SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2021
ORGANIZATION AND MANAGEMENT SERIES NO. 153

THE MINE LIQUIDATION PROCESSES IN SRK S.A. IN A COST APPROACH

Janusz SMOLIŁO[1], Andrzej CHMIELA[2*]

[1] Spółka Restrukturyzacji Kopalń S.A., Bytom; jsmolilo@srk.com.pl, ORCID: 0000-0003-4987-2881
[2] Spółka Restrukturyzacji Kopalń S.A., Bytom; achmiela@srk.com.pl, ORCID: 0000-0002-0833-0923
* Correspondence author

Purpose: The cost of the subsidy of liquidated mine is about 250 million PLN. Because of such financial outlays it is relevant to lead the processes of rationalization and minimization of the costs incurred what requires a complex scientific approach.
Design/methodology/approach: A statistical analysis of the course of the mine liquidation process in SRK S.A. was conducted. During the research panel survey and direct interviews were conducted with the Management Board of SRK S.A. and Directors of Branches.
Findings: The presented method of signaling deviations of mining plant liquidation costs from the mean value is a useful tool while implementing a process approach in the issue of the liquidation of the mine.
Research limitations/implications: The assessment method of the proposed mine liquidation process described in the publication is based on the analysis of total costs of liquidation. Further research will require the analysis of costs incurred in subsequent years of the liquidation processes.
Practical implications: The method can be used during the initial estimation of the costs of mining plant liquidation as a benchmark for detailed cost estimation of liquidated mines.
Social implications: The assessment method of the cost estimation of mining plant liquidation can be used as a reference point for detailed analysis and multi-criteria costs estimation of following liquidated mining plants. The cost accounting system is typical for SRK S.A. but thanks to some modifications the methodology can also be applied by another entity conducting the liquidation of mines.
Originality/value: The presented cost assessment procedure may help The Management Board of SRK S.A. to monitor incurred costs (rationalization and minimization of the costs). The tool can be useful in effective liquidation of mining plants which is especially important in a situation where the scientific literature in this area is extremely scarce.

Keywords: process management, restructuring of mining enterprises, liquidation of a hard coal mine.

Category of the paper: Research paper.

1. Introduction

After 1989 changes of political system affected the Polish economy. The economy had to be changed very quickly from centrally controlled to free market. In the hard coal mining industry those changes have a big influence on their processes. During the political system transformation the hard coal mining was completely unadjusted to the rules of the market competition with the huge overproduction, the excess of employment and the huge amount of non-productive assets.

Since the beginning of the 1990s the Polish hard coal mining industry has been implementing restructuring activities aimed at adapting the industry to the needs and conditions of the market economy. The most rational way of reducing costs in this industry is to liquidate nonprofit mines which have not got coal resources any more or which give unprofitable exploitation in particularly unfavorable mining and geological conditions.

The mine liquidation process started in 1994 and is still carrying out by Spółka Restrukturyzacji Kopalń S.A. established in 2000. The liquidation and securing of mining excavation sites or the liquidation of buildings from mining plants are carried out by 8 Branches of SRK S.A. (www.srk.com.pl). The Property Management Department deals with the management of industrial property after liquidated mines and The Housing Resource Administration is responsible for the management of non-industrial assets (apartments, garages, commercial premises, etc.) As a part of the securing of neighboring mines against flooding, the Company is also responsible for pumping water from sites of previously closed mines.

Until the end of 2023 on the basis of European Union approval, the Polish government obtained permission to finance the liquidation from the state budget. The value of the subsidy will amount to approximately 5 billion PLN. Because of such financial outlays it is relevant to lead the processes of rationalization and minimization of the costs incurred what requires a complex scientific approach. Such research has not been conducted so far.

2. Research problem

The existence of the mine is not only the period of extraction but also the period of its liquidation. Reducing the capital intensity of liquidated hard coal mines is a problem that affects both Mining Communities and the state budget. A lack of instruments and tools which support the cost management is one of the reason limiting the improvement of liquidation efficiency. In the hard coal mining industry, no comprehensive solutions tailored to the specifics of the industry have been developed so far. Solutions which have been developed concern mainly on

selected issues related to the efficiency of mining process or preparatory works. (Jonek-Kowalska, 2013; Przybyła, Chmiela, 2002, 2007; Turek, 2013; Turek, Jonek-Kowalska, 2013).

The total cost of liquidation of 17 mines in SRK S.A. since 2015 has amounted to approximately 5 billion PLN at the end of 2020. The average cost of liquidated branch is around 250 to 300 million PLN. In the case of liquidation of mines, no scientific research has been conducted so far to improve efficiency and effectiveness of its processes. The available literature concerns only on general issues related to that problem (Grajewski, 2012; Riesgo et al., 1997, 2000, 2001, 2003).

The process management in SRK S.A. requires further research in this area. The presented publication tries to propose a cost management support tool and identify research areas and problems that require further analysis. The method and conclusions presented will be the basis for further research aiming at improving the effectiveness and efficiency of the processes which are carrying out in the company dealing with liquidation of mines (Dźwigoł, 2007; Grajewski, 2012; Skrzypek, Hofman, 2010).

