SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

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

DYNAMICS OF BEARING OF COSTS IN PROCESSES LEADING TO REVITALIZATION OF MINE ASSETS IN SRK S.A.

Janusz SMOLIŁO[1], Andrzej CHMIELA[2*], Aleksander LUBOSZ[3], Paweł WRÓBLEWSKI[4]

[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
[3] Spółka Restrukturyzacji Kopalń S.A., Bytom; aleksander.lubosz@srk.com.pl, ORCID: 0000-0001-9461-924X
[4] Spółka Restrukturyzacji Kopalń S.A., Bytom; p.wroblewski@.srk.com.pl, ORCID: 0000-0001-8555-7171
* Correspondence author

Purpose: The restructuring of hard coal mines needs significant financial outlays. Carrying out the rationalization and minimization of the costs requires a complex scientific approach.
Design/methodology/approach: A statistical analysis of the liquidation processes in SRK S.A. on an annual basis was carried out as well as panel surveys and direct interviews with the Management Board of SRK S.A. and Directors of Branches.
Findings: The presented method of signalling of leaving the acceptable cost zone is a useful tool while implementing a process approach in the issue of the liquidation of the mine.
Research limitations/implications: The assessment method is based on the analysis of the total cost of liquidation. Further research will require the analysis of the connection between the structure and size of costs incurred in subsequent years of the liquidation processes.
Practical implications: The method can be used in the initial cost estimation of liquidated mining plants as a cost management tool.
Social implications: The method can be used as a comparison for a detailed analysis and a multi-criteria cost estimation of planned mining plants liquidation. After some modification, the methodology can also be applied by any entity carrying out the liquidation of mines.
Originality/value: The presented procedure may help to monitor incurred costs (rationalization and minimization of the costs). The tool can be useful in effective liquidation of mining plants.

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

1. Introduction

The Polish hard coal mining industry has been restructured since the beginning of the 1990s (Korski, Korski, 2015; Marek, 2006; Paszcza, 2010). Revitalization and restructuring activities are carried out mainly by Spółka Restrukturyzacji Kopalń S.A. The supervision and post – industrial property management of the liquidated mining plants are carried out by Coal Mines

in Liquidation Branches of SRK S.A. and the Housing Resource Administration is responsible for the management of non-industrial assets (apartments, garages, commercial premises, etc.). Besides, the Central Department of the Mine Dewatering Plant is responsible for the securing of neighbouring mines against flooding due to the pumping out water from sites of previously closed mines. SRK S.A. as the legal successor of restructured mining plants not only deals with the liquidation and securing of excavation gates and construction facilities but also copes with prevention of threats related to their liquidation. It is carried out by 8 branches of SRK S.A. (www.srk.com.pl).

The mine liquidation is the last stage of mining activity and the liquidation process itself is a natural stage of mining activity. The decision about the liquidation may be issued as a result of depletion of the resources of the exploited deposit, unprofitability of extraction, expiry of a concession or excessive environmental degradation (Duda, 2018, Wójcik, 2018). After the end of active mining exploitation, the abandoned mine infrastructure may be a problem for the former communities connected with mining industry. Based on the decisions of the European Union, it is possible to finance the hard coal mine liquidation from the state budget by the end of 2023.

2. Research Problem

The activity of the Management Board of SRK S.A. is to spend rationally obtained budget subsidy. The scientific research aimed at improving the rationalization and effectiveness of the processes of revitalization and restructuring mining plants is very scarce (Smoliło, Chmiela, 2021), although the average cost of mine liquidation may reach 300 million PLN. The available literature connected with mine liquidation refers only to general issues (Grajewski, 2012; Riesgo et al., 1997, 2000, 2001, 2003). Difficulties in improving the efficiency of processes of revitalization or mine liquidation may result from the lack of instruments supporting cost management. The presented publication is a continuation of research on the tools to support the cost management of liquidation processes. The proposed method of assessing the correctness of estimated costs on an annual basis may improve the efficiency of a mining enterprise that liquidates hard coal mines (Brilman, 2002; Dźwigoł, 2007; Grajewski, 2012; Smoliło, Chmiela, 2021; Skrzypek, Hofman, 2010).

3. Research methods

The aim of the research was to develop and propose another tool to access the course of liquidation process in the case of assessing the estimated costs on an annual basis. An additional aim of the research was to identify research areas and problems related to the rationalization and effectiveness of the restructuring processes, the revitalization processes and mining plants liquidation processes. The aim was achieved in two stages (Table 1). The research plan was implemented on the basis of updated liquidation programs of seventeen 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 2019 presents incurred costs and the period from 2020 to 2023 shows planned costs.

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

Research stage	Research Methods	Results of the use of research methods
I	- Study of literature - Analysis - Synthesis - Panel studies - Direct interview	- A statistical analysis of the researched liquidation process - Preparation of the data form - Proposition of an evaluation method - Indication of research areas and problems
II	- Face-to-face interview - Analysis - Synthesis	- A verification of correctness of operations of the assessment method - Modification of the assessment method of the course of liquidation processes - An identification of research areas and problems that need to be solved

Source: An own study.

In the first stage, the available literature referring to the management of processes was analysed and compared with SRK S.A. experience connected with restructuring post- mining assets. The results of analysis made it possible to propose the idea of a method of managing the costs of the processes of releasing industrial areas from unnecessary infrastructure. During this stage, a direct interview with experts was conducted concerning technical aspects related to the correctness of the course of individual processes in following years. The cause of larger deviations from the average values was clarified on an ongoing basis. The course of the process was presented in Figure 1. The preliminary cost estimation method was used in the second stage of the research.

In the second stage, the basic statistical analysis of the mining plants restructuring processes in SRK S.A. was carried out in the case of years of their course. Any ambiguities were consulted with experts. The correct operation of the proposed tool for assessing the cost structure of liquidation processes was carried out on the basis of hypothetical new branches of SRK S.A. As expected, the research revealed new areas and research problems that need to be solved.

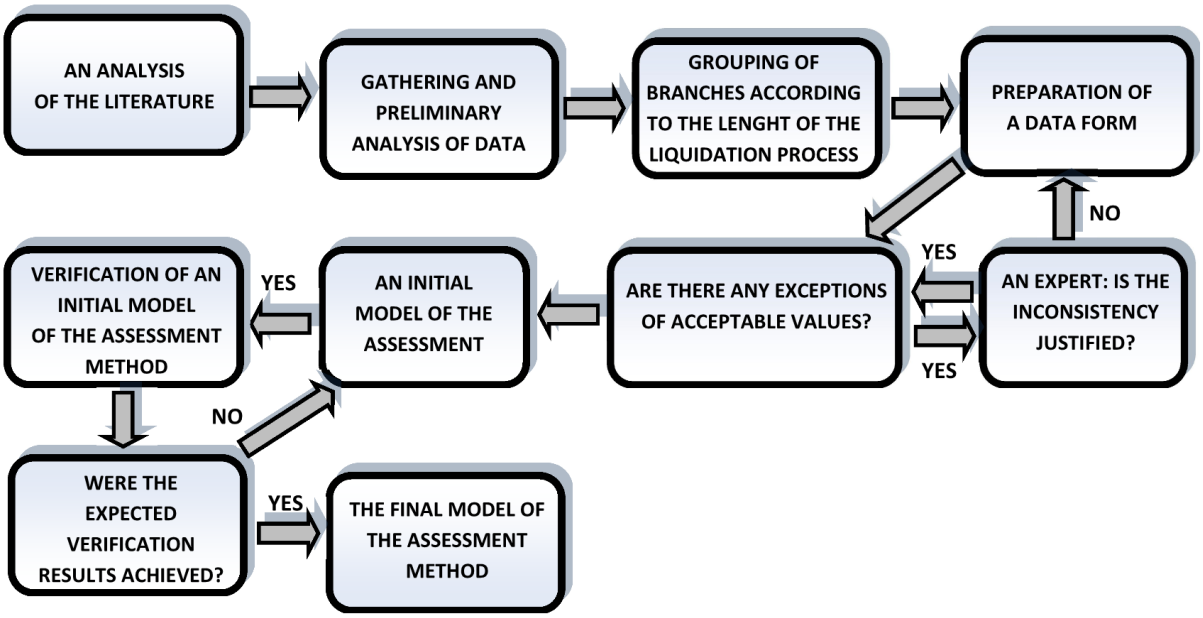

Figure 1. A research method. Source: An own study.

