GOSPODARKA SUROWCAMI MINERALNYMI

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Principles of data bases creation for stochastic simulation of driving costs of roadways in hard coal mines

Key words

Hard coal mining, economic and financial data bases, underground roadways

Abstract

A procedure used during creation of the economical – financial data bases for roadways with particular attention paid to probability distribution of driving costs has been described in the present study. Probability distributions of the driving costs can be used in stochastic simulation of the costs related to execution of roadways, which are designed for similar (comparable) geological – mining conditions, in order to assess the cost level, as well as to determine risk of its overrunning.

Introduction

A part of examinations executed in scope of big research project aimed at elaboration of integrated system aiding production management in hard coal mines has been described in the present study. The examinations are based on already described studies (Magda, Głodzik, Woźny, Jasiewicz 2007a), which were aimed at rules of geological – mining data bases creation for hard coal roadways, with particular attention paid to rate of advance and their probability distribution. The rules have been described on an example of three road heads executed in natural conditions in one of the mining companies.

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Probability distribution parameters of roadway's rate of advance, as well as of costs connected by area with their exploitation, collected in suitable data base, together with the other parameters describing geological – mining conditions, can be used in process of simulation of roadway driving in case if they are planned to be executed in similar (comparable) geological – mining conditions. Using the Monte Carlo method we can determine probability distributions of parameters influencing production output, which can be obtained in the future, as well as we can assess the risk of non-receiving or exceeding the assumed production output, or cost level. Experiences collected in the past, which are described by a set of information, data and parameters collected in suitable data base, can constitute valuable material for future production planning and design. Procedure of probability distributions of roadway rate of advance has been described (Magda, Głodzik, Woźny, Jasiewicz 2007a). In the present study, a creation procedure of probability distribution of costs connected by area to roadway's driving is described. In order to keep mutual relation of the material presented in both works, the discussion described in the present study is related to the same roadways, for which it was described in cited study. Technical – geological characteristics of these roadways can be found in the study cited above, thus its presentation in the present study is neglected.

1. Assumptions and procedure

Costs connected by area to roadway's driving are discussed in this chapter. Monthly costs for the examined roadways are collected and gathered in tables (roadways No. 1, 2 and 3), taking under consideration type of costs, excluding salary, material, energy, amortization, repairs, renting services and other costs. Monthly rate of advance is also shown in a separate column.

The following information is shown in tables:

— in Table 1 – data of the roadways No. 1,

— in Table 2 – data of the roadways No. 2,

— in Table 3 – data of the roadways No. 3.

Working days were taken as time units. Roadways No. 1 was driven during 132 working days (7 months), roadways No. 2 – by 101 working days (6 months) and roadways No. 3 – by 56 working days (3 months).

A hypothesis assuming division of costs connected by area with roadways into constant and variable costs with reference to rate of advance was proposed, whereas costs related to the roadways driving and reached output were taken as variable costs, and all other costs connected by area with the roadways, independently on the fact if the roadway is actually driven or not were taken as constant costs.

In order to create data base of the size big enough for statistical handling an afford of attributing of the monthly costs to individual working days was made under assumption that variable costs are attributed to days with rate of advance, whereas constant costs were

TABLE 1

Fixed and variable costs for roadway No. 1

TABELA 1

Koszty rodzajowe w aspekcie podziału na stałe i zmienne – wyrobisko korytarzowe nr 1