3. Research methods

An introduction of the process management system in SRK S.A. requires having knowledge about the current state of liquidation processes and ability to propose a tool for assessing the course of these processes. An additional aim of this research was to identify further areas and research problems that need to be solved. The aim was achieved in three stages (Table 1). The research plan was carried out on the basis of actual data collected which were concerned on existing processes of mines liquidation. The processes of mines liquidation and the liquidation plan for 17 mines or their parts were analyzed in a period from 2015 to 2023. In the group which was researched there were 6 liquidated mines or their parts and 11 mines or their parts which are currently liquidated in 8 Branches of SRK S.A. (www.srk.com.pl).

Table 1.
Methods and results of their use in individual research stages

Research stage	Research Methods	Results of the use of research methods
I	- Study of literature - Analysis - Synthesis - Direct interview	- An analysis of the current state of the process management in SRK S.A. - Development of the methodology of the assessment of the liquidation process
II	- Face-to-face interview - Panel studies - Analysis - Synthesis	- A statistical analysis of the researched liquidation process - Proposition of a tool for assessing the course of liquidation process - Indication of research areas and problems
III	- Analysis - Synthesis	- Verification of the results - Indication of further areas and research problems

Source: An own study.

In the first stage, the available literature on the management processes was analyzed and compared with personal experience of the mine liquidation. The possibility of adapting the process management concept to the specificity of SRK S.A. was analyzed. The results of the analysis made it possible to prepare data used in the second stage.

In the second stage, a statistical analysis of the researched liquidation process in SRK S.A. was carried out. During the research a face-to-face interview with The Management Board and Directors of Branches was conducted so as to explain deviations of actual values from their mean values. During this stage questions about the character of the process, technical problems while their implementation, the correctness of their course or suggestions for possible changes in a liquidation practice were asked. The process courses according to the Figure 1. Based on interviews with experts a methodology of general evaluation of the course of mines liquidation in SRK S.A. was prepared. This methodology is verified in the third stage of research. The research identify areas and problems that need to be solved.

In the third stage, the correctness of the proposed methodology of mines liquidation processes evaluation was checked. The correctness of the process assessment tool was carried out on the basis of hypothetical new Branches of SRK S.A. This stage also revealed further unresolved areas and research problems.

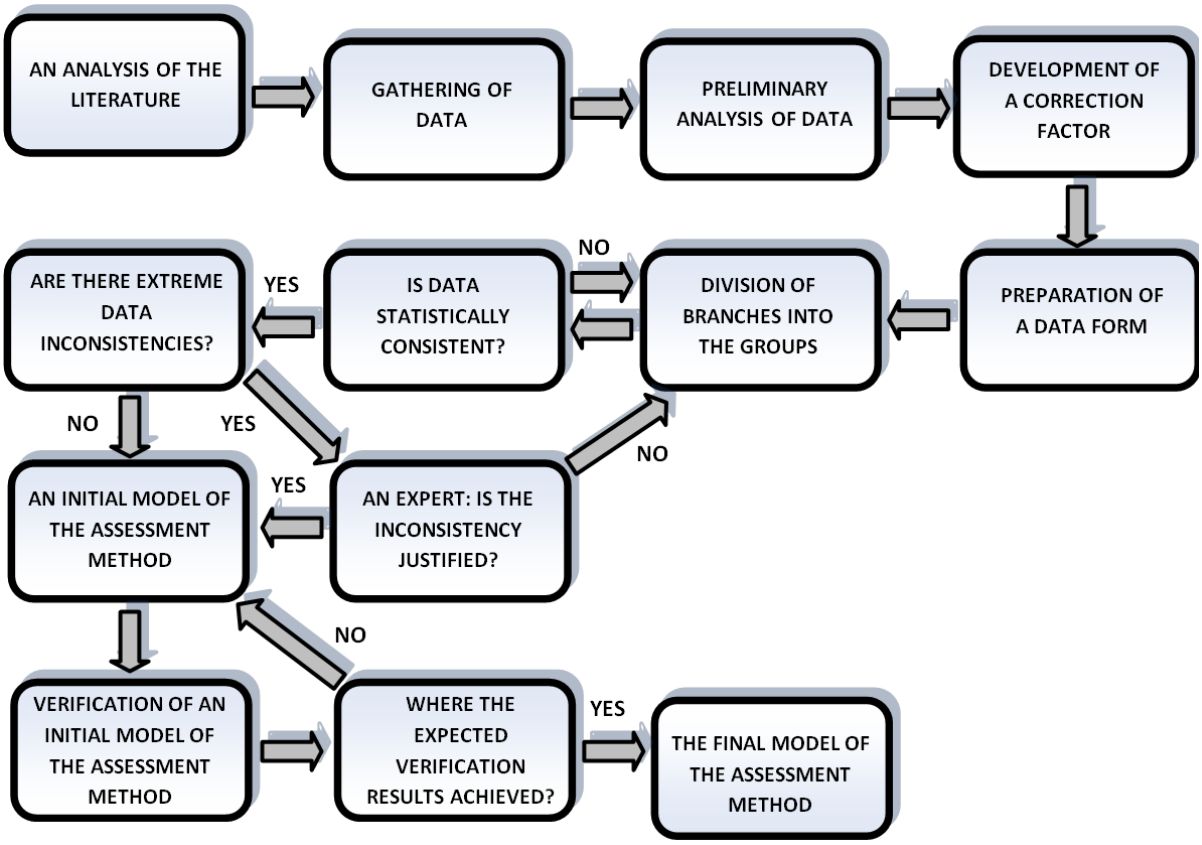

Figure 1. A map of the process of the research method. Source: An own study.

