Analysis of Fuzzy AHP-TOPSIS Methods in Multi Criteria Decision Making: Literature Review

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Abstract. With the development of technology and times, we have faced various alternative problems. The problem of making decisions is one of the problems that is often encountered in everyday life. In the matter of decision-making, there are several methods that can be used, one of which is Multi-Criteria Decision Making (MCDM). MCDM is a method to make decision based on theory, process and analytical methods that involved uncertainty, dynamics and various aspects of criteria. This journal will discuss the use of one of the MCDM methods, namely Fuzzy AHP-TOPSIS. Basically, AHP breaks down unstructured situations into its components and organize these components or variables in a hierarchical order and assign a scientific value as a subjective assessment of the proportionate significance of each variable. Fuzzy theory is used to represent ambiguity, inaccuracies, lack of information, and partial truth. Then the TOPSIS method uses the principle that the preferred alternative must have the farthest from the negative ideal solution and the shortest interval from the positive ideal solution to find the optimal solution from the available alternatives.

1. Introduction
Decision making is a result of the process of determining choices among several alternatives. The problem of decision making is one of the problems that are often encountered in daily life. Decision making problems occur in various scopes. In the problem of decision making there are several methods that can be done, one of which is Multiple-Criteria Decision Making (MCDM). MCDM is used to choose the best possible alternative from a number of alternatives based on several predetermined criteria. Measurements, rules or standards are some of the criteria used in decision making [1].

Morton first proposed the concept of the decision support system with the term Management Decision System. A number of companies, research institutions and universities then began to conduct research and support decision support systems, so that the resulting production can be concluded that this system is a computer-based system aimed at aiding decision making in using certain data and models to fix different unstructured problems [2].

Analytic Hierarchy Process (AHP) is proposed by Saaty in 2001. Basically, the AHP breaks up an unstructured and complex situation into its component elements and then organize these variables in a hierarchical order and give scientific values to subjective considerations about the relative importance of each variable. After that, synthesize these considerations to specify which variable has the best priority and act to impact the result of the situation [3].
Fuzzy analytic hierarchy process or FAHP is generally proposed with another MCDM methods according to Kubler. Fuzzy AHP in the combination of the MCDM method is used to handle uncertainty and vagueness in the given weights to evaluating alternatives [4].

Majid B et al in 2012 conducted a survey of the implementation of the TOPSIS method, where journals that use the TOPSIS method are categorized into 9 topics, consist of Design Engineering and Manufacturing Systems, Health Safety and Environment Management, Human Resource Management, Supply Chain Management and Logistics, Chemical Engineering, Business and Marketing Management, Energy Management, , Water Resource Management and Other Related Topics. Where the application of the TOPSIS method is most widely used in the field of Supply chain management and logistics, and based on this research, the TOPSIS method is most often combined with the Fuzzy set methods, the AHP method is ranked third as the method most often combined with TOPSIS approach [5].

A Ishak and N Hidayati Proposed Delphi method to determine the criteria and Sub-criteria in urban solid waste processing technology. The criteria and sub criteria determined by the Delphi method can be weighted using Fuzzy AHP, after which the determination of the best alternative can be done [6].

The goal of this literature study is to review the application of the AHP-TOPSIS Fuzzy decision support system based on its application field and the advantages of using the FAHP-TOPSIS method.

2. Theoretical Background

2.1. Multi Criteria Decision Making (MCDM)

Multi Criteria Decision Making (MCDM) is a decision-making method to establishes the best option from a collection of available option based on predetermined criteria. Criteria are generally in the form of standards, measures, or rules used in decision making. MCDM is divided into 2 types, namely Multi Attribute Decision Making (MADM) and Multi Objective Decision Making (MODM). [7].

2.2. Analytic Hierarchy Process (AHP)

According to Saaty, AHP is drafted to format a decision process in a scenario impacted by multiple independent factors. In the analysis, a sophisticated problem can be branched into several sub-problems/sub criteria that are arranged according to hierarchical levels, where each level stand for a set of criteria or attributes associated to each sub-problem [8].

In general, the step in using the AHP method are as follows [9, 10]:

- Identify the problem and determine the solution or the goal
- Producing a hierarchical structure starting with a common objective, criteria, criteria and choice alternatives.

