



An Effective multicriteria decision-making model for extraction of lithium from seawater/brine: Design and practice

Mahmoud Ismail*

Faculty of Computers and Informatics, Zagazig University, Zagazig, 44519, Egypt
Emails: mahsabe@yahoo.com; mmsabe@zu.edu.eg

Abstract

PROMETHEE II decision-making methodologies are integrated into a novel framework in this research. A real-world case study of lithium extraction techniques served as the basis for this investigation. Lithium extraction from brines and saltwater has become more difficult due to the limited natural resources of lithium and the worldwide desire to replace fossil fuels with clean and recyclable energy. Using a multicriteria decision-making approach, the suggested framework aids in selecting the best lithium extraction procedure from brines and saltwater. A case study of lithium extraction from brines and saltwater has been used. The findings of the study show that the suggested strategy is logical and enforceable.

Keywords: PROMETHEE II; MCDM; lithium Extraction; Decision Process; Seawater/brine

1. Introduction

The harvesting of metals from saltwater and brines has expanded significantly in recent years owing to a decrease in land resources, a shortage of mineral resources for certain nations, and a reduction in the environmental effect of desalination facilities. Lithium's low concentration in minerals and the broad range of uses in the fields of batteries, lubricating grease, ceramic glass, and so on have sparked a growing interest in the mineral [1]. It is possible to infer, however, that the globe is shifting away from fossil fuels in favor of a cleaner, more environmentally friendly energy source. This kind of energy is provided by lithium-ion batteries, which are utilized in a broad range of electric cars and other devices today. Lithium extraction from brines and sea water has received significant interest in nations without lithium ore resources because of the growing need for lithium in many uses, particularly in the production of lithium-ion batteries.

Lithium brine is among the primary sources of metal. The brines holding lithium ions may be readily discovered in most nations. Even though the lithium content in these sources is exceedingly low, the collection of lithium by them is nevertheless cost-effective due to the world's extraordinarily large brine capacity. It is possible to extract lithium from seawater and brines using a variety of methods, including precipitation (Ide et al., 1983), solvent extraction [2], and the use of membrane electrolysis [3]–[5], [6]–[9]. Nano-filtration [10] is another method that has been developed [11]. The more significant point is that different extraction techniques, equipment, and equipment are used in different methods; the extracted lithium also has its own set of values for criteria such as density, estimated extraction cost, retention time, and so on. The extracted lithium can be used in a variety of ways to make batteries. It is, therefore, possible to build a multicriteria decision-making process for determining the best approach for extracting lithium from brines (MCDM)

Systematic and objective strategies to enhance decision-making in situations where several criteria and actions are involved are known as MCDM [12]. A more accurate, reasonable, and effective decision-making process may be achieved via the use of MCDM [13], [14], which takes into account all relevant aspects of the choice issue. The two most common MCDM approaches are MODM (multiple objective decision making) and MADM (multiple attribute decision making). An alternative classification for the techniques of MCDM includes those that have specific weights or preferences and those that have unclear weights or preferences. Evaluations that take into account the ambiguity of weights and preferences often use fuzzy logic. Because of the inherent ambiguity in human judgment that is frequently present due to the use of language, fuzzy approaches may be useful in understanding decision-making processes. As an alternative, the use of a person or party of decision-makers may be utilized in MCDM situations. When making decisions in groups, we may rely on the collective wisdom and experience of a greater number of people.

A group's success may be greater than that of an individual's in certain cases. This means that a group, rather than a single person, can execute the choice more easily since group members are more involved in the decision[15].

Listed below are the sections of this paper that follow. The related work in section 2. MCDM assessment techniques and criterion weighting methods are discussed in Section 3 of the paper. See Section 4. Case studies on lithium extraction from brines and saltwater are presented. Conclusions are discussed in Section 5 of the paper.

