



Application of Various Multi Criteria Decision Making Methods for the Assessment of Different Waste Water Treatment Systems Case Study: JSPM Hadapsar Campus, Pune

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Abstract: Decision making in Environmental Engineering is a complex task due to the existence of various socio-economic, technical and environmental factors. Multi Criteria Decision Making (MCDM) analysis is used to make comparative assessments of various available alternatives by considering various criteria and sub criteria in complex situation. The paper shows the application of three MCDM techniques viz. - AHP, ANP and TOPSIS to a hypothetical problem concerning the choice of the most sustainable wastewater treatment technology amongst Activated Sludge Process (ASP), Bio Tower and Sequential Batch Reactor (SBR) for JSPM Hadapsar, an educational institute campus in Pune. These models enable to consider social, economic, technical and environmental aspects along with their sub criteria and to compare them to find the best alternative. The AHP, ANP and TOPSIS techniques are applied through specific software packages like Expert Choice 11, Super Decisions and Topsis Solver 2012 respectively. Five stakeholders from various field are consulted and their inputs and judgments are incorporated in the decision making process. A comparison of the judgments and merits obtained from the different models shows that Sequential Batch Reactor emerges as the most sustainable waste water treatment technology for JSPM Hadapsar, Pune.

Keywords: Decision making; Multi Criteria Decision Making; Analytic Hierarchy Process; Wastewater treatment; Activated Sludge Process

I. Introduction

Industrialization and civilization bring the prosperity but it has got dark side as well. Because of the discharge of untreated waste water from industries & habitations, stress is created on the ecology. According to the estimation of Thermax Waste Water Treatment and Recycling, around 60% of effluent generated from Industries & 74% of sewage generated in India goes untreated into the ecosystem [13]. Lack of waste water treatment systems creates extremely harmful effect on the entire civilization. A government report on Urban and Industrial Water Supply and Sanitation for the Twelfth Five - Year Plan (2012-2017) highlights some points about wastewater in India and are briefed below:

According to this report, an estimated 38354 million liters per day (MLD) sewage is generated in major cities of India, but the sewage treatment capacity is only of 11786 MLD. Also the cost is another important factor in this regard. According to the government report, in the mid-1990s, when the first-generation sewage treatment plants were built, they cost Rs 20 lakh to Rs 30 lakh (2-3 Million) per MLD. Today, the same plants cost close to Rs 1 crore (10 Millions) per MLD to build [14].

Considering educational institute's scenarios in India, either they don't have sewage treatments plants in their campus or they are not adopting sustainable waste water treatment method. Because, while selection of the waste water treatment technology (WWT), not only the economic factor but also all the other factors like social, technical, political, environmental influence the selection procedure. Due to this, the decision making can be considered as a complex system with several elements that have to be included in the evaluation. In such situations, Multi Criteria Decision Making (MCDM) analyses are used to make comparative assessments of alternative options. These methods allow several criteria to be considered simultaneously in a complex situation and are designed to help Decision Makers or stakeholders to integrate the different options [10].

The case illustrated in this paper refers to the selection of the most sustainable WWT technology for JSPM Hadapsar, an educational institute in Pune, India through the application of different MCDM methods like: Analytic Hierarchy Process (AHP), Analytic Network Process (ANP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). These methods are based on a multi criteria measurements theory.

II. Materials and Methods

Basic MCDM procedure is as follows:

1. Problem/Goal identification
2. Setting evaluation criteria and their weights
3. Defining feasible alternatives
4. Evaluating the alternatives
5. Making a decision

A. MCDM Technique- Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a structured technique for organizing and analyzing complex decisions. It is developed by Thomas L. Saaty. In this analysis, a complex problem can be divided into several sub-problems that are organized according to hierarchical levels, where each level denotes a set of criteria or attributes related to each sub problem. The top level of the hierarchy denotes the goal of the problem and the intermediate levels denote the factors of the respective upper levels. The bottom level contains the alternatives considered when achieving the goal [8] [10] [11]. The analysis is based on three fundamental principles viz; breaking down the problem; pairwise comparison of the various alternatives; synthesis of the preferences. The first step of the analysis consists in subdividing the decision making problem into several levels in such a way that they form a hierarchy with unidirectional hierarchical relationship between levels. Once the hierarchy is constructed, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy [4]. In making the comparisons, the decision makers can use their judgments about the elements' relative meaning and importance. The relative importance values are determined on a 9-point scale, the so- called "Saaty's Fundamental Scale" [4].

