INTEGRATION OF ANALYTIC HIERARCHY PROCESS WITH OTHER MCDM METHODS: A LITERATURE REVIEW

Selçuk Çebi[1], Sezi Çevik Onar[2], Başar Öztayşi[2], Cengiz Kahraman[2]
[1] Yildiz Technical University, Department of Industrial Engineering, 34349 Yildiz, Beşiktaş, Istanbul, Turkiye
[2] Istanbul Technical University, Department of Industrial Engineering, 34367 Maçka, Beşiktaş, Istanbul, Turkiye

ABSTRACT

The main objective of this study is to examine the integration of AHP method with other MCDM methods in the literature and to understand their role in the integration. For this purpose, the peer-reviewed AHP articles published in Scopus database have been analyzed and the studies were categorized according to the utilized MCDM methods. In terms of results and findings, this study shows that: (i) the number of studies including the integration of crisp AHP with other MCDM methods is considerably higher than the number of fuzzy AHP studies; (ii) from the first, TOPSIS, VIKOR, PROMETHEE, Entropy, and DEMATEL methods are the most integrated MCDM methods with AHP; (iii) among the integration applications of AHP, the popularity of the newly proposed methods such as WASPAS and COPRAS has been increasing recently.

Keywords: AHP, Fuzzy AHP, MCDM, Literature review.

1. Introduction

Decision-making is a cognitive process having an important role in human thought system since strategic and important decisions require different mental and psychological functions to work together. The increase in the number of options and constraints considered during the decision phase and especially the conflicting constraints in the process make it difficult to make a decision. For this reason, multi-criteria decision-making techniques are used in the decision-making process and there are many methods proposed in the literature. Analytical Hierarchy Process (AHP) and Analytical Network Process (ANP) based on pairwise benchmarking proposed by Thomas L. Saaty in order to determine criterion weights and to define alternative rankings are the best well-known two of multi-criteria decision-making methods (Saaty, 1977; 1996). In decision process, these methods that can evaluate quantitative and qualitative criteria, simultaneously and can operate preferences, experiences, intuitions, knowledge, judgments and thoughts of the group or individual enable complex problems to be solved by dealing with them in a hierarchical structure. The main difference between AHP and ANP in terms of their purpose of the offering to the literature is that AHP considers independent criteria and alternatives in a hierarchical structure while ANP considers relationships and interdependencies among criteria and alternatives in a network structure. In other words, ANP is a general form of the AHP method and AHP deals with the decision problem in a hierarchical structure, while ANP examines the problem in a network structure. When the studies in the literature are examined, it is seen that AHP/ANP methods are applied to the problem directly or by integrating it with another MCDM method. Mardani et al. (2015) conducted a literature review study on multiple criteria decision making (MCDM) methods and concluded that the most widely used method in the literature is AHP. The main

objective of this study is to examine the integration of AHP method with other MCDM methods in the literature and to understand their role in the integration. For this purpose, the peer-reviewed AHP articles published in Scopus database have been analyzed and the studies were categorized according to the utilized MCDM methods within the scope of this article. This article attempts to answer the following questions: (i). Which MCDM methods have been widely integrated to AHP method and fuzzy? (ii) Which of the AHP or fuzzy AHP integration is more preferred? And (iii) What is the main purpose in the integration?

The rest of this paper is organized as follows: Section 2 presents Classification of MCDM methods. Section 3 describes literature review on the integration of AHP with other MCDM methods. Finally, the concluding remarks, limitations and recommendations for future studies are given in Section 4.