2. Related Work

To our knowledge, this study is the first to use the MCDA/MCDM technique to determine the optimal procedure for extracting lithium from brines and saltwater. There is a paucity of research on the subject. However, there have been some studies on the use of MCDM approaches in the mineral resource manufacturing sectors. For surface mining,[16] used a hybrid AHP technique to choose the best technology. In a review of 150 case studies, [17]examined how MCDM methodologies were used in mining planning. The Nicholas methodology and MCDM techniques were reviewed critically by [18]for the determination of an optimal halting procedure in hard rock mineral extraction. [19] showed the application of a hybrid PROMETHEE-based technique to choose secondary breakage techniques for lime quarries.

Vikor and TOPSIS were proposed by [20]for the flotation machine choice issue as two MCDM approaches to try out. For efficient circuit design,[21] adopted an MCDM technique based on the utilization of interval-valued intuitionistic fuzzy sets. MCDM in mining and mineral processing has been extensively reviewed by Sitorus et al. [22] and explores future research areas in the development of MCDM approaches. There is a new approach to the crusher selection issue given by Sitorus and Brito-Parada [23]that incorporates FSAHP). It was the primary goal of their research to propose a novel sensitivity analysis technique for modeling uncertainty by adding a fuzzification component and a degree of disagreement among decision-makers. Several recent research is presented in the context of MCDM assessment methodologies and weighting criteria.

Making decisions has gotten more difficult for businesses and managers in today's complicated environment. When faced with a limited number of options and various criteria, the decision-maker uses MCDM approaches as an efficient tool for making the right choice[24]. MCDM has been used in a variety of real-world settings, including manufacturing, energy planning[25], location planning[26], quality control[27], risk assessment[28], and locating the best possible locations[29], [30]. Techniques for dealing with multicriteria decision-making (MCDM) have been developed over the past few decades. These include TOPSIS, AHP, elimination and choice expressing reality, and decision-making trial and evaluation laboratory. Few extensive investigations of the applications of MCDA methodologies have been done, as can be seen from the literature review on MCDA models. Cinelli et al.[31] provides a comprehensive overview and comparison of MCDA approaches (2020). The MCDA process they are divided into three stages: defining the issue at hand, formulating a suggestion, and last, evaluating the quality of the solution, and providing technical assistance. Other recent studies in this field include (2018)[32], [33], and others.

A typical MCDM issue consists of options, criteria, and significance weights, which are the three basic components. The goal of using MCDM approaches is to improve decision-making in many contexts by utilizing a more thoughtful and efficient approach. MCDM approaches have a

significant shortcoming in that they need exact evaluations of performance rankings and criterion weights, which are insufficient in many real-world decision situations. Bellman and Zadeh created a decision-advice procedure for fuzzy situations to address this limitation (1970).

As a result, MCDM issues involving fuzzy information have gotten a lot of attention, and numerous fuzzy MCDM approaches based on the fuzzy set theory have been proposed by several academics. As a result, this work employs TOPSIS and ELECTRE fuzzy techniques, which have a simple computing procedure and great flexibility, as problem-solving tools.