Month	Number of working days	Wages	Materials	Energy	Depreciation	Repairs	Servicies	Other costs	Total costs	Rate of advance
	days	zł	zł	zł	zł	zł	zł	zł	zł	m
IX	20	97 252	150 088	7 296		9 693		2 490	266 819	250.0
X	22	111 324	260 164	14 047	3 500	16 983		18 610	424 629	236.0
XI	20	103 008	277 576	12 173	3 500	1 696		27 520	425 473	240.0
XII	18	91 831	24 489	8 725	3 448	7 236		37 242	172 970	172.5
I	22	113 821	36 308	8 930	3 448	6 886		4 109	173 502	275.0
II	20	142 793	115 851	6 870	3 448	7 315		23 504	299 781	265.0
II	10	101 358	728 711	3 469	3 448	23 758		20 122	880 866	115.0
Total	132	761 388	1 593 187	61 510	20 790	73 567	0	133 598	2 644 039	1 553.5
Fixed and Variable costs	Fixed cost	1-ww	1-wm	1-we	1-wa	1-wr	1-wu	1-wp	Total fixed costs	Fixed costs per unit
	Coefficient	0.9	0.9	0.7	0	0.5	0	0.1	zł	zł/m
	zł	685 249	1 433 868	43 057	0	36 783	0	13 360	2 212 318	1 424
	Variable cost	ww	wm	we	wa	wr	wu	wp	Total variable costs	Variable costs per unit
	Coefficient	0.1	0.1	0.3	1.0	0.5	1.0	0.9	zł	zł/d
	zł	76 139	159 319	18 453	20 790	36 783	0	120 238	431 722	3 271

$k_{\text{roadway no. 1}} = f(p) = 1424 \cdot p + 3271$ [zł/d].

TABLE 2

Fixed and variable costs for roadway No. 2

TABELA 2

Koszty rodzajowe w aspekcie podziału na stałe i zmienne – wyrobisko korytarzowe nr 2

Month	Number of working days	Wages	Materials	Energy	Depreciation	Repairs	Servicies	Other costs	Total costs	Rate of advance
	days	zł	zł	zł	zł	zł	zł	zł	zł	m
VI	9	135 256	104 903	6 121		4 519		4 548	255 347.00	90.0
VII	23	312 438	204 698	24 575	342	8 556	20 076	17 800	588 485.00	246.0
VIII	21	271 458	333 876	38 038	342	7 679	43 310	14 682	709 385.00	242.0
IX	21	297 746	189 432	24 455	342	15 836	21 084	22 746	571 641.00	192.0
X	22	369 757	275 042	33 733	342	7 745	27 309	14 777	728 705.00	220.0
XI	5	94 604	81 060	6 424	342	0	27 323	5 087	214 840.00	35.5
Total	101	1 481 259	1 189 011	133 346	1 710	44 335	139 102	79 640	3 068 403.00	1 025.5
Fixed and Variable costs	Fixed cost	1-ww	1-wm	1-we	1-wa	1-wr	1-wu	1-wp	Total fixed costs	Fixed costs per unit
	Coefficient	0.9	0.9	0.7	0	0.5	0	0.1	zł	zł/m
	zł	1 333 133	1 070 110	93 342	0	22 168	0	7 964	2 526 717	2 464
	Variable cost	ww	wm	we	wa	wr	wu	wp	Total variable costs	Variable costs per unit
	Coefficient	0.1	0.1	0.3	1.0	0.5	1.0	0.9	zł	zł/d
	zł	148 126	118 901	40 004	1 710	22 168	139 102	71 676	541 686	5 363

$k_{\text{roadway no. 2}} = f(p) = 2464 \cdot p + 5363$ [zł/d].

TABLE 3

Fixed and variable costs for roadway No. 3

TABELA 3

Koszty rodzajowe w aspekcie podziału na stałe i zmienne – wyrobisko korytarzowe nr 3

Month	Number of working days	Wages	Materials	Energy	Depreciation	Repairs	Servicies	Other costs	Total costs	Rate of advance
	days	zł	zł	zł	zł	zł	zł	zł	zł	m
XII	11	57 458	455 052	14 819	0	4 932		15 363	547 623.12	85.5
I	21	126 646	135 807	22 887	570	40 773	211 090	9 857	547 629.71	331.5
II	20	126 647	148 867	13 349	640	1 395	211 090	5 628	507 614.80	309.0
III	4	21 948	25 485	12 917	643		211 090	–200 361	71 721.77	24.0
Total	56	332 699	765 210	63 972	1 852	47 099	633 270	–169 514	1 674 589.00	750.0
Fixed and Variable costs	Fixed cost	1-ww	1-wm	1-we	1-wa	1-wr	1-wu	1-wp	Total fixed costs	Fixed costs per unit
	Coefficient	0.9	0.9	0.7	0	0.5	0	0.1	zł	zł/m
	zł	299 429	688 689	44 781	0	23 550	0	–16 951	1 039 497	1 386
	Variable cost	ww	wm	we	wa	wr	wu	wp	Total variable costs	Variable costs per unit
	Coefficient	0.1	0.1	0.3	1.0	0.5	1.0	0.9	zł	zł/d
	zł	33 270	76 521	19 192	1 852	23 550	633 270	–152 562	635 092	11 341