4. Findings

The authors use the term "liquidation process". This concept is related to the phenomenon of the cyclicality. In the case of the mine liquidation we can distinguish some constantly occurring activities with a cycle length from 2 to 8 years therefore the mine liquidation operations can be treated as a long-term processes. In SRK S.A. the physical liquidation of mine is carried out with a division of 10 component processes. These processes are called "schedules". However, due to the possibility of misinterpretation of this word, the authors will use the term "process" in this publication. The mine liquidation processes in SRK S.A. are presented in the Table 2. Moreover, a map of the mine liquidation processes in SRK S.A. in a cost approach is presented in Figure 2.

Table 2.
The mine liquidation processes in SRK S.A.

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

Source: Data from SRK S.A.

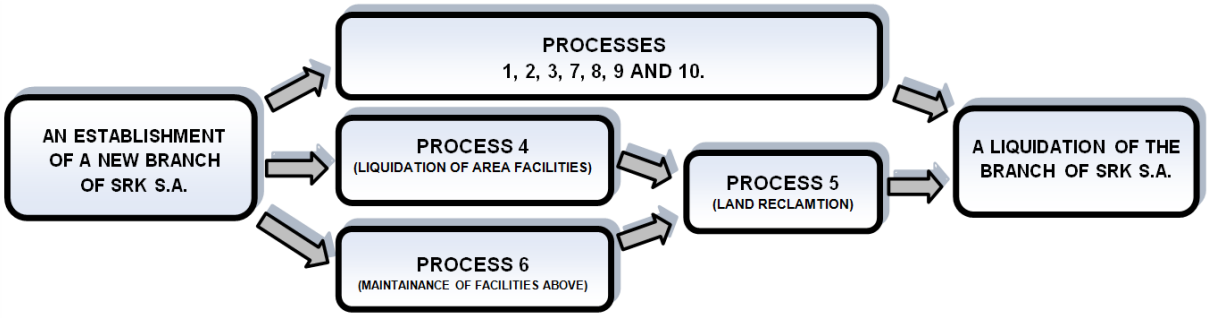

Figure 2. A map of the mine liquidation processes in SRK S.A. in a cost approach Source: Smoliło, Chmiela, 2021.

So as to create the process management system in SRK S.A. it is necessary to develop tools which support the management of process liquidation costs and identify in a qualitative and quantitative way additional areas and research problems that need to be solved. The aim was achieved in three stages (Table 1). The research plan was carried out on the basis of actual data concerning the existing mine liquidation processes. The research was conducted according to updated liquidation programs.

SRK S.A. has 8 Branches that deal with mine liquidation (www.srk.com.pl). For the research purposes the branches was divided into the storage mines. In this way a group of 11 branches was obtained. In order to increase the credibility of the research results, also 6 previously liquidated branches were analyzed. Summing up, 17 cases of mine plant liquidation were analyzed. In the research the authors ranked the liquidated branches in order of decreasing total cost. Due to the incomparability of costs in different years caused by inflation and changes in the cost of obtaining labor the coefficient of correction was used. The analysis took into account the liquidation cost estimated at the end of 2020. The branches were divided into their size resulting from the total cost of their liquidation. At this time, SRK S.A. carries out the liquidation according to the updated liquidation programs which should end before 2024. Nevertheless, it needs to be taken into account that because of COVID-19 the liquidation processes may be extended. Table 3 presents the division of liquidated Branches of SRK S.A. subjected to statistical analysis. In order not to reveal sensitive data the costs are calculated as a percentage value of total liquidation costs.

Table 3.
Liquidated Branches of SRK S.A. subjected to statistical analysis

Branch	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**
Liquidation cost	16,16%	12,75%	10,27%	9,98%	8,94%	6,93%	6,19%	5,88%	5,43%
Branch	**B10**	**B11**	**B12**	**B13**	**B14**	**B15**	**B16**	**B17**	
Liquidation cost	4,30%	3,00%	2,78%	2,24%	1,88%	1,62%	1,34%	0,32%	

Source: An own study.

In SRK S.A. a statistical mine is liquidated for less than 5 years, the average cost of liquidated branch is 5,88% of total cost of liquidation and each year of liquidation of the branch increases the total costs by 1,2% of this value. Every liquidated mine is different so there is no surprise that data is diverse. The average cost of liquidation of a small branch is 13,8% of the average cost of liquidation of a large branch. It is similar in the case of liquidation time where the minimum time of liquidation is 2 years and the maximum time is 8 years. The differentiation is even greater during the calculation of large, medium and small branches. In this case the cost of the largest branch liquidation is even 40 times bigger than the cost of the smallest branch liquidation.

During the statistical analysis of such diverse research group the problem of significant differentiation in the amount of cost incurred was encountered. It was analyzed by the coefficient of compliance according to the formula:

$$V = \frac{s}{\bar{x}} * 100\% \quad (1)$$

where:

V – compliance coefficient,

s – standard deviation,

$\bar{x}$ – arithmetic average.

Taking into account all branches the coefficient of differentiation was so high that further statistical analysis of mining liquidation as whole had to be resigned. Not only the size of the average coefficient of variation of the cost of liquidation process was calculated but also the coefficient of variation of total liquidation costs. The results are presented in Table 4. It has been found that the average coefficient of variation of the cost of liquidation process is not indicative and will be provided only for comparative purposes. Its variability results from different models of liquidation and changeable costs incurred in a various component processes. As an example the increase in costs for the construction of the pumping station will be "compensated" by the reduction of costs of shafts and workings liquidation. To state whether the analyzed group is statistically uniform the coefficient of variation of total liquidation costs was compared. For all the liquidated branches this coefficient amounted to 75,92% which proves enormous variability of the results.

