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Multi Criteria Decision Making Methods Applied in Waste Water Treatment: A Review

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A B S T R A C T

This Article presents an overview of different selection problems of Multi-Criteria Decision Making and their methods which is used in waste water treatment. The typical selection problem deals with the evaluation of a set of alternatives in terms of a set of decision criteria. In this paper Section A represents brief introduction of Multi Criteria Decision Making, Section B represents description of Multi Criteria Decision Making methods which is widely used in waste water treatment problems, Section C represents where MCDM methods can be applicable and section D represents the chart to compare the widely used method selection problems in waste water treatment.

Keywords: MCDM, AHP, ANP, DEMATAL, EDAS, PROMETHEE, TOPSIS

1. Introduction

Multiple criteria decision making (MCDM) is a process that allows to make decisions in the presence of multiple, usually conflicting criteria. The problems of MCDM can be broadly classified into two categories:

1.1. **Multiple attribute decision making (MADM):**

MADM involves the selection of the "best" alternative from pre-specified alternatives described in terms of multiple attributes;

1.2. **Multiple objective decision making (MODM):**

MODM involves the design of alternatives which optimize the multiple objectives of Decision Maker (DM)

Multi-Criteria Decision Making is a useful tool in many engineering fields like manufacturing, material selection,waste treatment, job selection, product design and development, and other various fields like military, constructional, agricultural sector etc. These problems specifically plays an important role in the fields of investment decision, project evaluation, economic benefit evaluation, staff appraisal and so on. Therefore, many techniques have been proposed to solve multiple attribute decision making problems. Multi-Attribute Decision Making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker. Making a decision implies that there are alternative choices to be considered and in a such case we won't only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values and so on. The remaining of the article is structured as follows: In the next section we give detailed review of multi-criteria decision making techniques that we have to compare. After the discussion of MCDM methods, in section III and IV we describe the selection problems in waste water treatment to apply the various analysis method of MCDM and finally, Section V concludes this paper.

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2. Review of MCDM Techniques

Following are the effective MCDM methods which will be used to analyze the problem and to find out best alternative-

1. Analytical Hierarchy Process(AHP)

One of the most popular techniques for complex decision-making problems is the analytic hierarchy process (AHP) developed by Saaty, which decomposes a decision making problem into a system of hierarchies of objectives, attributes (or criteria), and alternatives. An AHP hierarchy can have as many levels as needed to fully characterize a particular decision situation. A number of functional characteristics make AHP a useful methodology. These include the ability to handle decision situations involving subjective judgments, multiple decision makers, and the ability to provide measures of consistency of preference. Designed to reflect the way people actually think, AHP continues to be the most highly regarded and widely used decision-making method. AHP can efficiently deal with tangible (*i.e*., objective) as well as non-tangible (*i.e*., subjective) attributes, especially where the subjective judgments of different individuals constitute an important part of the decision process **[29].**

Pros:

- ✓ The advantages of AHP over other multi criteria methods are its flexibility, intuitive appeal to the decision makers and its ability to check inconsistencies. Generally, users find the pair wise comparison form of data input straightforward and convenient.
- ✓ The AHP method supports group decision−making through consensus by calculating the geometric mean of the individual pair wise comparisons.

Cons:

- ✓ With AHP the decision problem is decomposed into a number of subsystems, within which and between which a substantial number of pair wise comparisons need to be completed. This approach has the disadvantage that the number of pair wise comparisons to be made, may become very large (n (n−1)/2), and thus become a lengthy task.
- ✓ Another important disadvantage of the AHP method is the artificial limitation of the use of the 9 point scale. Sometimes, the decision maker might find difficult to distinguish among them and tell for example whether one alternative is 6 or 7 times more important than another **[29].**

Applications:

- ✓ Performance-type problems,
- ✓ Resource management,
- ✓ Corporate policy and strategy,
- ✓ Public policy,
- ✓ Political strategy, and
- ✓ Planning.