4. Findings

The research was carried out on the basis of updated mine liquidation programs currently conducted in SRK S.A. and on the basis of data of previously performed processes and activities. Restructuring in SRK S.A. is divided into ten component processes (Table 2). According to the updated liquidation programs, they should be completed by the end of 2023. Figure 2 shows the schedule of liquidation process with an unscaled timeline.

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 neighbouring 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.

A statistical analysis of six mining plants was carried out where the liquidation processes have already been fully completed. Moreover, the statistical analysis of a group of eleven mines currently being liquidated by 8 Branches of SRK S.A. (www.srk.com.pl) was carried out. Due to the inflation and incomparability of costs in different years, a proprietary correction coefficient (based on the data of the Central Statistical Office) was used to convert costs into the realities of the end of 2020. All costs were given as a percentage of the total liquidation costs.

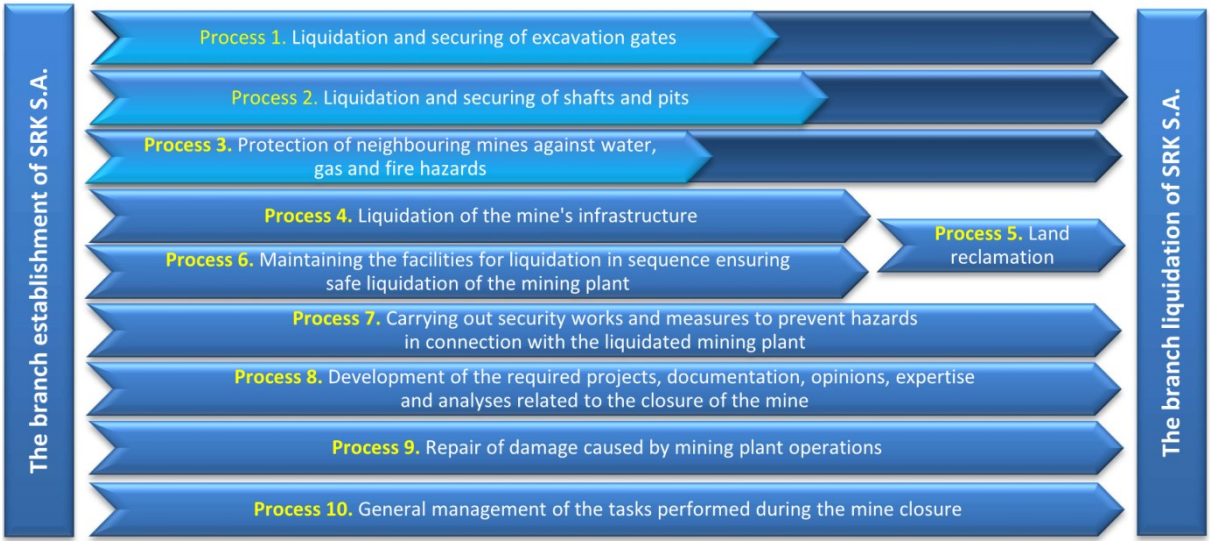

Figure 2. The schedule of the liquidation process. Source: Data from SRK S.A.

SRK S.A. liquidates mining plants in average of less than 5 years. The average cost of liquidation of the branch is 5,88% of the total liquidation cost, while in real this value ranges from 0,32% to 16%. The liquidation of a mine is an individual case which results in different lengths of their liquidation and the cost of their liquidation itself. The shortest liquidation time is 2 years and the longest liquidation time is 8 years. This dependence may change due to COVID-19 and it should be assumed that because of that fact the liquidation processes may last longer. Each subsequent year of extension of liquidation process of the statistical mining plant increases expenditures to about 1,2% of the total costs of liquidation.

Table 3.
The number of liquidated mining plants depending on the length of the liquidation process

Liquidation time	The average cost of branch liquidation	The maximum cost of branch liquidation	The minimum cost of branch liquidation	The total cost of liquidation of branches	Number of cases
8 years	11,37%	10,33%	10,33%	10,33%	1
7 years	12,53%	16,12%	8,93%	25,06%	2
6 years	8,63%	12,73%	6,18%	25,88%	3
5 years	4,86%	9,95%	1,62%	14,57%	3
4 years	3,25%	5,89%	0,32%	19,49%	6
3 years	2,36%	2,79%	2,79%	2,79%	1
2 years	2,31%	1,88%	1,88%	1,88%	1

Source: An own study.

Certain regularities can be found in such a diverse 'population'. The differences between the liquidation time and the associated costs most often result from the size of the task. The length of liquidation processes and their costs usually depend on the amount, size and type of liquidated facilities. Due to the length of the liquidation process the restructured branches have been divided into seven reference groups. The most numerous and the most diverse group is the group of mines liquidated for 4 years. This range includes both small and medium-sized mines. Due to the operational conditions of the neighbouring mines the liquidation time of a part of analysed branches was extended. From the point of view of the technical liquidation, the smallest units could be liquidated earlier and could increase the amount of mines liquidated for 2 or 3 years. It is similar with the example of the mine that has been liquidated for 8 years. In this case also the operational considerations of the neighbouring active mine lengthened artificially the restructuring process.

In the groups of mines liquidated for 4, 5, 6 and 7 years there are at least two similar cases and it is possible to obtain an average value. On the other hand, in the case of mines liquidated for 2, 3 and 8 years only one case can be statistically analysed. Due to the similarities between the neighbouring groups, the average value of the costs of mines population liquidated for 8 years was determined as the weighted average value with the group of mines liquidated for 7 years, giving this group a weight of 0,9. The same was done with mines liquidated for 2 and 3 years. In these cases, the second group was the reference point for the analysed group. When calculating the weighted average of the cost of mines liquidated for 2 years it was given a weight of 1 and when calculating the weighted average of the cost of mines liquidated for 3 years it was given a weight of 0.9. Similarly the average value of the cost of mines liquidated for 3 years obtained as the weighted average of the liquidation cost of this mine with a weight of 1 and for the mines liquidated for 2 years with a weight of 0.9.

Table 4.
Total restructuring costs on an annual basis

Process costs	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	SUM
Process 1	0,30%	0,37%	0,30%	0,11%	0,08%	0,11%	0,03%	0,02%	1,3%
Process 2	0,03%	1,04%	0,71%	1,99%	0,45%	0,33%	0,00%	0,06%	4,6%
Process 3	0,00%	0,00%	0,56%	1,71%	2,71%	2,32%	0,29%	0,00%	7,6%
Process 4	0,13%	0,54%	0,88%	1,71%	1,25%	0,57%	0,01%	0,07%	5,2%
Process 5	0,00%	0,04%	0,33%	1,34%	0,52%	0,16%	0,34%	0,03%	2,7%
Process 6	6,74%	5,15%	3,20%	1,82%	1,09%	0,52%	0,07%	0,07%	18,7%
Process 7	4,94%	6,35%	6,32%	5,74%	4,72%	4,07%	2,27%	1,10%	35,5%
Process 8	0,17%	0,22%	0,16%	0,16%	0,10%	0,06%	0,00%	0,00%	0,9%
Process 9	0,83%	1,50%	1,64%	2,79%	0,60%	0,20%	0,06%	0,03%	7,7%
Process 10	3,79%	3,48%	3,09%	2,59%	1,59%	0,91%	0,35%	0,11%	15,9%
SUM of costs	16,93%	18,69%	17,18%	19,95%	13,11%	9,24%	3,43%	1,48%	100%
Liquidation costs (Processes 1, 2, 4)	0,45%	1,96%	1,89%	3,80%	1,78%	1,00%	0,05%	0,15%	11,09%

Source: An own study.

The total costs of liquidation processes on an annual basis are presented in Table 4. Only 11,1% of the budget subsidy is allocated to the processes of physical liquidation of underground and surface facilities (Processes 1, 2 and 4). The remaining 89% of the total cost of liquidation is related to ensure the correct course of these liquidation processes. In the mining plant liquidation processes, potential optimization and rationalization opportunities can be considered. About 5 billion PLN is spent from the budget on liquidation of unnecessary hard coal mines production facilities. This amount results only from the liquidation of seventeen analysed mining plants. Each percentage reduction in the liquidation cost can result in measurable savings. The most obvious factor in reducing expenses is the intensification of liquidation processes and shortening liquidation time. Due to the correct sequence of the liquidation of facilities it may not be possible. Nevertheless it should be taken into account that only the part of expenses results from the passage of time.

