

Merging LCC into LCA – the example of Polish mining industry

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ABSTRACT: MERGING LCC INTO LCA – THE EXAMPLE OF POLISH MINING INDUSTRY

The main purpose of LCA is to identify and quantify environmental impact of goods and services during their entire life cycle. However, since LCA doesn't consider financial matters, the Life Cycle Cost (LCC) technique should be implemented to encompass all aspects of the project. LCC is defined as the total costs estimated to be incurred during the design, development, production, operation, maintenance, support and final disposal of a system over its anticipated useful life span. LCC consists of an inventory and analysis of the economic implications of the environmental impact of a given product or service. Decision-makers can reasonably expect that implementation of LCA and LCC will lead not only to minimisation of environmental impact of their activities, but also to more effective environmental, cost and waste management. This means savings through reducing the amount of waste emissions and decrease of fees and fines in consequence. Combination of LCA and LCC described in the paper will allow the decision making process to become more efficient, demonstrating the connection between the activity and devastation of the environment.

Keywords: LCA, LCC, mining.

Polish mining industry

Polish mining industry is facing challenges regarding environmental protection and competitiveness improvement. Ecological guidelines concern elimination of harmful solution and effective resource management, which form the basis for sustainable development. For underground mining production in Poland the main environmental problem include solid wastes disposal, mining water release as well as dust and gas emissions. The introduction of a minerals industry policy in 1989, which focused on sustainable development, resulted in the introduction of high fees and fines for environmental pollution. Since these charges became a significant cost factor in the industry, many companies started to invest in more environment friendly solutions. Consequently, the emissions to air and water have declined extensively. Moreover, following the Polish economic reform, energy prices increased, causing the pressure on the reduction of energy consumption in the mining industry. The technological changes, which were necessary from an economic point of view, influenced environmental impact. As a result some mining and processing companies started to apply for ISO 14001 certificate (e.g. Cedynia Copper Wire Mill), and to evaluate the influence on the environment according to Life Cycle Assessment (LCA) principles.

Life Cycle Assessment - LCA

The main purpose of LCA is to identify and quantify environmental impact of goods and services during their entire life cycle. Therefore LCA can be applied to assess the impact on environment of mining production and will allow mining companies to make better decisions regarding the environmental protection. LCA provides the means for the mining industry to assess and locate the points in the whole production, use and disposal process that carry the main environmental load. The basic analysis of Life Cycle Inventory for the Polish mining industry indicates that the highest

amount of wastes and pollution (the highest fee at the same time) are generated at two stages: mining and processing. Therefore these stages should be further divided into more simple elements (functional units) in order to create a database of wastes and pollutants, and to evaluate the significance of potential environmental impacts in any operation. Then solutions regarding minimisation of generated waste amount and pollution can be suggested in order to help decision-makers in their work (Life Cycle Improvement Analysis). Definitions of LCA fundamental concepts, its methodology and application are described in the ISO 14040-14049 series of standards. The concept of LCA is gaining increasing interest in mining industry, since it answers the question of environmental impact assessment together with indication of the possibilities of technology improvement in the existing production process in order to minimise the environmental impact.

Life Cycle Cost - LCC

Since LCA doesn't consider financial aspects, the Life Cycle Cost (LCC) technique should be implemented to encompass all characteristics of an analysed problem. LCC cover all the economic implications of the whole life cycle. LCC is defined as the sum of total costs estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposal of a major system over its anticipated useful life span. LCC refers to all costs associated with the system in the defined life cycle. To identify and reduce all environmental costs, analysis should be performed for each functional unit. The costs taken under consideration should include all environmental costs that, even though met by the company, are not considered to be related to environmental protection – hidden costs, non tangible costs, and potential future costs, as well as social costs and costs paid by other companies for the environmental damage.

Merging LCC into LCA in the Polish mining industry

The growing need to identify economically feasible and environmentally compatible solutions can be observed amongst mining companies today. The aim of merging the LCA and LCC analysis is to create a cost effective model solutions for predicted environmental impact of the particular mine, regardless whether it will be in operation, in liquidation or designated for closure. Any comparison study of the influence of the environmental cost on mining projects should be based on long-term cost-benefit analysis of environmental investment. Depending on the accuracy level of the model, the LCC calculation can consist of the sum of costs for functional units or a sum of costs for every process. This idea will be presented on the basis of Polish mining industry. Functional units are defined according to second (Life Cycle Inventory) and third (Life Cycle Impact Analysis) phase of LCA analysis as a single unit (machinery). Afterwards, LCC for different possible machinery combinations will be calculated.