2. Classification of MCDM methods

MCDM methods are classified into two categories (Figure 1): Multi-attribute Decision Making (MADM) and Multi-Objective Decision Making (MODM). MADM method is also called as discrete MCDM while MODM is continuous MCDM. This study focus on MADM techniques since AHP/ANP is in this class. It is said that the historical origins of MADM is based on the discussion on St. Petersburg paradox between Nicolas Bernoulli and Pierre Rémond de Montmort at the being of 17th century (Tzeng and Huang, 2011). The objective of MADM methods is to maximize the obtained benefit of the decision-makers at the end of the process by modeling the decision process according to criteria. MCDM methods are designed to identify the best alternative, classify alternatives in a small number of categories, and/or rank alternatives in subjective order of preference. For this, there are many methods proposed in the literature. In Table 1, the MADM methods that have been widely used in the literature are given.
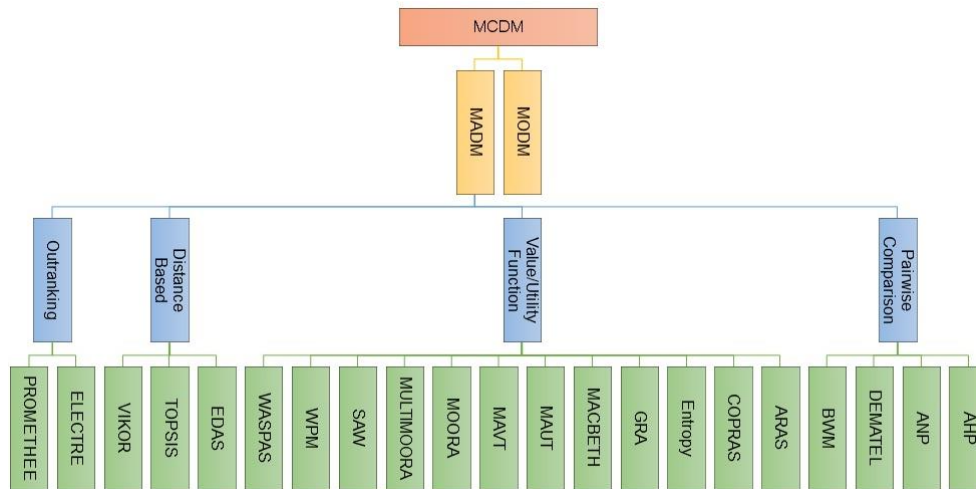

Figure 1. Classification of MCDM Methods

Table 1. The well-known MADM Methods in the literature

MADM Methods	Abbreviation	Reference
Entropy Method	Entropy	Shannon (1948)
Simple Additive Weighting	SAW	Churchman and Ackoff (1954)
Multi Attribute Utility Theory	MAUT	Fishburn (1965)

Elimination et choice Translating Reality	ELECTRE	Benayoun et al. (1966)
Multi-Attribute Value Theory	MAVT	Fishburn (1967)
Weighted Product Method	WPM	Miller and Starr (1969)
Decision Making Trial and Evaluation L.	DEMATEL	Fontela and Gabus (1976)
Simple Multi-Attribute Rating Technique	SMART	Edward (1977)
Analytic Hierarchy Process	AHP	Saaty (1977)
Similarity to an Ideal Solution	TOPSIS	Hwang and Yoon (1981)
Preference Ranking Organization Methods for Enrichment Evaluations	PROMETHEE	Brans et al. (1984, 1985)
Measuring Attractiveness by a Categorical Based Evaluation Technique	MACBETH	Bana e Costa and Vansnick, (1999)
Complex Proportional Assessment Mth.	COPRAS	Kaklauskas et. al (2006)
Analytic Network Process	ANP	Saaty (1996)
Gray Relation Analysis	GRA	Deng (1982)
Vise Kriterijumska Optimizacija I Kompromisno Resenje	VIKOR	Opricovic & Tzeng, (2002)
Multi-objective Optimization by Ratio A.	MOORA	Brauers and Zavadskas (2006)
Multiple Objective Optimization on the Basis of Ratio Analysis	MULTIMOORA	Brauers and Zavadskas (2010)
Additive Ratio Assessment	ARAS	Zavadskas and Turskis (2010)
Weighted Aggregated Sum Product Ass.	WASPAS	Zavadskas et al., (2013)
Evaluation Based on Distance from Average Solution	EDAS	Ghorabaee (2015)
Best-Worst Method	BWM	Rezaei (2015)

3. Literature Review on Integration of AHP with other MCDM Methods

The integration of AHP with MCDM techniques has been widely used in the literature to solve real-world problems. In this section, the articles published in scientific journals have been analyzed and the integration of traditional AHP and Fuzzy AHP methods with MCDM techniques is discussed separately. Figure 2 and Figure 3 show the frequencies of studies using AHP and MCDM integration. Figure 2 and Figure 3 show that TOPSIS, VIKOR, PROMETHEE, Entropy, and DEMATEL methods are the most integrated methods with both crisp AHP and fuzzy AHP, and it is revealed that the studies gained momentum after the 2000s. Furthermore, the number of annually published crisp AHP studies is drastically bigger than the number of fuzzy AHP studies.