Table I Shows the fundamental scale of pairwise comparison used in AHP

Intensity of Importance	Definition	Explanation
1	Equal Importance	Both the elements are favored equally
3	Moderate Importance	Experience and Judgment moderately favors one element over another
5	Strong Importance	Experience and Judgment strongly favors one element over another
7	Very Strong Importance	One element is favored very strongly over another
9	Extreme Importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities of 1.1, 1.2, 1.3 etc. can be used for elements that are very close in importance.		

(Source: Saaty, 1996)

The numerical judgments established at each level of the hierarchy make up pair matrices [4]. After comparison matrixes are created, relative weights of the elements of each level with respect to an element in the adjacent upper level are computed as the components of the normalized eigenvector associated to the largest Eigen value of their comparison matrix. Eigenvector method yields a natural measure of consistency [4].

B. MCDM Technique- Analytic Network Process (ANP)

Many decision making issues cannot be structured hierarchically, because they imply interactions and dependencies between the highest elements and the lowest. In order to take into account the complexities of real world problems, Saaty proposed the Analytic Network Process (ANP) model, a generalization of the AHP method [4] [12]. The ANP provides a solution for problems which cannot be structured hierarchically. The ANP represents the decision problem as a network of criteria and alternatives (called elements), grouped into clusters. The ANP requires a network structure to represent the problem, as well as a pairwise comparison to establish the relationships within the structure [12].

The analysis is based on the four fundamental principles: development of the structure of the decision- making process, pairwise comparison, super matrix formation and final priorities. The first step of the analysis consists in subdividing the objective into groups ("clusters") that are made up of various elements ("nodes") and alternatives which ultimately forms a network. The relationships between the different parts of the network must be identified [4]. Similar to AHP, in ANP also, a series of pairwise comparisons are made to establish the relative importance of the different elements with respect to a certain component of the network. As for the AHP methodology, in ANP also the comparisons are made with the Saaty's Fundamental Scale [4].

C. MCDM Technique- Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS was presented by Hwang and Yoon. TOPSIS is a multiple criteria method to identify solutions from a finite set of alternatives based upon simultaneous minimization of distance from an ideal point and maximization of distance from a nadir point. TOPSIS can incorporate relative weights of criterion importance. The basic principle of this method is that the chosen alternative must have the shortest distance to the positive ideal solution and the farthest distance to the negative ideal solution [5].

III. Presentation of the Case

The AHP, ANP and TOPSIS methodologies are applied to a hypothetical problem concerning the choice of a waste water treatment technology. Three different waste water treatment technologies have been taken into consideration, namely Activated Sludge Process (ASP), Biotower, and Sequential Batch Reactor (SBR), in relation to JSPM educational institute located at Hadapsar, Pune and the integral part of the study was to determine the most suitable waste water treatment solution at above mentioned location.

These types of methods require consulting experts who can enrich the decision with their judgments regarding the problem. Therefore, five Experts from the sector of waste water treatment were consulted. After a couple of brain storming session and discussions with these experts, some criteria and sub criteria were identified and finalized.

Table II Shows the identified criteria and sub criteria

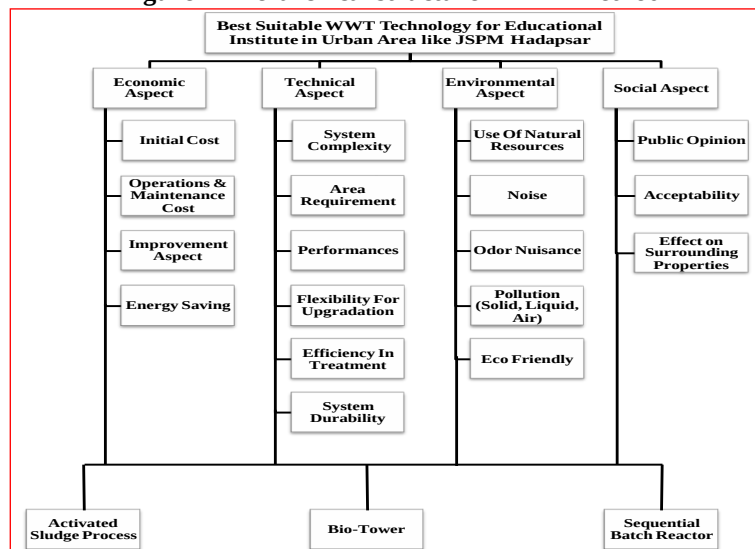
Criteria	Sub-Criteria
Economic	Initial Cost
	Operation & Maintenance Cost
	Improvement aspects
	Energy saving
Technical	System Complexity
	Area requirement
	Performances
	Flexibility for up gradation
	System durability
Social	Public opinion
	Acceptability
	Effect on surrounding properties
Environmental	Use of natural resources
	Noise
	Odour Nuisance
	Pollution (Solid, Liquid, Air)
	Ecofriendly

IV. Application of MCDM Methods

A. Application of AHP

The model has been developed through the use of the specific Expert choice 11 software. Fig. 1 shows the hierarchical structure which represents the decision-making problem in AHP.