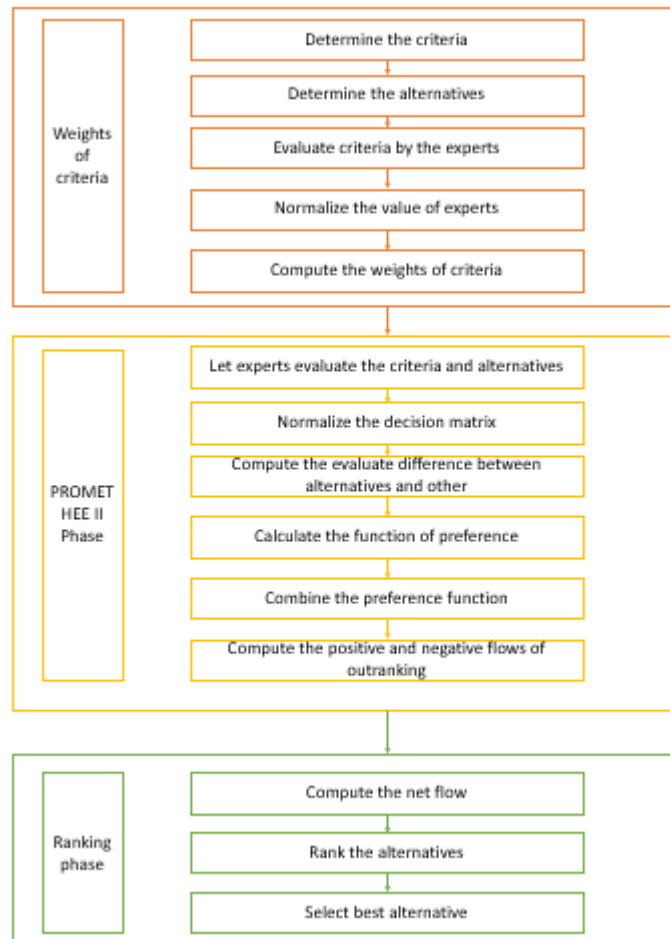


Figure 1: The steps of this methodology.

3. MCDM PROMTHEE II Method

The PROMETHEE MCDM approach is well-known and widely utilized. Brans (1982) was the first to propose this strategy, then Vincke and Brans [34] refined it (1985). Compared to other multicriteria approaches, PROMETHEE is a straightforward ranking strategy [35].

"As least as" and "As good as" are examples of weak preferences that may be used to compare options using the PROMETHEE approach.[36] For PROMETHEE to work, you'll need two kinds of data. First, the weights, and then the preference function of the decision-maker[37]. Researchers often employ PROMETHEE I and PROMETHEE II in their work.

Unlike PROMETHEE I, PROMETHEE II includes a complete rating of the choice options, which is more comprehensive. PROMETHEE II was established in this study to provide reliable findings by determining the whole ranking of suppliers' alternatives. To deal with MCDM problems, the PROMETHEE II approach is appropriate ([35], [38]. Figure 1 shows the steps of this methodology.

Step 1: Let experts evaluate the criteria and alternatives to build the decision matrix. Then aggregate the decision matrix.

Step 2: Normalize the decision matrix as:

$$N_{ij} = \frac{x_{ij}^- - x_{ij}^+}{x_{ij}^+ - x_{ij}^-}; \text{positive criteria} \quad (1)$$

$$N_{ij} = \frac{x_{ij}^+ - x_{ij}^-}{x_{ij}^+ - x_{ij}^-}; \text{negative criteria} \quad (2)$$

$$x_{ij}^+ = \max x_{ij} \quad (3)$$

$$x_{ij}^- = \min x_{ij} \quad (4)$$

Step 3: Compute the evaluation difference between alternatives and others.

Step 4: Calculate the function of preference

$$f_i(a, b) = 0 \text{ if } E_{ai} \leq E_{bi} \quad (5)$$

$$f_i(a, b) = E_{ai} - E_{bi} \text{ if } E_{ai} > E_{bi} \quad (6)$$

Step 5: Combine the preference function as:

$$P(a, b) = \frac{\sum_i^m w_i f_i(a, b)}{\sum_i^m w_i} \quad (7)$$

Where $i = 1, 2, 3 \dots m$

Step 6: Compute the positive and negative flows of outranking.

$$L^+ = \frac{1}{m-1} \sum_{i=1}^m P(a, b) \quad (8)$$

$$L^- = \frac{1}{m-1} \sum_{i=1}^m P(a, b) \quad (9)$$

Step 7: Compute the net flow as:

$$L = L^+ - L^- \quad (10)$$

Step 8: Rank the alternatives according to the highest value of L

4. Results and discussion

Lithium extraction through brines and saltwater is the focus of the present research, which includes the assessment and selection of the best procedure. The criteria and options that were explored are listed below. Literature evaluations, field studies, and the opinions of industry experts are used to compile the most important criteria for determining the optimal procedure for extracting lithium from brines. Descriptive and analytical criteria with both positive and negative features are included in the study. The following are their names:

Quantitative criteria with a positive aspect that reveals how much a solute is dissolved in an exact volume of solvent are the amount of extracted lithium.

Quantitative criteria:

- I. LEC1: lithium adsorption and lithium release from adsorbent are quantified by measuring the quantity of lithium that is recovered from the adsorbent relative to the amount of lithium that has been absorbed.

