Polish Academy of Sciences
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Cracow, Poland

Confidence of Coal Resources Estimation

Estimating Risk-Adjusted Discount Rate for Hard Coal Projects Depending on Geological Knowledge of the Deposit

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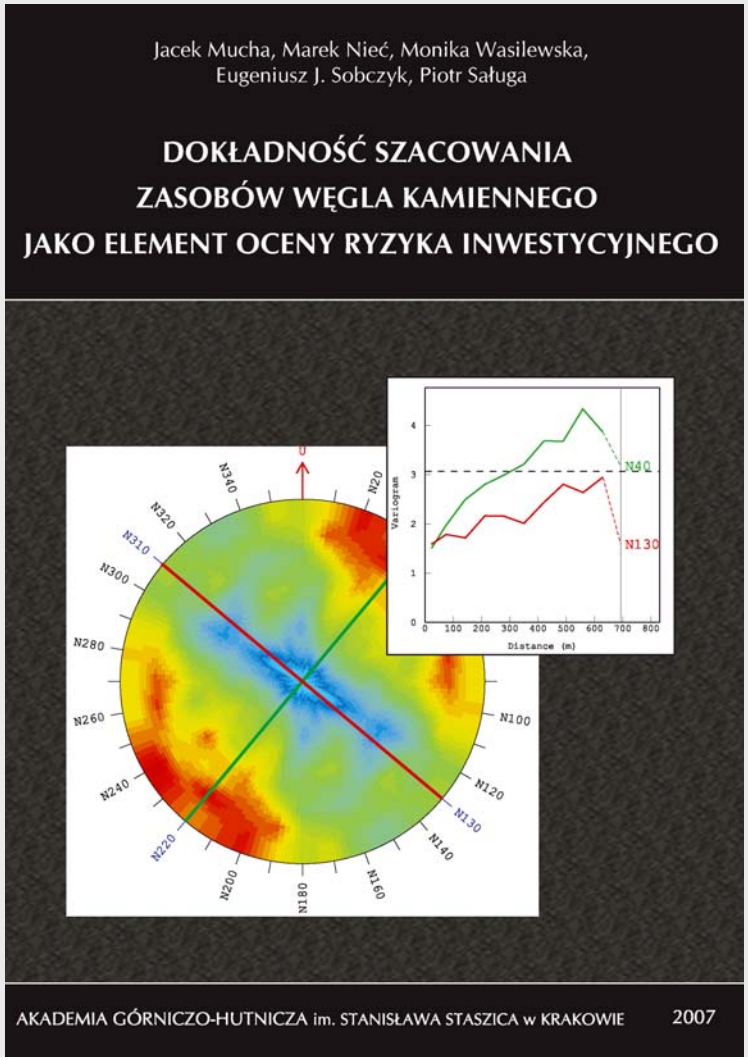
THE ACCURACY OF COAL RESOURCE ESTIMATION AS A FACTOR OF THE INVESTMENT RISK ASSESSMENT



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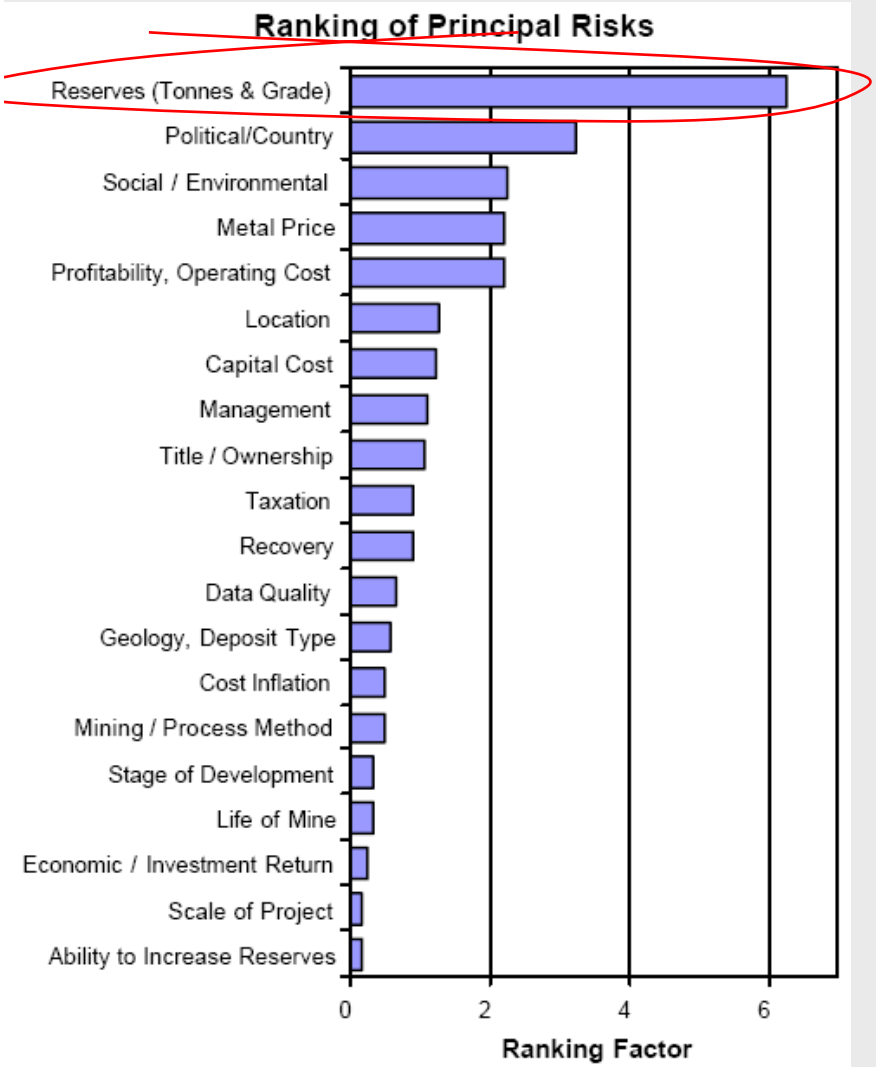
Principal Project Risks in Mining Indudtry