$k_{\text{roadway no. 3}} = f(p) = 1386 \cdot p + 11\,341$ [zł/d].

attributed to days with no rate of advance. It is probably not ideal solution, but from the heuristic point o view the solution combines cost sources with rate of advance and obtained output. Variable costs will occur if the excavation is executed, i.e rate of advance is obtained, whereas constant costs are borne in each case. Although eventual attribution of constant costs to current days and attribution of variable days to working days with rate of advance may be disputable, the proposed procedure deals with random parameters and exaggerated accuracy is not necessary.

In order to determine division of costs in PLN/24 hours into constant and variable costs depending on the rate of advance, the monthly costs were attributed to individual working days based on constant and variable costs in individual running costs, which were determined by experts.

Based on the information collected from cost experts the following values of factors defining participation of variable costs in individual running costs were used in practical calculations:

$$w_w = 0.1; \quad w_m = 0.1; \quad w_e = 0.3; \quad w_a = 1.0; \quad w_r = 0.5; \quad w_u = 1.0; \quad w_p = 0.9$$

Formal description of the cost attribution to individual working days is identical to that described formerly (Magda, Głodzik, Woźny 2007b).

Accepting rules of division of costs into constant and variable with respect to rate of advance, calculations of total cost attributed to individual working days during the period when the mentioned roadways No. 1, 2 and 3 were driven, have been made.

Results of calculations attributed according to described rules to individual working days of examined roadways No. 1, 2 and 3 are shown in Tables 4, 5 and 6.

Three data sets were obtained for examined roadways, which were then exposed to statistical handling with use of STATISTICA packet. The results obtained are graphically illustrated in Figures 1, 2 and 3.

Descriptive statistics of examined probability distributions of general costs attributed to working days considered as time units is shown in Table 7.

From calculated mean value and standard deviation we can conclude that the lowest mean value was noted in roadways No. 1 (20 031 PLN/24 hours), and then for roadways No. 3 (29 903 PLN/24 hours) and roadways No. 2 (30 380 PLN/24 hours), whereas standard deviation gives the following sequence: roadways No. 1 (4 059 PLN/24 hours), roadways No. 2 (7 000 PLN/24 hours) and roadways No. 3 (11 222 PLN/24 hours). Obtained parameters of the probability distribution can be useful in simulation of costs related with designed roadways, in which identical or similar technical equipment and work organization is used. Similar statistical studies were executed for a number of roadways, and obtained parameters enriched economical and financial data base, which was created for tested population of headings. New data allow current development and updating of the data base.