Table 4.
The size of the coefficient of variation in the grouping of liquidated branches

1.	**An analysis of Branches of SRK S.A. as a one group**			
Branches included in the group				All
I	The average coefficient of variation of the cost of liquidation process			119,41
II	The coefficient of variation of total liquidation costs			75,92
2.	**A division according to the size of the branch (three groups)**			
	Large	Medium	Small	
Branches	1, 2, 3, 4, 5, 9	6, 7, 8, 10, 11, 14, 16	12, 13, 15, 17	
I	73,15%	114,22%	63,96%	
II	34,19%	52,36%	61,00%	
		average	49,18%	
3.	**A division according to the amount of the liquidation cost (four groups)**			
	Large	Medium larger	Medium smaller	Small
Branches	1, 2, 3, 4	5, 6, 7	8, 9, 10, 11	12, 13, 14, 15, 16, 17
I	72,31%	61,18%	91,12%	59,9%
II	23,29%	19,4%	27,62%	49,66%
			average	29,99%

Source: An own study.

Another attempt to improve costs compliance was to propose the division of the liquidated mines due to their physical size. The division into large, medium and small mines was made. In large and small groups we could find mines that are liquidated as a whole and in medium groups we could find mines that are partly liquidated. Much better cost compliance was achieved (49,18%) especially in the case of large branches (34,19%). However, worse results were achieved in the case of small branches (61%) and that determined the search for an alternative division into groups. Ultimately the division of branches was made according to the total cost of liquidated branch. Table 5 presents the principles of the proposed statistical division into groups that are analyzed.

Table 5.
A division of branches according to the amount of the liquidation cost

Group	Group characteristic	Cost range	Amount of Branches	A share of the total cost
A	All	0 to 100%	17	100 %
L	Large	9% (inclusive) to 100%	4	49,2 %
ML	Medium larger	6% (inclusive) to 9%	3	22,1 %
MS	Medium smaller	3% (inclusive) to 6%	4	18,7 %
S	Small	0 do 3%	6	10,2 %

Source: An own study.

The results of the division into 4 groups were more satisfactory (29.99%) especially in the group of medium larger branches (19,4%). In that group the high cost compliance was achieved. Nevertheless taken into consideration must be the fact that lower cost compliance appears in the group of small branches. Table 6 presents the statistical data of liquidation of analyzed group.

Table 6.
Statistical characteristic of analyzed group

Branches	A	L	ML	MS	S
Average time of liquidation - [years]	4,9	6,5	6,0	4,3	3,7
Minimum liquidation time - [years]	2	5	5	4	2
Maximum liquidation time - [years]	8	8	7	5	5
Average cost of liquidated branch	5,88%	12,29%	7,35%	4,65%	1,70%
Average annual cost of liquidation	1,2%	1,9%	1,2	1,1%	0,5%

Source: An own study.

In the entire process of mine liquidation only 11,1% of total cost is allocated to the physical liquidation of underground workings and surface facilities (the sum of processes 1, 2 and 4) which is the fourth largest cost of liquidation. As a result, almost 89% costs incurred are spent on activities related to handling of liquidation. The largest group of costs (35,5%) are costs incurred to secure the liquidated mine (Process 7). The second largest group of costs are costs while maintenance of facilities dedicated to liquidation (Process 6). That group consumes almost 19% of financial outlays. The third group are costs of general management (Process 10) which accounts for approximately 16% of total costs.

Table 7 presents the percentage share of the cost of liquidation process in the total cost with a division into groups. With around 5 billion PLN of subsidy even a small percentage correction of the cost of liquidation processes has a big influence on budget savings. In each of the presented component process of liquidation some savings can be found. Only the mining damage process (Process 9) is independent of the Management Board and in that case the cost rationalization can be only found in the correctness and timeliness of compensation payments.

Table 7.
Percentage share of the cost of liquidation process in the total cost

The process of liquidation	A	L	ML	MS	S
Process 1 (liquidation of excavations)	1,32%	0,79%	0,13%	0,31%	0,08%
Process 2 (liquidation of shafts and pits)	4,61%	1,45%	0,31%	2,01%	0,84%
Process 3 (securing of neighboring mines)	7,59%	4,93%	2,64%	0,01%	0,00%
Process 4 (liquidation of area facilities)	5,16%	2,59%	1,20%	0,81%	0,57%
Process 5 (land reclamation)	2,75%	0,98%	0,38%	1,39%	0,00%
Process 6 (maintenance of facilities above)	18,65%	6,66%	4,03%	3,99%	3,97%
Process 7 (securing of liquidated mine)	35,49%	21,20%	8,56%	4,30%	1,42%
Process 8 (projects, expertise etc.)	0,86%	0,40%	0,22%	0,15%	0,10%
Process 9 (mining damage)	7,66%	3,17%	0,75%	3,15%	0,58%
Process 10 (general management)	15,91%	6,98%	3,84%	2,48%	2,60%
Sum 1, 2 and 4 (liquidation)	11,10%	4,83%	1,64%	3,14%	1,49%

Source: An own study.

