hand, panel 4 showed the cost structure perfectly consistent with the average values in the group of branches liquidated for 7 years (Table 10).

GAMMA Branch is a mine that has been liquidated for 5 years. The cost of its liquidation is equal to the average values for the group of Medium Smaller Branches (MSB). The analysis of GAMMA Branch was another test of the method for the analysis of the standard element (Table 10). When preparing the hypothetical costs of liquidating GAMMA Branch, it was taken into account carefully the diversification of annual outlays. Nevertheless, in order not to exceed the limit of acceptable values for the total and annual costs of running component processes expressed in money. According to the expectations, the method indicated that the analyzed mine belongs to the group of Medium Smaller Branches (MSB) and moreover, as panel 2 indicated, its total costs of liquidation components are within the range of acceptable values. The dark gray color of processes 1, 2 and 6 in the group of Small Branches (SB) or the light gray color of process 9 for the group of Medium Larger Branches or the group of all units may be disturbing. As it was mentioned, in the earlier analysis of ALPHA Branch, the average costs of processes 1, 2 and 6 are lower than for the group of Small Branches (SB), and the average values of process 9 are higher in the group of Medium Smaller Branches (MSB) than in the group of Medium Larger Branches (MLB). For this branch, Panel 3 indicated full compliance of the amount of expenditures with the range of acceptable values expressed in money. The selection of data described earlier resulted in a change in the structure of annual outlays. The analysis of GAMMA Branch had to indicate the need for an independent analysis of the structure of incurred costs, which, according to the authors, was successfully shown (Table 10).

Table 10

The analysis of the hypothetical branch called GAMMA

Panel 2	ALL	L	ML	MS	S	Micro		
Process 1	879	879	879	879	879	879		
Process 2	7254,5	7254,5	7254,5	7254,5	7254,5	7254,5		
Process 3	199,9	199,9	199,9	199,9	199,9	199,9		
Process 4	6834,7	6834,7	6834,7	6834,7	6834,7	6834,7		
Process 5	3764	3764	3764	3764	3764	3764		
Process 6	31482,6	31482,6	31482,6	31482,6	31482,6	31482,6		
Process 7	49629	49629	49629	49629	49629	49629		
Process 8	1720,2	1720,2	1720,2	1720,2	1720,2	1720,2		
Process 9	35453,9	35453,9	35453,9	35453,9	35453,9	35453,9		
Process 10	38780,6	38780,6	38780,6	38780,6	38780,6	38780,6		
Sum	175998,4	175998,4	175998,4	175998,4	175998,4	175998,4		
Panel 3	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Process 1	217,4	486	159,5	15,6	0,5			
Process 2	0,5	59	1645	2450	3100			
Process 3	0,7	0,7	0,7	82	115,8			
Process 4		224,7	2090	960	3560			
Process 5			92,1	1946,3	1725,6			
Process 6	9000	6850	8500	4750	2382,6			
Process 7	7900	13400	10000	12600	5729			
Process 8	170	630	730	90	100,2			
Process 9	700	3100	2900	21000	7753,9			
Process 10	4000	9800	9000	9500	6480,6			
SUM	21988,6	34550,4	35117,3	53393,9	30948,2			
Panel 4	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Process 1	24,73%	55,29%	18,15%	1,77%	0,06%			
Process 2	0,01%	0,81%	22,68%	33,77%	42,73%			
Process 3	0,35%	0,35%	0,35%	41,02%	57,93%			
Process 4		3,29%	30,58%	14,05%	52,09%			
Process 5			2,45%	51,71%	45,84%			
Process 6	28,59%	21,76%	27,00%	15,09%	7,57%			
Process 7	15,92%	27,00%	20,15%	25,39%	11,54%			
Process 8	9,88%	36,62%	42,44%	5,23%	5,82%			
Process 9	1,97%	8,74%	8,18%	59,23%	21,87%			
Process 10	10,31%	25,27%	23,21%	24,50%	16,71%			
SUM	12,49%	19,63%	19,95%	30,34%	17,58%			

Source: An own study [6, 25].

The most interesting and at the same time, the most difficult example for the method to verify its operation, is the analysis of the liquidation costs of DELTA Branch (Table 11). The authors managed to present a very early variant of the system of estimated costs of the liquidation of the branch that was being liquidated for 8 years. This cost structure was later repeatedly updated by subsequent more accurate estimation processes and by several years of verification by the liquidation practice. It should be taken into account that the liquidation of this mine is not over yet. Panel 2 indicated that DELTA Branch, due to its component cost structure, should be assessed in the group of Medium Larger Branches (MLB), and (Table 2) due to the total expenditures it should belong to the group of Large Branches (LB). In all of the method panels, you can see costs that are within the acceptable value range, but most of the costs are above or below the lower limit of the acceptable value (Table 11). The comparison of the results of the presented analysis with the current system of liquidation costs of DELTA Branch showed that the majority of indicated deviations from the average value were fully or partially corrected in accordance with the method suggestions.

