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THE SYSTEM OF OPERATIONAL RISK IDENTIFICATION IN MINING COMPANY ACCORDING TO NATURAL THREATS

Abstract: In the article the method of operational risk identification is presented. At the beginning the operational risk is defined and then the methodology of research is described. In the next three parts operational risk is estimated on the example of Polish mining companies in the years 2003-2008. Finally the results are aggregated and one class of operational risk is determined.

Keywords: risk, operational risk in company, mining companies.

1. Introduction

Operational risk is a kind of risk connected with operational activity of a company [Peng, Nunes 2009, pp. 926-942]. The risk means the possibility of bearing loss as a consequence of making wrong decisions regarding inner processes of a company and because of outer occurrences affecting a company [Staniec, Klimczak 2008, p. 144].

As mentioned above, it is the risk connected with the basic activity of a business that is influenced by processes taking place in its inside and factors connected with the closer and further environment [Tchankova 2002, pp. 290-297].

Generally, operational risk is shaped by the following factors:
– processes taking place inside the company,
– systems adapted by the company,
– human resources,
– outer occurrences [Staniec, Klimczak 2008, pp. 36-37].

With regard to statements above, a very important matter in the right description of operational risk is identification of potential threats for operational activity of a business. The identification means implication of possible situations, occurrences and activities that may trigger risk appearance. In other words, it is the indication of risk sources in operational activity of a company.

The indication of operational risk in a company is a very difficult task. There are many methods which diagnose risk zones in a fragmentary way. Limited access to

information makes the process of operational risk management difficult for a company [Chandra, Calderon 2009, pp. 220-232]. There is a lack of systemic methods of operational risk assessment in a business [Liu, Low 2009, pp. 170-186]. In this chapter it is attempted to make holistic identification and quantification of operational risk in mining companies by linking and modifying various methods known from literature [Williams et al. 2006, p. 67-87].

While making a research, the most important natural and technical threats have been taken into account, i.e. threats such as: gas, dust and fire. Examination of the intensity and variability of the above-mentioned threats was carried out in the years of 2003-2008 basing on statistic risk assessment methods using arithmetic mean, standard deviation and variation coefficient [Olsen 2009, pp. 97-105]. Then the attempt was made to aggregate the results received in the means of risk operational matrix regarding natural and technical threats. While creating risk matrix the investigation has been undertaken concerning intensity and variability of researched gas, dust and fire threats. Relying on these two factors, four basic classes of operational risk were determined according to three types of threats as follows:

1) **risk class 1**, being characterized by low intensity of researched threat and low variability,

2) **risk class 2**, which regards to low threat intensity but being described by high variability,

3) **risk class 3**, in accordance with high intensity threats and low variability,

4) **risk class 4**, typical of high intensity and variability of researched threats.

The graphic description of above-mentioned classes of risk is shown in Fig. 1.

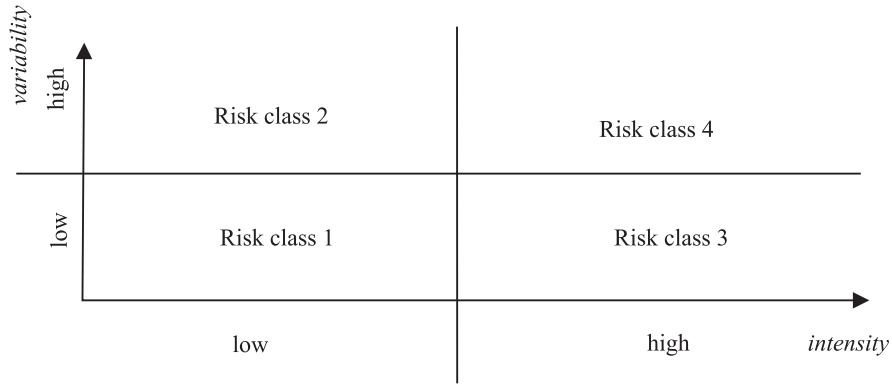

Fig. 1. Risk operational matrix concerning natural and technical threats

Source: own work.