Processes carried out by SRK S.A. are complex and their size is caused by numerous factors. Only the most important components of individual processes were indicated in the analysis. Any estimation of future liquidation costs must also take into account other cost components.

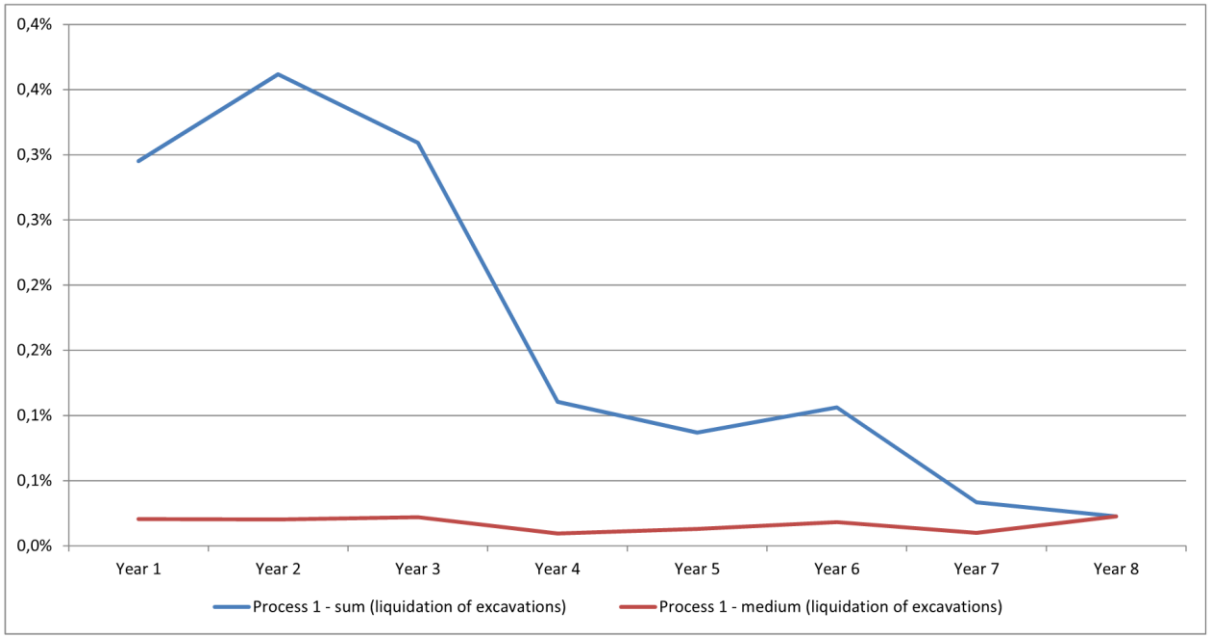

Figure 3. Process 1 – Liquidation and securing of excavation gates. Source: An own study.

Process 1 – Liquidation and securing of excavation gates consumes about 1,32% of the total costs, with the average value for a branch that is 0,08% (Figure 3). The cost of this process depends on the number of sidings in the ventilation network and natural hazards (mainly methane hazard) which increases costs because of the need to use explosion – proof insulation structures there. According to predictions, the total outlays incurred in this process in the following years are decreasing due to the earlier ending of the liquidation of smaller mining plants. In the first year, lower outlays may result from the need to develop expert opinions on the necessary changes of the ventilation networks. The cost of carrying out this process for individual branches ranges from 1,1% to 1,8%.

Process 2 – Liquidation and securing of shafts and pits (Figure 4) is approximately 4,61% of the total liquidation costs and approximately 0,27% on average. According to experts' opinions, the amount of this cost is a derivative of the number of shafts, their length and diameter, the occurring hazards and the number of available levels. This process is usually slightly delayed in relation to Process 1 and should be completed after its completion, because the entire underground infrastructure of the mine is liquidated using these shafts. Statistically, the auxiliary shafts are liquidated in the second year and the main shafts are liquidated in the penultimate year. The average time of branch liquidation is around 5 years, so it should not be surprising that the expenditures will increase in the fourth year of liquidation. The average value of a branch does not exceed 0,1% of costs per year.

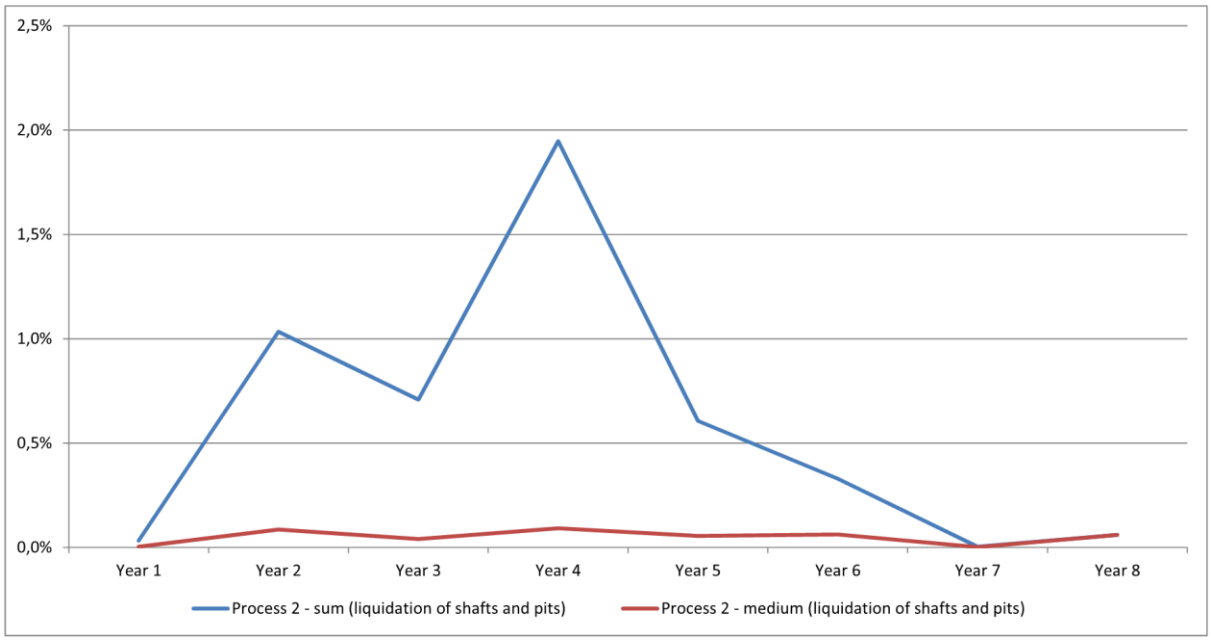

Figure 4. Process 2 – Liquidation and securing of shafts and pits. Source: An own study.

The cost of protection of neighbouring mines (Process 3) depends on the shape of the deposit and the decisive factor of the necessity to conduct this process is securing neighbouring mines against water hazards (Figure 5). SRK S.A. allocates 7,59% of liquidation costs to carry out this process, the most in fifth year (the average time of the branch existence is approximately 5 years). In this case, it is hard to interpret the mean value. Part of the branches of SRK S.A. secures neighbouring mines and some of them do not which results from the target mine model. Additionally, if there are already activities in this process, they are usually carried out in the last years of the branch existence. The average value of 0,2% is calculated only for the branches that incur costs in this case.