In this paper, the underground units used in large mining companies during underground loading (stripper loaders) and hauling (carts/trucks) processes will be taken into consideration. Inputs, outputs and determining factors are given as follows:

inputs: ore to transport (t),

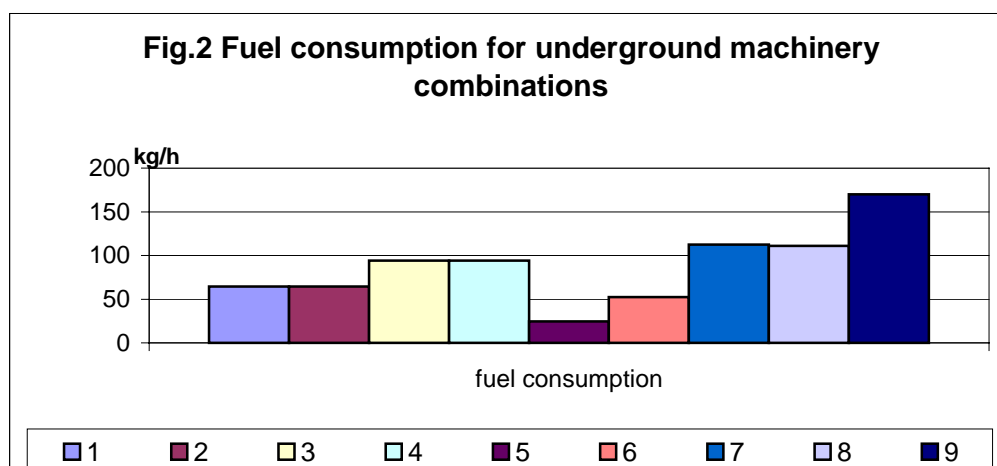
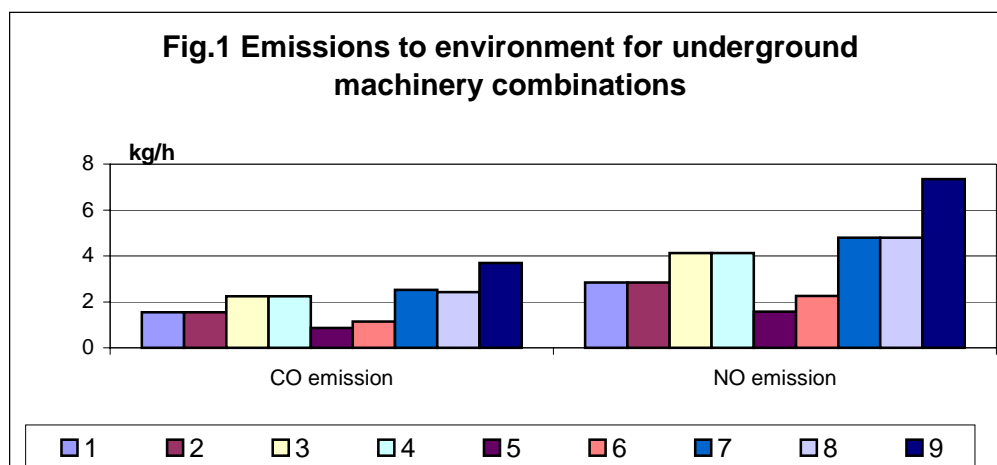
outputs: transported ore (t), CO emission (g/kWh), NO emission (g/kWh), fuel consumption (g/kWh),

determining factors: bucket size (m^3)/capacity (kg) of functional unit (for typical resolver one cubic meter is 1,8 t, but generally it is ca. 2 t), rating of used motor, number of activities per hour (2 for cart, 3 for movable loader and 4 for stationary loader).

The objective is to find optimal machinery combination for underground works, concerning both, environmental and economical criterion. In this case nine reasonable combinations have been chosen and compared by every mentioned output, as it is presented in table 1, and on fig.1 and 2.