TABLE 4

Total costs ascripted to working days [zł/day] for roadway No. 1

TABELA 4

Koszty ogółem przypisane dniom roboczym [zł/d] – wyrobisko korytarzowe nr 1

month→ ↓day	IX	X	XI	XII	I	II	III
1		20 424				25 530	18 722
2		22 126	17 020		20 424		
3	10 212	23 828		15 318	20 424		
4	20 424	23 828			20 424	18 722	22 126
5	20 424	18 722	18 722	15 318		20 424	13 616
6	18 722		18 722	13 616		20 424	23 828
7	18 722		18 722	20 424	25 530	23 828	18 722
8		20 424	18 722	20 424	25 530	22 126	15 318
9		17 020	17 020		25 530		
10	17 020	20 424		20 424	23 828		
11	17 020	20 424		17 020	15 318	17 020	17 020
12	20 424		17 020	18 722		25 530	23 828
13	18 722		25 530	20 424		25 530	22 126
14	20 424		25 530	15 318	13 616	25 530	20 424
15		17 020	23 828	12 765	17 020	23 828	
16		20 424	15 318		23 828		
17	23 828	15 318		11 914	25 530		
18	23 828	15 318		15 318	22 126	25 530	
19	25 530	15 318	23 828	15 318		25 530	
20	25 530		25 530	15 318		23 828	
21	25 530		25 530	15 318	17 020	22 126	
22		15 318	25 530		17 020	22 126	
23		17 020			8 510		
24	20 424	23 828			18 722		
25	23 828	15 318			25 530	20 424	
26	23 828	15 318	20 424			20 424	
27	25 530		17 020	15 318		22 126	
28	25 530		17 020	15 318	25 530	20 424	
29		13 616	17 020		25 530		
30		15 318	20 424		25 530		
31		15 318			25 530		

TABLE 5

Total costs ascripted to working days [zł/day] for roadway No. 2

TABELA 5

Koszty ogółem przypisane dniom roboczym [zł/d] – wyrobisko korytarzowe nr 2

month→ ↓day	VI	VII	VIII	IX	XI
1		32 913	35 905		29 921
2		34 409	20 945	29 921	22 441
3		35 905		17 953	10 472
4		35 905		22 441	29 921
5		23 937	32 913	28 425	
6			32 913	20 945	
7			32 913		22 441
8		35 905	35 905		32 913
9		23 937	20 945	23 937	29 921
10		35 905		31 417	29 921
11		32 913		14 961	35 905
12		23 937	32 913	25 433	
13			35 905	22 441	
14			35 905		29 921
15		35 905			32 913
16		35 905	23 937	29 921	32 913
17		35 905		32 913	25 433
18	11 968	35 905		28 425	32 913
19	26 929	23 937	23 937	32 913	
20	29 921		35 905	22 441	
21	32 913		41 889		32 913
22		35 905	38 897		22 441
23		35 905	38 897	31 417	35 905
24	35 905	29 921		32 913	25 433
25	35 905	26 929		37 401	32 913
26	32 913	22 441	38 897	25 433	
27	32 913		41 889	25 433	
28	29 921		41 889		37 401
29		35 905	38 897		37 401
30		32 913	41 889	37 401	35 905
31		32 913			

TABLE 6

Total costs ascripted to working days [zł/day] for roadway No. 3

TABELA 6

Koszty ogółem przypisane dniom roboczym [zł/d] – wyrobisko korytarzowe nr 3

month→ / ↓day	*XII*	I	II	III
1			40 190	13 397
2		17 862		
3		29 026		
4		40 190	40 190	20 095
5			40 190	11 164
6			37 957	8 931
7		33 492	31 259	
8			31 259	
9		36 841		
10		40 190		
11	10 048	40 190	40 190	
12	24 561		37 957	
13	26 793		33 492	
14		40 190	37 957	
15		40 190	37 957	
16		40 190		
17		40 190		
18	6 698	40 190	31 259	
19	3 349		40 190	
20	10 048		40 190	
21	15 630	40 190	40 190	
22		20 095	29 026	
23		40 190		
24		33 492		
25			37 957	
26	20 095		33 492	
27	20 095	26 793	15 630	
28	33 492	40 190	13 397	
29		26 793		
30		33 492		
31	20 095	40 190		

