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The application of analytic hierarchy process for innovative solution: A review

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Abstract. The Analytic Hierarchy Process (AHP) serves as an all-inclusive and logical approach to evaluate complex decisions making. This paper discusses a review on the methods of AHP in various power plant and production plant for multiple factors as well as indicates potential gaps from the researchers' perspectives. Many analyses have identified various AHP applications to solving problems that necessitate both qualitative and quantitative elements. Generally, the applications of AHP cover large scale (complicated and real) and industrial oriented problems. A larger part of these applications or AHP case studies are arranged and a couple of paper focused on adding to AHP displaying prior to applying practical problems. As evidenced in this review, AHP has been applied in innovative solutions in industries such as biological treatment process, hydropower plant, electricity generation, and plastic waste management. Hence, this review provides a comprehensive list of the various applications of AHP in activities and fosters a system for highlighting the areas that that future researchers should focus on to assure a more thorough evaluation of the gaps.

1. Introduction

Multicriteria Decision Making (MCDM) has been widely utilised to simplify the options into mathematical equation by comparing between two choice elements at a time in order to quantify the weightage of each element and find the ideal alternatives. This paper discusses a review on innovative solutions regarding power plants and production plants through the use of the Analytic Hierarchy Process (AHP) method. Generally, the initial step of AHP is defining the goal of the outcome of the analysis then come up with several alternatives along with several criteria or even sub-criteria to evaluate it against. In essence, the AHP is mainly effective in limiting the biases among evaluator by assigning numerical value to intangible factor through pairwise comparison between the criteria and alternatives. AHP is one of the most well-known and widely utilised soft-computing MCDM procedure.

Analytic Hierarchy Process (AHP), since its development, has been an instrument because of decision makers and researchers, and it stands among the most popular methods of multi-criteria decision-making (MCDM). Numerous exceptional works in relation to AHP have been highlighted: they incorporate AHP applications in various fields like planning, deciding on the best alternative, allocating portions, settling conflict, improvement, and mathematical expansions of AHP [1]. The speciality of AHP is its adaptability to be incorporated with various strategies like Linear Programming, Quality Function Deployment, Fuzzy Logic and others. This empowers the user to extract the benefits from all the consolidated techniques, and thus, accomplish the ideal objective in a superior manner [1].

AHP is essentially centred around building models of decision in a limited arrangement of recently identified alternatives. This technique revolves around the notion that decision-making tasks are based on the construction of a multi-level hierarchy comprising key elements such as alternatives, hierarchy focus, and selection criteria, which are compared to one another to acquire evaluations of the power of common impact for evaluating the benefit of options relative to the fundamental goal. AHP's advantages as a coordinated technique for displaying multi-measures decision-making issues include the fact that hierarchy building, which is contingent on the systematic approach principles, helps to fill in any gaps in the model, organise the decision-making process, and formalize the connections among its components; thus, the AHP considers the evaluation and comparison of alternatives via qualitative subjective criteria, which are non-quantifiable, in addition to upholding its stability in inconsequential violations of consistency of expert decision-making consistency [2].

Generally, sustainable development (SD) is a complex topic that has a variety of definitions and involves various variable systems. Similarly, the interrelated notion of "sustainability" itself has reflected a concept that is rather difficult to describe because it may signify different things in a variety of different sectors [3]. Evidently, the AHP is one of the most popular and widely utilized decision-making techniques [4]. As an MCDM method, the AHP typically organizes and systematizes the decision-making process using pairwise comparisons in reference to a numerical scale [5, 6].