Figure 1 Hierarchical structure in AHP method

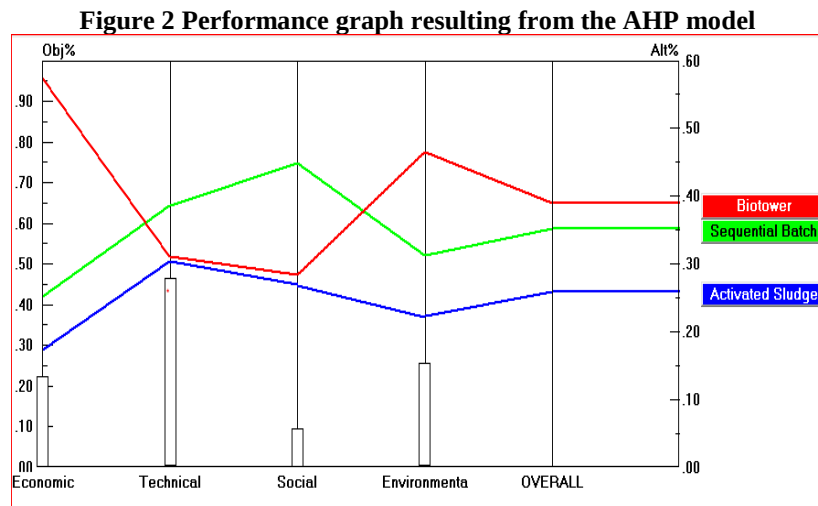


Once hierarchy is constructed, pairwise comparison is carried out. Following Table 3 shows the representative table, showing pairwise comparison for AHP model.

Table III Shows the comparison of the relative importance of criteria with respect to: Goal

	Economic	Technical	Social	Environmental	Priority vector
Economic	1	6	7	6	0.24
Technical	1/6	1	8	7	0.63
Social	1/7	1/8	1	7	0.03
Environmental	1/6	1/7	1/7	1	0.10

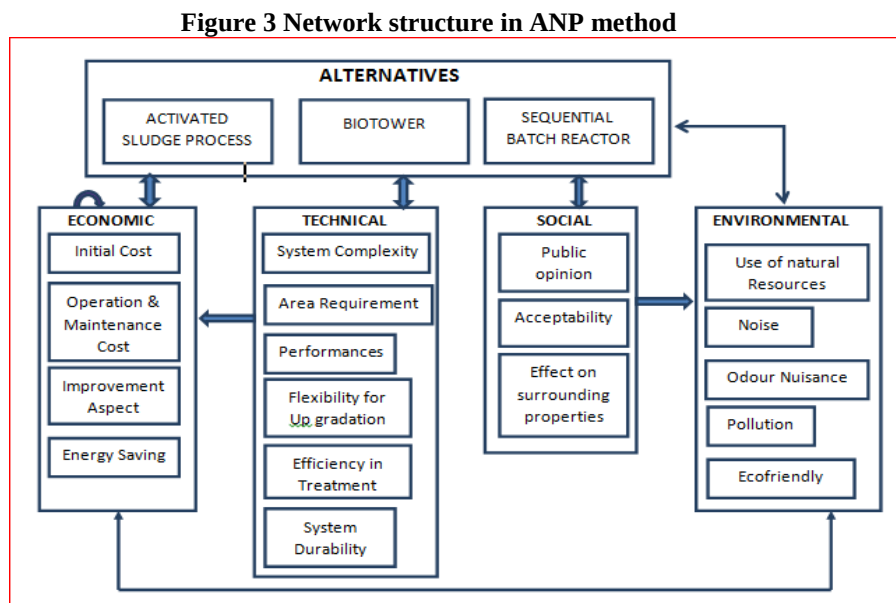
The performance graph shows the result obtained by combining judgments of all decision makers. Fig.2 shows the performance graph.



Performance graph indicates that in AHP model, Biotower (38.9%) is given highest priority over Sequential Batch Reactor (35.2%) and Activated Sludge Process (25.9%).

B. Application of ANP

The ANP application has been developed through the use of the specific Superdecision software version 2.2.3. Fig.3 shows the network structure in ANP model.