In the liquidation cost analysis of such diverse "population" of liquidated mines certain regularities can be found. The increase of costs is mostly related to the "scale" of the project. Usually higher liquidation costs are connected with the size of the branch so they depend on the number of liquidated facilities and this is the result of other costs. Table 8 shows the average percentage share of the cost of liquidation process of the branch in the total cost.

Table 8.
Average percentage share of the cost of liquidation process in the total cost

The process of liquidation	A	L	ML	MS	S
Process 1 (liquidation of excavations)	0,08%	0,20%	0,04%	0,08%	0,01%
Process 2 (liquidation of shafts and pits)	0,27%	0,36%	0,10%	0,50%	0,14%
Process 3 (securing of neighboring mines)	0,45%	1,23%	0,88%	0,00%	0,00%
Process 4 (liquidation of area facilities)	0,30%	0,65%	0,40%	0,20%	0,09%
Process 5 (land reclamation)	0,16%	0,25%	0,13%	0,35%	0,00%
Process 6 (maintenance of facilities above)	1,10%	1,66%	1,34%	1,00%	0,66%
Process 7 (securing of liquidated mine)	2,09%	5,30%	2,85%	1,07%	0,24%
Process 8 (projects, expertise etc.)	0,05%	0,10%	0,07%	0,04%	0,02%
Process 9 (mining damage)	0,45%	0,79%	0,25%	0,79%	0,10%
Process 10 (general management)	0,94%	1,75%	1,28%	0,62%	0,43%

Source: An own study.

Each of those processes conducted in SRK S.A. is very complex and depend on many different factors. In the analysis presented below the authors tried to indicate only the most important factors that have influence on the cost of individual liquidation processes. The authors point out that estimation of liquidation costs cannot be based only on the factors mentioned and it must always be a comprehensive and multi – criteria process.

SRK S.A. spends about 1,32% of the total costs on Process 1 connected with the liquidation of excavations. The mean value for the statistical branch is 0,08%. According to the opinions of the experts this cost depends mainly on the number of independent sidings that can be insulated with the help of dams and natural hazards. In the event of methane hazard the increase in cost of liquidation is due to the need of installation of explosion- proof plugs. An additional cost in this process can be the cost of recovering the equipment of liquidated excavation. Work aimed at recovery of equipment should be supported by a cost effectiveness analysis.

The increase in the cost of liquidation of medium smaller branches results from the fact that this group included separate parts of mines which had been small independent mines with lots of working and shafts before.

The liquidation of shafts and pits (Process 2) absorbs 4,61% of the total liquidation costs. The mean value of the branch is 0,27% of this cost. The cost of this process results from the amount of shafts, their volume (length and diameter) and the number of available levels and hazards. In the case of large branches the increase in costs is connected with the liquidation of entire mine. The deviation of amount of costs in the process in medium smaller branches follows similarly to Process 1. It is caused by the nature of liquidated branches.

SRK S.A. allocates 7,59% of liquidation costs for securing of neighboring mines. In that case it is hard to mention the mean value. In the majority of cases the securing of neighboring mines is conducted or not. It is related to the target model of liquidated mine. The cost of securing the neighboring mines depends on the geology of its deposit and the most important decisive factor for the necessity to conduct this process is the possibility of flooding neighboring active mine. An open research problem is the difference between the total cost of liquidation of the mine and the cost of liquidated mine leaving the pumping station.

According to Table 8 the liquidation of area facilities (Process 4) runs in accordance with the size of the branch and consumes 5,16% of total cost of liquidation. In this case some approximation can be taken. If all branches have the same aim, they will have the same objects with the significant difference that small branches have small objects and low cost of liquidation and large branches have huge objects and high cost of liquidation. According to the experts opinion, the cost of this process results from the amount of objects, their structure and volume.

SRK S.A. allocates 2,75% of costs for land reclamation (Process 5). In that case, as in Process 3, the mean value is not reliable. In some of the branches land reclamation is not carried out because of the fact that in most cases a part of the mine is usually liquidated that is situated in the area of active mine. The most important cost factor in this process is the area of reclamation.

The cost related to the maintenance of facilities above (Process 6) as in Process 4 grows with the size of liquidated branch. SRK S.A. allocates 18,65% of total cost liquidation and 1,1% on average for a branch. The size of this cost is related to the amount of objects, their structure and volume held until their physical liquidation and also to the period of waiting for liquidation. Every delay of liquidation causes an increase in outlays. Taking this aspect into account savings should be sought.

The securing of liquidated mine (Process 7) is similar to Process 4 and 6. The cost increases within the size of the branch. In the case of mine liquidation it is the most capital intensive process. SRK S.A. allocates around 35,49% of total costs. Experts claim that the greatest impact in this process has the size of a mine which is associated with the amount of objects that requires securing and the size of the area that need to be protected. Minimizing the period of liquidation would significantly reduce the costs incurred in this process.

In Process 8 external entities are commissioned to carry out projects, expert opinions or analysis which are required by regulations. SRK S.A. allocates 0,86% of total costs. Data analysis shows that the cost increases with the size of the branch. The variety performed in this process is so huge that it is impossible to identify the dominant factor. The best way to reflect the reality is to refer to the widely understood size of the branch. Rationalization of this process cannot result from the amount of commissioned work because these result from separate regulations. Rationalization should result from economical spending of money for individual orders.