2. Case studies of Analytic Hierarchy Process (AHP)

2.1 Selection of Best Renewable Energy Source for A Sustainable Electricity Generation System Using AHP Method In Malaysia

AHP is implemented to four major criteria, social, technical, economic, and environmental as well as 12 sub-criteria to rank the best renewable power plants for Malaysia [7]. The selected criteria and sub-criteria were organized into four tiers: a goal in the top tier, criteria in the second tier, followed by sub-criteria in the third tier, and finally available renewables resources [7]. Large hydropower was except as one of the alternatives and to apply in the feed-in tariff as one of the sub-criteria, only solar photovoltaics (PV) was considered as solar power while biomass comprises of biogas and municipal solid waste [7]. The assessment showed through AHP that solar energy is the most optimum renewables followed with biomass, hydro, and wind, furthermore, it was found out that each renewables resources are prone towards distinct major elements [7]. The data acquired for this study came from the United States and other developed nations due to the lack of such data in the context of Malaysia. To deal with much complication of data analysis, a powerful multicriteria decision making model is required because such a model may not only deliberately divide a perplexing decision issue into smaller yet related subproblems but also consolidate subjective and quantitative sustainable resources data, thereby screening out conflicting decisions on these sustainable resources. Thus, AHP is viewed as a suitable procedure to be utilised for fostering the expected model to rank sustainable resources for generating electricity, especially in the Malaysian context [7]. The details of assessment criteria of electricity generation using AHP method is labelled in Table 1 and Figure 1.

Table 1. Assessment criteria of electricity generation using AHP method [7].

Criterion	Sub-criteria	Description
Technical	Efficiency	Highly efficient alternatives being taken into account
	Maturity	Commercially accessible technology with fewer initial flaws
	Lead time	Duration of the process from construction until operation
Economical	Feed – in – tariff	Total payment made to the generator per kWh generated
	Operational life	Number of years prior to decommissioning
	Resource potential	Access to renewable energy sources for generating power
	Technology cost	Installation and equipment expenditure
Social	Job creation	Potential of energy projects to provide job opportunities
	Public acceptance	Public perceptions of a certain technology

Environmental	Environmental impact	Measuring the impact of power plants on the visual environment and biodiversity
	Land requirement	Land requirement for the physical installation and fuel supply of power plants
	Reduced CO_2 emission	Renewable energy's capacity to lessen the emission of CO_2

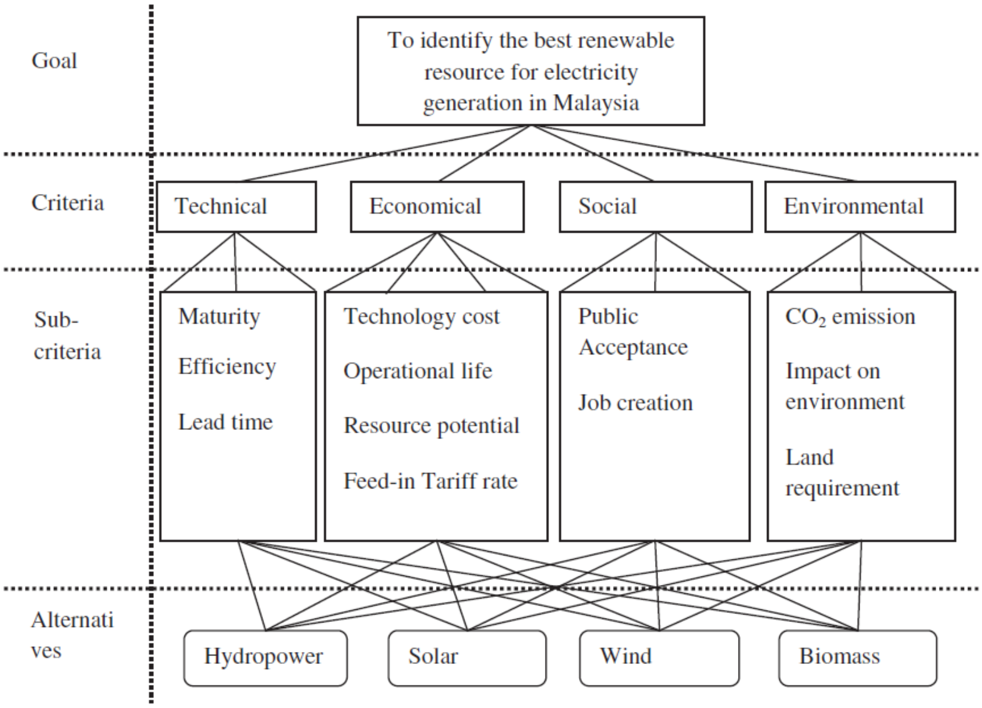

Figure 1. Hierarchy model of identifying the best renewable resource for electricity generation using AHP method [7].