2. Analytical Network Process (ANP)

The **Analytic Network Process** (**ANP**) is a more general form of the AHP used in MCDM**.** AHP structures a decision problem into a hierarchy with a goal, decision criteria, and alternatives, while the ANP structures it as a network. Both then use a system of pairwise comparisons to measure the weights of the components of the structure, and finally to rank the alternatives in the decision.

In the AHP, each element in the hierarchy is considered to be independent of all the others—the decision criteria are considered to be independent of one another, and the alternatives are considered to be independent of the decision criteria and of each other. But in many real-world cases, there is interdependence among the items and the alternatives. ANP does not require independence among elements, so it can be used as an effective tool in these cases.

To illustrate this, consider a simple decision about buying an automobile. The decision maker may want to decide among several moderately-priced full-size sedans. He might choose to base his decision on only three factors: purchase price, safety, and comfort. Both the AHP and ANP would provide useful frameworks to use in making his decision.

The AHP would assume that purchase price, safety, and comfort are independent of one another, and would evaluate each of the sedans independently on those criteria.

The ANP would allow consideration of the interdependence of price, safety, and comfort. If one could get more safety or comfort by paying more for the automobile (or less by paying less), the ANP could take that into account. Similarly, the ANP could allow the decision criteria to be affected by the traits of the cars under consideration. If, for example, all the cars are very, very safe, the importance of safety as a decision criterion could appropriately be reduced.

3. Decision making trial and evaluation laboratory (DEMATAL)

Decision making trial and evaluation laboratory (DEMATEL) technique was first developed by the Geneva Research Centre of the Battelle Memorial Institute to visualize the structure of complicated causal relationships through matrixes or digraphs. As a kind of structural modeling approach, it is especially useful in analyzing the cause and effect relationships among components of a system. The DEMATEL can confirm interdependence among factors and aid in the development of a map to reflect relative relationships within them and can be used for investigating and solving complicated and intertwined problems. This method not only converts the interdependency relationships into a cause and effect group via matrixes but also finds the critical factors of a complex structure system with the help of an impact relation diagram.

Pros and Cons:

- ✓ Due to its advantages and capabilities, the approach of DEMATEL has received a great deal of attention in the past decade and many researchers have applied it for solving complicated system problems in various areas.
- ✓ In addition, the DEMATEL has been extended for better decision making under different environments since many real-world systems include imprecise and uncertain information **[31]**.

Applications:

- ✓ Banking performance,
- ✓ Business performance,
- ✓ Automotive Industry,
- ✓ Education,
- ✓ Demand Forecasting,
- ✓ Material Selection

4. Evaluation based on distance from average solution (EDAS)

The evaluation based on distance from average solution (EDAS) method was introduced by Keshavarz Ghorabaee for inventory ABC classification. It was presented that the EDAS method has good efficiency and needs fewer computations in comparison with other ABC classification methods. Moreover, the efficiency of the EDAS method as an MCDM method was demonstrated by comparing it with some commonly used methods. The evaluation of alternatives in this method is based on distances of each alternative from the average solution with respect to each criterion. In this study, the EDAS method is extended to deal with the fuzzy MCDM problems. In this paper, these linguistic terms are defined by trapezoidal fuzzy numbers to extend the EDAS method in fuzzy environment. A case study of supplier selection is employed to describe the process and demonstrate the effectiveness of the proposed extended method. We also perform a sensitivity analysis with different sets of simulated criteria weights to represent the validity and stability of the ranking results when the weights of criteria are changed. The results of sensitivity analysis show that the proposed fuzzy method is stable in different weights of criteria and has a good efficiency in a fuzzy environment **[32].**

Pros:

- ✓ Very practical method in conditions with contradictory attributes
- ✓ The method characterized as a highly efficient method
- ✓ Calculations are quite simple
- ✓ Popular when used for various fuzzy cases

Cons:

- ✓ The method is limited by its hypothesis that the evaluation criteria are compensatory
- ✓ The method has the same disadvantages as the TOPSIS method; rank reversals not stable **[33].**