![Figure 1. Hierarchy](image)

- Pairwise comparison matrices are created to describe the relative effect of each element on the level of objectives or criteria above it. Comparisons are made based on choices or considerations of decision makers by appraising the importance of an element compared to other elements.
Table 1. Basic comparison criteria

| Intensity Importance | Meaning |
|----------------------|---------|
| 1                    | Both elements are the same important |
| 3                    | One of the elements is somewhat preferred than the other |
| 4                    | One of the elements is more preferred than the other elements |
| 7                    | One of the elements is strongly preferred than another element |
| 9                    | One of the elements is absolutely preferred than the other elements |
| 2,4,6,8              | The values between the two considerations are close together |

- Normalizing the data is by dividing the value of each element in the paired matrix by the total value of each column
- Repeat steps 3 until 5 for all levels of the hierarchy
- Calculate the eigenvector value (weight of each element) of each pairwise comparison matrix.
- Test hierarchy consistency. If it does not adhere with $CR < 0.1$ then the assessment must be repeated.

$$CI = \frac{\lambda_{\text{max}} - n}{n-1}$$

Where:
- $n$ is the number of items compared
- $\lambda_{\text{max}}$ is an average value calculated earlier

The Random index can be seen in Table 2.

| N  | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|----|---|---|---|---|---|---|---|---|----|
| RI | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.51 |

Consistency Ratio = \frac{\text{Consistency Index}}{\text{Random Index}}

2.3. Fuzzy Association Theory
The Fuzzy set theory is a mathematical framework used to represent inaccuracy, obscurity, uncertainty, lack of information, and partial truth. Lack of information, in solving problems, is often found in various fields of life. The discussion of vagueness began in 1937, when a philosopher named Max Black expressed his opinion about obscurity. Black defines a proportion of obscurity as a proportion where the probable status of the proportion is not clearly defined. For example, to state that someone belongs to the young category, the statement "young" can give a different interpretation than by each individual, and we cannot give a certain age to say someone is young or not young [7].

2.3.1. Triangular Fuzzy Number (TFN). Triangular Fuzzy Number is utilized in the pairwise comparison process to describe subjective judgments in Fuzzy AHP. The TFN is determined by three real numbers, consist of "M" = {l, m, u}. The parameters l, m and u signify the smallest possible value, the most promising value and the largest value that describes each fuzzy event [11].

Laarhoven and Pedrycz in the Yu-Lung Hsu journal introduced the Fuzzy Analytic Hierarchy Process in 1983, which is an usage of integration of Fuzzy number and Analytic Hierarchy Process (AHP). The linguistic scale of the traditional AHP method can articulate uncertainty/vagueness when decision makers make decisions [12].

Triangular fuzzy number is a combination of two lines (Linear). The graph of the triangular membership function is depicted into form of a triangular curve as seen in Figure 2 [13].
Triangular fuzzy numbers are used to assist in assessments related to human subjective conclusion using language or linguistics. The essence of fuzzy AHP lies in the pairwise comparison which is illuminated by the ratio scale associated with the fuzzy scale. Triangular Fuzzy Numbers are symbolized and the following membership function provisions for 5 scale linguistic variables.

| AHP scale | Fuzzy Number | Invers Value of Fuzzy Number | Definition |
|-----------|--------------|------------------------------|------------|
| 1         | (1,1,1)      | (1,1,1)                      | Equally important |
| 2         | (1,2,3)      | (1/3,1/2,1)                  | Scale between the same and a little more important |
| 3         | (2,3,4)      | (1/4,1/3,1/2)                | Low dominance |
| 4         | (3,4,5)      | (1/5,1/4,1/3)                | Scale between low dominance and high dominance |
| 5         | (4,5,6)      | (1/6,1/5,1/4)                | High dominance |
| 6         | (5,6,7)      | (1/7,1/6,1/5)                | Scale between high dominance and very high dominance |
| 7         | (6,7,8)      | (1/8,1/7,1/6)                | Very high dominance |
| 8         | (7,8,9)      | (1/9,1/8,1/7)                | Scale between very high dominance and absolute dominance |
| 9         | (8,9,9)      | (1/9,1/9,1/8)                | Absolute dominance |

2.4. TOPSIS
TOPSIS was first introduced by Yoon and Hwang in 1981. TOPSIS based on the principle that the chosen alternative must have the shortest geometric distance from the positive ideal solution and the farthest geometric distance from the negative ideal solution. The positive ideal solution is defined as the sum of all the best values that can be achieved for each attribute, while the negative-ideal solution consists of all the worst values achieved for each attribute [14].

3. Research Methodology
The method used in this paper is a literature review study. This paper presents several works of literature on Fuzzy AHP-TOPSIS approach. The collected journals are journals that discuss the integration of Fuzzy AHP and TOPSIS. The journals are collected through the Google Scholar and Science Direct websites from 2017 to 2019.

4. Result
4.1. Fuzzy AHP

The data that is not clear from the results of data processing may be the result of information that cannot be measured, is incomplete, and cannot be obtained. They are often declared with finite ranges, ordinal data (ranking order), or fuzzy numbers.