According to research CIM MES one of the most important contributors to the total risk of a mining project is uncertainty of resource tonnage and quality called resource risk

Relations between different categories of resources
(A) in the Polish classification
(B) in international classifications

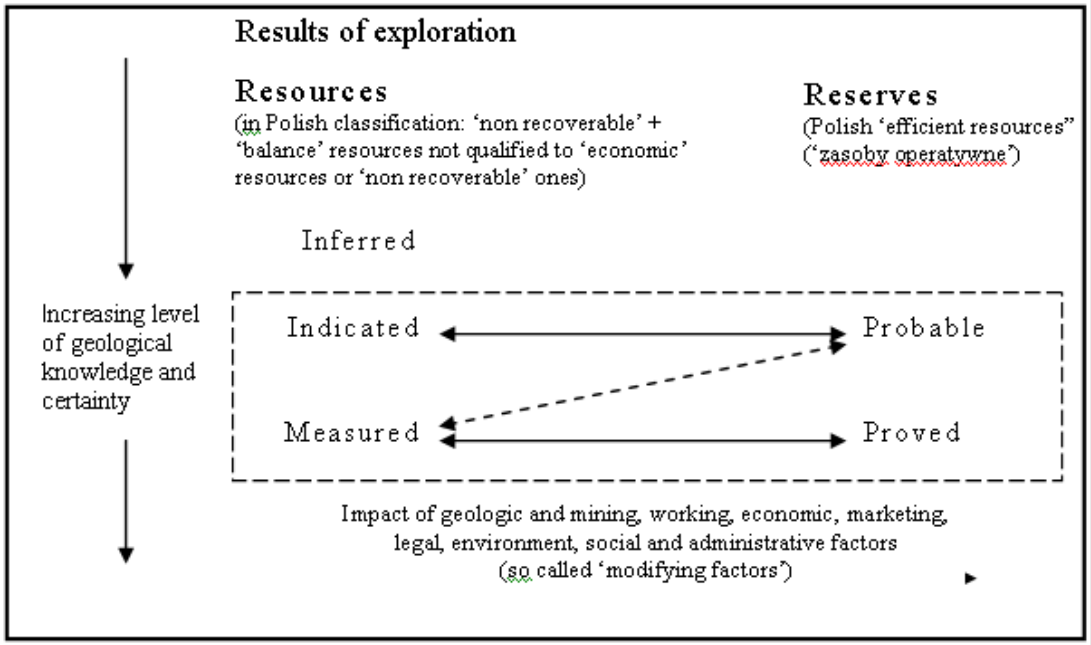
(A)

<table>
<tr><td colspan="4">Total resources (in Polish: ‘zasoby geologiczne’)</td></tr>
<tr><td rowspan="3">‘Out-of-balance’ resources
(in Polish: ‘zasoby pozabilansowe’)</td><td colspan="3">‘Balance’ resources (Pol.: ‘zasoby bilansowe’)</td></tr>
<tr><td rowspan="2">‘Non-recoverable’ resour resources ces
(in Polish: ‘zasoby nieprzemysłowe’)</td><td colspan="2">‘Economic’ resources
(in Polish: ‘zasoby przemysłowe’)</td></tr>
<tr><td>Losses</td><td>‘Efficient’ resources (in Polish: ‘zasoby operatywne’) = reserves</td></tr>
</table>

(B)

Reserves		Resources
In the Polish classification: ‘*zasoby operatywne*’ (‘efficient resources’)	+	In the Polish classification the total of the following resources: 1) non-recoverable (in Polish: ‘*zasoby nieprzemysłowe*’), 2) ‘balance resources’ but not classified as ‘recoverable resources’ or ‘non-recoverable resources’

General relationship between the results of exploration, the resources category and the 'reserves' category



The equivalents of the Polish categories of geological confidence with respect to particular parts of deposit used when documenting solid minerals deposits, are as follows:

A, B – measured resources / proved reserves;
C1 – indicated resources / probable reserves;
C2, D – inferred resources.

Categorization uncertainty in the geological exploration in Poland

The required accuracy of the diagnosis depending on the geological knowledge

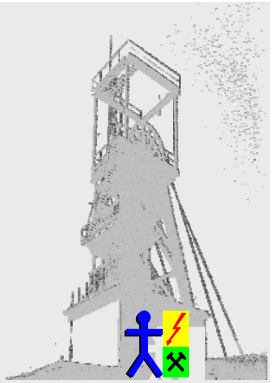
- category D, C_2 – ±40%,
- category C_1 – ±30%,
- category B – ±20%,
- category A – ±10%.