5. PROMETHEE

The PROMETHEE I (partial ranking) and PROMETHEE II (complete ranking) were developed by J.P. Brans and obtainable for the first time in 1982 at a conference organised by R. Nadeau and M. Landry at the University Level, Quebec, Canada (L Ingenierie de la Decision. Elaboration d instruments d Aidea la Decision). The same year several applications using this methodology were already treated by G. Davignon in the field of Heath care. A few years later J.P. Brans and B. Mareschal developed PROMETHEE III (ranking based on intervals) and PROMETHEE IV (continuous case). The same authors proposed in 1988 the visual interactive module GAIA which is providing a marvellous graphical representation supporting the PROMETHEE methodology. In 1992 and 1994, J.P. Brans and B. Mareschal further suggested two nice extensions: PROMETHEE V (MCDA including segmentation constraints) and PROMETHEE VI (representation of the human brain). A considerable number of successful applications has been treated by the PROMETHEE methodology in various fields such as Banking, Industrial Location, Manpower planning, Water resources, Investments, Medicine, Chemistry, Health care, Tourism, Ethics in OR, Dynamic management. The achievement of the methodology is basically due to its mathematical properties and to its particular friendliness of use.

Usually this is a ill-posed mathematical problem as there exists no alternative optimizing all the criteria at the same time. However most (nearly all) human problems have a multi criteria nature. According to our various human aspirations, it makes no sense, and it is often not fair, to select a decision based on one evaluation criterion only. In most of cases at least technological, economical, environmental and social criteria should always be taken into account. Multi criteria problems are therefore extremely important and request an appropriate treatment **[28].**

Pros:

- ✓ PROMETHEE (as all outranking methods) can simultaneously deal with qualitative and quantitative criteria. Criteria scores can be expressed in their own units.
- ✓ PROMETHEE needs much less inputs.

Cons:

- ✓ PROMETHEE suffers from the rank reversal problem when a new alternative is introduced
- ✓ PROMETHEE does not provide the possibility to really structure a decision problem. In the case of many criteria and options, it thus may become difficult for the decision maker to obtain a clear view of the problem and to evaluate the results **[29].**

Applications:

- ✓ Environmental,
- ✓ Hydrology,
- ✓ Water management,
- ✓ Business and finance,
- ✓ Chemistry,
- ✓ Logistics and transportation,
- ✓ Manufacturing and assembly,
- ✓ Energy,
- ✓ Agriculture

6. Technique of Order Preference by Similarity of Ideal Solution (TOPSIS)

This method is based on the concept that the chosen alternative should have the shortest Euclidean distance from the ideal solution, and the farthest from the negative ideal solution. The ideal solution is a hypothetical solution for which all attribute values correspond to the maximum attribute values in the database comprising the satisfying solutions; the negative ideal solution is the hypothetical solution for which all attribute values correspond to the minimum attribute values in the database. TOPSIS thus gives a solution that is not only closest to the hypothetically best, that is also the farthest from the hypothetically worst **[29]**.

Pros:

- ✓ It takes input as any number of criteria and attributes.

- ✓ Fairly intuitive physical meaning based on consideration of distances from ideal solutions.

Cons:

- ✓ Easy, can give unreliable results.
- ✓ TOPSIS in its standard form is deterministic and does not consider uncertainty in weightings **[29].**

Applications:

- ✓ Supply chain management and logistics,
- ✓ Engineering,
- ✓ Manufacturing systems,
- ✓ Business and marketing,
- ✓ Environmental,
- ✓ Human resources, and
- ✓ Water resources management.