The matrix of operational risk shown in Fig. 1 has been created in three options, for gas, dust and fire threats. The results have been aggregated by assigning weights

to the threats specified through interviewing experts on coal. The final result has become one collective yearly class of operational risk concerning natural and technical threats for the researched hard coal mining company.

2. The analysis and assessment of gas threats in the researched mining company

The research on operational risk started from analyzing **gas** threats. Methane presence in hard coal mines and explosion threats regarding it are one of the most dangerous natural phenomenon connected with coal mining. Although better methods of recognizing and fighting this threat are being introduced it is still visible that this threat is increasing in many mining zones.

In central and southern parts of Upper-Silesia hard coalfields are strongly prone to methane threats occurrence. Carbon deposits in this region are overlapped by tertiary and quaternary rocks specific for high pulp level. Such structure of rock strata implied methane stopping in coal layers and significantly troubled mining activities and extraction of coal layers.

While making research on **gas threats** the measure of methane threat intensity has been used, namely, absolute methane content described as million cube meters of methane per year – mil m^3 CH_4/year. To achieve results, a comparison has been made regarding absolute methane contents of all coalmines belonging to Kompania Węglowa SA (Coal Corporation) in the years of 2003-2008. Next, arithmetic mean of methane content has been calculated in successive periods as well as standard deviations that show the variation of absolute methane content in coalmines. The results of calculation are shown in Table 1.

According to the results from Table 1, the lowest methane threat in the researched company appeared in years of 2003-2004. The significant absolute methane content growth was observed in years of 2005 and 2007. The years of 2006 and 2008 are characterized by average value of absolute methane intensity. It must be stressed that the hard coalmines the corporation consists of have a great variability regarding absolute methane content. Such great variability influences high values of variation coefficient and in practice it requires various methods of methane threats monitoring and individual instruments of operational risk management in this matter.

After identifying the intensity of gas threats in considered mining company, the estimation of threats has also been done among all the functioning coalmines in mining industry. The results are shown in Table 2.

Data from Table 2 have been used to determine the intensity of methane threats in considered mining company. It has been assumed that high level of gas threats intensity (H) is the level above the average value of absolute methane content in the whole mining industry. Low threat level (L) is the level below the average absolute methane content. Moreover, it has been assumed that high variability of researched

Table 1. Absolute methane content in coalmines belonging to Kompania Węglowa SA in the years 2003-2008

No.	Coalmine	Absolute methane content in mln m^3/year					
	Year	2003	2004	2005	2006	2007	2008
1	Bobrek-Centrum	0	0	0	0	0	0
2	ZG Piekary	0	0	0	0	0	0
3	Bolesław Śmiały	0	0.02	0.31	1	1.51	1.2
4	Knurów	8.06	10.83	14.53	12.8	21.61	15.8
5	Sośnica-Makoszowy	38.14	41.79	47.15	52	59.62	48.8
6	Szczygłowice	13.42	16.37	18.82	42.8	61.97	35.3
7	Brzeszcze-Silesia	136.6	101.28	129.14	134.4	134.52	137.1
8	Piast	0	0	0	0	0	0
9	Ziemowit	0	0	0	0	0	0
10	Halemba	28.19	32.25	68.4	36.1	34.66	21.6
11	Pokój	0.57	0.58	0.23	0.2	0.95	0.3
12	Bielszowice	31.37	31.78	24.91	25	21.39	24.3
13	Chwałowice	3.9	6.86	7.46	7.94	6.52	9.3
14	Jankowice	19.9	19.9	34.25	21.66	20.76	37.3
15	Marcel	24.19	24.19	14.68	15.33	16.12	15.8
16	Rydułtowy-Anna	45.53	34.39	46.84	33.32	22.66	26.6
	Arithmetic mean	**21.87**	**20.02**	**25.42**	**23.91**	**25.14**	**23.34**
	Standard deviation	34.21	26.13	34.70	34.08	35.36	34.11
	Variation coefficient	**63.92%**	**76.60%**	**73.25%**	**70.15%**	**71.11%**	**68.42%**

Source: own work based on data from Kompania Węglowa SA.

