EVALUATING SUSTAINABILITY IN A METALLURGICAL COMPANY

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Abstract

The paper presents a methodology for the evaluation of sustainability in metallurgical companies. The methodology is based on the Analytic Network Process (ANP), which is used to solve the complex decision-making problems, whose structures can be mapped as non-linear networks. The methodology is verified on the generalized model of a metallurgical supply chain.

Keywords: Metallurgical company, sustainability, multi-criteria decision making method, analytic Network Process

1. INTRODUCTION

Sustainable development is currently one of the main global objectives of large metallurgical companies. The metallurgical companies which have focused only on economic targets in the past are facing a high level of pressure from stakeholders (customers, employees, citizenry and government) in recent years, requiring the implementation of sustainability. From this perspective, the most discussed topic is environmental protection, especially with an emphasis on local air pollution. At the same time, large metallurgical enterprises are expected to have social responsibility towards the region in which they operate. To implement a sustainable strategy it is necessary to know how to effectively measure and evaluate each area of sustainability. This article aims to draft the methodology for the evaluation of sustainability in metallurgical companies.

2. SUSTAINABILITY AND ITS EVALUATION IN METALLURGICAL COMPANIES

Although there exists a divergence of definitions of sustainability, these differences are not too great. Most definitions of sustainability incorporate a consideration of environmental, economic, and social dimensions:

- Sustainability is a wise balance among economic development, environmental stewardship, and social equity [1].
- Sustainability includes equal weightings for economic stability, ecological compatibility and social equilibrium [2].

These definitions are based on the Elkington's [3] triple bottom line (the intersection of environmental, social, and economic performance).

Sustainability in the field of metallurgy is a very fundamental topic. Proof of this assertion is the extensive published strategies of sustainability of leading reputable metallurgical companies such as ArcelorMittal [4] Nippon Steel [5] or POSCO [6]. The emergence of the new professional magazine "Journal of Sustainable Metallurgy", which has been published by Springer since 2015, is also a good example. There are professional articles from the field of metallurgy dealing with a general description of the problems, or evaluating the situation in a particular country [7, 8, 9]. In addition, specific environmental problems are examined: emissions [10] or waste [11], or in the social field: Corporate Social Responsibility (CSR) [12] or Business Ethics [13].

A neglected topic, however, is sustainability assessment, which is now monitored only through sub-indicators [14] or on a national level, as stated in studies such as [15]. A comprehensive monitoring and evaluation at the enterprise level would provide an opportunity for individual companies to determine the level of implementation of the sustainability strategy. Based on this information, benchmarking for example of individual companies within a holding structure could be done, or monitoring over a longer period of time.

3. METHODOLOGY PROPOSAL AND ITS METHODOLOGICAL BASIS

The proposed methodology of sustainability evaluation in the metallurgical company has five basic stages. The basic stages of the methodology include: I) Analysis of triple bottom line of sustainability; II) Draft of sustainability indicators; III) Creation of a network system of sustainability indicators; IV) Evaluation of the sustainability of metallurgical company, and V) Interpretation of obtained results. Stages III, IV and V are supported by Analytic Network Process (ANP).

The ANP, developed by Saaty, is a multistage decomposition method used to solve decision-making problems involving more than one criterion of optimality [16]. The main principle behind ANP is to view decisions as based on a framework of interconnected factors and evaluate the given factors in relationship to each other. These evaluations are represented by weights, which are determined on the basis of pair comparisons.

ANP is performed on the basis of three basic steps (modified according to [16, 17, 18]):

1) Model construction. A decision-making problem is analysed by researchers and transformed into a network structure. This network contains elements, clusters and connections. The elements symbolise fundamental building blocks of the network. They represent both criteria and alternatives. Clusters are groupings of elements, which are logically related factors of the decision. Connections determine interdependence among elements.