3. MCDM Applications in Waste Water Treatment

Reference Number	Title of the Article	MCDM methods	Focus area/Results	Applications
1	Evaluation of wastewater treatment technologies using TOPSIS	TOPSIS	In this paper has presented a prototype framework using the TOPSIS algorithm as an effective tool for supporting machine selection decisions.	Power plant
2	Application of Various Multi Criteria Decision Making Methods for the Assessment of Different Waste Water Treatment Systems Case Study: JSPM Hadapsar Campus, Pune	AHP , ANP and TOPSIS	These models enable to consider social, economic, technical and environmental aspects along with their sub criteria and to compare them to find the best alternatives among the methods.	Power Plant
3	Application of EDAS Method on Water Requirement in Agriculture	EDAS	In this paper an agricultural situation in a locality is considered where various parameters on water management in agricultural crops are considered	Agriculture
4	A Fuzzy Approach for the Assessment of waste water treatment alternatives	DEMATAL and Fuzzy TOPSIS	The proposed framework enables managers to deal with multi-granular information, and thus, allows for the use of different semantic types by decision-makers.	Power plant
5	Using the Fuzzy Analytical hierarchy method for selecting wastewater facilities at prefecture level	AHP	In environmental management issues to the various sectors, it is compared the AHP is a viable evaluation strategy	Production
6	Multi-criteria evaluation of wastewater treatment technologies in constructed wetlands	AHP and TOPSIS	A decision-making problem is hierarchically structured and the AHP-based pair wise comparisons are used to derive the weights of criteria and local weights of orderings regarding each criterion. With the decision matrix created in this way, the weighting and distance methods are used along with the AHP to declare the best ordering of technologies by segments.	Construction
7	A comparison of multiple criteria analysis techniques for water resource management	PROMETHEE		Production
8	ANALYTIC HIERARCHY PROCESS TO ASSESS	AHP	The use of AHP methodology helped to inspect the actual technology	Water Treatment Plants

	TECHNOLOGICAL SYSTEM IN WATER TREATMENT PLANTS		provision of production & treatment water plants, and to determine the plants requiring achieving a technological standard. Consequently, the implementation will contribute to the improvement of the quality of service.	
9	Selection of wastewater treatment process based on the analytical hierarchy process and fuzzy analytical hierarchy process methods	AHP and Fuzzy AHP	Selection of the best wastewater treatment process is a multi-criteria decision making problem. Conventional methods are inadequate for dealing with the imprecise or vague nature of linguistic assessment. To overcome this difficulty, the fuzzy analytical hierarchy process is proposed for dealing with the vagueness of decision makers' judgments	Office Admistration (Other)
10	Fuzzy based decision support method for selection of sustainable wastewater treatment technologies	Fuzzy- DSM	The DSM relied on performance evaluation in order to rate effectiveness of wastewater treatment technologies	Other
11	Wastewater treatment evaluation for enterprises based on fuzzy-AHP comprehensive evaluation: a case study in industrial park in Taihu Basin, China"	Fuzzy-AHP	Analytical hierarchy process (AHP) procedure to evaluate the wastewater treatment for enterprises	Other
12	DEMATEL METHOD IN PRACTICE: FINDING THE CAUSAL RELATIONS AMONG KEY COMPETENCIES	DEMATAL	The evaluation of competencies will be done by five experts in the company and they will decide in consensus on the competencies preferences.	Other
13	MULTI-CRITERIA ASSESSMENT TO AUTOMATE WATER TREATMENT PLANTS USING THE ANALYTICAL HIERARCHY PROCESS	AHP	The study provides a basis for setting priorities and decision making s for incorporating an automated system to WT and WWT plants at any locality	Production
14	Application of Entropy Weight TOPSIS Method for Optimization of Wastewater Treatment Technology of Municipal Wastewater Treatment Plant	TOPSIS	Entropy Weight TOPSIS method, used in the assessment of the wastewater treatment technology is flexible, convenient, scientific and suitable for the assessment of sewage disposal technology.	Other
15	Decision Support Concept to Selection of Wastewater Treatment Plant Location—the Case Study of Town of Kutina, Croatia	AHP	In this study, the results indicate that it is possible to develop such a concept based on multi criteria methods on which decision-makers can rely	Production
16	Evaluation of wastewater treatment technologies using TOPSIS	TOPSIS	Based on this research, the activated sludge process is recommended as the best option, followed by the nano-filtration method and TOPSIS.	Other
17	Integrated Water Resource Security Evaluation of Beijing based on Grey Relation Analysis and TOPSIS	TOPSIS	The study and analysis of water resource security indicated that the pressure of water resource was constantly increasing	Other
18	Integrated Evaluation of Hybrid Water Supply Systems Using a PROMETHEE–GAIA Approach	PROMETHEE	The centralized system combined with storm water harvesting and the centralized system combined with treated wastewater and rainwater tanks yielded the first and second most preferred scenarios, while the centralized water supply system combined with treated wastewater yielded the	Other