The central part of this method is a network. Hence, in this method problem is broken down into closely interconnected clusters and nodes with inner and outer dependencies and feedbacks which form a network. In the present problem, there are four distinguished clusters representing main criteria and a cluster representing alternatives. Individual nodes represent sub criteria. All the elements in the clusters are connected to the alternatives.

According to ANP method, the most sustainable waste water treatment solution is SBR (49.6%), followed by Biotower (33%) and ASP (17.4%).

C. Application of TOPSIS

In TOPSIS method, pairwise comparison is not carried out as in case of AHP and ANP. Instead of that weights are given to rate each alternative and criteria individually. Following Table 4 shows the qualitative labels used for the ratings of the alternatives according to the importance weighting of each sub criterion for TOPSIS method. Each label is associated to a weight in order to simplify further statistical analyses.

Table III Shows the linguistic labels and weights used in TOPSIS method

Label	Description	Weights
vL	Very low	0
L	Low	0.1
mL	Medium low	0.3
m	Medium	0.5
mH	Medium high	0.7
H	High	0.9
vH	Very high	1.0

Following Table 5 represents the data of the weights that each expert gave to the group of criteria.

Table V Shows weights for each group of criterion according to experts (E1-E5) and group decision (G)

Experts	Criteria			
	Economic aspect	Technical aspect	Social aspect	Environmental aspect
E1	0.9	1.0	0.7	0.7
E2	0.5	0.7	0.1	0.9
E3	0.7	0.9	0.3	0.3
E4	0.9	0.9	0.7	0.5
E5	0.9	0.7	0.9	1.0
G	0.78	0.84	0.54	0.68

In TOPSIS method the most sustainable solution refers to SBR (0.592), followed by the ASP (0.499) and Biotower (0.452).

V. Results and Discussion

From the analysis of the final results it is possible to note some findings-

In the AHP model, the most suitable solution is the Biotower (38.9%) followed by the Sequential Batch Reactor (35.2%) and Activated Sludge Process (25.9%). The ANP model shows that the most suitable solution is Sequential Batch reactor (49.6%), followed by Biotower (33%) and ASP (17.4%). The TOPSIS model confirms the ANP results and the priority list obtained from the application of the TOPSIS proves that the best technology is represented by the Sequential Batch Reactor (0.592), while ASP has a better score than before (0.499) and the preference for the Biotower is low (0.452).

From the above results, it emerges that the Biotower and SBR systems have high scores in the AHP model but the percentage difference between the two technologies increases in the ANP model, where SBR becomes the most preferable solution. AHP considers one-way interactions while ANP considers interdependencies among the criteria and alternatives that apply additional effect in the model. In fact, AHP suffers from the limitation of only being applicable to straightforward hierarchical structures and ANP can solve complex decision problems that involve several issues. Hence, it is possible to conclude that, the more the model is complicated, the greater are the chances to arrive at the correct decision as several elements related to problem being taken into account.

Also TOPSIS supports the ANP results, though it calculates the priorities in completely different manner than AHP and ANP. But this does not mean that, the results determined from the AHP would necessarily differ from those determined from the ANP and TOPSIS. However, in cases involving interdependence and feedbacks in the problem, the ANP model is suitable method for selecting the best alternative.

VI. Conclusions

The results obtained from the development of the three models- AHP, ANP and TOPSIS show that the Sequential Batch Reactor is the most sustainable solution for the waste water treatment, in the case of educational institute in urban area like JSPM Hadapsar.

Also it can be concluded that in this present study, technical criteria and economic criteria continue to dominate above environmental and social criteria.

The present study illustrates some insights of AHP, ANP and TOPSIS methods as well. To start with, the present work indicates that the AHP and ANP analyses are suitable to deal with complex decision-making problems because they allow several criteria to be considered and compared in a systemic way. These approaches make the decision process more traceable, justifiable and reliable and thus help to move forward with more methodological decisions. Secondly, The ANP method overcomes the limitation of AHP of one way interaction as it incorporates the feedbacks and interdependent relationships between elements from different levels or within levels, which are not considered in AHP. Thirdly, the TOPSIS method is useful when quantitative data is available. TOPSIS incorporates the importance of the weightage in the comparison procedures and finally considering the final ranking of the alternatives that come from the AHP and ANP models, the gap among the scores of the options increases as the level of complexity of the technique increases. Thus ANP gives more consistent results than AHP and these results are confirmed by TOPSIS method though TOPSIS calculates the priorities in a far different manner than AHP and ANP.

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