2) Pair wise comparison matrices and local priority vectors. The determination of weights is based on node pair wise comparisons when one element depends on two or more different elements from one cluster and on cluster pair wise comparisons when elements (one or more) from one cluster depend on two or more elements from other clusters. The relative importance values are determined using Saaty's 1-9 scale. Pair wise comparisons are performed in the framework of node and cluster matrices, and local priority vectors are derived as estimates of the relative importance associated with the elements or clusters being compared.

3) Supermatrix construction. In the first step, the unweighted supermatrix is created directly from all local priority vectors. In the second step, the weighted supermatrix is calculated by multiplying the values of the unweighted supermatrix with their affiliated cluster weights. By normalizing the weighted supermatrix, it is made column-stochastic. In the third and final step, the limit supermatrix is processed by raising the entire supermatrix to powers until it converges in terms of lines. Limit priority values within this supermatrix indicate the flow of influence of an individual element towards the overall goal. Since the decision alternatives are elements of an original cluster of the network, their limit priorities are synonymous with their contributions to the goal and are used for the ranking of alternatives, being normalized within the cluster [19].

4. CASE STUDY

To verify the proposed methodology, a generic representative of a European metallurgical enterprise has been created. This enterprise has a closed metallurgical cycle, production of approx. 2 million tons of steel per year, turnover of approx. EUR 1.25 billion per year and Earnings Before Interest and Taxes (EBIT) of almost EUR 1 billion per year. The enterprise is part of a global holding structure and produces and delivers mainly flat and long steel products.

In the first phase it is necessary to analyze the triple bottom line of sustainability (the intersection of environmental, social, and economic performance). The analysis has been conducted in the form of brainstorming, with the participation of the authors and managers from metallurgical practice. Its aim was to analyze a wide range of possible indicators from individual areas.

In the second phase, specific indicators have been selected, which best describe each area for the selected representative metallurgical enterprise. These indicators have been specified in detail with a global scale with which it is possible to express their fulfilment. The scale has been designed using a simple principle of a subjective grading scale, so that its use is fast and simple for the managers in the field. The scale has a range of 0 - 5 and the individual scores express the following:

0) the enterprise achieves the worst values on the global scale for the given indicator.
1) the enterprise achieves the worst values on the European scale for the given indicator.
2) the enterprise achieves below-average values on the global scale for the given indicator.
3) the enterprise achieves average values on the global scale for the given indicator.
4) the enterprise achieves the best values on the European scale for the given indicator
5) the enterprise achieves the best values on the global scale for the given indicator.

The individual indicators together with their values in the metallurgical enterprise under evaluation are shown and described in **Table 1**.

Table 1 Basic description of individual criteria

Area	Indicator name	Abbreviation	Basic description	Value
Environmental	Energy intensity	EI	Total average energy consumption per one ton of production	3
	Material intensity	MI	Total average material consumption per one ton of production	4
	Air pollution	AP	Total emission load per 1 year	4
	Noise pollution	NP	Average noise pollution in and around the plant	1
Social	Health and safety	H&S	The number of accidents and occupational diseases per one year and 1,000 employees	3
	Staff development	SD	Assessment of the HR development system	2
	Region supporter	RS	Financial support of regional development per 1 year (schools, non-profit organizations, environment…)	5
	Stable employer	SE	Interim increase of the number of work positions (Note. updated evaluation scale, 3 = interim increase equals 0)	3
Economic	Revenues	R	Revenues from industrial activity per 1 year (plan/reality)	3
	EBIT	EBIT	Earnings before Interest and Taxes per 1 year (plan/reality)	3
	Capacity utilization	CU	Annual utilization of available capacity	2
	Production costs	PC	Average production costs per 1 ton of production	4

In the third stage, the network structure of sustainability indicators has been designed. The structure is shown in **Figure 1**. The figure clearly shows that the individual indicators are widely interconnected. The full lines represent the basic hierarchical structural bonds, which show the dependency of sustainability of all the selected indicators. The dashed lines show the relationships between the indexes, while 26 of such relations have been found.