Table 1. Efficiency and environmental pollution (per h): underground machinery combinations.

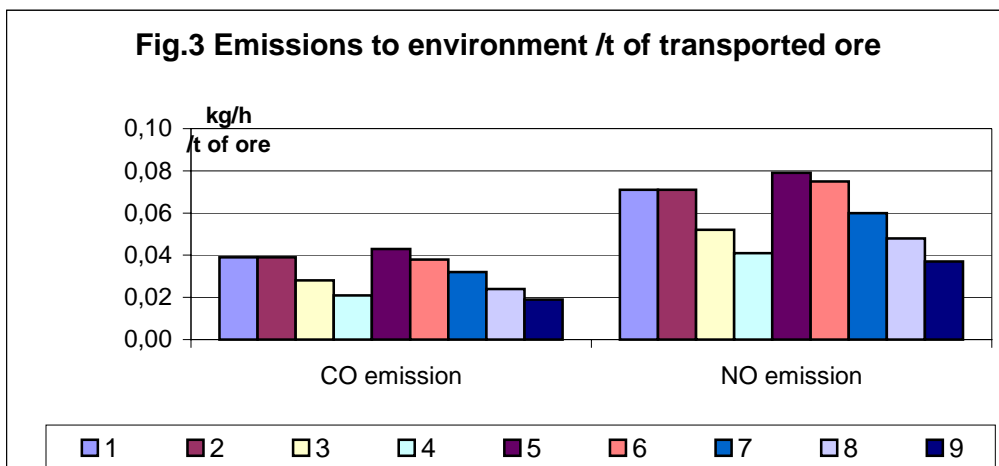
No	Combinations:	Ore Transportation (kg/h)	CO Emission (kg/h)		NO Emission (kg/h)		Fuel Consumption (kg/h)	
1.	Small loader (@2m ³) Small cart (@20,000kg)	40,000	0.86	= 1.55	1.58	=2.85	34.4	=64.3
2.	Medium loader (@3.5m ³) Small cart (@20,000kg)	40,000	0.86	= 1.55	1.58	=2.85	34.4	=64.3
3.	Medium loader (@3.5m ³) 2 small carts (@20,000kg)	80,000	0.86	= 2.24	1.58	=4.12	34.4	=94.3
4.	Medium loader (@3.5m ³) Large cart (@50,000kg)	100,000	0.86	= 2.14	1.58	=4.12	34.4	=93.1
5.	Medium loader (@3.5m ³)	20,000	0.86		1.58		34.4	
6.	Large loader (@6 m ³)	30,000	1.14		2.26		52.4	
7.	Large loader (@6 m ³) 2 small carts (@20,000kg)	80,000	1.14	= 2.52	2.26	=4.80	52.4	=112.3
8.	Large loader (@6 m ³) Large cart (@50,000kg)	100,000	1.14	= 2.42	2.26	=4.80	52.4	=111.1
9.	Large loader (@6 m ³) 2 large carts (@50,000kg)	200,000	1.14	= 3.70	2.26	=7.34	52.4	=169.8