As it was mentioned before, it is a little influence on the costs incurred in Process 9 connected with mining damage. The necessity of payments results from legal consequences of previous mining activities. It can be assumed that the value of the cost connected with the area of influence of conducted exploitation in the period of 5 years preceding the end of production. SRK S.A. allocates 7,66% of total outlays. Some of the analyzed branches do not bear costs in this process because they were taken over without mining areas and SRK S.A. in that cases is not a legal successor.

Process 10 referring to the costs of general management is the third according to the size of outlays incurred. SRK S.A. allocates 15,91% of outlays for liquidation processes. The cost of this process increases with the size of the branch. In this case the dominant factors influencing the amount of expenditure are salaries, employee claims, taxes and fees.

The statistical analysis made it possible to propose an assessment method of the amount of the estimated cost of possible liquidation of mines independently from the company responsible for liquidation. This method signals to the designer obtained cost deviations of mine liquidation as a whole or in division to particular processes. Due to the significant diversity of analyzed branches it will depend on the user how far the estimated costs may be from the base value. To better illustrate the assessment in this publication the acceptable deviation on the level of 20% was assumed. The compliance rate of this value shows that results are very consistent. The mean value which was calculated for each group of branches that was reduced and increased by the standard deviation was calculated for the value of the consistency factor giving the upper and lower of the acceptable cost range. Signaling exceeding the upper limit in red and the lower limit in green may indicate mistake which were made in estimating of liquidation cost. In that case, the correctness of the process of estimated cost liquidation should be analyzed. Due to the huge diversity of liquidated mining plants signaling of deviation from the mean value is not the same as finding mistakes. The differences may result from the specific nature of the liquidated plant. Additionally, the authors proposed signaling on yellow the fact of not incurring costs in a given process. It is both information and a question directed to the designer whether this process should actually be skipped.

Table 9.
A list of the costs of liquidated branches analyzed with the deviation of the average value (a comparison method)

Group	Large				Medium larger			Medium smaller				Small					
Branch	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17
∑ costs	16,16	12,75	10,27	9,98	8,94	6,93	6,19	5,88	5,43	4,30	3,00	2,78	2,24	1,88	1,62	1,34	0,32
Percentage share of the liquidated cost of analyzed branch according to the total cost																	
Process 1	0,28	0,22	0,19	0,10	0,05	0,06	0,02	0,04	0,24	0,03	0,01	0,01	0,01	0,02	0,01	0,04	0,00
Process 2	0,28	0,36	0,06	0,76	0,08	0,15	0,09	1,29	0,49	0,03	0,20	0,18	0,21	0,10	0,12	0,21	0,03
Process 3	4,40	0,53	0,00	0,00	1,12	1,52	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00
Process 4	0,31	1,12	0,40	0,76	0,38	0,42	0,39	0,12	0,41	0,03	0,26	0,11	0,08	0,03	0,18	0,16	0,01
Process 5	0,02	0,10	0,05	0,81	0,38	0,00	0,00	0,86	0,30	0,00	0,23	0,00	0,00	0,00	0,00	0,00	0,00
Process 6	1,24	1,32	1,16	2,94	0,47	1,82	1,74	1,94	1,22	0,17	0,66	0,96	1,28	0,42	0,80	0,27	0,24
Process 7	6,93	5,44	6,52	2,31	4,87	1,64	2,05	0,43	1,31	1,77	0,79	0,29	0,25	0,38	0,07	0,43	0,00
Process 8	0,12	0,18	0,03	0,07	0,07	0,08	0,06	0,03	0,03	0,03	0,06	0,01	0,03	0,02	0,02	0,01	0,01
Process 9	0,85	1,28	0,41	0,63	0,08	0,09	0,58	0,74	0,64	1,65	0,13	0,28	0,07	0,23	0,00	0,00	0,00
Process 10	1,73	2,19	1,45	1,61	1,44	1,14	1,25	0,44	0,79	0,59	0,66	0,93	0,33	0,67	0,42	0,22	0,03
Percentage share of the liquidated cost of analyzed branch according to the cost of the process																	
Branch	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17
Process 1	21,0	16,8	14,4	7,8	3,5	4,7	1,5	2,9	18,1	2,2	0,6	1,0	0,6	1,2	0,6	2,9	0,0
Process 2	6,0	7,8	1,2	16,4	1,7	3,2	1,9	28,0	10,6	0,7	4,4	4,0	4,5	2,1	2,6	4,5	0,6
Process 3	58,0	7,0	0,0	0,0	14,8	20,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,0	0,0
Process 4	6,0	21,7	7,8	14,7	7,4	8,1	7,6	2,3	7,9	0,5	5,1	2,2	1,5	0,7	3,5	3,0	0,1
Process 5	0,9	3,8	1,8	29,3	13,8	0,0	0,0	31,4	10,9	0,0	8,2	0,0	0,0	0,0	0,0	0,0	0,0
Process 6	6,7	7,1	6,2	15,8	2,5	9,7	9,3	10,4	6,5	0,9	3,5	5,1	6,8	2,2	4,3	1,5	1,3
Process 7	19,5	15,3	18,4	6,5	13,7	4,6	5,8	1,2	3,7	5,0	2,2	0,8	0,7	1,1	0,2	1,2	0,0
Process 8	13,8	21,1	3,3	7,8	8,0	9,8	7,4	3,1	4,0	3,1	6,7	1,4	3,2	2,3	2,5	1,4	1,1
Process 9	11,1	16,8	5,3	8,2	1,1	1,2	7,6	9,6	8,3	21,5	1,7	3,7	0,9	3,1	0,0	0,0	0,0
Process 10	10,9	13,8	9,1	10,1	9,1	7,2	7,9	2,7	5,0	3,7	4,2	5,9	2,1	4,2	2,6	1,4	0,2

Source: an own study.