To deal with imprecision and subjective perceptions effectively, fuzzy numbers are combined with AHP, enabling expressions of appropriate linguistic evaluation according to Calabrese et al. in 2016. Also, fuzzy numbers are used to deal with ambiguity influencing subjective inclination in determining real-world decision-making problems.

By using triangular fuzzy numbers (TFNs) in the pairwise comparison matrix, Fuzzy AHP method was proposed by Van Laarhoven and Pedrycz in 1983. Then, many other methods have been proposed, using different types of fuzzy numbers such as trapezoidal membership functions or Gaussian / bell-shaped membership functions. In recent years, FAHP has been largely used in the field of selection and evaluation, combining or integrating FAHP with other methods, particularly with Delphi, QFD, TOPSIS, and ANP [4].

4.2. FAHP-TOPSIS

The objective of the TOPSIS method combination in Fuzzy AHP is to choose best option to gain a balance to be as near as possible to the positive-ideal solution and as far as possible from the ideal-negative solution. Negative-ideal solution symbolize the worst option, which will compile by selecting the worst performance for each parameter among the actual proposals. The ideal-positive solution represents the best option which will be compiled by choosing the best performance for each parameter between the actual proposals.

TOPSIS also can be applied to rank alternatives suitable for distinct variable that estimate both their farness to the virtual worst option and their adjacency to the virtual best option [4].

Table 4 below shows a list of journals that use the FAHP-TOPSIS method and their application fields based on Majid B article. The distribution of 10 articles from 2017 to 2019 has been selected, investigated and reviewed for further analysis.

Table 4. A selected references of previous research studies

| Authors             | Title                                                                 | Approaches       | Applied in                       | Findings                                                                 |
|---------------------|----------------------------------------------------------------------|------------------|----------------------------------|--------------------------------------------------------------------------|
| Sutami, B Soedijono and Hendri [15] | Evaluation of quality web services using Fuzzy AHP-TOPSIS Integration Model | Fuzzy AHP-TOPSIS | Business and Marketing Management | They rank each E-trading securities on each criterion, and the results of this ranking are evaluated the strengths and weaknesses of the service quality of each security. |
| Umit H and Hasan D [16] | A Comparative Performance Evaluation on Bipolar Risks in Emerging Capital Markets Using Fuzzy AHP-TOPSIS and VIKOR Approaches                                      | Fuzzy AHP-TOPSIS and VIKOR | Business and Marketing Management | The purpose of this paper is to assist investors in determining the capital markets of developing countries. By considering the bipolar risk of capital markets using a multi-criteria hybrid decision analysis method in the economic field. The two methods used in determining alternatives, consist of VIKOR and TOPSIS, have several limitations and differences in their definitions. The differences between both |
methods can be summed up according to their procedural basis, normalization, aggregation and solution. The comparative rating results obtained are that both the Fuzzy AHP VIKOR and Fuzzy AHP TOPSIS methods show the same results in stock market selection in developing countries.