Therefore it was decided to make an attempt to determine the level of the discount rate RADR depending on the level of risk resource, with a separate major sources of risk.

1. **Assessment of mean deposit quality parameters' estimation error levels.**

2. **Determination of the risk adjusted discount rate in relation to the deposit parameter assessment error.**

Assessment of mean deposit quality parameters' estimation error levels



Material for testing

- The assessment of mean deposit quality parameters' estimation error levels was based on the sampling of eight coal seams, of which six were in the Upper-Silesian Coal Basin (USCB) and two in the Lublin Coal Basin (LCB)

- The coal seams were chosen to represent different stratigraphic links in the stratigraphic sequence and to have different thickness, structure and quality.

Characteristics of the hard coal seams in the USCB and the LCB selected for the research

(after the mines' geological and production data)

Coal basin	Lithostratigraphic series – strata	Coal seam	Coal mine	Mean ash content	Total sulphur content [%]	Mean seam width	partings
USCB	Krakow sandstone – Libiaz strata	116/2	KWK Janina (Poludniowy Koncern Weglowy Comp.)	Average (13.3%)	2.29	Average (1.8 m)	none
		118		High (8.8%)	1.87	Average (3.2 m)	1-2 partings
	Krakow sandstone series – Laziska strata	206/1-2	KWK Piast (Kompania Weglowa Comp.)	Average (11.0%)	1.10	Average (2.0 m)	1-3 partings
		207		Average (12.4%)	1.50	Average (2.9 m)	none
	Mudstone series – Zaleze strata	352	KWK Brzeszcze (Kompania Weglowa Comp.)	High (8.5%)	0.35	Thin seam (1.4 m)	One parting locally in the eastern part
		405/1		Average (11.8%)	0.90	Average (2.6 m)	some partings
LCB	Lublin strata	382	LW Bogdanka Comp.	Average (18.0%)	1.4	Average (1.7 m)	some partings
		385/2		High (8.4%)	1.1	Thin seam (1.45 m)	some partings

The test procedure

Using geostatistical block kriging assessment errors the following parameters were estimated:

1) seam thickness, which determines resource tonnage and therefore the length of life of the mine,
2) quality parameters, determining coal price:
   - calorific value,
   - ash content,
   - total sulphur content.

Methodology

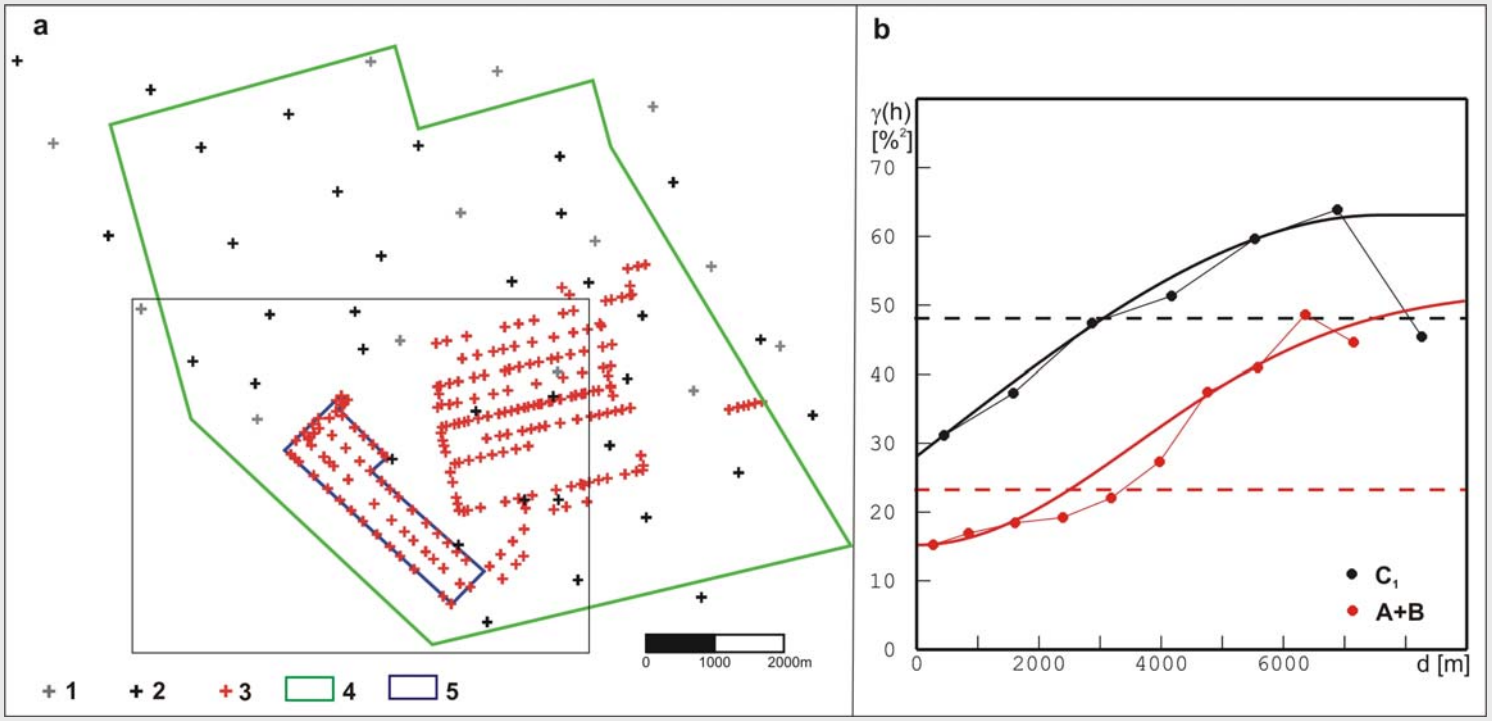
- As a measure of accuracy with which mean parameters in the computational areas were estimated two types of errors were determined: projected and actual (demonstrated).