Table 2. Absolute methane content in Polish hard coal mining industry in the years 2003-2008

Data	2003	2004	2005	2006	2007	2008
Absolute methane content in million m^3/year	798,1	825,9	851,1	870,3	878,9	880,9
Average absolute methane content for a mining company	19,95	22,32	23,64	24,18	24,41	25,17

Source: own work based on [Konopko (red.) 2003-2009].

feature (H) describes variation coefficient above 40% and low variability of variation coefficient (L) below 40%. The results of intensity and variability of gas threats with risk class indication for considered mining company are enclosed in Table 3.

According to the data above, the variability of absolute methane content in considered coal corporation in the whole analyzed period is very high. The variation

Table 3. Operational risk class concerning gas threats in Kompania Węglowa SA in the years 2003-2008

Data	2003	2004	2005	2006	2007	2008
Variability	H	H	H	H	H	H
Intensity	H	L	H	L	H	L
Risk class	4	2	4	2	4	2

H – high, L – low.

Source: own work.

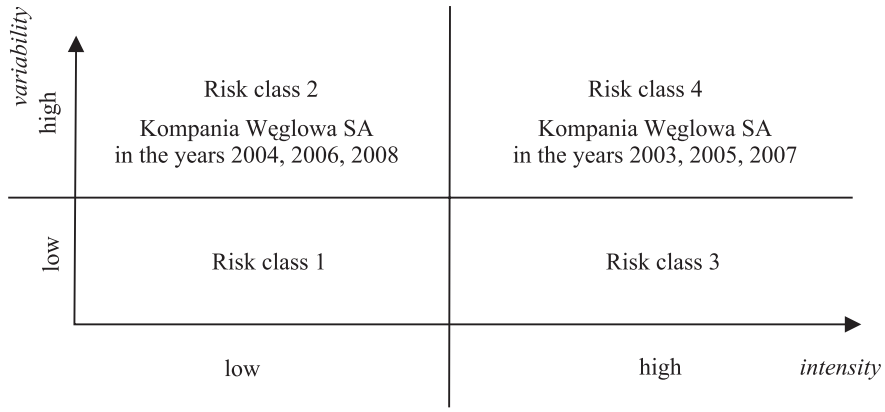

Fig. 2. Operational risk classes regarding gas threats in Kompania Węglowa SA

Source: own work.

coefficients exceed 60%. Furthermore, absolute methane content in coal corporation is lower than the industry average in the years of 2004, 2006 and 2008 – then threat intensity was defined as high. In the other periods absolute methane content exceeds the industry average value and intensity was found high. In effect, in accordance to methodology stated in introduction, Kompania Węglowa SA has been assigned operational risk classes in successive years regarding methane threats. Synthetically, the classes are shown in Fig. 2.

3. Analysis and assessment of dust threats in considered mining company

Dust threats have been analyzed in a similar way and they, besides gas threats, are ones of the most important factors of natural and technical risk. In hard coalmines, while coal mining, transporting, storing and processing significant amounts of coal dust appear. It is a dangerous dust which may trigger and transfer an explosion. To

neutralize it in coalmines, stone dust is used that includes non-fire still parts. It is added to coal dust and makes the mix unable to catch fire and transfer the explosion [Konopko (red.) 2009, p. 40].

When making research on dust threats, the amount of stone dust used in mines belonging to Kompania Węglowa SA is an indicator of the intensity of threats. The amount of yearly average stone dust usage in the whole mining industry is also mentioned. The amounts of stone dust used in mines of Kompania Węglowa SA in the years 2003-2008 are enclosed in Table 4.