			worst hybrid water supply option.	
19	Evaluation of different natural wastewater treatment alternatives by fuzzy PROMETHEE method	PROMETHEE	The result was closely similar to the fuzzy PROMETHEE result except for soil filter and RWI which interchanged their position of the rank	Other
20	Comparative Analysis of Wastewater Treatment Technologies	PROMETHEE	The results show NF as the best method with Activated Sludge (AS) been the second most preferred method for wastewater treatment, though may not be feasible for developing where power supply is a problem. Further understanding of the PROMETHEE method	Other
21	Site Selection for Wastewater Treatment Plants in Rural Areas Using the Analytical Hierarchy Process and Geographical Information System	AHP	In this study, the site was located at the lowest elevation compared to the villages in each complex	Other
22	Selecting the Optimal Urban Wastewater Treatment Process in the Various Climates by Using Analytic Hierarchy Process (AHP)	AHP	The ultimate goal of this approach is to identify the best option and also sort all possible options according to compatibility with all decision criteria simultaneously	Other
23	Application of analytical hierarchy process to water resources policy and management in Beijing, China	AHP	In this study, the results provide both qualitative and quantitative information to decision makers on the policies, as well as on their priorities from the point of view of regional water planning and development	Other
24	Wastewater treatment plant site selection using AHP and GIS: a case study in Falavarjan, Esfahan	AHP and TOPSIS	In order to locate the site with the minimum effect on the environment, AHP and TOPSIS used as the most preferable option	Other
25	Multi criteria evaluation of alternative wastewater treatment processes at municipality level	AHP	The results obtained by AHP showing that this approach is a viable tool and offers good communication with decision maker.	Other
26	Sustainability Analysis of Domestic Wastewater Treatment Technology Applied on Human Settlement in Swamp Area	AHP	In this study, the result of dry and separated toilet with container consider as the most sustainable system (with score 0.832) and both floating pods/ garden and tripikon-S system are the second highest score (0.666).	Other
27	Analytical Hierarchy Process in Concept Selection of Wastewater Treatment Plant	AHP	In this study, it is clear that using AHP the score for SBR is by far better than UASB; the difference appears significant and as such, SBR is the best concept option to recommend.	Other

4. Types of Waste Water Treatment Applications in MCDM

In this study about Waste Water Treatment analysis, we found MCDM has been applied in power plant, production sector, agricultural sector, construction, water treatment plants, and other sectors like logistic, medical, control, municipal and rivers.

Table No. 1: Uses of Application Areas in Waste Water Treatment

Applications Area	Number of Papers in MCDM
Power Plant	3
Agriculture	1
Production Sector	4
Construction	1
Water Treatment Plants	1
Others	17

The majority of MCDM applications to prevent the wastewater treatment used in other sectors like management, municipal and corporation, office administration, rivers and other areas. Among them the other application areas can be mostly MCDM to analyzed the selection, ranking and evaluation of alternatives which is as follows in the pie chart.