In the selection of the optimal renewable resources for electricity generation using AHP method, the study developed pair-wise comparison matrix using the hierarchy model of Figure 1 [7]. The matrix explains the numerical importance of every element with other elements being compared. To convert qualitative data into numerical values, a 9-point scale was employed and the priority weight of criteria relative to the goal is multiplied when the entire priority weights over various alternative levels have been established. Equation 1 below shows the computation of this process [7].

[Priority weights of alternatives with respect to criteria] x [priority weight of criteria with respect to goal] = [Hydro Solar Wind Biomass] (1)

Using AHP tool, this study shows solar is the best renewable energy for electricity generation in Malaysia following by biomass. Overall, solar power recorded a priority weight of 0.358, followed by biomass at 0.246, hydropower at 0.235, and wind at 0.171. The rankings of renewable resources in accomplishing the research goal using AHP method is shown in the Figure 2. It shows solar energy has highest rank with all the sub-criteria listed the hierarchy model.

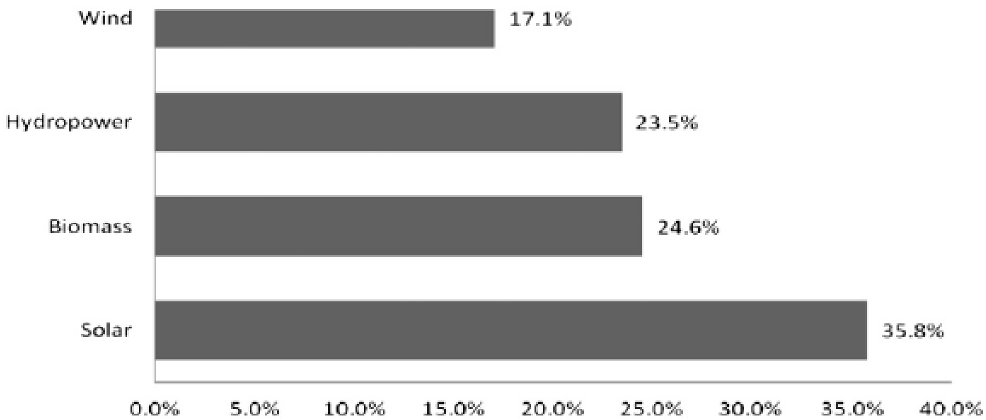

Figure 2. Ranking of renewable resources using AHP method [1].

Therefore, the development and use of these solar resources might be the focus of the Malaysian government. Since it is more economically viable, Malaysia could emphasis on this particularly [1].

2.2 Plastic Waste Collection System Using AHP Method

An AHP evaluation to investigate the optimal waste collection system where the analysis showed that Deposit and Refund is the best approach to achieve Circular Economy [8]. According to Figure 3, the study evaluates among five different alternatives which are Vehicular Collection method (VC), Curbside Collection method (CC), Drop Off Recycling (DOC), Buy Back Centre (BBC) and Deposit/Refund method (D/R) with the goal to discover the best approach for a Circular Economy. The criteria set for the assessment were ease of collection, operational cost, social and environmental impact which were evaluated by 200 experts including government officials and academicians with background in civil engineering [8]. The AHP is effective in validating and minimizing the inconsistency of individuals judgment by having pairwise comparison between each criterion. The optimal waste collection method was chosen base off their low operational cost, reduce social and environmental impact as well as ease of sorting which resulted with the Deposit and Refund alternative.