Table 4. The amounts of stone dust used mines of Kompania Węglowa SA in the years 2003-2008

No.	Data	The amount of stone dust used in tones					
	Year	2003	2004	2005	2006	2007	2008
1	Bobrek-Centrum	639.6	1060.9	753	677.9	570.9	1403.3
2	ZG Piekary	1042	1099.5	795	668.7	534	791.1
3	Bolesław Śmiały	26.1	20	19.5	30	39	64.6
4	Knurów	1840.7	2608	1768	1652.6	1496.7	1937.2
5	Sośnica-Makoszowy	1963	2221.5	3136.5	3564.4	3651.7	3534.2
6	Szczygłowice	1675	1750	1605.9	1730	1624	2107
7	Brzeszcze-Silesia	1803.4	1733.5	1455	1347.3	1375.7	1415
8	Piast	7.9	25	8.5	12	20.8	31.1
9	Ziemowit	17.3	27	28.8	37.5	41.6	49.2
10	Halemba	1256.7	1512	1731.8	1362	3394.8	3777.4
11	Pokój	1156.4	221.3	828.7	1016.1	1267.8	1267.6
12	Bielszowice	1478	1607.2	897.2	736	1710.6	2598
13	Chwałowice	2968	2300	2420	2266	2300	1869.3
14	Jankowice	2104.5	2318	2050	1687	1909	2014
15	Marcel	2885.4	2647.3	2348.9	2223.2	2562.3	2774
16	Rydułtowy-Anna	2899.9	2483.05	2281.65	2045.5	2174	2143.5
	Arithmetic mean	**1485.24**	**1477.14**	**1383.03**	**1316.01**	**1542.06**	**1736.03**
	Deviation	985.70	965.55	949.68	965.39	1124.18	1141.11
	Variation coefficient	**150.68%**	**152.98%**	**145.63%**	**136.32%**	**137.17%**	**152.13%**

Source: own work based on [Konopko (red.) 2003-2009].

The amounts of yearly stone dust usage in Kompania Węglowa SA ranged between 1383.03 tons in 2004 and 1736.03 tons in 2008. Because of very high values of variation coefficients for absolute data, the usage of stone dust has been additionally calculated per 1000 tons of coal extraction. The results are shown in Table 5.

The data enclosed in Table 5 are strongly varied for stone dust usage in mines belonging to Kompania Węglowa SA. In order to make final assessment of dust

Table 5. The rates of stone dust usage in t/1000 t coal extraction in Kompania Węglowa SA in the years 2002-2008

Data		The amount of stone dust usage in tons per 1000 tons of extraction					
Year		2003	2004	2005	2006	2007	2008
1	Bobrek-Centrum	0.238	0.358	0.270	0.249	0.247	0.504
2	ZG Piekary	0.436	0.322	0.266	0.230	0.225	0.400
3	Bolesław Śmiały	0.020	0.013	0.012	0.020	0.023	0.035
4	Knurów	0.693	0.885	0.647	0.620	0.619	0.790
5	Sośnica-Makoszowy	0.414	0.465	0.594	0.693	0.706	0.773
6	Szczygłowice	0.702	0.640	0.585	0.646	0.772	1.152
7	Brzeszcze-Silesia	0.633	0.502	0.454	0.431	0.580	0.624
8	Piast	0.001	0.004	0.002	0.002	0.004	0.007
9	Ziemowit	0.004	0.006	0.006	0.009	0.010	0.010
10	Halemba	0.429	0.520	0.548	0.442	1.021	1.427
11	Pokój	0.338	0.062	0.256	0.322	0.768	0.734
12	Bielszowice	0.590	0.568	0.360	0.303	0.649	1.212
13	Chwałowice	1.278	0.872	0.911	0.875	0.931	0.748
14	Jankowice	0.791	0.674	0.524	0.443	0.543	0.695
15	Marcel	1.408	1.135	0.941	0.914	1.032	0.992
16	Rydułtowy-Anna	0.790	0.645	0.648	0.596	0.831	0.761
	Arithmetic mean	**0.548**	**0.480**	**0.439**	**0.425**	**0.560**	**0.679**
	Deviation	0.408	0.340	0.293	0.288	0.354	0.418
	Variation coefficient	**134.14%**	**141.20%**	**149.99%**	**147.62%**	**158.20%**	**162.21%**

Source: own work based on [Konopko (red.) 2003-2009].

threat intensity in Kompania Węglowa SA a comparison has been made with the usage of the amount of stone dust in the coal mining industry in the years of 2003-2008. The industry comparison is shown in Table 6.