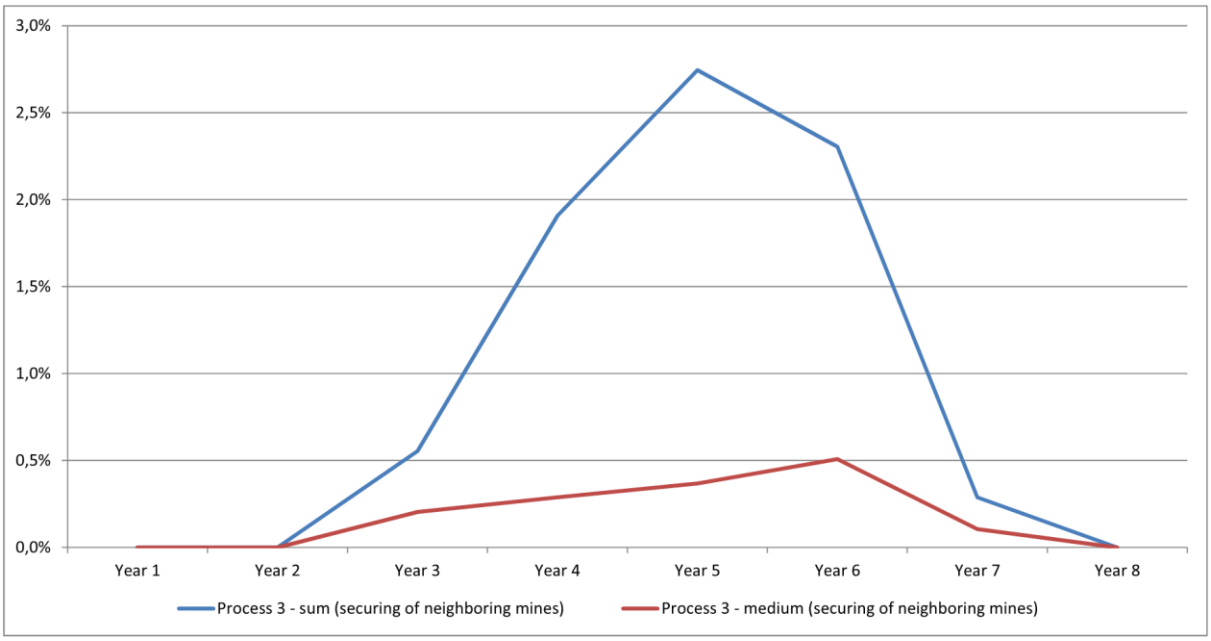

Figure 5. Process 3 – Protection of neighbouring mines against water, gas and fire hazards. Source: An own study.

Process 4 – Liquidation of the mine's infrastructure reaches its maximum values in the fourth or fifth year of the branch liquidation (Figure 6). As in the previous processes, it is related to the statistical size of the mining plant. 5,16% of the total budget subsidy is allocated to this process. The average value fluctuates around 0,06%. In the years from 1 to 3, lower values result from the size of liquidated branches. During this period, the population of small branches with low liquidation costs is included in the average value. Experts' opinions indicate that the cost of this process results from the amount of objects, their structure and cubature. Small branches liquidate similar objects as large ones, however they are smaller objects with a lower liquidation cost.

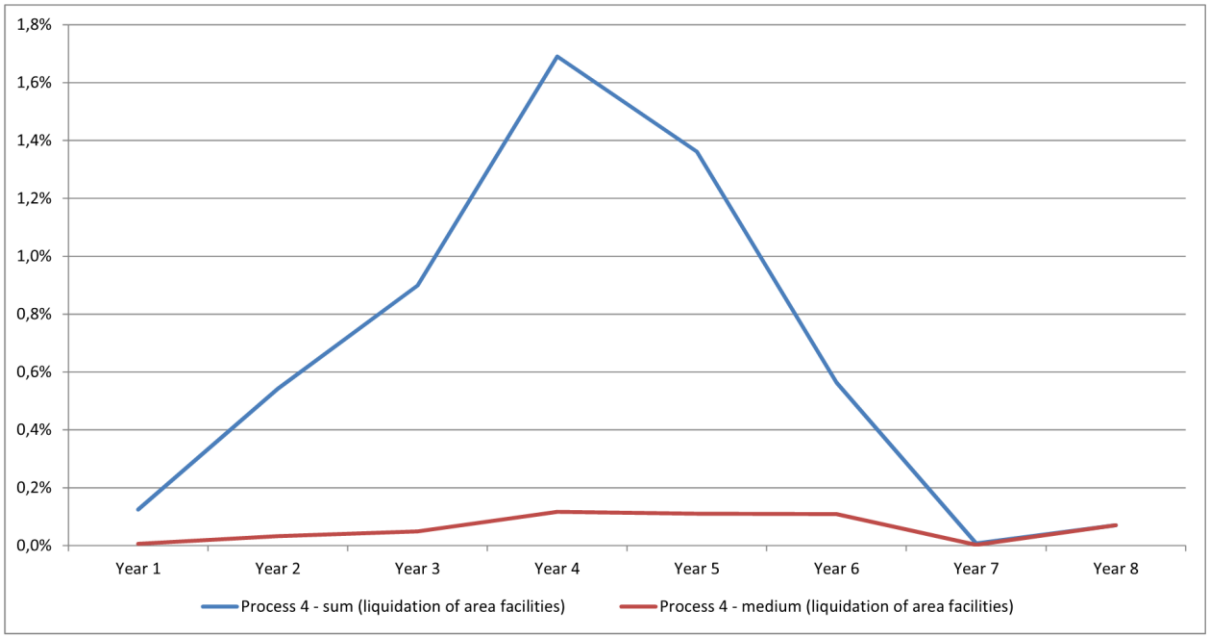

Figure 6. Process 4 – Liquidation of the mine's infrastructure. Source: An own study.

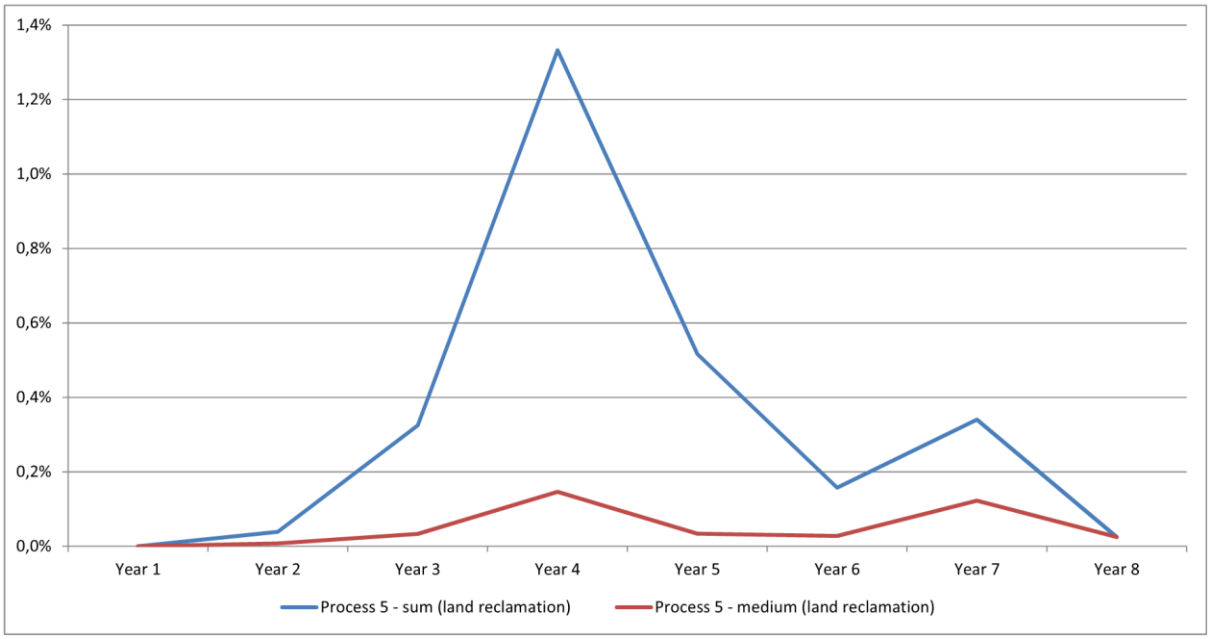

Figure 7. Process 5 – Land reclamation. Source: An own study.

The decisive factor influencing the amount of expenditures on the Process 5 (land reclamation) is the area requiring clearance and reclamation. SRK S.A. spends 2,75% of costs on this process and similarly to the previous cases, the highest values occur in the fourth and fifth year of its processes (Figure 7). Usually, the reclamation process begins in the last years of liquidation, after the completion of Processes 4 and 6. As in the case of Process 3, the mean value is difficult to estimate. For branches carrying out reclamation it is 0,05%. For branches liquidating a part of a mining plant located in the main area of another active mine, reclamation is usually not carried out and no costs are incurred in this regard.