Table 9 presents a list of the costs of liquidated branches analyzed with the deviation of the average value. A huge discrepancy in the obtained data may be alarming. The coefficient of convergence calculated for the entire "population" of liquidated mining plants exceeds 70% which proved that analyzed data is very inconsistent. During the statistical analysis people who are in charge of liquidation of analyzed branches were interviewed. Interviews allow to explain most of the deviations of the actual values from their mean values. We can assume the correctness and compliance with "the mining art" of conducted liquidation process. Tabular data are monetary values converted into a percentage value in relation to the total cost of liquidation and in relation to the total cost of individual processes. The same results were obtained in the statistical analysis of the monetary value as well as when converting cost of the mine liquidation process on the mean and maximum value of the entire process. Due to the volume of the publication these analysis were not included. The compliance of conversions may prove the correctness of the method used.

In near future there is no further branches that are going to be taken so as to liquidate therefore in order to verify the proposed methodology the authors proposed a theoretical acquisition of four hypothetical branches. The estimated liquidation costs were taken from the group of large branches. Due to the higher parameter values that group is the best to illustrate the correctness of procedure methodology. One of the hypothetical branches called Alpha which characterizes by maximum costs of liquidation of individual processes. A branch named Beta is a branch characterized by the average costs in the group of large branches and the branch called Gamma is associated with minimum values for the group of large branches. The last one is a branch called Delta where the cost values were assumed as random values of liquidation process costs from the group of large branches (in Table 9 underlined numbers are put in the form of letter "S"). The analysis of verification of the hypothetical cost liquidation of new Branches of SRK S.A. presents Table 10.

Although the liquidation costs come from the group of large branches only the cost of two of them (Alpha and Beta) put them in this group. The branch called Gramma was qualified to the group of medium larger branches and the branch called Delta to the group of medium smaller branches. The cost analysis was conducted in accordance with the affiliation to the reference group. For the liquidation process costs of branches Alpha and Beta this method worked as expected. In the case of the branch Alpha all the fields turned red what indicates that the upper limit of the acceptable value has been exceeded. The total cost of liquidation of this branch amounted to 20,90% of all costs incurred for liquidation that is about 1 billion PLN. Data of the branch Beta was mean values and did not cause a reaction as expected (the fields were uncolored). In the case of the branch Gamma the total cost of liquidation was in the zone of acceptable values, however processes 1, 9 and 10 exceeded the upper limit for the group of medium larger branches. Processes 2, 3, 4 and 8 signaled the possibility of an underestimation.

The total cost of liquidation such as Processes 1 and 9 of the branch Delta in the group of medium smaller branches signaled that the upper limit of the acceptable area was exceeded while Processes 2, 4, 5 and 8 were below the lower limit of this area. One field turned into yellow which signalized that no costs were incurred in this process which was consistent with the assumptions. It was assumed that the liquidation will be carried out without leaving the pumping station. Similar results were obtained when analyzing the costs of liquidation process and the total cost of liquidation.

Table 10.
Verification of the hypothetical cost liquidation of new Branches of SRK S.A.

A new branch	**Alpha**	**Beta**	**Gamma**	**Delta**
Total cost of liquidation	20,90%	12,29%	7,61%	5,85%
Group	L	L	ML	MS
Percentage share of the cost of liquidation of a new Branch according to the total cost				
Process 1 (liquidation of excavations)	0,28%	0,20%	0,10%	0,10%
Process 2 (liquidation of shafts and pits)	0,76%	0,36%	0,06%	0,06%
Process 3 (securing of neighboring mines)	4,40%	1,23%	0,53%	0,00%
Process 4 (liquidation of area facilities)	1,12%	0,65%	0,31%	0,31%
Process 5 (land reclamation)	0,81%	0,25%	0,10%	0,02%
Process 6 (maintenance of facilities above)	2,94%	1,66%	1,16%	1,16%
Process 7 (securing of liquidated mine)	6,93%	5,30%	2,31%	2,31%
Process 8 (projects, expertise etc.)	0,18%	0,10%	0,03%	0,03%
Process 9 (mining damage)	1,28%	0,79%	1,28%	0,41%
Process 10 (general management)	2,19%	1,75%	1,73%	1,45%
Percentage share of the cost of liquidation of a new branch according to the cost of the process				
A new branch	Alpha	Beta	Gamma	Delta
Process 1 (liquidation of excavations)	21,00%	15,00%	7,77%	7,77%
Process 2 (liquidation of shafts and pits)	16,42%	7,86%	1,25%	1,25%
Process 3 (securing of neighboring mines)	58,05%	16,25%	6,97%	0,00%
Process 4 (liquidation of area facilities)	21,69%	12,52%	5,97%	5,97%
Process 5 (land reclamation)	29,27%	8,93%	3,78%	0,86%
Process 6 (maintenance of facilities above)	15,78%	8,93%	6,22%	6,22%
Process 7 (securing of liquidated mine)	19,53%	14,94%	6,50%	6,50%
Process 8 (projects, expertise etc.)	21,09%	11,49%	3,26%	3,26%
Process 9 (mining damage)	16,77%	10,35%	16,77%	5,33%
Process 10 (general management)	13,78%	10,98%	10,88%	9,13%

Source: An own study.

