USING DODGSON, KEMENY AND KOHLER PRIORITIZATION STRATEGIES TO INTEGRATE THE RESULTS OF DIFFERENT ENVIRONMENTAL IMPACT ASSESSMENT METHODS

Sajjad Mohebali[1,3], Soroush Maghsoudy[2,3] , Faramarz Doulati Ardejani[2,3] *

[1] *School of Progress Engineering, Iran University of Science & Technology, Tehran, Iran.*
mohebali_s@pgre.iust.ac.ir
[2] *School of Mining, College of Engineering, University of Tehran, Tehran, Iran*
s.maghsoudy@ut.ac.ir
[3] *Mine Environment & Hydrogeology Research Laboratory (MEHR Lab), University of Tehran, Tehran, Iran*
fdoulati@ut.ac.ir

Abstract: Mining industries have always been a major source of environmental concern for human societies. Coal extraction and processing has a high potential for creating the various types of environmental pollutions, due to its nature. In this research, the Alborz Sharghi coal washing plant in Iran and its effects on the surrounding environment have been investigated using different environmental impact assessment methods. First of all, a list of plant activities and the environmental impacts of these activities was prepared, then the environmental impacts of the plant was measured by modified Folchi matrix, analytical hierarchy process, and rapid impact assessment matrix. Experts opinions showed that "wastewater from the plant", "toxic pollutants" and "tailings discharge" with scores of 8, 7.9, and 7.9, respectively, were the most important impacting factors of the plant. The differences between the results of various EIA methods have always been a challenge in environmental impact assessment. In the present study, it has been attempted to combine the results of different EIA methods using various integration strategies such as Borda, Copeland, Kemeny, Kohler, and the Direct Ranking Strategy (DRS). Using the method of Coupled Environmental Impact Assessment (C-EIA) to combine the different methods, showed that four components of "groundwater", "area landscape", "soil of the area" and "ecology" with about 0.12 score are the most critical environmental components of the plant, respectively.

Keywords: Coal washing plant, C-EIA method, Integration strategies, Environmental Impact Assessment, Alborz Sharghi.

1- INTRODUCTION

Environmental Impact Assessment detects different impacts of a project on the environment. Understanding these impacts can provide a suitable plan to prevent and reduce the hazardous effects. In the past decades, several studies have been conducted to assess the environmental impacts of different industries. These studies gradually become systematic, and the modern EIA methods was developed. Luna B. Leopold is one of the environmental impact assessment pioneers. In the late 1960s, Leopold created a method to assess the environmental impacts of different types of developments. This method is considered as one of the first EIA methods.

Wang et al. (2006) conducted an EIA method using the evidential reasoning approach that is based on the recursive nature of qualitative and quantitative evaluation of information. Considering the uncertainty in the common EIA methods, Deng et al. (2014) invented the D-number approach. This method was modified and used by Wang and Wei (2017).

The main ongoing challenge is to understand which EIA method is the appropriate one and which one is closer to reality. The current research attempts to find a combined method to

* Corresponding Author

integrate different EIA methods and accordingly, to provide a unique solution for environmental issues. As a case study, we have implemented our findings on the Alborz coal washing plant in Northeastern Iran.

Regarding the environmental concerns in the area, an environmental impact assessment was carried out using three methods, Folchi Matrix, AHP method, and RIAM Matrix.

Finally, obtained results were integrated using integration strategy algorithms such as Kemeny, Dodgson and Kohler and a single result was proposed to investigate the environmental status of the coal washing plant.

2- METHODS

The Folchi method is one of the most widely used methods of environmental impact assessment that was introduced by Roberto Folchi in 2003. In this method, first a matrix is built that shows the impact factors in rows and environmental components in columns. This matrix is called the Global Matrix. In this matrix, the impacting factors show the activities of the evaluated plant or project, which is under environmental evaluation. It also provides the quantitative values of the impact weights for each activity in the plant. It is an M*1 matrix that is also called the Weighted Criteria Matrix.

These two matrices are filled in by the experts who are familiar with different EIA methods and know the study area and project. Ultimate result shows the magnitude of components that impact the environment and is obtained through Eq.1:

$$[C]_{n\times 1} = [F]_{n\times m}[M]_{m\times 1} \quad (1)$$

- Physicochemical (PC)
- Biological – Ecological (BE)
- Social – Cultural (SC)
- Economic – Operational (EO)

The important criteria are divided into two categories; those showing the importance of an impact's greatness and status that are shown with *A*, and those illustrating the importance of the location and are shown with *B*. The score value of each criteria group (*A* or *B*) is provided through a series of simple equations. The scoring process for group *A* is carried out through multiplying the attributed score values to each criterion using Eq. 2. Therefore, each of these criteria would have a higher weight in the scoring, but the score of group *B* is obtained by the summation of score values of each criterion (*B1*, *B2*, *B3*) (Eq. 3).