- Projected errors were determined directly by the kriging method for the data for each geological confidence category.

- Actual (demonstrated) errors were determined by subtracting from the mean value of a parameter, estimated by the kriging method, the mean value established from the production data, or, if there were none, the mean value estimated for the highest geological confidence category.

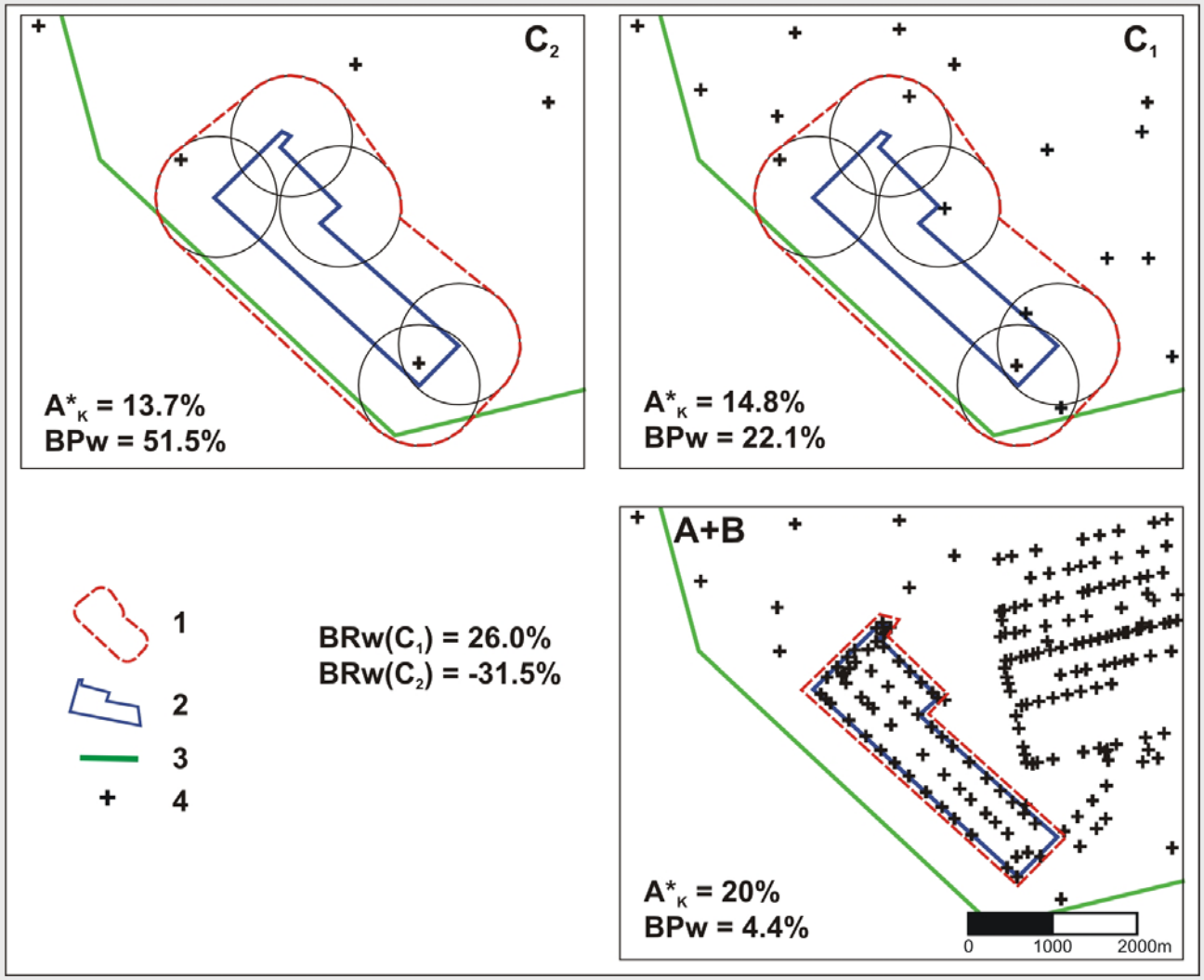
Location of panels and semiwariograms

Location of panels computing



Geostatistical models of the variability of ash content for the categories of geological knowledge C_1 i A+B.

Way of determining the coverage area around the panels count data for the computational identification category C_2, C_1 and A+B and the evaluation of projected and actual errors.