- II. LEC2: Quantitative criteria that reflect the amount of time it takes to develop an output from the beginning of the extraction process to its end:
- III. LEC3: The inverse relationship between lithium extraction and lithium concentration in brine: a positive indicator of the method's impact on lithium extraction and concentration.
- IV. LEC4: stabilization is required), the extraction method necessary to restore lithium from the adsorbed material, and the adsorbed material's ability to perform lithium adsorption.
- V. LEC5: Adsorbent adsorption of lithium is hampered by many factors, including, but not limited to: temperature conditions (either controlled or ambient), test conditions (such as whether a stir or PH
- VI. LEC6: the estimated financial worth of the resources necessary to carry out the extraction process, as measured in terms of its negative quality criteria. Adsorbent price, processing price, equipment cost, and adsorbent value utilized to accomplish given adsorption are all sub-criteria that must be taken into account to meet this criterion.

As an alternative, certain brines with high manganese-to-lithium or magnesium-to-lithium concentration ratios are being studied for their ability to extract lithium. Because of their low lithium concentrations compared to other metal ions, these alternatives are suitable for practically all of the brine; this makes them a logical choice.

- I. New separation technique investigated from an electrical point of view employing LiFePO₄/FePO₄ as anode material: Membrane electrolytic. LEA1
- II. Adsorption, Type 2 The adsorbent for lithium extraction is a spinel-type magnesium dioxide (MnO₂) with a nanotube shape. Additionally, the lithium pilot brine was used in the process. LEA2
- III. Adsorption, Type 3 MnO₂ nanotubes were utilized as an adsorbent to recover lithium from the spinel-type dolomite dioxide (MnO₂). Brine is also used to extract lithium. LEA3
- IV. A4 The effects of operation conditions on the Li⁺ redox potential and electrode stability of LiFePO₄/FePO₄-based membrane electrolysis electrode materials have been studied. LEA4
- V. Accumulation of TiO₂ nanotubes with mica schist tio₂ nanoparticles (TiO₂) adsorbs the lithium. LEA5
- VI. Lithium extraction from brine and saltwater was the focus of a recent pilot project, the findings of which are detailed in this section. Three DM specialists are entrusted with selecting the best lithium extraction technique from a list of possible possibilities for the manufacture of lithium batteries. All of them are judged on the same scale, each of the six essential requirements. LEA6

Step 1: Three decision-makers have an expert in this field to evaluate the criteria. Then normalize their values to compute the weights of the criteria as shown in figure 2. Then let three experts evaluate the criteria and alternatives. In this study, we used six main criteria and five alternatives. We obtained three decision matrices from three decision-makers. They aggregate their opinions into one matrix, as shown in table 1.

Step 2: Normalize the decision matrix by using Eqs. (1,2) as shown in table 2.

Step 3: Compute the evaluation difference between alternatives and others.

Step 4: Calculate the function of preference by using Eqs. (5,6)

Step 5: Combine the preference function by using Eq. (7), as shown in table 3.

Step 6: Compute the positive and negative flows of outranking by using Eqs. (8,9)

Step 7: Compute the net flow using Eq. (10)

Step 8: Rank the alternatives according to the highest value of L. The best alternative is LEA3, and the worst alternative is LEA4. The rank of alternatives is shown in figure 3.