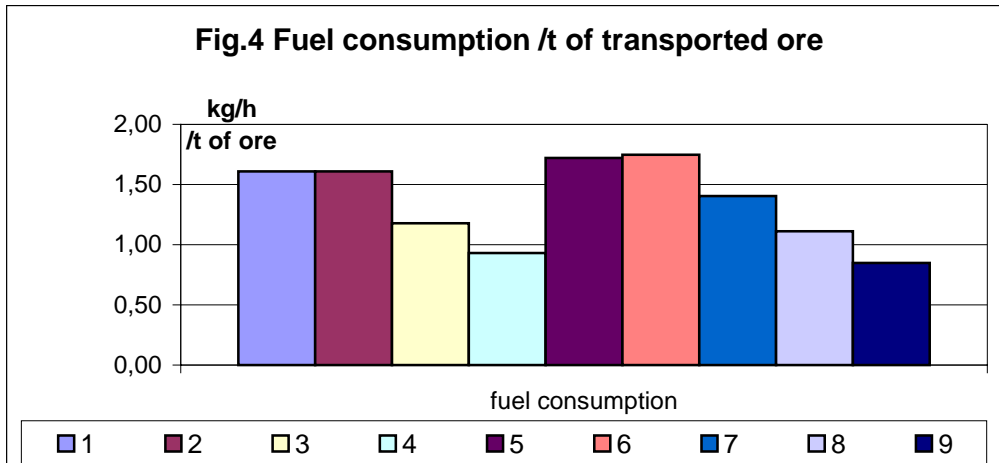


Initial results of comparison (per hour) can be easily estimated: bigger number of functional units result in higher ore transportation volume, as well as in negative environmental effect. This kind of calculation proves to be useful in very few cases due to non-proportional increase in transported ore volume versus emissions and fuel consumption. Therefore further calculations have to be performed: outputs per transported ore (tab. 2, fig. 3, 4).

Table 2. Efficiency and environmental pollution (per t of transported ore): underground machinery combinations.

No	Combinations:	kg of CO/t of transported ore	kg of NO/t of transported ore	kg of fuel/t of transported ore
1.	Small loader (@2m ³) small cart (@20,000kg)	0.039	0.071	1.608
2.	Medium loader (@3.5m ³) Small cart (@20,000kg)	0.039	0.071	1.608
3.	Medium loader (@3.5m ³) 2 small carts (@20,000kg)	0.028	0.052	1.179
4.	Medium loader (@3.5m ³) large cart (@50,000kg)	0.021	0.041	0.931
5.	Medium loader (@3.5m ³)	0.043	0.079	1.720
6.	Large loader (@6 m ³)	0.038	0.075	1.747
7.	Large loader (@6 m ³) 2 small carts (@20000kg)	0.032	0.060	1.404
8.	Large loader (@6 m ³) large cart (@50,000kg)	0.024	0.048	1.111
9.	Large loader (@6 m ³) 2 large carts (@50,000kg)	0.019	0.037	0.849



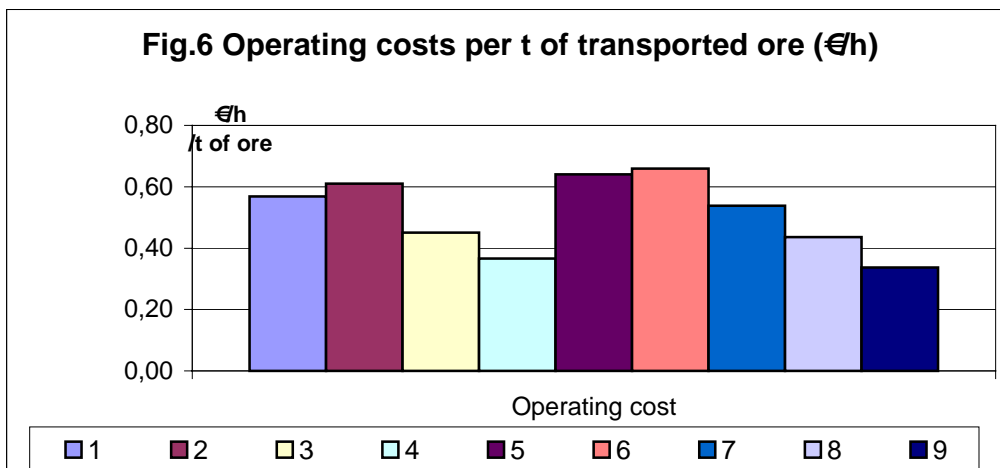
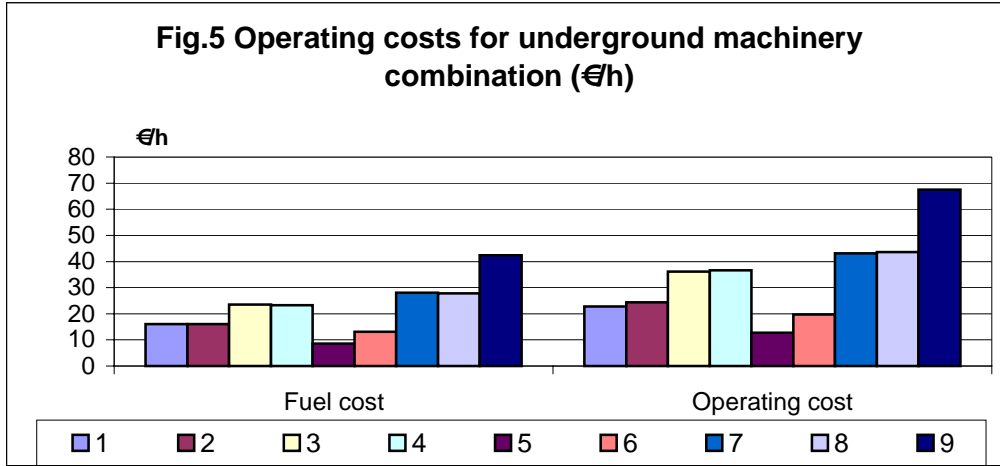