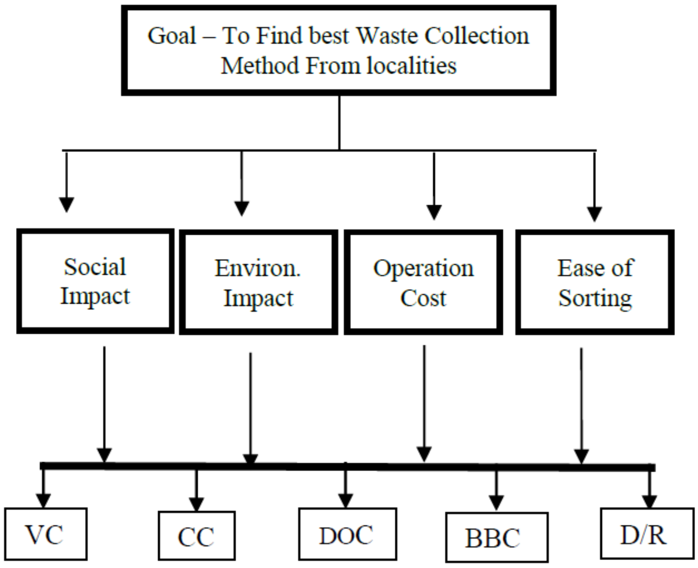

Figure 3. Hierarchy model of choosing the best waste collection method using AHP method [2].

The result of selecting best waste collection method shows that the collection of plastic waste via Deposit and Refund (D/R) is preferred to other alternatives of waste collection methods. Table 2 shows the D/R method has the highest weightage, which is 0.3411, followed by Vehicular Collection method (VC) which is 0.2797, Buy Back Centre (BBC) which is 0.2024, Drop Off Recycling (DOC) which is 0.911, and lastly Curbside Collection method (CC) which is 0.0788. Thus, selecting the method of waste collection produces both a clean surrounding and effective economy for the society which helps in monetary and good exchange. Thus, this the solution for circular economy by refusing plastic-based plastics. However, there will be various properties of plastics, both physical and economical, that do not simply just appear; thus, a gradual transition is needed to make the earth to be a better place to live on.

Table 2. Final weightage of alternatives of plastic waste collection [8].

	Weightage
VC	0.2797
CC	0.0788
DOC	0.0911
BBC	0.2024
D/R	0.3411

2.3 Selection of Best Hydropower Plant Using AHP Method In Spain

A case study at small run-of-river hydropower plant in Spain's Mino-Sil river basin using AHP was performed on the alternative proposed by three different private parties with the population of local fish, the quality of water, change in landscape, seasonal flow rate, flora and fauna preserved as the main criteria selected [9]. The process began by defining the goal of the assessment and the alternatives proposed then the designated team will evaluate the optimum alternatives along with available information. Additionally, the individual expert listed individual criteria which then analysed in a group discussion to choose the main criteria for the whole evaluation and evaluated through pair-wise comparison to obtain the weightage of each main criteria. The best alternatives evaluated is the project proposed by the company Energia of Galicia. The various stages of the work are listed in Table 3. The author of the paper uses the stages to select the best hydropower plant in Spain's Mino-Sil river basin.

Table 3. Selection stages used in hydropower plant using AHP method [9].

Phase	Sub-phase
A: Initial stage	A1: Explanation of the decision problem's primary objective A2: Explanation of alternatives A3: Development of study team
B: Criteria	B1: Personal list composition proposals for the criteria of evaluation B2: Focus group discussion B3: Pairwise comparisons of criteria
C: Alternatives	Comparison of priorities for each criterion from one alternative to another
D: Evaluation	Mathematical intervention via Expertchoice and Conclusions

In essence, the AHP demonstrates a decision problem in a hierarchical manner, with the primary goal in the top tier, followed by the alternatives in the second tier, and finally the decision criteria and sub-criteria (if relevant) at the next level below. Therefore, to decide the requirements for the priorities of alternatives in relation to the chosen criteria, this AHP utilises pairwise comparisons for assigning weights to the items at every level by estimating relative significance through ratios or scale shown in Table 4. Inclination proportions and significance proportions are determined when making comparisons of the alternatives and criteria, respectively, as shown in the Saaty comparison scale, Table 4.

Table 4. Saaty's comparison scale [9].