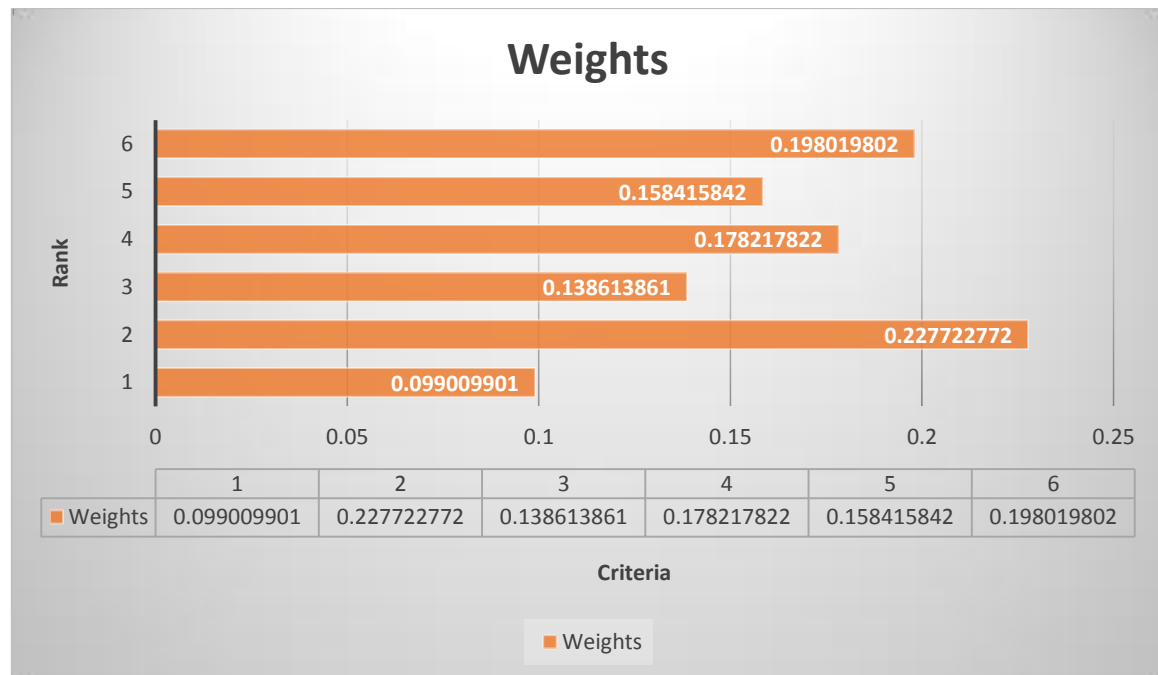


Figure 2: The weights of the criteria

Table 1: The aggregated decision matrix.

| | LEC1 | LEC2 | LEC3 | LEC4 | LEC5 | LEC6 |
|------|----------|----------|----------|----------|----------|----------|
| LEA1 | 7 | 5.666667 | 4 | 3.666667 | 3 | 7 |
| LEA2 | 7.333333 | 7.666667 | 7.666667 | 6.666667 | 5.666667 | 6.666667 |
| LEA3 | 3.666667 | 7 | 6 | 4 | 7.333333 | 1.666667 |
| LEA4 | 3.666667 | 7.666667 | 4.666667 | 5.333333 | 6 | 1.666667 |
| LEA5 | 5.666667 | 5.666667 | 3.666667 | 6 | 7 | 5.666667 |

Table 2: The normalized decision matrix.

| | LEC1 | LEC2 | LEC3 | LEC4 | LEC5 | LEC6 |
|------|-------------|----------|----------|-------------|------------|--------|
| LEA1 | 0.909090909 | 0 | 0.909091 | 0 | 1 | 0 |
| LEA2 | 1 | 1 | -0.9091 | 1 | 0.38461538 | 0.0625 |
| LEA3 | 0 | 0.666667 | 0.363636 | 0.111111111 | 0 | 1 |
| LEA4 | 0 | 1 | 0.727273 | 0.555555556 | 0.30769231 | 1 |
| LEA5 | 0.545454545 | 0 | 1 | 0.777777778 | 0.07692308 | 0.25 |

Table 3: The combined preference of function.

| | LEC1 | LEC2 | LEC3 | LEC4 | LEC5 | LEC6 |
|------|----------|----------|----------|----------|----------|----------|
| LEA1 | 0 | 0.236101 | 0.324032 | 0.224884 | 0.182234 | 0 |
| LEA2 | 0.427318 | 0 | 0.394263 | 0.190404 | 0.361075 | 0 |
| LEA3 | 0.369637 | 0.24865 | 0 | 0 | 0.30033 | 0.420042 |
| LEA4 | 0.524752 | 0.299055 | 0.254264 | 0 | 0.412795 | 0.674306 |
| LEA5 | 0.20072 | 0.188344 | 0.273212 | 0.131413 | 0 | 0.392924 |