| Authors                  | Title                                                                 | Method          | Application                                                                 |
|--------------------------|-----------------------------------------------------------------------|-----------------|----------------------------------------------------------------------------|
| Magdalena L and Piotr P  | Determination of Most Suitable Low-emission Energy Technologies Development in Poland using Integrated Fuzzy AHP-TOPSIS Method | Fuzzy AHP-TOPSIS Energy Management | This paper using Fuzzy AHP-TOPSIS to rank low emission energy technology development, with 15 respondent to decide about 5 alternatives with 3 main criteria. The research divided into two stages, The Fuzzy AHP method is used to calculate the criteria weights, after that, the ranking is done by the TOPSIS method and the aggregate weighted score approach. |
| Abolfazl K, Hossein S G and Norouz M | The Data on the Effective Qualifications of Teachers in Medical Sciences: An Application of Combined Fuzzy AHP and Fuzzy TOPSIS Methods | Fuzzy AHP and Fuzzy TOPSIS Human Resource Managements | In this article the qualifications of teachers of medical courses is carried out using hybrid fuzzy AHP-TOPSIS from viewpoints of students of allied medicine school in Teheran University. The assessments conducted by students use 3 criteria, namely technical qualifications, professional qualifications and personal qualifications |
| Li-Ru C, Kai-Hao L, Fang-Pin L, Shao-Shiun C and Kou-Yi L | Measuring the Quality of Financial Electronics Payment System: Combines with Fuzzy AHP and Fuzzy TOPSIS | Fuzzy AHP and Fuzzy TOPSIS Business and Marketing Management | This paper using Fuzzy AHP and Fuzzy TOPSIS approach to measure and evaluate the system quality of Financial electronic payment. The main criteria in this assessment are communication quality, system quality, service quality and safety quality. |
| Xiunian Z and Jasmine S L L | A Fuzzy-Delphi-AHP-TOPSIS Framework to Identify Berries in Other Topics | Fuzzy-Delphi_AHP-TOPSIS method and | This research framework first identifies a list of success factors and constraints in the Delphi survey. The Delphi |
| Big Data Analytics Adoption: Case Maritim Organizations | VIKOR method validation | method is widely used to obtain convergent expert opinions on cross-disciplinary topics. Then Fuzy AHp is used to evaluate the relative significance of each success factor and its relationship. Then the TOPSIS method is used to rank obstacles in the implementation of big data. The VIKOR approach is used to validate the ratings generated by FAHP-TOPSIS |
|---|---|---|
| Analysis of the Efficiency of Insurance Companies in Serbia Using the Fuzzy AHP and TOPSIS Methods | Fuzzy AHP and TOPSIS | Business and Marketing Management | The study draws on financial data from 28 insurance companies operating in Serbia. The financial statements are used as the basis for analyzing the criteria for evaluating insurance companies. Fuzzy AHP is preferred in solving this problem because the AHP approach does not provide satisfactory results in situations that can be characterized as uncertain, especially in processing human opinions expressed in numbers. |
| Ranking the banks through Performance Evaluation by Integrating Fuzzy AHP and TOPSIS Methods: A Study of Iranian Private Banks | Fuzzy AHP and TOPSIS | Business and Marketing Management | Mohammad R and Saeedeh K rank 21 Private banks in Iran through performance evaluation. The research used 8 criteria to assess the banks performance. The result shown that the criteria of portfolio and Equity is the most significant parameter in banks performance assessment. |
| Fuzzy AHP-TOPSIS approaches to Prioritizing Solutions for Reverse Logistics Barriers | Fuzzy AHP-TOPSIS | Supply chain management ad logistics | This paper discuss the barrier that makes the implementation of reverse logistics difficult or unsuccessfull. The research using 8 criteria to rank the most influential factor that holding up the implementation of reverse logistics. In this study, the sensitivity analysis is used to test the sensitivity of criteria weight. The first 29
The proposed of this article was to determine the effective criteria for choosing a heat stress index by using the Delphi model, then the weights of each criteria were calculate by using Fuzzy AHP approach. The first round of Delphi method was proposed 30 assessment criteria, due to the same concept and lack of relevance, then it was decreased to 11 criteria. The result of this paper shown that the Wet Bulb Globe Temperature index is appropriate for heat stress indicators in surface mining. 

In addition, D. M. Priyantha Wedagama using Fuzzy AHP and TOPSIS method to determine road handling priority in Bandung regency and compare it to past reseach that used AHP to evaluate the SK.NO.77/KPTS/Db/1990 regulation. The hierarchy contains 4 criteria and 16 criteria to selecting the highway to be handled. FAHP is employed to determine the weights of the criteria by decision makers and subsequently TOPSIS method is used to determine rankings of road links. Their study shows that Fuzzy AHP and TOPSIS methods have considered vagueness and fuzziness of the decision makers compared to the past research that used the AHP method to determine the priority of road handling in Bandung District where the results differed from SK.NO.77/KPTS/Db/1990 [25]. 

The ranking results obtained from the two mix methods show that the financial orders for stock market selection in developing countries are the same, using both the FAHP VIKOR and FAHP TOPSIS methods.

5. Discussion
This literature study shows that the integrated Fuzzy AHP-TOPSIS method was mostly applied in business and marketing management fields. The AHP method is a decision support model that will describe a complex multi-factor or multi-criteria problem into a hierarchy. Fuzzy numbers are integrated with AHP to effectively handle subjective perceptions, allowing the appropriate expression of linguistic evaluation. TOPSIS method is used to select the option that best achieves a balance between two conditions: to be as far as possible from the negative-ideal solution and as close as possible to the positive-ideal solution.

In applying AHP and TOPSIS method there is also weakness in both method. The weakness of the AHP method is the dependence of its hierarchy structure and respondent answer as the main input. This main input is in the form of an expert's perception so that it involves subjectivity and AHP method is
only a mathematical method without statistical testing so there is no confidence limit of the correctness of the model formed [7].

The weakness for the TOPSIS method is that there must be a weight calculated using AHP method [25] to perform further data calculations.

6. Conclusion
The Integration of Fuzzy AHP-TOPSIS method is mostly applied in business and marketing management fields. The reason why Fuzzy AHP is used more often than classical AHP is because the AHP method is difficult to make decisions in uncertain circumstances, especially in human assessments where there are difficulties in expressing opinions with numbers. The TOPSIS method is integrated into Fuzzy AHP to select options / alternatives closest to the positive-ideal solution and farthest to the ideal-negative solution.

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