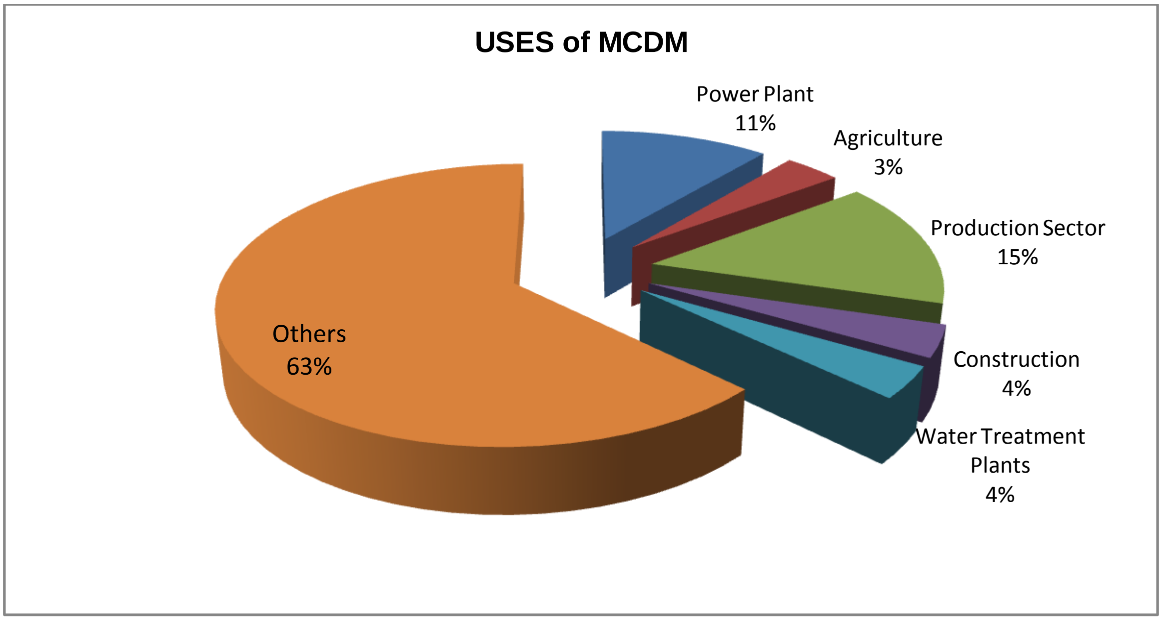

Figure 1: Pie Chart analysis of MCDM

5. Types of Waste Water Treatment Methods by MCDM

In this study about Waste Water Treatment analysis, we found the percentage of MCDM methods has been applied in power plant, production sector, agricultural sector, construction, water treatment plants, and other sectors like logistic, medical, control, municipal and rivers.

Table No. 2: Uses of MCDM Methods in Waste Water Treatment

Methods	Number of Papers in MCDM
AHP, ANP	15
DEMATAL	2
EDAS	1
PROMETHEE	3
TOPSIS	8

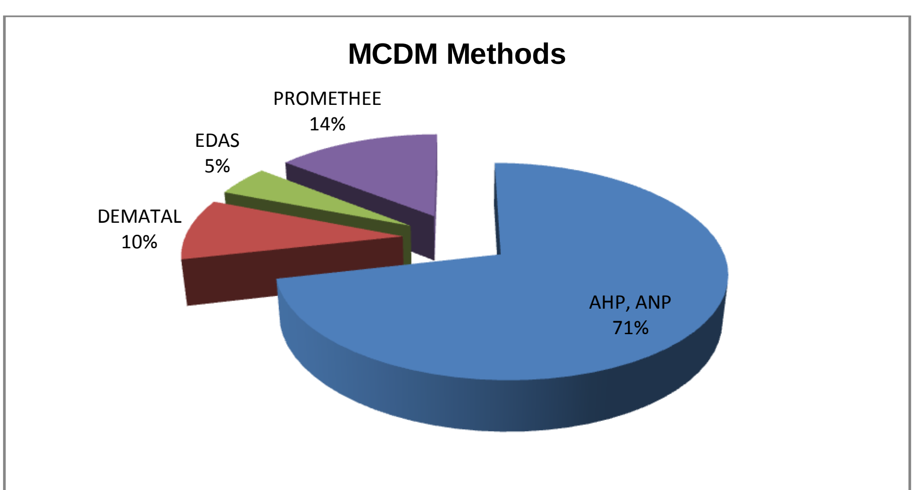

Figure 2: Percentage of MCDM methods uses

6. Conclusion

An attempt has been made in this paper to review and analyze different multi criteria decision making methods applied in Waste Water Treatment. The paper things to see different application areas where multi criteria decision making methods are used to treatment the waste water. **Table No.1** and **Table No.2** shows different selection problems in different sectors where there is the application of MCDM. Even though the searching for finding the best Multi Criteria Decision Making method for selection problems may never end. Research in this area is critical and valuable.

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