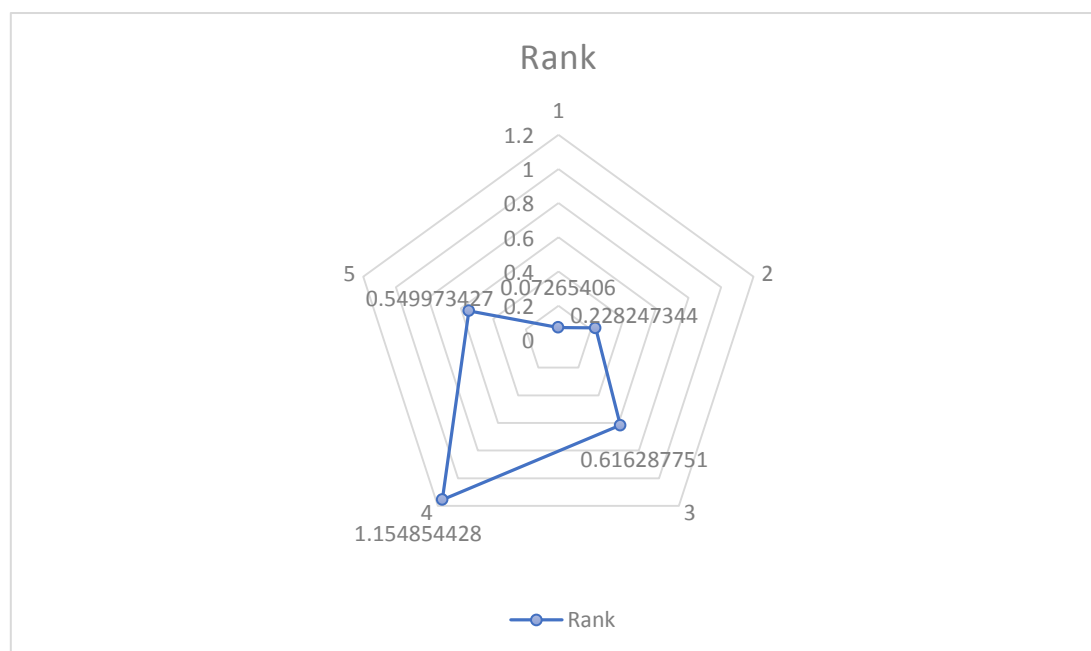


Figure 3: The rank of alternatives

5. Conclusion

An MCDM framework was developed in this research to evaluate and choose the best lithium extraction procedure from brines and saltwater. The normalization method is used to compute the weights of the criteria. Then the PROMETHEE II is used to compute the rank of alternatives. We used six criteria, five alternatives, and three decision-makers to evaluate criteria and alternatives.

A decision maker's preferences may also be considered using this method. Using PROMETHEE is a strong tool for decision-makers since it is simple to grasp the management and calculation procedures. Using such a strategy, lithium extraction may be handled in complicated decision-making circumstances for the selection issue. PROMETHEE employed both equal and unequal weights.

One of the most widely used and well-researched methods is PROMETHEE II. In this study, we developed an approach that addresses two issues with the PROMETHEE II method, which were motivated by the PROMETHEE II method. Two factors influence the performance indices: the weight vector of criteria and the number of calculations in the indices.