As shown in Eq. 4, to obtain the environmental score (*ES*) that shows the environmental condition of project activities, *BT* is multiplied by AT.

$$A_1 \times A_2 = AT \quad (2)$$

$$B_1 + B_2 + B_3 = BT \quad (3)$$

$$AT \times BT = ES \quad (4)$$

Another approach used in this study is the AHP method. The first step is to conduct a pairwise comparison between the criteria. The pairwise comparison means the ratio of row score to column score in each cell. In this matrix, the weight of each criterion (alternative) is obtained through geometrical averaging of the score of each row. These weights are finally normalized and used in the computations. It should be noted that these scoring comparisons are made by the experts. Thomas Saaty limited these scores between 1 and 9 (Saaty 1980).

In the next step, the pairwise comparison matrix of alternatives' scores is built for each criterion. This matrix has to be built separately for each criterion. The relative weight of each alternative in this matrix is the geometric average of the rows. Finally, the relative weights should be normalized. Based on Eq. 5, the final or absolute weight of each alternative results from the summation of multiplied weights of each criterion by the weight of its corresponding alternative.

$$A_{Score} = \sum_{j=1}^{n} a_{ij} w_j \qquad \text{i=1,2,3, ..., m} \quad (5)$$

Where a_{ij} is the relative importance of the alternative i corresponding to the criterion j, and w_j is the importance of the criterion j. This equation provides the final weight (A_{score}) of each alternative

3- FINDINGS AND ARGUMENT

Since every environmental impact assessment method has its specific advantages and disadvantages, in different projects, several approaches are usually implemented in order to obtain the best result. The integration of the results from different methods would provide the best and the most comprehensive results with a higher precision and a lower risk or uncertainty.

This would reveal the efficiency of different methods in the environmental impact assessment of a specific project. Therefore, in this study, an appropriate method was presented to integrate different EIA results. At first, results of different methods were graphically compared as shown in Fig. 1. As shown in this figure, RIAM and Folchi methods were closely matched and their results were nearly the same, but the results of AHP method were slightly different.

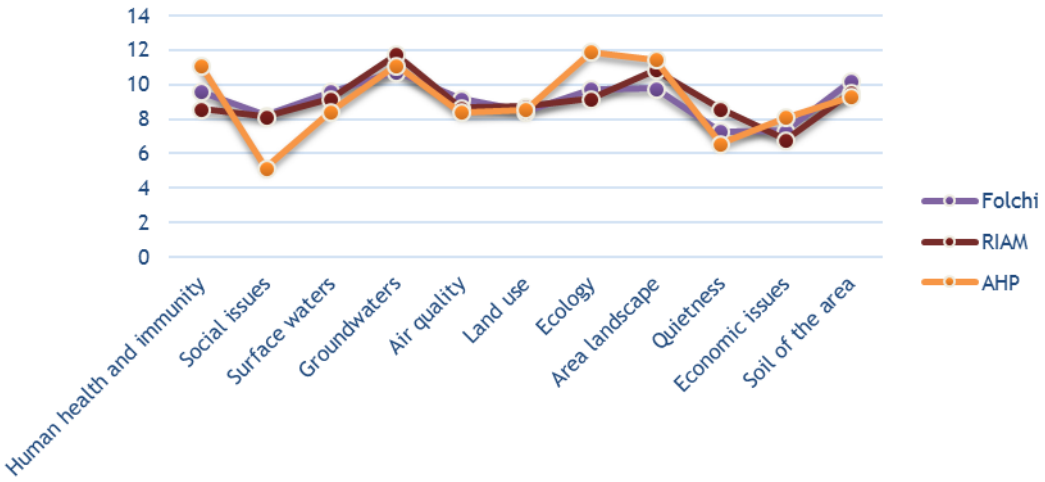

Figure 1. Comparing the results of Folchi, RIAM and AHP methods in EIA evaluation

The graphical comparison of different methods showed that sometimes they do not present same responses, while a unique result is required for the environmental impact assessment of a plant. Accordingly, to integrate the results of different methods, a prioritization strategy had to be implemented. Final results are shown in Table 1.

Table 1. Final ranking of different integrated methods

Methods	Ranking
Borda	D>H>G>J>C>A>F>E>I>B
Copeland	D>H=G>J=C=A=F=E=I=B
Maximin	D>H>J>G>C>A>F>E>I>B
Dodgson	D>H>J>G>C>A>F>E>I>B
Kemeny	D>H>J>G>C>A>F>E>I>B
Kohler	D>H>J>G>C>A>F>E>I>B
Arrow & Raynaud	D>H>J>G>C>A>F>E>I>B
DRS-I	D>H>J>G>C>A>F>E>I>B
DRS-II	D>H>G>J>C>A>F>E>I>B
Final ranking	**D>H>J>G>C>A>F>E>I>B**