Numerical scale	Definition	Explanation
1	Equal importance	The goal is influenced equally by two factors
3	Moderate importance of one element over another	One element is moderately preferred to another through experience and judgment
5	Strong importance of one element over another	One element is strongly preferred to another
7	Very strong importance of one element over another	One element is dominantly preferred to another
9	Extreme importance of one element over another	One element is extremely preferred to another by at least an order-of-magnitude discrepancy
2,4,6,8	Intermediate values between two adjacent judgments	A middle ground or compromise those bridges two judgments

The hydroelectric plant involved in the current case is situated on the banks of the Couso River within the municipality of Avion in the Ourense province, particularly in the Mino-Sil river basin of Galicia, Spain. According to the Table 5, there are three alternatives have been chosen by the authors of the paper which are Cortizo Hidroelectrica, Energia of Galicia and Hidroelectrica of Avion.

Table 5. Abstract of the alternatives of the hydroelectric plant selection in Mino-Sil river [9].

Alternative	Power plant (kW)	Water head (m)	Weir	Flow (l/s)	Setting channel	Forebay	Penstock	Powerhouse	Turbine	Generator (kVA)
A1: Cortizo Hidroeléc-trica	2080	103	Gravity type	2500	Concrete slabs; 13.2 m length	22.5 m^3	Diameter of 1000 mm and a length of 320 m	20 m × 10 m	Francis type	2277
A2: Energía of Galicia	4100	125.5	Gravity type	4000	Concrete slabs	11 m of length, 2.2 m of wide and variable depth	Diameter of 1300 mm and a length of 280 m	25 m × 10 m	Francis type	5000
A3: Hidroeléc-trica of Avión	2035	122.5	Gravity type	2000	Carbon steel pipeline of 1118 mm diameter and a length of 1734 m	–	Diameter of 1067 mm and a length of 353 m	19.50 m × 11.20 m	Francis type	2500

Nine decision criteria were selected in this study after a joint analysis. Protected founa criteria leads all criteria as shown in Figure 4. When the alternatives are compared, Energia of Galicia is the highest score which is 35.7%, followed by Hidroelectrica of Avion which is 31.3% and lastly Cortizo Hidroelectrica which is 33.1%. Based on the results, all three alternatives recorded extremely comparable percentages with only a difference of 4.4% between the first and the last alternatives. The projects' technical and financial viability in utilizing the river's hydroelectric potential may account for such a difference. As can be seen in Table 5, Energia of Galicia power plant would be the better choice based on the properties of the plant. Besides, the alternatives were likewise suitable for the environment because they had undergone EIA and received a favorable Record of Decision [9].