References

- [1] M. Moazeni, H. Hajipour, M. Askari, and M. Nusheh, "Hydrothermal synthesis and characterization of titanium dioxide nanotubes as novel lithium adsorbents," *Materials Research Bulletin*, vol. 61, pp. 70–75, 2015.
- [2] J. R. Nelli and T. E. Arthur Jr, "Recovery of lithium from bitterns." Google Patents, November 03, 1970.
- [3] X. Li *et al.*, "Recovery of potassium from landfill leachate concentrates using a combination of cation-exchange membrane electrolysis and magnesium potassium phosphate crystallization," *Separation and Purification Technology*, vol. 144, pp. 1–7, 2015.
- [4] M. L. Bosko, M. A. S. Rodrigues, J. Z. Ferreira, E. E. Miro, and A. M. Bernardes, "Nitrate reduction of brines from water desalination plants by membrane electrolysis," *Journal of membrane science*, vol. 451, pp. 276–284, 2014.
- [5] A. E. Bukhovets, A. M. Savel'Eva, and T. V. Eliseeva, "Separation of amino acids mixtures containing tyrosine in electromembrane system," *Desalination*, vol. 241, no. 1–3, pp. 68–74, 2009.
- [6] M. Yoshio, R. J. Brodd, and A. Kozawa, *Lithium-ion batteries*, vol. 1. Springer, 2009.
- [7] P. S. Klein and D. A. Melton, "A molecular mechanism for the effect of lithium on development," *Proceedings of the National Academy of Sciences*, vol. 93, no. 16, pp. 8455–8459, 1996.
- [8] B. Scrosati, J. Hassoun, and Y.-K. Sun, "Lithium-ion batteries. A look into the future," *Energy &*

- Environmental Science*, vol. 4, no. 9, pp. 3287–3295, 2011.
- [9] J. B. Bates, N. J. Dudney, B. Neudecker, A. Ueda, and C. D. Evans, “Thin-film lithium and lithium-ion batteries,” *Solid state ionics*, vol. 135, no. 1–4, pp. 33–45, 2000.
- [10] F. Ide, L. Vergara-Edwards, and P. Pavlovic-Zuvic, “Solar pond design for the production of potassium salts from the Salar de Atacama Brines,” in *Proceedings of the sixth international symposium on salt*, 1985, vol. 2, pp. 367–375.
- [11] A. Somrani, A. H. Hamzaoui, and M. Pontie, “Study on lithium separation from salt lake brines by nanofiltration (NF) and low pressure reverse osmosis (LPRO),” *Desalination*, vol. 317, pp. 184–192, 2013.
- [12] R. T. Clemen, *Making hard decisions: an introduction to decision analysis*. Brooks/Cole Publishing Company, 1996.
- [13] X. Wang and E. Triantaphyllou, “Ranking irregularities when evaluating alternatives by using some ELECTRE methods,” *Omega*, vol. 36, no. 1, pp. 45–63, 2008.
- [14] I. N. Durbach and T. J. Stewart, “Using expected values to simplify decision making under uncertainty,” *Omega*, vol. 37, no. 2, pp. 312–330, 2009.
- [15] T. Simons, L. H. Pelled, and K. A. Smith, “Making use of difference: Diversity, debate, and decision comprehensiveness in top management teams,” *Academy of management journal*, vol. 42, no. 6, pp. 662–673, 1999.
- [16] C. Stojanovic, D. Bogdanovic, and S. Urosevic, "Selection of the optimal technology for surface mining by multicriteria analysis," *Kuwait Journal of Science*, vol. 42, no. 3, 2015.
- [17] M. J. Mahase, C. Musingwini, and A. S. Nhleko, "A survey of applications of multicriteria decision analysis methods in mine planning and related case studies," *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 116, no. 11, pp. 1051–1056, 2016.
- [18] R. Kant, P. Sen, P. S. Paul, and A. A. Kher, “A review of approaches used for the selection of optimum stoping method in hard rock underground mine,” *International Journal of Applied Engineering Research*, vol. 11, no. 11, pp. 7483–7490, 2016.
- [19] A. Bouhedja, A. Idres, A. Boutrid, M. Bounouala, A. Benselhou, and K. Talhi, “Application of promethee mathematical model for choosing a secondary breakage process of the oversized blocks in limestone quarries,” *Mining Science*, vol. 23, 2016.
- [20] Z. Štirbanović, D. Stanujkić, I. Miljanović, and D. Milanović, “Application of MCDM methods for flotation machine selection,” *Minerals Engineering*, vol. 137, pp. 140–146, 2019.
- [21] D. Stanujkić, E. K. Zavadskas, D. Karabasevic, D. Milanovic, and M. Maksimovic, “An approach to solving complex decision-making problems based on IVIFNs: A case of comminution circuit design selection,” *Minerals Engineering*, vol. 138, pp. 70–78, 2019.
- [22] F. Sitorus, J. J. Cilliers, and P. R. Brito-Parada, “Multi-criteria decision making for the choice problem in mining and mineral processing: Applications and trends,” *Expert systems with applications*, vol. 121, pp. 393–417, 2019.
- [23] F. Sitorus and P. R. Brito-Parada, “Equipment selection in mineral processing-a sensitivity analysis approach for a fuzzy multiple criteria decision making model,” *Minerals Engineering*, vol. 150, p. 106261, 2020.
- [24] R. Venkata Rao and B. K. Patel, “Decision making in the manufacturing environment using an improved PROMETHEE method,” *International Journal of Production Research*, vol. 48, no. 16, pp. 4665–4682, 2010.
- [25] M. Beccali, M. Cellura, and M. Mistretta, “Decision-making in energy planning. Application of the Electre method at regional level for the diffusion of renewable energy technology,” *Renewable energy*, vol. 28, no. 13, pp. 2063–2087, 2003.
- [26] A. Awasthi, S. S. Chauhan, and S. K. Goyal, "A multicriteria decision making approach for location planning for urban distribution centers under uncertainty," *Mathematical and Computer Modelling*, vol. 53, no. 1–2, pp. 98–109, 2011.
- [27] T. Yang and P. Chou, “Solving a multiresponse simulation-optimization problem with discrete variables using a multiple-attribute decision-making method,” *Mathematics and Computers in simulation*, vol. 68, no. 1, pp. 9–21, 2005.
- [28] Q. Dong and O. Cooper, “An orders-of-magnitude AHP supply chain risk assessment framework,” *International Journal of Production Economics*, vol. 182, pp. 144–156, 2016.
- [29] J. M. Sánchez-Lozano, M. S. García-Cascales, and M. T. Lamata, “Comparative TOPSIS-ELECTRE TRI methods for optimal sites for photovoltaic solar farms. Case study in Spain,” *Journal of cleaner production*, vol. 127, pp. 387–398, 2016.
- [30] A. Mohammed, I. Harris, A. Soroka, and R. Nujoom, “A hybrid MCDM-fuzzy multi-objective programming approach for a G-resilient supply chain network design,” *Computers & Industrial Engineering*, vol. 127, pp. 297–312, 2019.