4- CONCLUSIONS

Detailed and continuous assessment of the environmental impacts of industrial projects, as well as presenting a solution to reduce environmentally adverse impacts can minimize the existing environmental problems in the world. In this study, three environmental impact assessment approaches were applied to the activities of a coal washing plant in Iran. Each of these approaches had its specific results, and a coupled environmental assessment approach called C-EIA was presented to integrate the results of different methods, and to provide a single response

on the final EIA result. In order to integrate different EIA methods, several integration strategy methods were used which have been implemented before in economic and social science. Various methods were used in the present study including Borda, Copeland, Maximin, Kemeny, Kohler, Dodgson and Arrow & Reynaud. Also, two methods of DRS-I and DRS-II were developed and used accordingly and their performance were evaluated. Three methods were analyzed and compared, AHP, Folchi, and RIAM. The final response of the C-EIA method showed that four components of "groundwater", "area landscape", "soil of the area" and "ecology" were the most critical components in the area of interest, whose impacts need to be reduced.

Modification and amendment measures on the plant proved to be required in order to minimize the impact of the factors mentioned above as much as possible. Therefore, in order to assess the efficiency of the amendment measures on the project, expert opinions could be used to evaluate the impacts of these components. A focus on the components with higher priorities can overcome most of the plant's environmental issues in a short time. It also enables national organizations and institutions to compare different industrial, mining and civil development projects in the country, in terms of their impact on the environment, in order to make major decisions in this regard. Since selecting an appropriate EIA approach is a challenge in the environmental impact assessments process, results of this study and also the application of C-EIA method can resolve the issue of selecting the proper assessment method. Results of different EIA methods can be integrated to provide the final response. This integrated response will contain lower risk and will be more comprehensive, for several methods with different sensitivities have been used.

Refrences

- Borda, J. C. "Mémoire sur les élections au scrutin, Histoire de l'Académie royale des sciences pour 1781." Paris (English Translation by De Grazia, A. 1953. Isis 44) (1784).
- Deng, Xinyang, Yong Hu, Yong Deng, and Sankaran Mahadevan. "Environmental impact assessment based on D numbers." Expert Systems with Applications 41, no. 2 (2014): 635-643.
- Folchi, Roberto. "Environmental impact statement for mining with explosives: a quantitative method." In Proceedings of the annual conference on explosives and blasting technique, vol. 2, pp. 285-296. ISEE; 1999, 2003.
- Klamler, Christian. "On the closeness aspect of three voting rules: Borda–Copeland–Maximin." Group Decision and Negotiation 14, no. 3 (2005): 233-240.
- Leopold, Luna Bergere. "A procedure for evaluating environmental impact". Vol. 28, no. 2. US Department of the Interior, 1971.
- Mirmohammadi, Mirsaleh, Javad Gholamnejad, Vahidoddin Fattahpour, Pejman Seyedsadri, and Yousef Ghorbani. "Designing of an environmental assessment algorithm for surface mining projects." Journal of environmental management 90, no. 8 (2009):

2422-2435.

- Saaty, Thomas L. "The analytical hierarchy process, planning, priority." Resource allocation. RWS publications, USA (1980).
- Wang, Ningkui, and Daijun Wei. "A modified D numbers methodology for environmental impact assessment." Technological and Economic Development of Economy 24, no. 2 (2018): 653-669.
- [1] L. B. Leopold, F. E. Clarke, and B. B. Hanshaw, A procedure for evaluating environmental impact, vol. 28, no. 2. US Dept. of the Interior, 1971.
- [2] X. Deng, Y. Hu, Y. Deng, and S. Mahadevan, "Environmental impact assessment based on D numbers," Expert Syst. Appl., vol. 41, no. 2, pp. 635–643, 2014.
- [3] N. Wang and D. Wei, "A modified D numbers methodology for environmental impact assessment," Technol. Econ. Dev. Econ., vol. 24, no. 2, pp. 653–669, 2018.
-
- [4] R. Folchi, "Environmental impact statement for mining with explosives: a quantitative method," in Proceedings of the annual conference on explosives and blasting technique, 2003, vol. 2, pp. 285–296.
- [5] M. Mirmohammadi, J. Gholamnejad, V. Fattahpour, P. Seyedsadri, and Y. Ghorbani, "Designing of an environmental assessment algorithm for surface mining projects," J. Environ. Manage., vol. 90, no. 8, pp. 2422–2435, 2009.
- [6] T. L. Saaty, "The analytical hierarchy process, planning, priority," Resour. Alloc. RWS Publ. USA, 1980.
-
- [7] J. C. Borda, "Mémoire sur les élections au scrutin, Histoire de l'Académie royale des sciences pour 1781," Paris (English Transl. by Grazia, A. 1953. Isis 44), 1784.

- C. Klamler, "On the Closeness Aspect of Three Voting Rules: Borda – Copeland – Maximin," Gr. Decis. Negot., vol. 14, no. 3, pp. 233–240, May 2005.