According to Figure 2 and Figure 3, the integration of AHP and TOPSIS methods is the most preferred method among distance based MCDM methods under both crisp and fuzzy environments. The first study which proposed the integration of AHP and TOPSIS methods was published in 2022. The technique was applied to evaluate urban fire risks by Ye et al (2002). Then, the integration of Fuzzy AHP and TOPSIS was proposed in 2004 by Chen and Tzeng (2004). Among the outranking-based methods, the number of studies using PROMETHEE has increased significantly since 2020 while the number of studies integrating PROMETHEE and ELECTRE methods with crisp AHP was almost close to each other before 2020. When fuzzy AHP-based studies are examined, it is seen that the studies using PROMETHEE integration have increased significantly only in 2020, while the number of studies preferring ELCETRE and PROMETHEE methods is almost close to each other in other years. The first integration of AHP and PROMETHEE methods was published in 1995 by Urli and Beaudry (1995) while fuzzy AHP and PROMETHEE integration was published in 2011 by Özgen et al. (2011). Among the utility/value based

MCDM methods, the integration of Entropy and AHP method under crisp and fuzzy environments is considerably higher than the others. The first use of AHP and entropy methods was realized in 1993 by Noble and Sanchez (1993) while fuzzy AHP and entropy method was introduced in 1994 by Mon et al. (1994). Furthermore, among the utility/value based MCDM methods, it is seen that the number of studies preferring the integration of AHP with WASPAS and COPRAS methods which are newly proposed to literature has increased significantly in recent years. Among the pairwise comparison based MCDM methods, the number of studies including the integration of DEMATEL method with both crisp AHP and Fuzzy AHP is bigger than the number of studies including the integration of BWM. However, the difference between AHP-based DEMATEL and AHP-based BWM increased in 2022 although the number of these studies was nearly the same in 2021. The first combination of AHP and DEMATEL method to evaluate the criteria of employment service was proposed in 2010 by Wu et al. (2010) while its fuzzy version was published in 2011 by Shahraki and Paghaleh (2011)
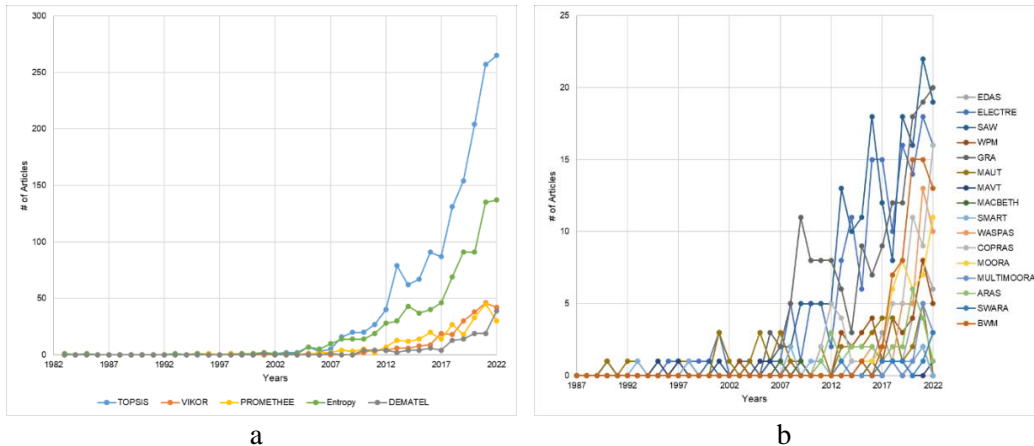