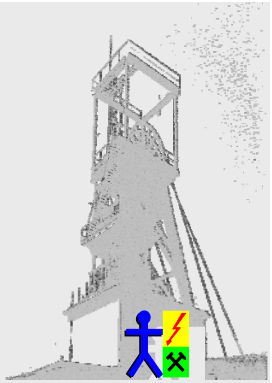


Estimation error levels - results

Mean deposit parameters' assessment errors for extraction areas of analyzed hard coal seams

Seam parameter	Geological confidence category	Relative absolute errors		
		Arithmetic mean of errors [%]	min./max value [%]	Max. possible mean errors at confidence levels of 0.95 [%]
Seam thickness excluding partings *M*[m]	A	2	0.5/4.5	
	B	2	0.0/3.7	10
	C.	6	0.0/24.8	25
	C_2	18	0.7/44.1	35
Ash content *A* [%]	A	n/a	n/a	n/a
	B	16	0.0/52.9	30
	C,	28	0.0/88.4	45
	C_2	30	4.5/84.9	60
Total sulphur content S_t [%]	A	n/a	n/a	n/a
	B	15	0.0/52.5	25
	C,	18	0.8/57.3	35
	C_2	26.2	0.5/67.5	75
Calorific value *Q* [MJ/kg]	A	n/a	n/a	n/a
	B	1	0.0/4.4	5
	C.	4	0.0/20.4	10
	C_2	5	0.4/20.5	12

Determination of the risk adjusted discount rate in relation to the deposit parameter assessment error



The most popular method for economic evaluation of projects - DCF Analysis

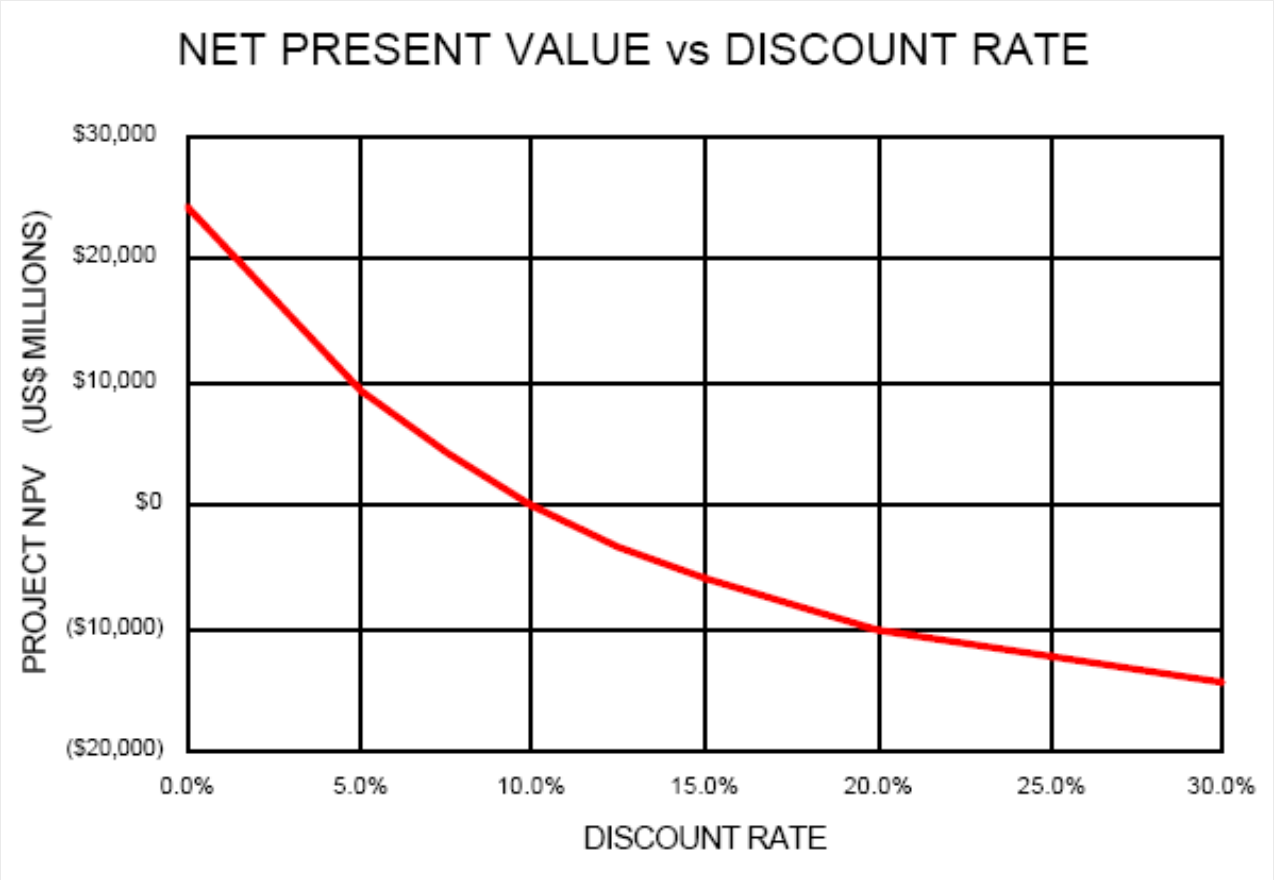
$$NPV = \left[\sum_{t=1}^{n} \frac{CF_t}{(1+i)^t} \right] - I_0$$

The level of the discount rate reflects the risk level project

NPV – net present value
CF_t – cash flow in year t
I_0 – initial investment = CF_0
i – rate adjusted for risk
N – number of years

The variables that have the greatest impact on a discounted cash flow evaluation are:

- the reserves,
- the prices,
- the discount rate.