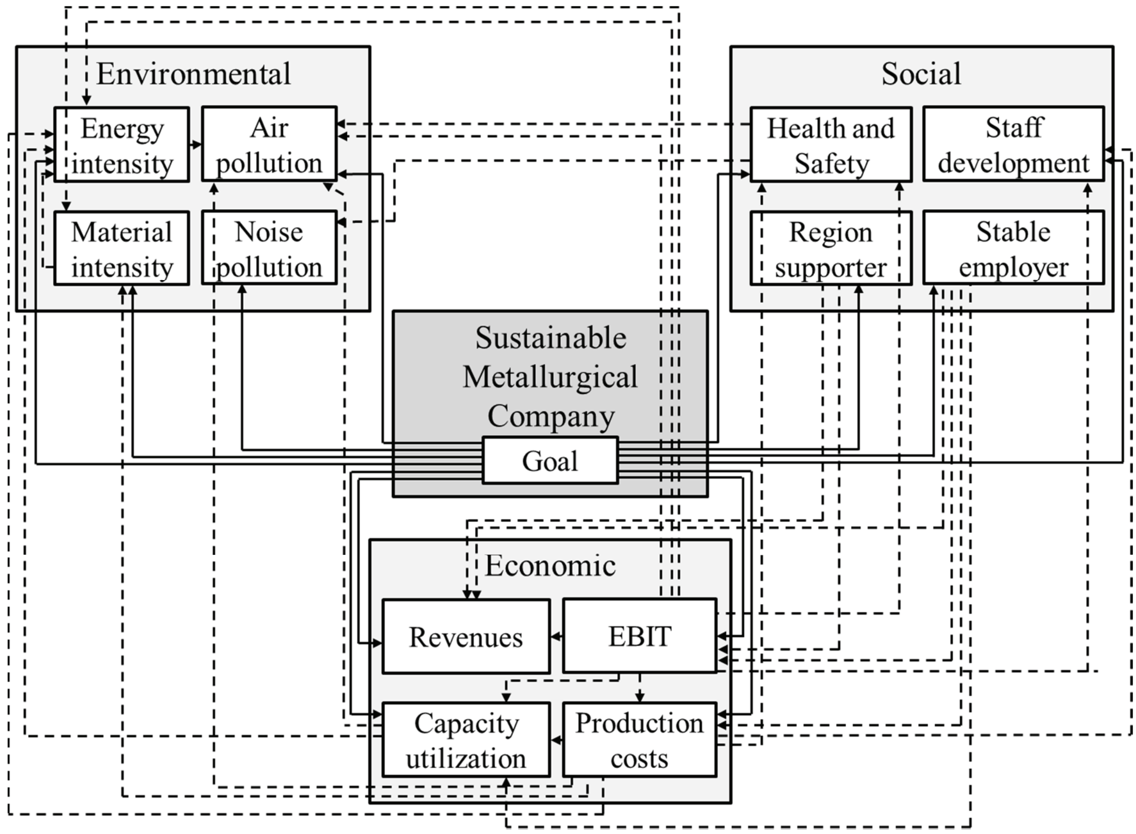

Figure 1 The network structure of sustainability assessment

The fourth phase is based on a separate sustainability assessment based on the ANP principles and which consists of creation and calculation of 1) Pair wise comparison matrices and local priority vectors and 2) Supermatrix.

Considering the high number of mutual relations, it is necessary to create and calculate 15 different pair wise comparison matrices, to determine the local priority vectors. **Table 2** captures the pair wise comparison matrices of type „cluster", which are used to create the cluster supermatrix. **Table 3** shows the pair wise comparison of type „node", which together with standardized values of the investigated enterprise create the unweighted supermatrix. Grey indicates the tables based on the hierarchical structure. The final limit supermatrix, with the requested results, is created using the procedure described in Chapter 3. For the calculation, the SuperDecisions software has been used, which greatly simplifies and speeds the entire process up, allowing its application in practical terms. Based on these calculations, two groups of results are obtained, which are shown in **Table 4** and **Figure 2**.