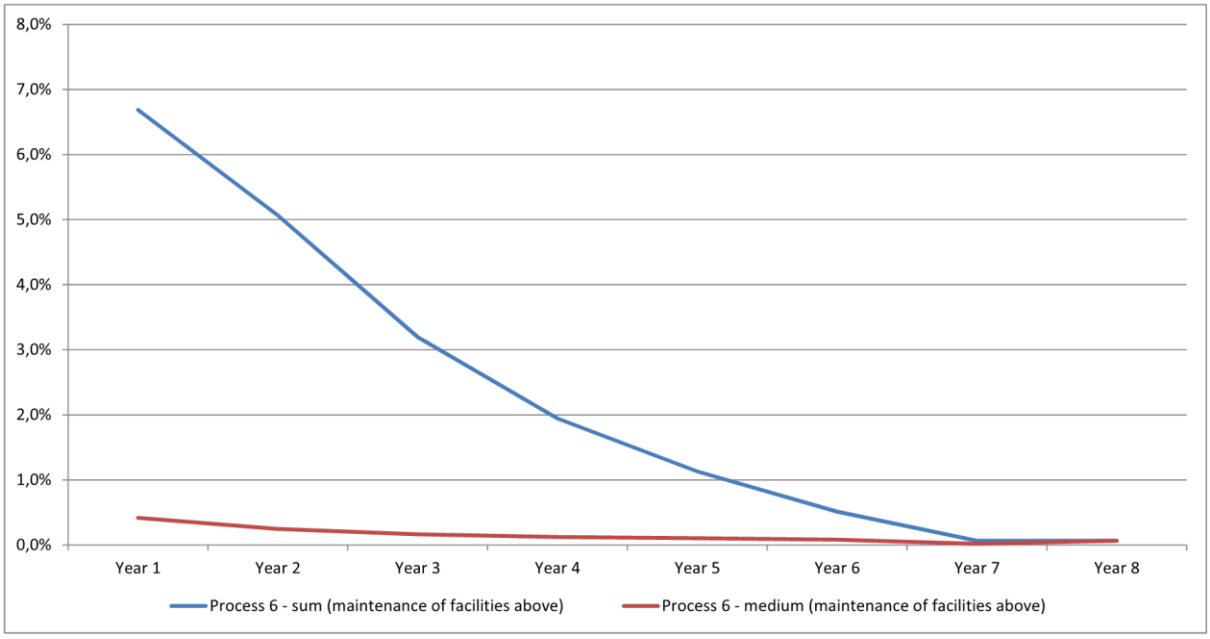

Figure 8. Process 6 – Maintaining the facilities for liquidation in sequence ensuring safe liquidation of the mining plant. Source: An own study.

Process 6 – maintaining the facilities for liquidation in sequence ensuring safe liquidation of the mining plant (Figure 8) is the second largest of the amount of financial outlays for implementation. Similarly to Process 4, it grows proportionally to the size of the liquidated branch and decreases on an annual basis with the decreasing number of maintained facilities. This task ends before the beginning of the reclamation process and consumes 18,65% of the total liquidation cost (1,1% on average per a branch). The duration of the maintenance of facilities, their amount, structure and cubature have an influence on outlays. The largest components are expenditures on the maintenance of the tops of liquidated shafts – about 40% of this process, the maintenance of surface facilities – about 27% of this process and the maintenance of power networks – about 14% of this process. SRK S.A. has a potential impact only on the possibility of intensifying the liquidation processes and optimization can be carried out in this case. However, the length of technological processes and the associated minimum liquidation time may prevent such activities.

Process 7 – carrying out security works and measures to prevent hazards in connection with the liquidated mining plant (Figure 9) is the most capital – intensive process. SRK S.A. allocates about 35,49% of the total costs to this process (0,61% on average per a branch). Experts pointed out that thelargest impact on this costs is the broadly understood size of the mining plant, that is the amount and area of facilities that require protection and supervision. The intensification of liquidation would limit the expenditures on this process. The largest components of this process are the costs of the maintenance of shafts and excavation gates – about 40% of costs and the supervision of the works performed – about 20%of costs. On an annual basis, the cost is gradually decreasing according to the decrease in the number of objects. On the other hand, in the case of the mean value it increases with the passage of time. According to the calculations about the time lapse of this value, it eliminates small branches and in the following years the average value is calculated from large branches with higher liquidation costs. The group of branches liquidated for 6, 7 and 8 years includes all large and very large branches.

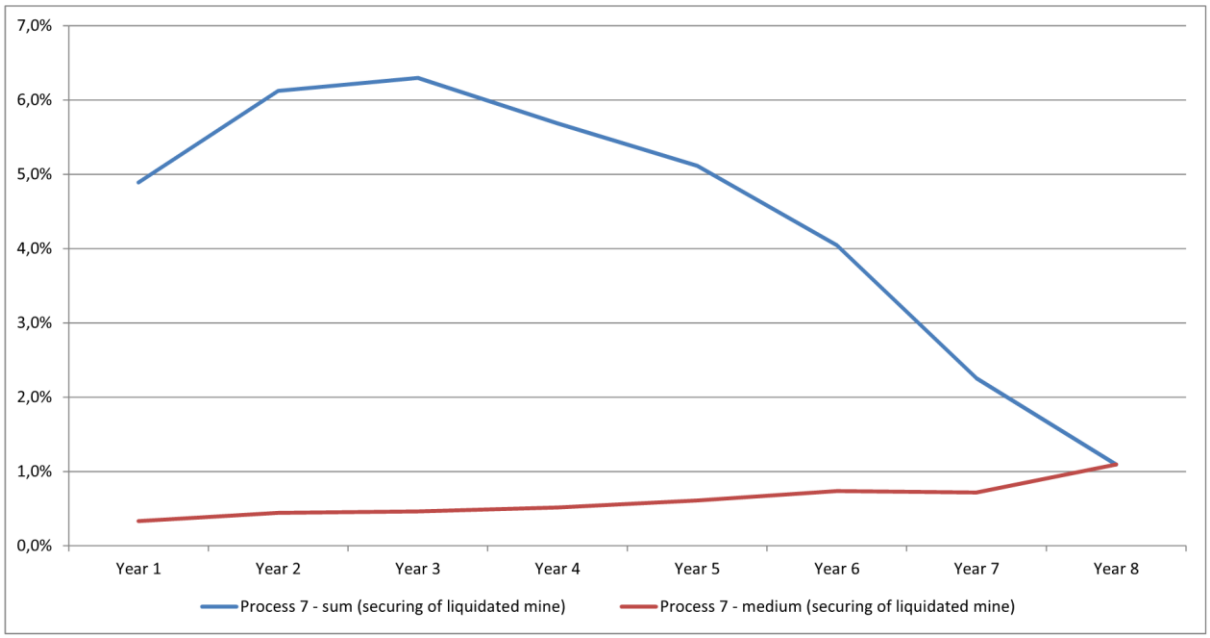

Figure 9. Process 7 – Carrying out security works and measures to prevent hazards in connection with the liquidated mining plant. Source: An own study.

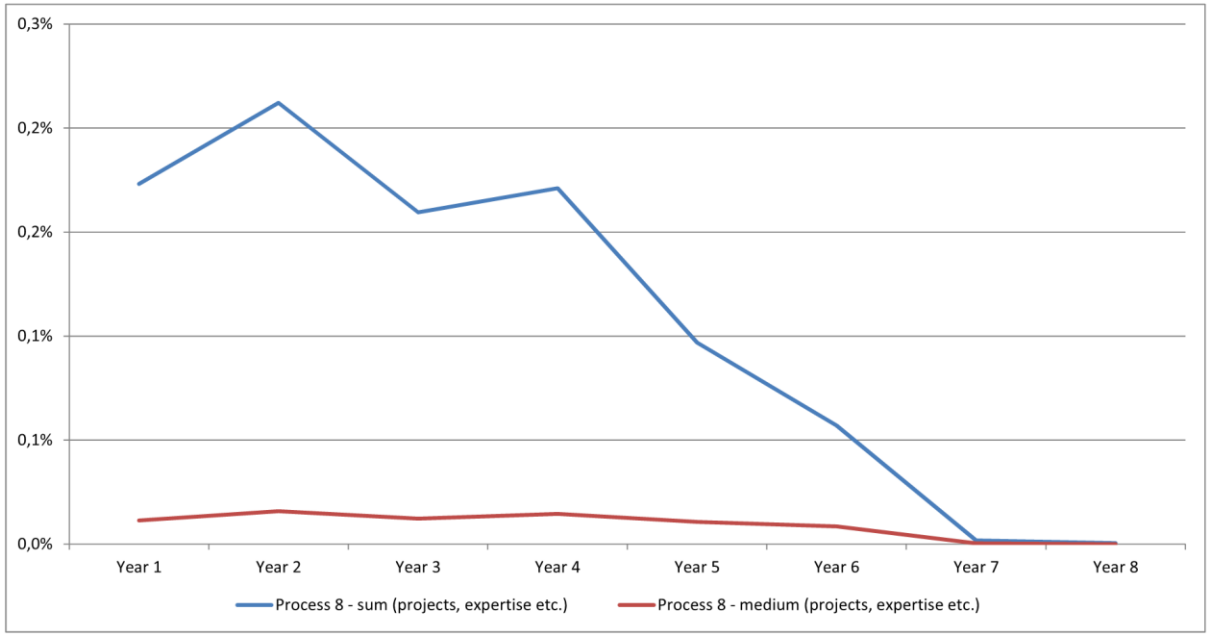

Figure 10. Process 8 – Development of the required projects, documentation, opinions, expertise and analyses related to the closure of the mine. Source: An own study.