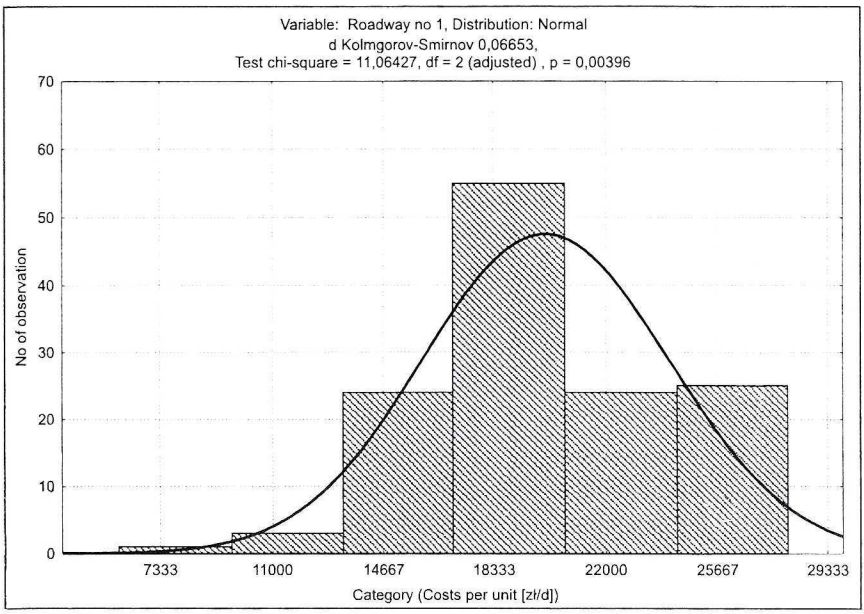

Fig. 1. Results of statistical distribution testing for roadway No. 1

Rys. 1. Wyniki testowania rozkładu statystycznego kosztów ogółem dla wyrobiska korytarzowego nr 1

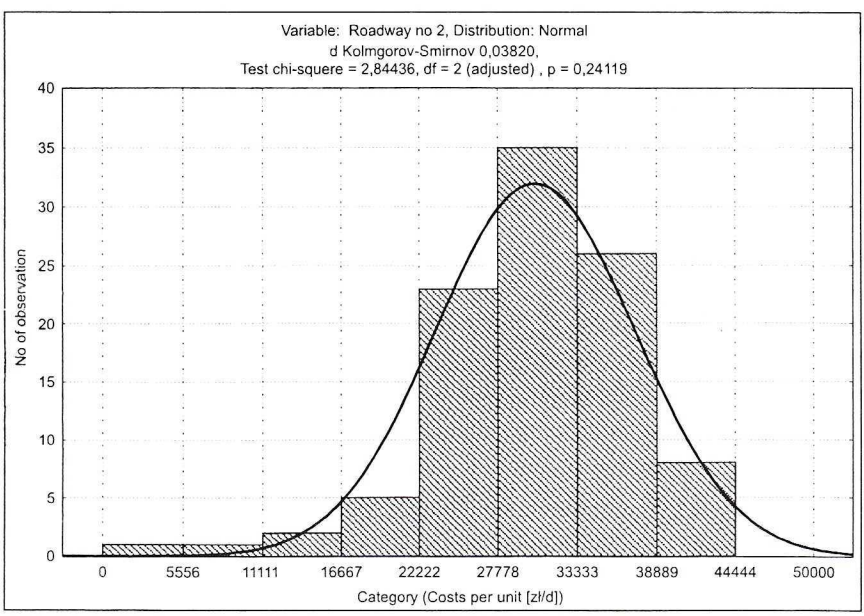

Fig. 2. Results of statistical distribution testing for roadway No. 2

Rys. 2. Wyniki testowania rozkładu statystycznego kosztów ogółem dla wyrobiska korytarzowego nr 2