- [31] M. Cinelli, M. Kadziński, M. Gonzalez, and R. Słowiński, “How to support the application of multiple criteria decision analysis? Let us start with a comprehensive taxonomy,” *Omega*, vol. 96, p. 102261, 2020.
- [32] T. Li, A. Li, and X. Guo, “The sustainable development-oriented development and utilization of renewable energy industry—A comprehensive analysis of MCDM methods,” *Energy*, vol. 212, p. 118694, 2020.
- [33] A. T. de Almeida-Filho, D. F. de Lima Silva, and L. Ferreira, “Financial modelling with multiple criteria decision making: A systematic literature review,” *Journal of the Operational Research Society*, vol. 72, no. 10, pp. 2161–2179, 2021.
- [34] J. P. Brans, “The engineering decision: Development of instruments to support the decision,” *The PROMETHEE method*, 1982.
- [35] J.-P. Brans and P. Vincke, “Note—A Preference Ranking Organisation Method: (The PROMETHEE Method for Multiple Criteria Decision-Making),” *Management science*, vol. 31, no. 6, pp. 647–656, 1985.
- [36] J. Chai and E. W. T. Ngai, “Decision-making techniques in supplier selection: Recent accomplishments and what lies ahead,” *Expert Systems with Applications*, vol. 140, p. 112903, 2020.
- [37] A. Albadvi, S. K. Chaharsooghi, and A. Esfahanipour, “Decision making in stock trading: An application of PROMETHEE,” *European journal of operational research*, vol. 177, no. 2, pp. 673–683, 2007.
- [38] Z. Andreopoulou, C. Koliouka, E. Galariotis, and C. Zopounidis, “Renewable energy sources: Using PROMETHEE II for ranking websites to support market opportunities,” *Technological Forecasting and Social Change*, vol. 131, pp. 31–37, 2018.