0,86% of the total costs are spent on Process 8 and it is 0,01% on average per a branch (Figure 10). External entities are commissioned to carry out projects, expert opinions or analysis required by the regulations, which is the part of this task. Due to the thematic diversity of executive orders, it is not possible to identify the most important cost component. The statistical analysis shows that the costs increase with the size of the branch. The sum value and the average value tend to decrease with the matter of time. The number of commissioned experts opinions results from separate regulations, so the rationalization and optimization of costs may only rely on the price negotiations of individual orders.

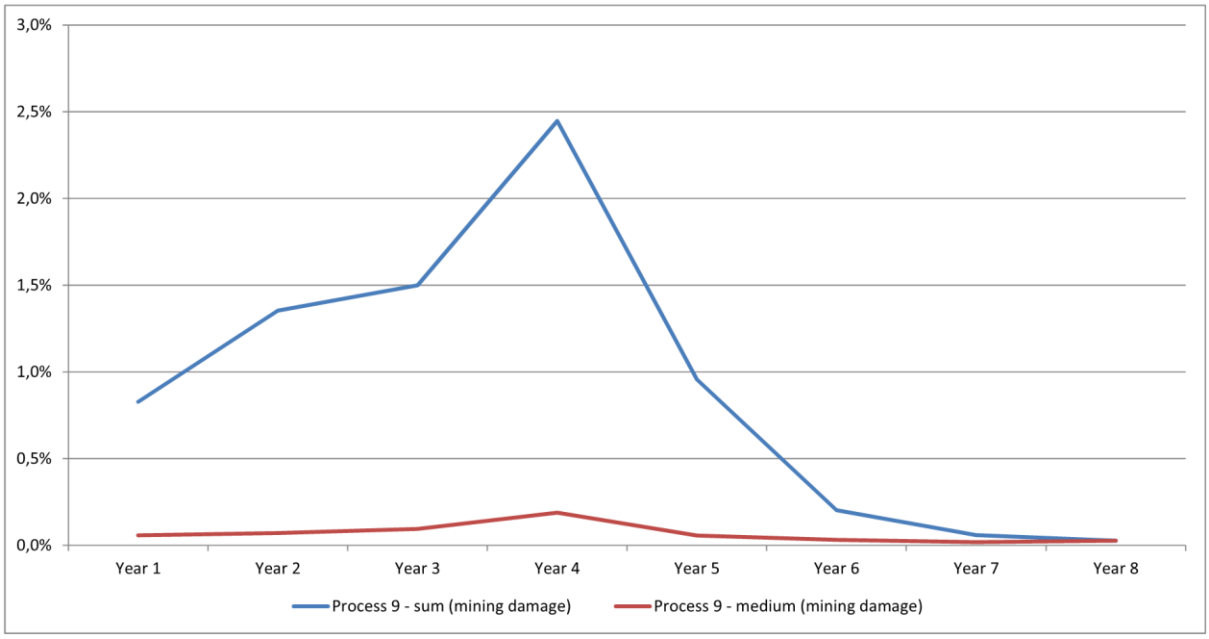

Figure 11. Process 9 – Repair of damage caused by mining plant operations. Source: An own study.

Due to the legal consequences of previous mining activities, the Management Board has no major influence on the costs incurred in Process 9 – repair of damage caused by mining plant operations. Pro – effective activities can only rely on rational and timely payment of compensation. According to the experts' opinions, the amount of the cost is related to the projected area of influence on exploitation conducted in the period of 5 years preceding the end of production (Figure 11). 7,66% of the total expenditures are allocated to the payment of mining damages and it is 0,07% on average per a branch. The average value is also calculated only for the branches that incur costs in this matter. Some branches do not bear any costs because when liquidating a part of mining plant it is usually taken over without the deposit and SRK S.A. is not a legal successor to the previous mining operations. When analysing the annual system, the increase in the total costs in the fourth year can be noticed. The increase in costs results from the simultaneous acquisition of several mines with mining areas and a temporary increase in the number of claims for damages. When analysing the individual branches, the cost of this process is more or less constant over the entire period of the branch existence.

After Process 7 and 6, Process 10 – general management of the tasks performed during the mine closure is the next most capital intensive process. 15,91% of the total expenditures are allocated to this process and it is 0,19% on average per a branch. The cost of this process increases with the size of the branch. The largest components of this process are salaries – about 38%, employee claims – about 27% and taxes and fees – about 19%. On an annual basis, the amount of the total and average cost decreases over time, while the analysis of branches shows that the cost is virtually unchanged throughout the existence of the branch. A potential place for savings could be outsourcing more operations while reducing employment.

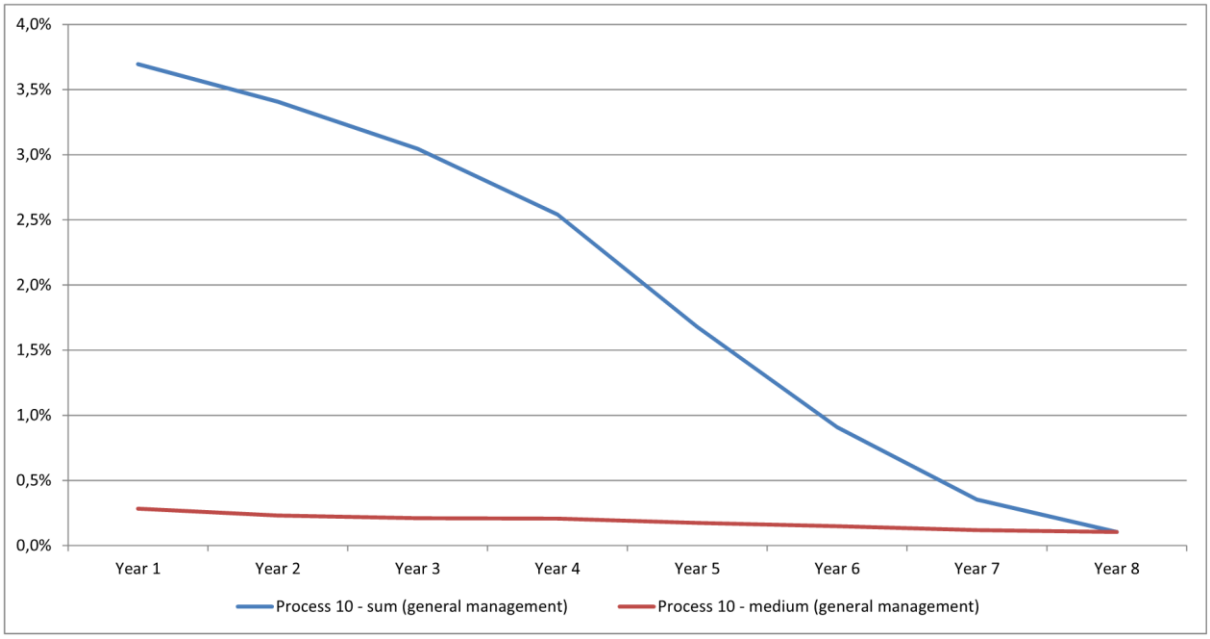

Figure 12. Process 10 – General management of the tasks performed during the mine closure. Source: An own study.