| a | b |

Figure 2. The integration of AHP method MADM methods: a. widely integrated methods, b. the others
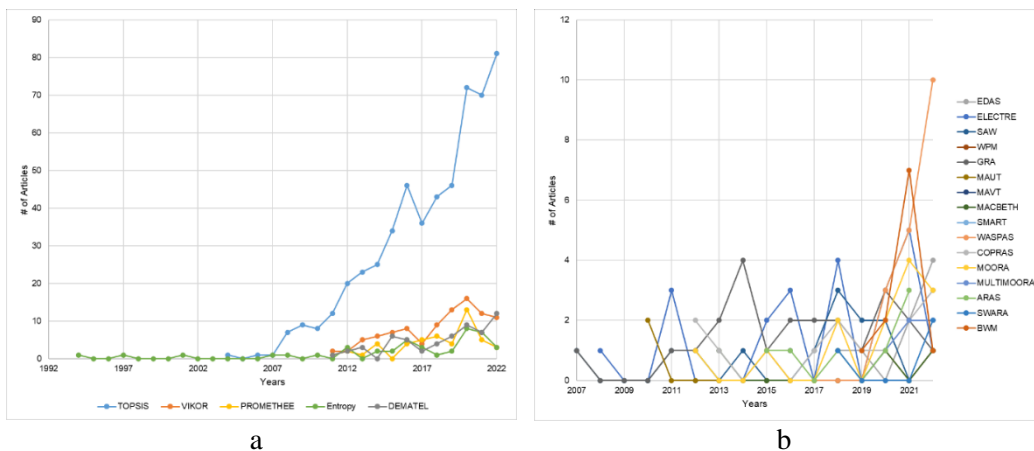

| a | b |

Figure 3. The integration of fuzzy AHP method MADM methods: a. widely integrated methods, b. the others

4. Conclusions

The main objective of this study aims to provide a perspective on the integration of AHP method with other MCDM methods. Based on this review, the following remarks for the integration of AHP with other MCDM methods can be concluded. First of all, the number of studies including the integration of crisp AHP with other MCDM methods is considerably higher than the number of fuzzy AHP studies. The number of studies involving TOPSIS integration is in the first place under both crisp and fuzzy environments for each year. Entropy method are in the second place under crisp environment while VIKOR method is in the second place under fuzzy environment. It is revealed that the popularity of the newly proposed methods such as WASPAS and COPRAS has been increasing recently. The popularity of the newly proposed methods such as WASPAS and COPRAS has been increasing recently. Although the type of integrated method has been differentiated, a large number of studies uses AHP method to determine the weight of the criteria instead of a decision tool.

The contribution of this paper to the published literature is that this review work could be a reference for researchers who aim to use the integration of AHP with other MCDM methods. For further studies, this paper can be extended with the studies including the integration ANP method with other MADM methods. Furthermore, MODM methods can also be included in the next research.

References

Bana e Costa, C. A; Vansnick, J.-C. (1999). *The MACBETH approach: Basic ideas, software, and an application. Advances in Decision Analysis. Mathematical Modelling: Theory and Applications.* Springer. 4: 131–157. doi:10.1007/978-94-017-0647-6_9. ISBN 978-90-481-5167-7.

Benayoun, R., B. Roy, and N. Sussman. (1966). *Manual de reference du programme electre. Note De Synthese et Formaton*, No. 25, Direction Scientifique SEMA, Paris, France.

Brans, J.P., and Ph. Vincke. (1985). A preference ranking organization method (The PROMETHEE method for MCDM). *Management Science* 31 (6): 647–56

Brans, J.P., B. Mareschal, and Ph. Vincke. (1984). *PROMETHEE: A new family of outranking methods in multi-criteria analysis*. In Operational Research, ed. J.P. Brans, 408–21. North-Holland: Elsevier Science Publishers B.V.

Brauers, W. K. M. & Zavadskas, E. K. (2010). Project management by MULTIMOORA as an instrument for transition economies. *Technological and Economic Development of Economy*, 16, 5–24.

Brauers, W., & Zavadskas, E. K. (2006). The MOORA method and its application to privatization in a transition economy. *Control and Cybernetics,* 35, 445–469.

Chen, M.-F., Tzeng, G.-H. (2004). Combining grey relation and TOPSIS concepts for selecting an expatriate host country, *Mathematical and Computer Modelling,* 40(13), 1473-1490.

Churchman, C.W., and R.L. Ackoff. (1954). An approximate measure of value. *Journal of Operations Research Society of America* 2 (1): 172–87.

Deng, J. (1982). Control problem of grey systems. *Systems and Control Letters* 1 (5): 288–94.

Edwards, W. (1977). How to use multiattribute utility measurement for social decisionmaking. *IEEE Transactions on Systems, Man, and Cybernetics* SMC-7:5, 326–340.