5. Conclusions

The method of signaling of cost liquidation deviations of a new branch of SRK S.A. from the average value presented by the authors is a useful tool when trying to implement a process approach in the issue of mine liquidation in terms of rationalization and minimization of costs incurred. Especially it is important in a situation of insufficient research on this field.

The assessment method of the size of the estimated cost of possible mine liquidation presented by the authors is simple, understandable and easy to use in engineering and design projects.

The method can be used in initial estimation of costs of liquidated mining plants as a reference point for detailed analysis. This aspect requires more detailed research.

The assessment method of liquidation process proposed by the authors gives the same results when converted into the total cost of liquidation, the total cost of the process, the average cost of branch liquidation as well as converted into the maximum value of these costs. This compliance may prove the correctness of the method that was applied. The biggest disadvantage of this method is significant cost diversification in a particular group of branches. The diversification index indicates an enormous differentiation of the results which results from the huge variety of liquidated mines. During further research there will be need to propose an alternative method of classification of new group of branches so as to gain greater consistency of results in particular groups.

The assessment method of liquidation process described in this publication is based on analysis of the total cost of liquidation. The analysis of cost incurred in the process of liquidation for the next few years will require further research.

Another scientific problem that is not solved is the interaction between main processes and their interdependence.

References

1. Dźwigoł, H. (2007). *Model restrukturyzacji organizacyjnej przedsiębiorstwa górnictwa węgla kamiennego*. Warszawa: Difin.
2. Grajewski, P. (2012). *Procesowe zarządzanie organizacją*. Warszawa: PWE.
3. Jonek-Kowalska, I. (2013). Analiza i ocena kosztów w cyklu istnienia wyrobiska wybierkowego – wnioski dla rachunkowości zarządczej. *Scientific Papers of Silesian University of Technology, series: Organization and Management, vol. 66,* pp. 195-206.
4. Korski, J., Korski, W. (2015). Underground mine as a system of processes. *Mining – Informatics, Automation and Electrical Engineering, 2(522),* pp. 19-27.
5. Marek, J. (2006). Conditions and course of the liquidation process of hard coal mines. Studia Ekonomiczne, Zarządzanie strategiczne w przedsiębiorstwie, nr 37. Akademia Ekonomiczna w Katowicach, pp. 269-283.
6. Paszcza, H. (2010). Restructuring processes in the Polish hard coal mining industry in terms of the implemented changes and changes in the resource base. *Górnictwo i Inżynieria, nr 3,* pp. 62-82.

7. Przybyła, H., Chmiela, A. (2007). *Organizacja i ekonomika w projektowaniu wybierania węgla*. Gliwice: Wydawnictwo Politechniki Śląskiej.
8. Przybyła, H., Chmiela, A. (2002). *Technika i organizacja w robotach przygotowawczych*. Gliwice: Wydawnictwo Politechniki Śląskiej.
9. Riesgo Fernandez, P., Chmiela, A., Stanienda, K. (2003). The situation of coal mining in Spain after joining the European Union. *Scientific Papers of Silesian University of Technology, 1600, series: Mining, vol. 258.* Gliwice, pp. 291-301.
10. Riesgo Fernandez, P., Przybyła, H., Chmiela, A. Kołodziejczyk, P., Wesołowski, M. (2001a). Economic policy towards coal mining in Spain. Cz. 1. *Wiadomości Górnicze, nr 3*, pp. 118-123.
11. Riesgo Fernandez, P., Przybyła, H., Chmiela, A. Kołodziejczyk, P., Wesołowski, M. (2001b). Economic policy towards coal mining in Spain. Cz. 2.: *Wiadomości Górnicze, nr 4*, pp. 136-143.
12. Riesgo Fernandez, P., Przybyła, H., Chmiela, A., Kołodziejczyk, P., Wesołowski, M. (2000). Coal restructuring program in Spain. *Scientific Papers of Silesian University of Technology, 1480, series: Mining, vol. 246.* Gliwice, pp. 453-465.
13. Riesgo Fernandez, P., Wesołowski, M., Chmiela, A. (1997). Financing of mining investment projects in Spain with intensive capital expenditure. *Scientific Papers of Silesian University of Technology, 1378, series: Mining, vol. 236*, Gliwice, pp. 249-258.
14. Skrzypek, E., Hofman, M. (2010). *Zarządzanie procesami w przedsiębiorstwie*. Warszawa: Oficyna Wolters Kluwer business.
15. Smoliło, J., Chmiela, A. (2021). A liquidation of the mine in SRK S.A. in a processive approach. *Scientific Papers of Silesian University of Technology, series: Organization and Management*.
16. Turek, M. (2013). *Analiza i ocena kosztów w górnictwie węgla kamiennego w Polsce*. Warszawa: Difin.
17. Turek, M. (2013). *System zarządzania kosztami w kopalni węgla kamiennego w cyklu istnienia wyrobiska wybierkowego*. Warszawa: Difin.
18. Turek, M., Jonek-Kowalska, I. (2013). Contemporary cost accounting as an inspiration for the cost accounting in the life cycle of a mining excavation. *Scientific Papers of Silesian University of Technology, series: Organization and Management, vol. 66*, pp. 113-184.