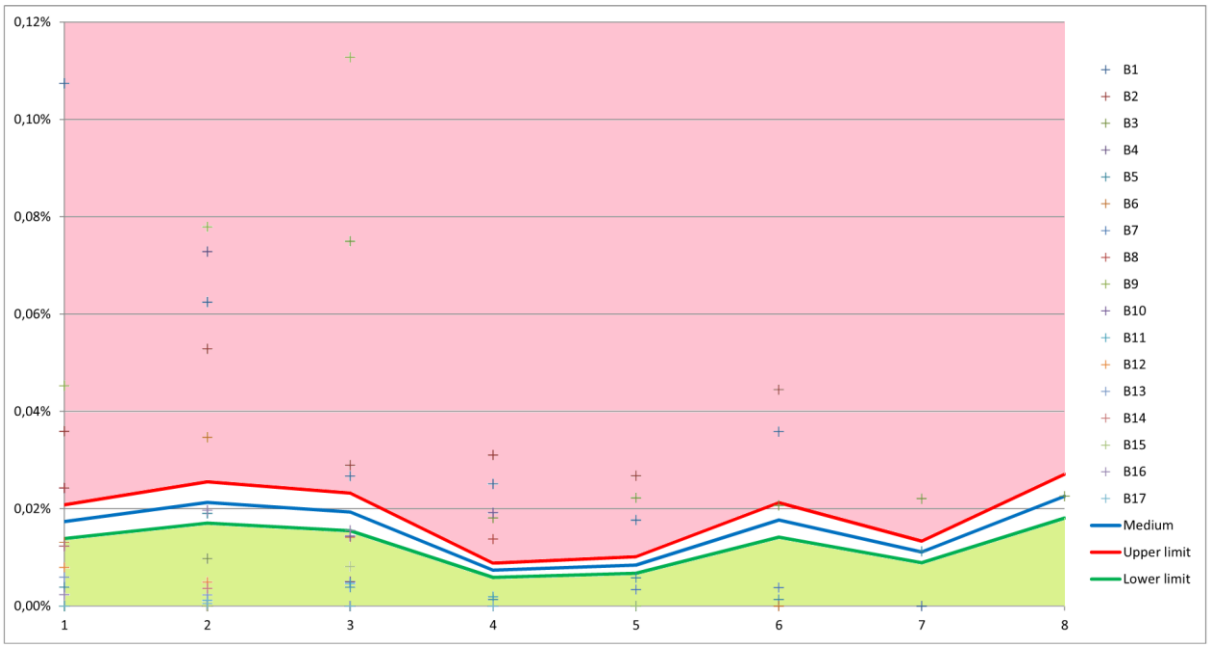

Figure 13. The idea of assessment method of cost structure on an annual basis on the example of Process 1. Source: An own study.

Tools that assess the amount and structure of capital expenditures for individual tasks are useful for proper supervision of the cost of restructured mines. The interviews with the Management Board and Directors of Branches carried out during the research explained most of the technical doubts and performed liquidation processes that can be considered as properly carried out and treated as comparative example for the development of a method for assessing the cost of mining plants liquidation. Figure 13 presents the idea of assessment method of cost structure on an annual basis on the example of Process 1 in all analysed liquidation examples. The proposed method signals that the analysed value of the mine liquidation cost is leaving the

zone of acceptable values. Most of the costs differ from the average value, therefore the zone of acceptable values has been determined (Figure 13 – the field between the green and red lines). The zone of acceptable values is the average value of the processes that have been carried out so far, in division into individual processes and subsequent years of the procedure. The zone is defined by the user who determines the size of the coefficient of variation for each of the component processes and for the total cost. The mean value reduced and increased by the standard deviation calculated for this value of the coefficient of variation determines the lower and upper limits of the acceptable zone (Figure 13). The publication assumes that the acceptable deviation will be at the level of 15%, which corresponds to a high compliance population. When the entered costs exceed the upper limit of the acceptable value, the field turns into red and the digits turn into brown. When the costs is below the lower limit of the acceptable zone, the field and the digits turn into green. Additionally, the yellow colour indicates that no costs are incurred in a given process. Signalling of leaving the acceptable zone is only information for the designer as it may result from the specific nature of liquidated branch. In order to find the values the most distant from the optimal value (the average resulting from the experience of SRK S.A.), the user may increase the value of the coefficient of variation and the software will immediately eliminate the signalling of deviations that are less different from the average value. The analysis of branches is carried out in groups corresponding to the period of their existence so as to increase the compliance of the calculations with reality.

The method was verified in two stages. In the first stage, the correctness of the method was tested, on the basis of four hypothetical branches called B18, B19, B20 and B21. Branch B18 is a branch with estimated liquidation costs equal to the average value. Branch B19 is a branch with the highset component costs for all analysed 17 mining plants that have been liquidated since 2015, without any division into reference groups. Branch B20 is a branch with costs equal to the average costs for the group of branches liquidated for 4 years (this is the largest group of six examples). The last of the hypothetical branches is Branch 21 and its liquidation costs were assumed as random values. In practice, the costs of liquidated branch for 2 years were entered three times in the data table, resulting the branch liquidated for 6 years. The cost structure of this branch is very unusual.

Table 5.
An analysis of liquidation costs of Branch B18

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	SUM
Process 1	0,02%	0,02%	0,02%	0,01%	0,01%	0,03%	0,02%	0,02%	0,15%
Process 2	0,00%	0,06%	0,04%	0,20%	0,06%	0,08%	0,00%	0,06%	0,52%
Process 3	0,00%	0,00%	0,03%	0,17%	0,39%	0,58%	0,14%	0,00%	1,32%
Process 4	0,01%	0,03%	0,05%	0,17%	0,18%	0,14%	0,00%	0,07%	0,66%
Process 5	0,00%	0,00%	0,02%	0,13%	0,07%	0,04%	0,17%	0,03%	0,47%
Process 6	0,40%	0,30%	0,20%	0,18%	0,16%	0,13%	0,03%	0,07%	1,47%
Process 7	0,29%	0,37%	0,40%	0,57%	0,67%	1,02%	1,13%	1,10%	5,56%
Process 8	0,01%	0,01%	0,01%	0,02%	0,01%	0,01%	0,00%	0,00%	0,08%
Process 9	0,05%	0,09%	0,10%	0,28%	0,09%	0,05%	0,03%	0,03%	0,71%
Process 10	0,22%	0,20%	0,19%	0,26%	0,23%	0,23%	0,18%	0,11%	1,62%
SUM	1,00%	1,10%	1,07%	2,00%	1,87%	2,31%	1,71%	1,48%	12,54%

Source: An own study.

According to expectations, in the case of Branch B18 the method showed that both the lower and upper limits of the acceptable zone were exceeded (Table 5). Due to the total liquidation cost which is 12,54%, this branch should be classified as a large branch. The amount of the total costs was influenced by the long duration of the process and the method of calculating the average. The average was calculated only for the branches incurring costs in each of the component processes (the average without zero). For this reason, most exceeded the upper limit. The lack of exceedances in the eighth year of liquidation results from the method of estimating the average value, which is the weighted average of one liquidation example over 8 years and the average for the group liquidated over 7 years. The calculated average value is a model for calculations which cannot signal any deviations.

The case of Branch B19 with the highest costs incurred by SRK S.A. so far caused the signalling that the upper limit of acceptable values was exceeded in almost all processes and years, except from the eighth year of liquidation (Table 6). It results from the similar factors as in the case of Branch B18 (long liquidation time and the method of calculating the average). Such a reaction was expected, as the cost of liquidating such a branch equal to 28,23% is approaching to the amount of approximately 2 billion PLN.

Table 6.
An analysis of liquidation costs of Branch B19

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	SUM
Process 1	0,11%	0,08%	0,11%	0,03%	0,03%	0,04%	0,02%	0,02%	0,45%
Process 2	0,02%	0,34%	0,13%	0,95%	0,44%	0,16%	0,00%	0,06%	2,11%
Process 3	0,00%	0,00%	0,48%	0,88%	1,37%	1,85%	0,20%	0,00%	4,78%
Process 4	0,05%	0,20%	0,24%	0,58%	0,43%	0,18%	0,01%	0,07%	1,75%
Process 5	0,00%	0,04%	0,30%	0,52%	0,49%	0,08%	0,32%	0,03%	1,77%
Process 6	0,97%	0,72%	0,60%	0,45%	0,22%	0,15%	0,06%	0,07%	3,24%
Process 7	0,90%	1,33%	1,25%	1,06%	1,13%	1,04%	1,10%	1,10%	8,91%
Process 8	0,03%	0,04%	0,03%	0,06%	0,04%	0,03%	0,00%	0,00%	0,22%
Process 9	0,20%	0,42%	0,44%	1,04%	0,19%	0,10%	0,03%	0,03%	2,46%
Process 10	0,68%	0,36%	0,39%	0,35%	0,27%	0,25%	0,15%	0,11%	2,55%
SUM	2,95%	3,52%	3,98%	5,93%	4,60%	3,88%	1,90%	1,48%	28,23%

Source: An own study.