Fishburn, P. C. (1965). *Utility theory*. Management Science, 14, 335–378.

Fishburn, P.C. (1967) Methods of estimating additive utilities, *Management Science*. 13, 435–453.

Fontela, E., & Gabus, A. (1976). *The DEMATEL observer*, DEMATEL 1976 Report. Switzerland Geneva: Battelle Geneva Research Center, USA.

Hwang, C.L., and K. Yoon. (1981). Multiple attribute decision making, methods and applications. Lecture Notes in Economics and Mathematical Systems, 186. *Now York: Springer-Verlag*.

Kaklauskas, A., Zavadskas, E. K., Raslanas, S., Ginevicius, R., Komka, A., & Malinauskas, P. (2006). Selection of low-e windows in retrofit of public buildings by applying multiple criteria method COPRAS: A Lithuanian case. *Energy and Buildings*, 38, 454–462.

M. Keshavarz Ghorabaee, E. K. Zavadskas, L. Olfat, and Z. Turskis, (2015) ''Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS),'' *Informatica*, 26(3), 435–451.

Miller, D.W.; M.K. Starr (1969). *Executive Decisions and Operations Research*. Englewood Cliffs, NJ, U.S.A.: Prentice-Hall, Inc.

Mon, D.-L., Cheng, C.-H., Lin, J.-C. (1994). Evaluating weapon system using fuzzy analytic hierarchy process based on entropy weight, *Fuzzy Sets and Systems* 62(2), 127-134

Noble, E.E., Sanchez, P.P., (1993). A note on the information content of a consistent pairwise comparison judgment matrix of an AHP decision maker, Theory and Decision 34(2), pp. 99-108

Opricovic, S., & Tzeng, G. H. (2002). Multicriteria planning of post-earthquake sustainable reconstruction. *Computer-Aided Civil and Infrastructure Engineering*, 17, 211–220.

Özgen, A., Tuzkaya, G., Tuzkaya, U.R., Özgen, D., (2011). A multi-criteria decision making approach for machine tool selection problem in a fuzzy environment, *International Journal of Computational Intelligence Systems*, 4(4), pp. 431-445

Rezaei, J. (2015). Best-worst multi-criteria decision-making method, *Omega*, 53, pp. 49-57.

Saaty, T.L. (1977). A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology* 15 (3): 234–81.

Saaty, T.L. (1980). *The Analytic Hierarchy Process*. New York: McGraw-Hill.

Saaty, Thomas L. (1996). *Decision Making with Dependence and Feedback: The Analytic Network Process*. Pittsburgh, Pennsylvania: RWS Publications. ISBN 0-9620317-9-8.

Shahraki, A.R., Paghaleh, M.J. (2011) Ranking the voice of customer with fuzzy DEMATEL and fuzzy AHP, Indian Journal of Science and Technology 4(12), 1763-1772

Shannon C E, 1948. A mathematical theory of communications. Bell Systems *Technical Journal,* 27(3): 379-423

Tzeng G-H., Huang J-J, (2011). *Multiple Attribute Decision Making Methods and Applications.* CRC Press, Taylor & Francis Group, Boca Raton, ISBN: 978-1-4398-6157-8.

Urli, B., Beaudry, D. (1995). A multicriteria approach for ressource allocation in health [Une approche multicritere d'allocation des ressources financieres dans le domaine de la sante], *RAIRO Recherche Operationnelle*, 29(4), 373-389

Wu, H.-H., Shieh, J.-I., Li, Y., Chen, H.-K., (2010). A combination of AHP and DEMATEL in evaluating the criteria of employment service outreach program personnel, *Information Technology Journal*, 9(3), 569-575

Ye, Z., Li, S., Li, M., Lou, Z. (2002). Application of AHP and TOPSIS in urban fire risk assessment, *Process in Safety Science and Technology Part B*, 3, 983-986.

Zavadskas, E. K. & Turskis, Z. (2010). A new additive ratio assessment (ARAS) method in multicriteria decision-making. *Technological and Economic Development of Economy*, 16(2), 159–172.

Zavadskas, E. K., Turskis, Z., Antucheviciene, J., & Zakarevicius, A. (2012). Optimization of weighted aggregated sum product assessment. *Elektronika ir elektrotechnika*, 122(6), 3–6.