Table 6. The rates of stone dust usage in coal mining industry in Poland in the years 2003-2008

Year	2003	2004	2005	2006	2007	2008
Rate	0.709	0.680	0.655	0.633	0.758	0.846

Source: own work based on [Konopko (red.) 2003-2009].

The industry rates above have let to determine the intensity of dust threats in Kompania Węglowa SA. The results are enclosed in Table 7.

As shown above, in the whole examined period the values of stone dust usage rates in Kompania Węglowa SA were lower than the average in the coal mining in-

Table 7. Operational risk class concerning gas threats in Kompania Węglowa SA in the years 2003-2008

Data	2003	2004	2005	2006	2007	2008
Variability	H	H	H	H	H	H
Intensity	L	L	L	L	L	L
Risk class	2	2	2	2	2	2

H – high, L – low.

Source: own work based on [Konopko (red.) 2003-2009].

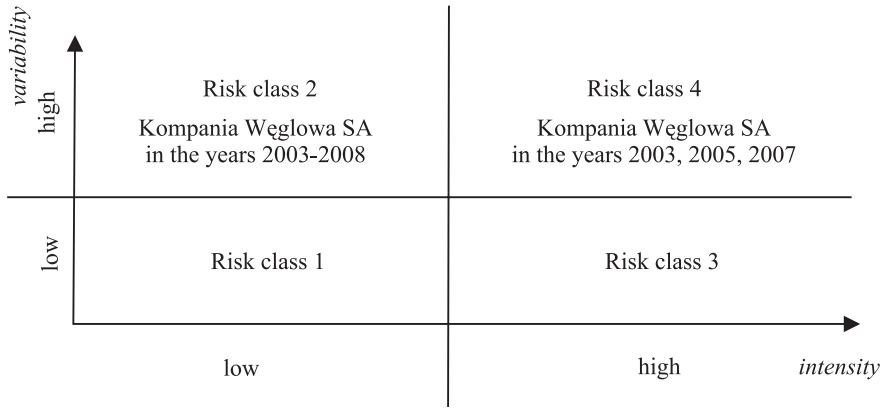

Fig. 3. Operational risk class according to dust threats in Kompania Węglowa SA

Source: own work.

dustry in Poland. However, when looking at single companies, the rates were strongly varied, which caused the great variability of the researched feature. In effect, in the years 2003-2008 Kompania Węglowa SA was qualified to the operational risk class 2 according to dust threats (Fig. 3).

4. Analysis and assessment of fire threats in the examined mining company

The last group of the analyzed natural and technical threats are **fire threats.** When analyzing the threats the information used comes from the coal mines, The Central Station of Mining Rescue and The Main Mining Institute. Because of incidental character and low frequency, in this case statistic analysis could not be carried out. Therefore to make the assessment of fire threats, the fire rate calculated for single companies and the whole mining industry was used. The rate is the relation of number of fires to the amount of coal extraction in million tons. The values of rates in 2003--2008 are enclosed in Table 8.

Table 8. The values of fire rates in mining industry in the years 2003-2008

The examined companies	Data	2003	2004	2005	2006	2007	2008
Altogether in coal mining industry	The amount of mining in mil tons	100.41	99.17	96.99	94.27	87.21	83.38
	The number of fires	5.00	7.00	9.00	3.00	4.00	9.00
	Fire rate values	**0.05**	**0.07**	**0.09**	**0.03**	**0.05**	**0.11**
Jastrzębska Spółka Węglowa SA	The amount of mining in mil tons	13.65	13.74	12.82	12.43	11.82	13.64
	The number of fires	0.00	0.00	0.00	0.00	0.00	3.00
	Fire rate values	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.22**
	Risk class	1	1	1	1	1	3
Kompania Węglowa SA	The amount of mining in mil tons	56.83	53.81	52.59	51.45	46.76	44.54
	The number of fires	5.00	4.00	4.00	3.00	2.00	3.00
	Fire rate values	**0.09**	**0.07**	**0.08**	**0.06**	**0.04**	**0.07**
	Risk class	2	3	2	4	2	1
Katowicki Holding Węglowy SA	The amount of mining in mil tons	18.84	18.45	17.70	16.98	15.44	14.05
	The number of fires	0.00	1.00	3.00	0.00	0.00	1.00
	Fire rate values	**0.00**	**0.05**	**0.17**	**0.00**	**0.00**	**0.07**
	Risk class	1	2	4	1	1	1
Independent mines	The amount of mining in mil tons	11.10	13.17	13.88	13.41	13.19	11.15
	The number of fires	0.00	2.00	2.00	0.00	2.00	2.00
	Fire rate values	**0.00**	**0.15**	**0.14**	**0.00**	**0.15**	**0.18**
	Risk class	1	4	3	1	4	2