The cost analysis of Branch B20 also resulted in the expected reaction of the method to the case of the reference object. The software only coloured yellow fields with zero values, signalling no costs in Processes 3 and 5 and remaining fields were without the method's response (Table 7). Due to the amount of the liquidation cost (3,25%), this branch can be classified as small branches.

Table 7.
An analysis of liquidation costs of Branch B20

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	SUM
Process 1	0,01%	0,02%	0,02%	0,00%	0,00%	0,00%	0,00%	0,00%	0,06%
Process 2	0,00%	0,09%	0,04%	0,24%	0,00%	0,00%	0,00%	0,00%	0,37%
Process 3	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Process 4	0,01%	0,02%	0,03%	0,07%	0,00%	0,00%	0,00%	0,00%	0,13%
Process 5	0,00%	0,01%	0,05%	0,14%	0,00%	0,00%	0,00%	0,00%	0,19%
Process 6	0,27%	0,36%	0,18%	0,05%	0,00%	0,00%	0,00%	0,00%	0,85%
Process 7	0,15%	0,21%	0,19%	0,14%	0,00%	0,00%	0,00%	0,00%	0,70%
Process 8	0,01%	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,02%
Process 9	0,05%	0,15%	0,10%	0,21%	0,00%	0,00%	0,00%	0,00%	0,51%
Process 10	0,11%	0,11%	0,09%	0,08%	0,00%	0,00%	0,00%	0,00%	0,40%
SUM	0,62%	0,98%	0,70%	0,94%	0,00%	0,00%	0,00%	0,00%	3,25%

Source: An own study.

Last but not the least analysed hypothetical Branch B21 was the most difficult case for the cost assessment method (Table 8). Due to the liquidation costs (5,63%) this branch is classified to a medium- sized branches and is characterised by an unstable and chaotic cost structure. In this case, the method also worked properly and signalling the deviations from the average value is consistent with the opinion of experts.

Table 8.
An analysis of liquidation costs of Branch B21

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	SUM
Process 1	0,01%	0,00%	0,01%	0,00%	0,01%	0,00%	0,00%	0,00%	0,05%
Process 2	0,00%	0,10%	0,00%	0,10%	0,00%	0,10%	0,00%	0,00%	0,30%
Process 3	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Process 4	0,00%	0,03%	0,00%	0,03%	0,00%	0,03%	0,00%	0,00%	0,10%
Process 5	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Process 6	0,33%	0,09%	0,33%	0,09%	0,33%	0,09%	0,00%	0,00%	1,25%
Process 7	0,19%	0,20%	0,19%	0,20%	0,19%	0,20%	0,00%	0,00%	1,14%
Process 8	0,02%	0,00%	0,02%	0,00%	0,02%	0,00%	0,00%	0,00%	0,06%
Process 9	0,13%	0,11%	0,13%	0,11%	0,13%	0,11%	0,00%	0,00%	0,70%
Process 10	0,40%	0,27%	0,40%	0,27%	0,40%	0,27%	0,00%	0,00%	2,03%
SUM	1,07%	0,80%	1,07%	0,80%	1,07%	0,80%	0,00%	0,00%	5,63%

Source: An own study.

In the second stage of the verification, that hypothetical examples were presented to the Directors of the Branches of SRK S.A. so as to evaluate. The experts agreed with the conclusions of the method and approved the correctness of its operation. At this stage, suggestions for further research in this area appeared and indicated areas and research problems the need to be solved were pointed out.

5. Conclusions

The proposed method of assessing the estimated costs of liquidated mining plants on an annual basis can be used as a reference point for cost estimation with the possible takeover of further branches. After some modifications of the structure of component processes (developed by Spółka Restrukturyzacji Kopalń S.A.) the proposed method may be applied by another mine enterprise.

The presented tool may be one of the components of increasing the effectiveness of mining plants liquidation. The procedure may help the Management Board to rationalize and minimize the costs incurred.

The described methodology is based on a statistical analysis of the cost of liquidation process divided into subsequent years of liquidation processes. Further research will require the connection between the structure of incurred costs with the size of the branch in a matter of time. In the group of liquidated branches for 4 years there are small, medium and very small branches which may lead to incorrect results. The total cost of the branch with the highest liquidation cost is 18 times higher than the total cost of the branch with the lowest liquidation cost.

The unresolved scientific problem is the interaction between the main processes and the structure of the amount of costs of liquidation processes. We have only the unsystematic knowledge of practitioners.

In the case of liquidation for 2, 3 and 8 years, there is only one case of the branch and becomes the benchmark. When analysing above cases, the calculation of the weighted average value gave good results for 2 and 3 years of liquidation. The period of 8 years gave slightly worse but satisfactory results. The proposed method requires further research. Nevertheless, can be a very useful auxiliary tool in initial design works and ongoing engineering works.

References

1. Bijańska, J., Wodarski, K. (2020). Model of process management system in enterprises of the hard coal mining industry. *Management Systems in Production Engineering, Vol. 28, Iss. 2*, pp. 112-120.
2. Bijańska, J., Wodarski, K. (2018). Process management in a mining enterprise – basic areas and research problems. *Scientific Papers of Silesian University of Technology, series: Organization and Management, vol. 120*, pp. 35-50.
3. Brzychczy, E., Napieraj, A., Sukiennik, M. (2018). Modelling of processes with use of process mining techniques. *Scientific Papers of Silesian University of Technology, series: Organization and Management, vol. 116*, pp. 23-36.

4. Duda, A. (2018). Identification of environmental events associated with mine closures in selected countries of the European Union. *Przegląd Górniczy, nr 3*, pp. 7-15.
5. Dźwigoł, H. (2007). *Model restrukturyzacji organizacyjnej przedsiębiorstwa górnictwa węgla kamiennego*. Warszawa: Difin.
6. Fernandez de la Buelga, L., Chmiela, A. (1995). The Spanish Energy Sector: Regulatory Changes and Prospects. *Scientific Papers of Silesian University of Technology, 1307, series: Mining, vol. 225*. Gliwice, pp. 59-72.
7. Grmela, A., Harat, A., Adamczyk, Z. (2017). Proces likwidacji kopalń jako problem środowiskowy, ekonomiczny i prawny. *Ecological Engineering, vol. 18, 4*, pp. 39-45.
8. Harat, A., Grzesik, B., Adamczyk, Z. (2017). Ocena oddziaływania na środowisko i jej zastosowanie w procesie inwestycyjnym likwidacji kopalni. *Budownictwo, nr 23*, pp. 110-115.
9. 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.
10. Korski, J., Korski, W. (2015). Underground mine as a system of processes. *Mining – Informatics, Automation and Electrical Engineering, 2(522),* pp. 19-27.
11. Marek, J. (2006). Conditions and course of the liquidation process of hard coal mines. Studia Ekonomiczne, Akademia Ekonomiczna w Katowicach 37/2006, Zarządzanie strategiczne w przedsiębiorstwie, pp. 269-283, (2006).
12. 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.
13. Przybyła, H., Chmiela, A. (2007). *Organizacja i ekonomika w projektowaniu wybierania węgla*. Gliwice: Wydawnictwo Politechniki Śląskiej.
14. Przybyła, H., Chmiela, A. (2002). *Technika i organizacja w robotach przygotowawczych*. Gliwice: Wydawnictwo Politechniki Śląskiej.
15. 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.
16. 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.
17. 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.
18. 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.

19. 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.
20. Rother, M., Shook, J. (2009). *Naucz się widzieć, eliminacja marnotrawstwa poprzez mapowanie strumienia wartości*. Lean Enterprise Institute.
21. 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*.
22. Smoliło, J., Chmiela, A. (2021). The mine liquidation processes in SRK S.A. in a cost approach. *Scientific Papers of Silesian University of Technology, series: Organization and Management*.
23. Turek, M. (2013). *Analiza i ocena kosztów w górnictwie węgla kamiennego w Polsce*. Warszawa: Difin.
24. Turek, M. (2013). *System zarządzania kosztami w kopalni węgla kamiennego w cyklu istnienia wyrobiska wybierkowego*. Warszawa: Difin.
25. 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.
26. Wójcik, J. (2018). Former mining areas of Wałbrzych Basin 20 years after mine closures. *Przegląd Geograficzny, nr 2*, pp. 267-290.