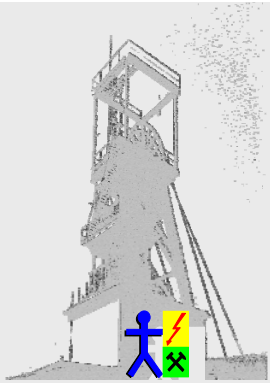
Designing a model of economic evaluation

A cash flow (DCF) spreadsheet for a typical mining capital project carried out at a hypothetical coal mine "X„ was designed.

Assumptions in the economic model *the base case*

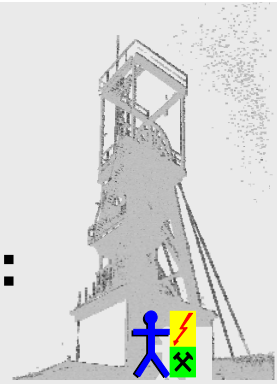
1. capital expenditure: 94.1 mln. zł,
   - longwall – 73.7 mln. zł,
   - development (3000 м) – 20.4 mln. zł.
2. working capital: 33.6 mln. zł.
3. depreciation
   - primary development – 4.5%,
   - machinery and equipment – 20-25%.
4. reserves in the extraction area – 3.361 mln. Mg,
5. longwall parameters :
   - height – 2.34 m,
   - length – 250 m,
   - enclosure – 1000 м.

Assumptions in the economic model *the base case* (cont.)



6. coal quality parameters:
   - calorific value: 22 000 MJ/kg,
   - ash content: 21%,
   - total sulfur content: 0,9%;
7. coal yield: 85.4%.
8. coal price: 152,80 zł/Mg.
9. unit operating cost: 135.00 zł/Mg.
10. unit waste location cost: 12 zł/Mg.
11. The progress of heading development: 176.4 м/month)
12. real discount rate: 4.0%.
13. projected inflation rate: 3.3%.

The following methodology was applied to assess the risk associated with a given variable:



1) Design of spreadsheet computing NPV

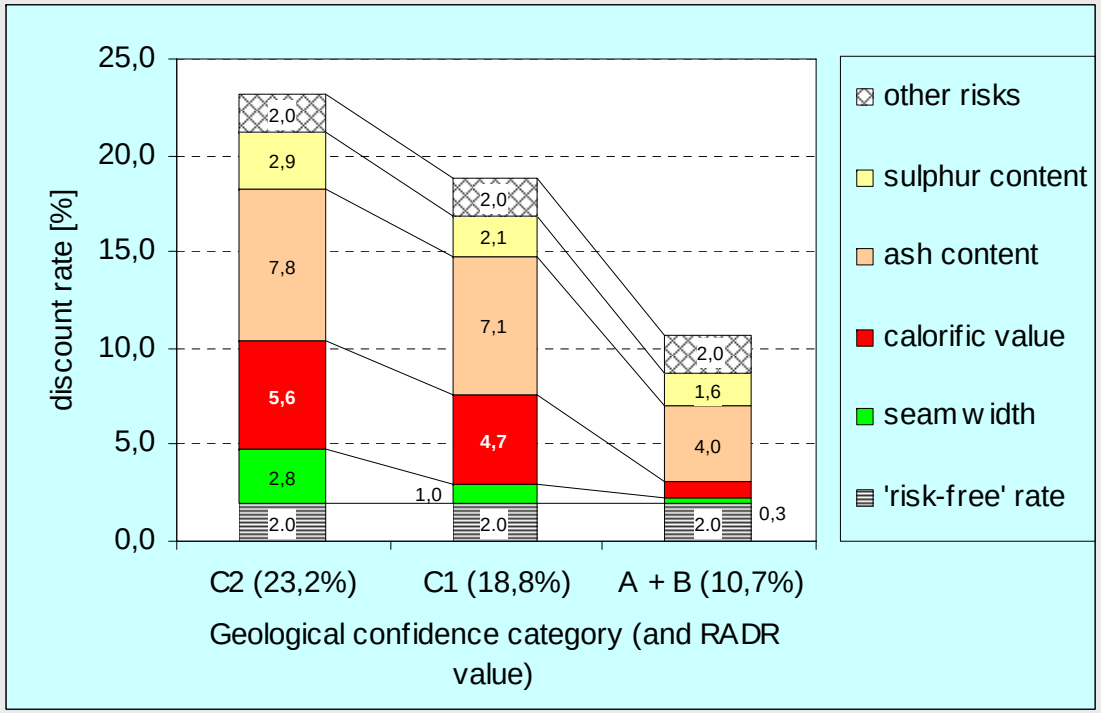
2) Knowing the mean and maximum assessment errors for each deposit parameter, its most unfavorable value was calculated for each geological confidence category.

3) The calculated values were entered into the base NPV spreadsheet and the value of the discount rate at which NPV = 0 was searched for.

4) Risk associated with the given variable was calculated as a difference of the assumed (4 percent) and the calculated discount rates.