Table 11

The analysis of the hypothetical branch called DELTA

Panel 2	ALL	L	ML	MS	S	Micro		
Process 1	10037	10037	10037	10037	10037	10037		
Process 2	2964	2964	2964	2964	2964	2964		
Process 3								
Process 4	21088	21088	21088	21088	21088	21088		
Process 5	2516	2516	2516	2516	2516	2516		
Process 6	61863	61863	61863	61863	61863	61863		
Process 7	339379	339379	339379	339379	339379	339379		
Process 8	1497	1497	1497	1497	1497	1497		
Process 9	21543	21543	21543	21543	21543	21543		
Process 10	77237	77237	77237	77237	77237	77237		
Sum	538124	538124	538124	538124	538124	538124		
Panel 3	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Process 1		532	4084	988	1212	1026	1087	1108
Process 2								2964
Process 3								
Process 4		426	1488	420	12786	2400	121	3447
Process 5							1289	1227
Process 6	19072	13369	8694	4064	5407	4816	3175	3266
Process 7	9442	35359	35721	45381	54771	51239	53821	53645
Process 8		383	271	186	382	214	38	23
Process 9	57	238	2399	8266	4851	2764	1648	1320
Process 10	7321	13174	16762	13969	9466	6006	5415	5124
SUM	35892	63481	69419	73274	88875	68465	66594	72124
Panel 4	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**
Process 1		5,30%	40,69%	9,84%	12,08%	10,22%	10,83%	11,04%
Process 2								100,00%
Process 3								
Process 4		2,02%	7,06%	1,99%	60,63%	11,38%	0,57%	16,35%
Process 5							51,23%	48,77%
Process 6	30,83%	21,61%	14,05%	6,57%	8,74%	7,78%	5,13%	5,28%
Process 7	2,78%	10,42%	10,53%	13,37%	16,14%	15,10%	15,86%	15,81%
Process 8		25,58%	18,10%	12,42%	25,52%	14,30%	2,54%	1,54%
Process 9	0,26%	1,10%	11,14%	38,37%	22,52%	12,83%	7,65%	6,13%
Process 10	9,48%	17,06%	21,70%	18,09%	12,26%	7,78%	7,01%	6,63%
SUM	6,67%	11,80%	12,90%	13,62%	16,52%	12,72%	12,38%	13,40%

Source: An own study [6, 25].

When verifying the correctness of the method, the values of liquidation costs of hypothetical branches were entered and analyzed twice. Firstly, the amount of costs expressed in money (monetary units) was entered. Then in the multi-criteria value for the liquidation costs of all 17 analyzed examples of mining plants (cost structure) was entered. The obtained software reaction was the same, so no additional results were presented, because it would be a copy of those already presented. The obtained software reaction was the same, so no additional results were presented, because it would be a copy of those already presented.

In the second stage of verification, hypothetical examples were presented for evaluation to the practitioners who manage the branches of SRK S.A. The experts agreed with the conclusions of the method and approved the correctness of its operation. The analysis of DELTA branch with its unstable cost structure aroused emotions the most. Nevertheless, in the case of DELTA branch, the method was accepted by practitioners. At this stage, the experts' suggestions regarding the directions of further research appeared, and the areas and research problems requiring solutions in the field of the processes of the liquidation of mining plants were indicated.

CONCLUSIONS

In the mine enterprises conducting the mine liquidation there is a lack of comprehensive and consistent solutions referring to the implementation and application of the management processes methodology. However, there are many components of this concept. In order to increase the effectiveness and efficiency and create long-term value of mine enterprises liquidating mines it is a matter of great importance to develop a model of the process management system aimed at improving the competitiveness of the functioning of enterprise. The proposed procedure of multifaceted assessment of the cost components of liquidation processes can be a form of filling this gap. The presented tool may be one of the components of increasing the effectiveness of mining plants liquidation and help the Management Board to rationalize and minimize the use of the budget subsidy.

The described method bases on the statistical analysis of the total costs of liquidation processes and in the division of subsequent years of liquidation processes that are taking place. In the presented method the assessment of inputs is carried out in three stages. In the first stage (panel 2) the total costs of the components of liquidation processes are compared with their average value in the reference groups determined by the size of the mine. In the second and third stage the costs of carrying out those processes are compared on an annual basis with reference groups determined by the length of the liquidation procedure. The second stage (panel 3) analyses the costs of those processes expressed in money. The third stage (panel 4) examines an annual structure of incurred expenditures. The examined cost may be introduced by any unit, constant for a specific input. Nevertheless, it should be taken into account that in this case only panel 4 of the software will present the correct results and that allows for the optimization that is independent of the scale of the task.

The proposed method of the assessment of the liquidation process gives the same results when data is entered

in money and in multi-criteria conversion of costs into dimensionless values (the examined values is divided by the maximum value for this process). This compliance may prove the correctness of the applied method.

In the group of Micro Branches there is only one case of liquidation, so it becomes a point of reference. Not only analyzing the examples presented above but also in other unrepresented cases, it was noticed that in this group panel 2 correctly signals deviations from the reference value when logically balanced sizes of costs are entered. When introducing random (illogical) values, the procedure very quickly shows that the reference value is exceeded by more than 3 standard deviations. It seems that the range of acceptable values should be slightly extended in this group of branches.

This method is adapted to over 20 years of experience of Spółka Restrukturyzacji Kopalń S.A. but it can also be used by another enterprise carrying out the liquidation of mines. Nevertheless, it would require a mutual adjustment of the component processes structure.

The described method is simple, understandable and easy to use, however it requires further research, tests, analysis and expert opinions. It does not disqualify the proposed method that in present form is a very useful auxiliary tool in designing work of mine plants liquidation and may contribute to the rationalization of incurred expenditures on the restructuring of post-mining assets.

An unresolved scientific problem is a mutual interaction of main processes and the relationship between the structure of incurred costs with the passage of time and the size of liquidation task. There is only the unsystematic knowledge of practitioners. This aspect requires more detailed research.

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