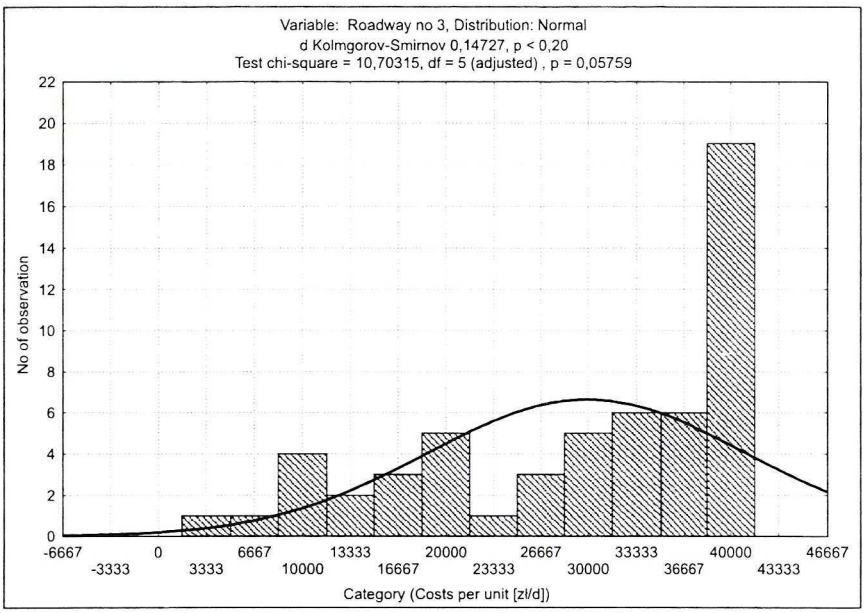

Fig. 3. Results of statistical distribution testing for roadway No. 3

Rys. 3. Wyniki testowania rozkładu statystycznego kosztów ogółem dla wyrobiska korytarzowego nr 3

TABLE 7

Descriptive statistics of investigated distribution of roadway's total costs

TABELA 7

Statystyki opisowe badanych rozkładów prawdopodobieństwa kosztów dobowych ogółem w wyrobiskach korytarzowych

Variable	Sample	Mean	Confidence intervals		Total	Min	Max	Range
			–95%	95%				
Roadway No. 1	132	20 031	19 332	20 730	2 644 039	8 510	25 530	17 020
Roadway No. 2	101	30 380	28 998	31 762	3 068 403	4 488	41 889	37 401
Roadway No. 3	56	29 903	26 898	32 909	1 674 589	3 349	40 190	36 841

Variable	Variation	Std. Deviation	Std. Error	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis
Roadway No. 1	16 478 453	4 059	353	–0.223	0.211	–0.761	0.419
Roadway No. 2	49 004 446	7 000	697	–0.979	0.240	1.330	0.476
Roadway No. 3	125 934 684	11 222	1 500	–0.804	0.319	–0.675	0.628

Summary

Procedure of the creation of economic and financial data bases for roadways was proposed in the present study. The data bases can be useful in decision making related to planning and design of the future production in hard coal mines. The data bases comprise probability distribution parameters of costs connected by area with roadways. Because of extensive range of the problems in question, this study was aimed only at the procedure limited to an example of general costs. However the procedure can easily be extended onto individual running costs. In case of future exploitation planning in comparable geological and mining conditions, with use of identical or similar technical equipment and work organization, information and data collected in the data base can be used for stochastic simulation of roadway's advance and assessment of the adequate costs.

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ROMAN MAGDA, STANISŁAW GŁODZIK, TADEUSZ WOŹNY, JAN JASIEWICZ

ZASADY TWORZENIA BAZ DANYCH NA POTRZEBY SYMULACJI STOCHASTYCZNEJ KOSZTÓW DRĄŻENIA WYROBISK KORYTARZOWYCH WYKONYWANYCH W KOPALNIACH WĘGLA KAMIENNEGO

Słowa kluczowe

Górnictwo węgla kamiennego, bazy danych ekonomiczno-finansowych, wyrobiska korytarzowe

Streszczenie

W artykule opisano pewien sposób postępowania przy opracowywaniu bazy danych ekonomiczno-finansowych dla wyrobisk korytarzowych, ze szczególnym uwzględnieniem rozkładów prawdopodobieństwa kosztów ich drążenia. Rozkłady prawdopodobieństwa kosztów drążenia mogą zostać wykorzystane w procesie symulacji stochastycznej kosztów związanych z wykonywaniem wyrobisk korytarzowych, projektowanych dla podobnych (porównywalnych) warunków geologiczno-górniczych, w celu oszacowania poziomu kosztów oraz określenia ryzyka jego przekroczenia.