Source: own work based on [Konopko (red.) 2003-2009].

When examining fire threats it was impossible to define the variability of examined feature, therefore in order to assign the class to operational risk the ranking has been used. The mines with the lowest fire rates in a certain year have been assigned risk class 1. The other ones have been assigned the next risk classes, namely 2, 3 and 4. The results are shown in Table 8.

5. The aggregation of research results – determining the complex operational risk class concerning natural and technical threats

When including the characterized threats, the aggregation of operational risk assessment allows for determining the complex risk class in this matter. The summary of the results described in previous stages are included in Table 9.

The results above have been proceeded to further aggregation through defining the share of threats in shaping holistic operational risk. The results of the final stage are enclosed in Table 10.

Table 9. Operational risk classes resulting from natural and technical threats in Kompania Węglowa SA in the years 2003-2008

Years	2003	2004	2005	2006	2007	2008
Risk class – gas threats	4	2	4	2	4	2
Risk class – dust threats	2	2	2	2	2	2
Risk class – fire threats	2	3	2	4	2	1

Source: own work.

Table 10. The aggregation of operational risk stemming from natural and technical threats in Kompania Węglowa SA in the years 2003-2008

Positions	2003	2004	2005	2006	2007	2008
Gas threats						
Class	4	2	4	2	4	2
Weight	0.5	0.5	0.5	0.5	0.5	0.5
Dust threats						
Class	2	2	2	2	2	2
Weight	0.3	0.3	0.3	0.3	0.3	0.3
Fire threats						
Class	2	3	2	4	2	1
Weight	0.2	0.2	0.2	0.2	0.2	0.2
Risk class of natural and technical threats (weighted mean of the individual classes)	**3**	**2**	**3**	**2**	**3**	**2**

Source: own work.

The assigned weights to the threats in table 10 have been calculated according to interviews with experts on safety management in mining companies. In effect, it has been stated that in the considered period Kompania Węglowa SA was specific for operational risk concerning natural and technical threats of risk class level 2 and 3. The most important influence on the risk had gas threats of a high rank that are characterized by high variability and intensity. The level of dust threats was stable, however, the level of dust and fire threats was differentiated.

The presented methodology of operational risk measurement concerning natural and technical threats allows to aggregate the detailed and complex information about the level of individual threats. It enables quick and legible comparison of individual coal mines with reference to holistic operational risk. Moreover, it creates the basis to analyze operational risk within time. As its advantage, it can also be stressed that grounding on available and gathered data makes this method reasonably prices and easy to proceed [McGrew, Billota 2000, pp. 293-200].

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SYSTEM IDENTYFIKACJI RYZYKA OPERACYJNEGO W PRZEDSIĘBIORSTWIE GÓRNICZYM W KONTEKŚCIE ZAGROŻEŃ NATURALNYCH

Streszczenie: W artykule przedstawiono metodę identyfikacji ryzyka operacyjnego. Na wstępie zdefiniowano ryzyko operacyjne. Następnie przedstawiono ogólną metodykę badań. W trzech kolejnych częściach podjęto próbę oszacowania ryzyka operacyjnego w latach 2003-2008 na przykładzie polskiego przedsiębiorstwa górniczego. W końcowej części wyniki zostały zagregowane i ustalono jedną wynikową klasę ryzyka operacyjnego dla badanego przedsiębiorstwa.