Table 2 Cluster pairwise comparison

SMC	ENVIRO	SOCIAL	ECO
ENVIRO	1	1	1/3
SOCIAL	1	1	1/3
ECO	3	3	1

ECO	ENVIRO	SOCIAL	ECO
ENVIRO	1	2	1/2
SOCIAL	1/2	1	1/3
ECO	2	3	1

SOCIAL	ENVIRO	ECO
ENVIRO	1	1/2
ECO	2	1

ENVIRO	ENVIRO	ECO
ENVIRO	1	3
ECO	1/3	1

Table 3 Node pair wise comparison

ENVIRO	EI	MI	AP	NP
EI	1	2	3	4
MI	1/2	1	2	3
AP	1/3	1/2	1	3
NP	1/4	1/3	1/3	1

SOCIAL	H&S	SD	RS	SE
H&S	1	3	2	1
SD	1/3	1	1/2	1/3
RS	1/2	2	1	1/3
SE	1	3	3	1

ECO	R	EBIT	CU	PC
R	1	1/3	1	1
EBIT	3	1	3	3
CU	1	1/3	1	1
PC	1	1/3	1	1

SE	R	EBIT	CU	PC
R	1	1/3	1	1
EBIT	3	1	3	3
CU	1	1/3	1	1
PC	1	1/3	1	1

PC	EI	MI	AP
EI	1	1/2	2
MI	2	1	3
AP	1/2	1/3	1

EBIT	R	CU	PC
R	1	2	1
CU	1/2	1	1/2
PC	1	2	1

EBIT	EI	MI	AP
EI	1	1/2	2
MI	2	1	3
AP	1/2	1/3	1

PC	H&S	SD
H&S	1	1/3
SD	3	1

RS	R	EBIT
R	1	1/3
EBIT	3	1

H&S	AP	NP
AP	1	3
NP	1/3	1

EBIT	H&S	SD
H&S	1	1
SD	1	1

Table 4 captures the global weights of the individual indicators. It can be stated that the most significant sustainability indicators for a metallurgical enterprise are, in descending order EBIT, Capacity utilization, Material intensity and Energy intensity. This result has been confirmed by the team members and can be considered as correct.

Table 4 Global weights of indicators

Environmental	Energy intensity	11.3994	Social	Health and Safety	4.9726	Economic	Revenues	9.2200
	Material intensity	15.1972		Staff development	3.4565		EBIT	16.7888
	Air pollution	6.8746		Region supporter	1.7466		Capacity utilization	16.2796
	Noise pollution	2.0394		Stable employer	3.2419		Production costs	8.7834

Figure 2, output from the SuperDecisions software, shows the final sustainability assessment of the investigated metallurgical enterprise. The investigated enterprise currently fulfills the sustainability strategy to 64.8 %. This corresponds to the slightly above-average value on the global scale. However, due to the current trend that considers sustainability as a fundamental priority of metallurgical enterprises, it is possible to identify a high potential to increase the sustainability of the investigated metallurgical enterprise.

Name	Graphic	Ideals	Normals	Raw
Maximum		1.000000	0.606781	1.000000
Minimum		0.000020	0.000012	0.000020
Real		0.648020	0.393206	0.648020

Figure 2 Graphical interpretation of results

5. CONCLUSION

The results of the case study demonstrated the viability of the proposed methodology for evaluation of sustainability in metallurgical companies. Since sustainability is included in the strategic management of metallurgical enterprise, the indicators used to measure the triple bottom line of sustainability are closely mutually connected. In such a situation, the methods of multi-criteria decision making cannot be used for assessment, because they do not take this fact into account. From this perspective, the ANP may be considered an appropriate methodological starting point of the proposed methodology. The possible deficiency of the proposed methodology is the assessment of the used indicators in the form of a subjective point scale. Also the pair wise comparison is loaded by a relatively high degree of subjectivity. To address these shortcomings, further research will be dedicated to adding fuzzy logic to ANP (Fuzzy Analytic Network Process - FANP).

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REFERENCES

[1] SIKDAR, S. K. Sustainable Development and Sustainability Metrics. *AIChE Journal*, 2003, vol. 49, no. 8, pp. 1928-1932.