The results

Risk-adjusted discount rates for different geological confidence categories of hard coal seams in Poland (mean errors)

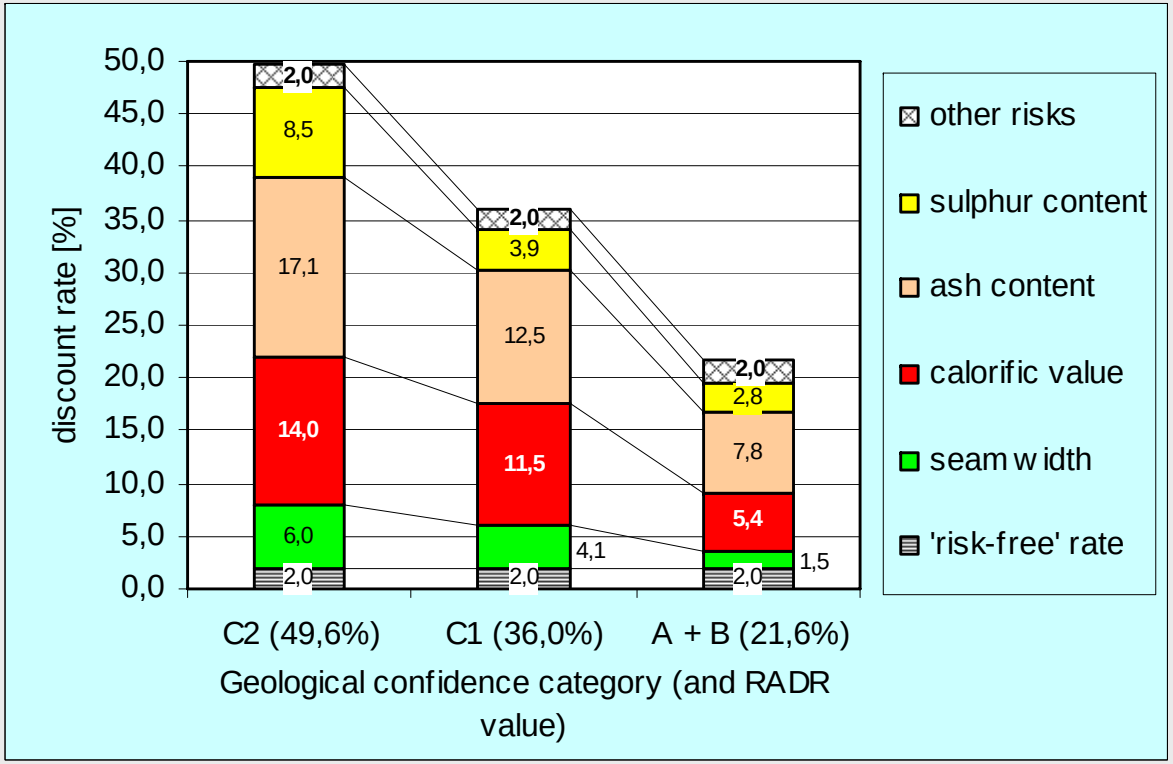


The total risk related to geological confidence decreases as the scope and quality of geological knowledge of the deposit grows.

– 19,2% – category C_2,
– 14,8% – category C_1,
– 6,7% – category A+B.

The results (cont.)

Discount rates for the maximum error



The total risk related to geological confidence

– category C_2 – 45,6%,
– category C_1 – 32,0%,
– category A + B – 17,6%

Conclusions

1. The most important risk factor in a typical hard coal mining project in Poland is the error of assessing coal quality, particularly the error of estimating ash content.

2. Coal seam thickness, which after all determines the length of any project's life, to be the least important risk factor of all the analyzed parameters.

Conclusions (cont.)

3. These values may be used as starting points when calculating RADR for projects where resources are classified into a given category.