Concluding this stage of comparison, obtained results recommend (under all criteria) combinations containing medium or large loader and one or even two large carts. Additionally, combinations containing small loaders and carts seem to be inefficient when mining conditions require several equipment pieces working simultaneously. At this level economical aspects should be added to answer the question about profitability of more environmental friendly solutions. Simple comparison can be provided when capital cost will be spread into working hours (20 years, 3,000 h/year) as an amortisation cost, then added to operational cost – in this case: fuel consumption (tab. 3, fig. 5,6).

Table 3. Underground machinery combinations – profitability (per t of transported ore).

No	Combinations:	Capital cost (€)	Fuel cost (€/h) (250€/t)	Operating cost (fuel + 5% amortisation)/h	Op. cost (/h)/t of transported ore
1.	Small loader (@2m ³) small cart (@20,000kg)	150,000 250,000	8.60 7.48 =16.08	11.10 11.65 =22.75	0.278 0.291 =0.569
2.	Medium loader (@3.5m ³) Small cart (@20,000kg)	250,000 250,000	8.60 7.48 =16.08	12.77 11.65 =24.42	0.319 0.291 =0.610
3.	Medium loader (@3.5m ³) 2 small carts (@20,000kg)	250,000 500,000	8.60 14.98 =23.58	12.77 23.31 =36.08	0.160 0.291 =0.451
4.	Medium loader (@3.5m ³) large cart (@50,000kg)	250,000 550,000	8.60 14.68 =23.28	12.77 23.85 =36.61	0.128 0.238 =0.366
5.	Medium loader (@3.5m ³)	250,000	8.60	12.77	0.638
6.	Large loader (@6 m ³)	400,000	13.10	19.77	0.659
7.	Large loader (@6 m ³) 2 small carts (@20,000kg)	400,000 500,000	13.10 14.98 =28.08	19.77 23.31 =43.08	0.247 0.291 =0.538
8.	Large loader (@6 m ³) large cart (@50,000kg)	400,000 550,000	13.10 14.68 =27.78	19.77 23.85 =43.62	0.198 0.238 =0.436

9.	Large loader (@6 m ³) 2 large carts (@50,000kg)	400,000 1,100,000	13.10 29.35 =42.45	19.77 47.68 =67.45	0.099 0.238 =0.337
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An initial economical analysis also indicates that combinations containing medium/large loaders and large carts are preferred solutions, especially two of them: first, with large loader and 2 large carts, and second, with medium loader and one cart. That conclusion is based on operating cost per hour / 1 ton of transported ore (operating costs per hour without consideration of transport possibility is not a best measure in this case). The solutions including small loaders and small carts seem to be significantly more expensive.

Conclusions

LCA provides the means for the mining industry to assess and situate the “hot spots” in the whole production, use and disposal process that carry the main environmental load. The basic analysis of Life Cycle Inventory for the Polish producers indicates that the most significant environmental liability – expressed in the amount of waste and pollution – is caused at the mining and processing stage. As presented, an economic approach to Life Cycle Assessment (LCA) – Life Cycle Cost (LCC) – is useful for evaluation of new and ongoing investment profitability. Implementation of LCA together with LCC analysis would help in more effective environmental and cost management, mainly due to:

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Engineering for sustainable development
- an obligatory skill of the future engineer



- cost savings through reduced waste emissions - resulting in reduced fees and fines,
- identification of specific costs, establishing “centres of responsibility” in places where costs are incurred – quantity savings,
- comparison of capital intensity (operational and overall) for different processes and methods of production – potential for decreased costs over the long term,
- demonstration of the connection between the activity and destruction of the environment,
- improvement of companies’ image on domestic and foreign markets.

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