[2] GONCZ, E., SKIRKE, U., KLEIZEN, H., BARBER, M. Increasing the Rate of Sustainable Change: a Call for a Redefinition of the Concept and the Model for its Implementation. *Journal of Cleaner Production*, 2007, vol. 15, no. 6, pp. 525-37.

[3] ELKINGTON, J. Enter the Triple Bottom Line. In HENRIQUES, A., RICHARDSON, J. (Eds), *The Triple Bottom Line: Does It All Add up?* London: Earthscan, 2004, pp. 1-16.

[4] ARCELOR MITTAL. ArcelorMittal unveils new approach to sustainability, 2016. Available from: reporting,http://corporate.arcelormittal.com/news-and-media/news/2016/april/27-04-2016

[5] NIPPON STEEL & SUMITOMO METAL. Sustainability Report, 2014. Available from: http://www.nssmc.com/en/csr/report/nssmc/pdf/report2014_all.pdf

[6] POSCO. Sustainability Management System, 2016. Available from: http://www.posco.com/homepage/docs/eng5/jsp/sustain/able/able_01.jsp?mdex=posco26

[7] BLUSZCZ, A., KIJEWSKA, A. Challenges of sustainable development in the mining and metallurgy sector in Poland. *Metalurgija*, 2015, vol. 54, no.2, pp. 441-444.

[8] SHATOKHA, V. The Sustainability of the Iron and Steel Industries in Ukraine: Challenges and Opportunities. *Journal of Sustainable Metallurgy*, 2016, vol. 2, pp. 106-115.

[9] RADOVIĆ, N., KAMBEROVIĆ, Ž., PANIAS, D. Cleaner metallurgical industry in Serbia: A road to the sustainable development. *Chemical Industry and Chemical Engineering Quarterly/CICEQ*, 2009, vol. 15, no. 1, pp. 1-4.

[10] JAHANSHAHI, S. et al. Development of Low-Emission Integrated Steelmaking Process. *Journal of Sustainable Metallurgy*, 2015, vol. 1, no. 1, pp. 94-114.

[11] LEE, H., SOHN, I. Global Scrap Trading Outlook Analysis for Steel Sustainability. *Journal of Sustainable Metallurgy*, 2015, Vol. 1., No. 1, pp. 39-52.

[12] METAXAS, T., TSAVDARIDOU, M. CSR in metallurgy sector in Greece: A content analysis. *Resources Policy*, 2013, vol. 38, no. 3, pp. 295-309.

[13] GAJDZIK, B. Social and Ethical Challenges for Metallurgical Companies. *Metalurgija*, 2008, vol. 47, no. 1, pp. 61-63.

[14] GIODA, A. et al. Evaluation of air quality in Volta Redonda, the main metallurgical industrial city in Brazil. *Journal of the Brazilian Chemical Society*, 2004, vol. 15, no. 6, pp. 856-864.

[15] ZHANG, X. et al. Emergy evaluation of the sustainability of Chinese steel production during 1998-2004. *Journal of Cleaner Production*, 2009, vol. 17, no.11, pp. 1030-1038.

[16] SAATY, T. L., VARGAS, L. G. *Decision Making with the Analytic Network Process: Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks*. New York: Springer, 2013.

[17] SAATY, T. L. Fundamentals of the analytic network process - multiple networks with benefits, costs, opportunities and risks. *Journal of Systems Science and Systems Engineering*, 2004, vol. 13, no. 3, pp. 348-379.

[18] SAATY, T. L. Fundamentals of the analytic network process - dependence and feedback in decision-making with a single network. *Journal of Systems Science and Systems Engineering*, 2004, vol. 13, no. 2, pp. 129-157.

[19] WOLFSLEHNER, B., VACIK, H., LEXER, M. J. Application of the analytic network process in multi-criteria analysis of sustainable forest management, *Forest Ecology and Management*, 2005, vol. 207, no. 1, pp. 157-170.