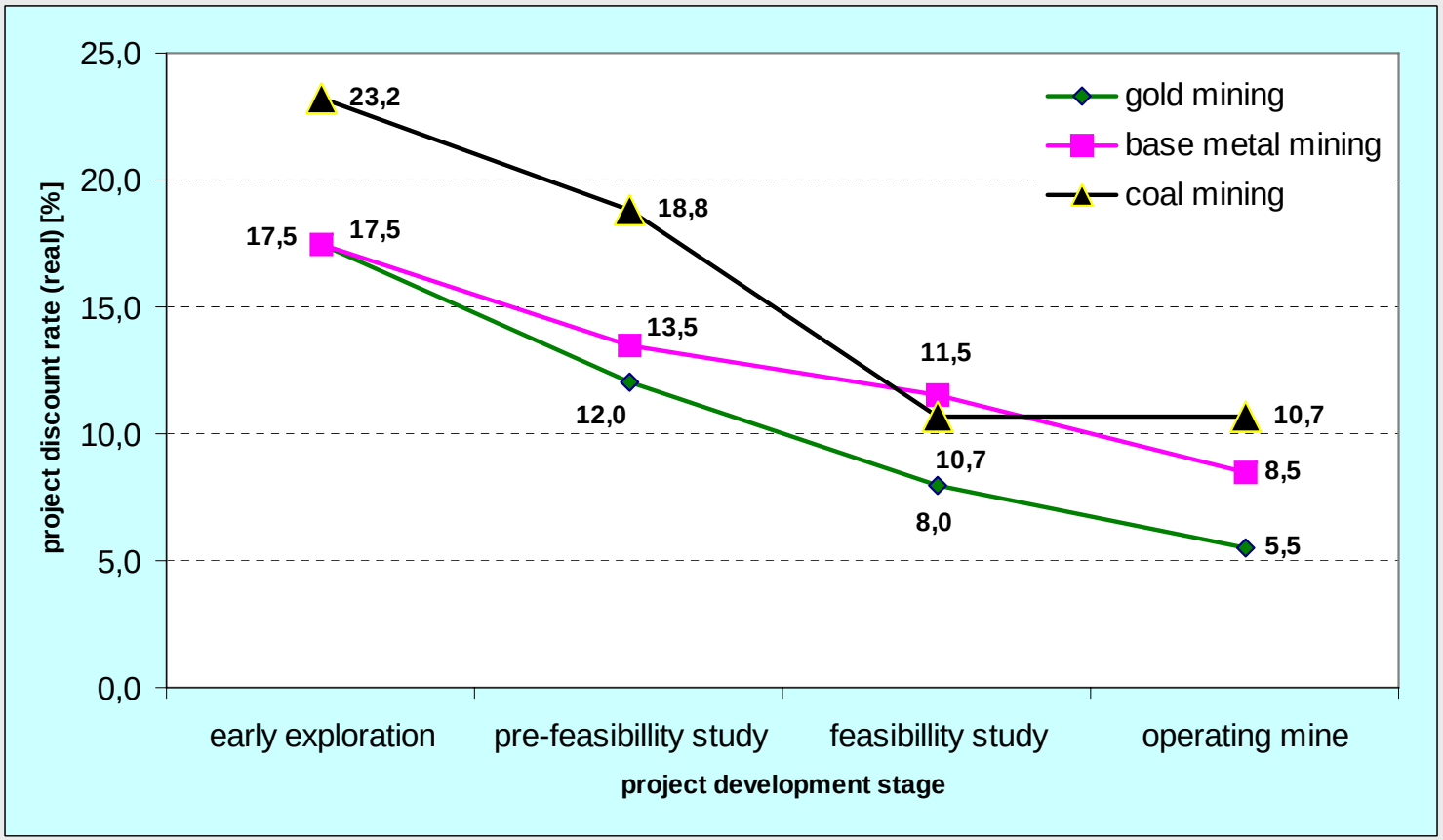
4. Assuming that the real ,,risk-free" rate and the total risk associated with factors other than geological are both equal to 2%, risk adjusted discount rates (real) for projects involving different categories of resources should be as follows:
   - for category C_2 – 23,2%,
   - for category C_1 – 18,8%,
   - for category A+B – 10,7%.

Conclusions (cont.)

5. High value of RADR for resources in C_2 category denotes that these resources should not be used in a discounted cash flow analysis.

6. This is confirmed by the calculated values of possible maximum errors. Total risk for particular categories are as following:
   for category C_2 – 45,6%,
   for category C_1 – 32,0%,
   for category B – 17,6%

Risk adjusted discount rates used in Canada and the USA to evaluate base metals mining projects at different development stages (Smith 2000)



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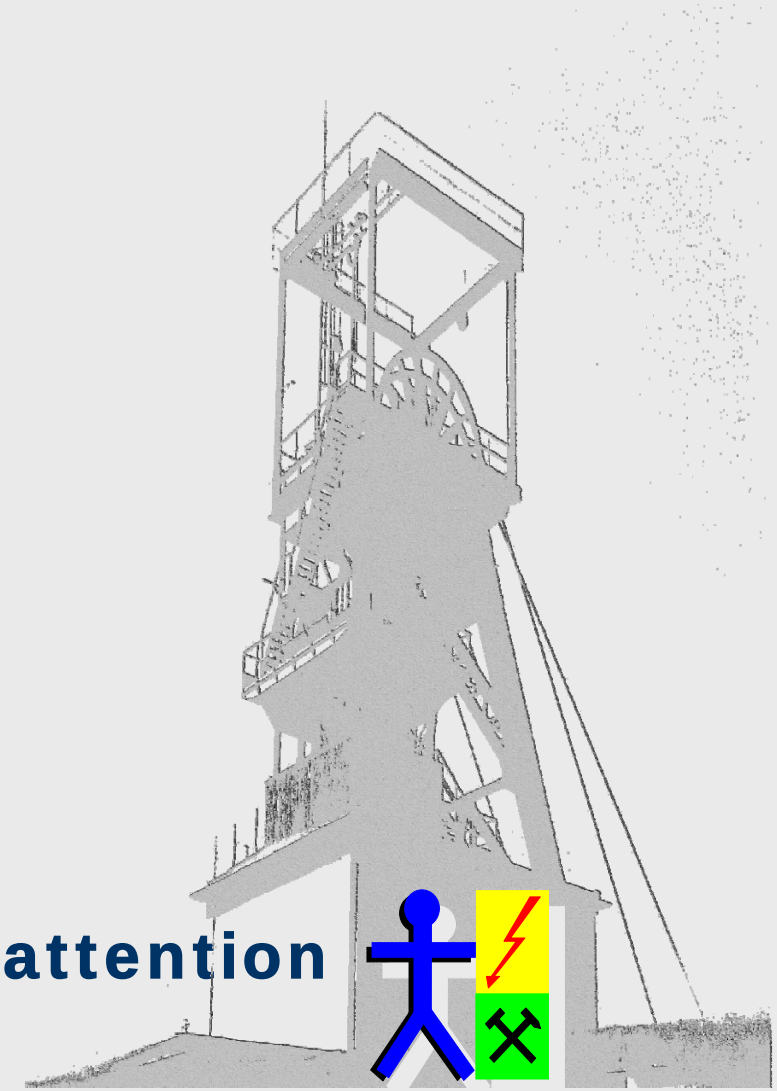

Thank you for attention

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