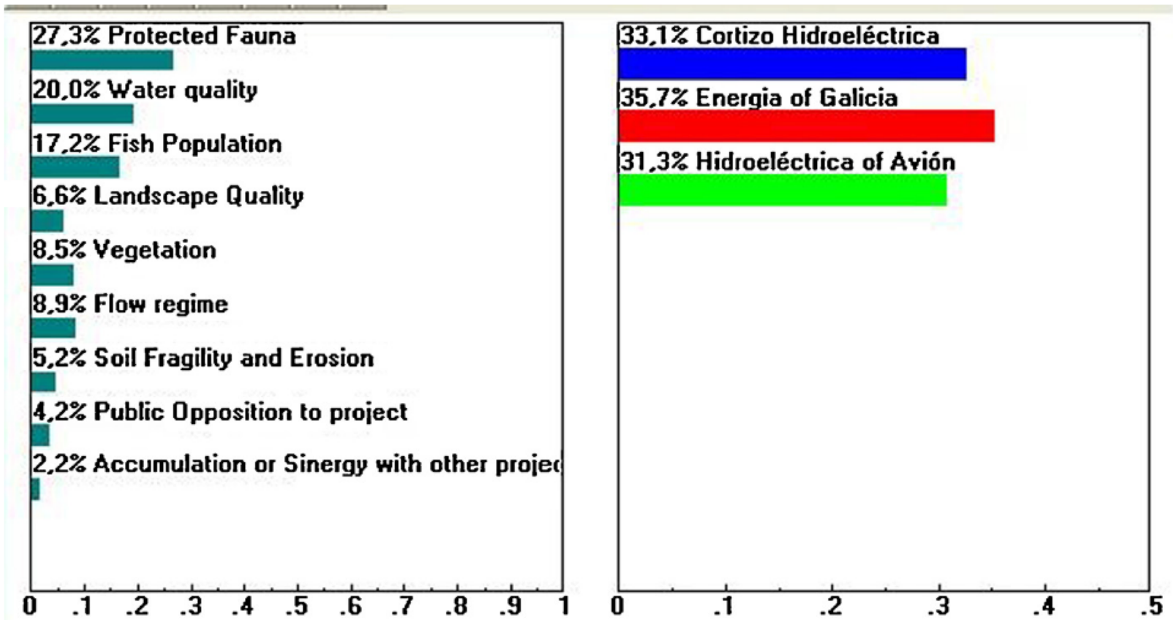

Figure 4. Results of hydroelectric plant selection by experts in Mino-Sil river [9].

2.4 *Selection of Biological Treatment of Coking Wastewater Using AHP Method*

AHP is described in their study to rank the optimum biological treatment of coking wastewater technologies [10]. The three main process to consider in an AHP assessment are the goal to establish the outcome of the evaluation, criteria, and sub-criteria together as the factor assessed to achieve the goal and finally the proposed alternatives for the analysis. The alternatives are consisting of six types of reactor combinations which then assessed based on the primary criteria involving the technical factors, the economic factors, the environmental factors, and the administration factors as well as 18 other sub-criteria [10]. According to Figure 3, the 18 sub-criteria are assessed and compared. They are classified into alternative layer with two groups of low and high load groups [10].

The decision maker selected include twenty experts from both government and private organizations as well as universities to evaluate the weightage of each indicator. The indicators that are hard to quantify are normalized through transformation rules that will generate either positive or negative value to obtain a valid AHP outcome.

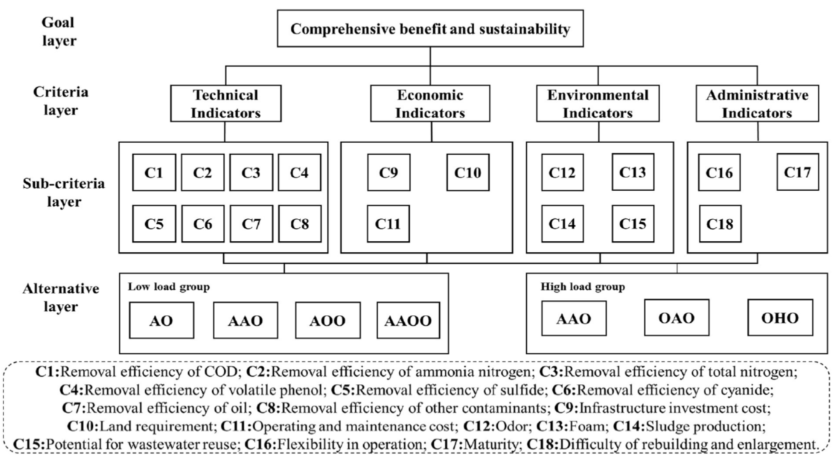

Figure 5. Hierarchy model to select optimum biological treatment of coking wastewater using AHP method [10].

Biological process designs for coking wastewater treatment plants (CWTP) entail anoxic-oxic (A/O) or anaerobic-anoxic-oxic (A/A/O) with other combinations that extend to hydraulic retention times (HRT) – anoxic – oxic – oxic (A/O/O), anaerobic-anoxic-oxic-oxic (A/A/O/O), oxic-hydrolytic-oxic (O/H/O). Six combinations of biological reactors, namely A/O, A/O/O, A/A/O, A/A/O/O, O/A/O, and O/H/O processes, were evaluated as an AHP alternative layer based on the opinions of experts and coking wastewater treatment plant (CWTP) surveys on a full scale. The biological influent loadings of 0.8 and 1.6 kg COD (m3 d-1) were divided into low and high load groups under the equal CW flow hypothesis and the respective indicator weights of the groups were then compared via AHP. There are four indicators are investigated in this study and the standards for each indicator as per listed Table 6.

Table 6. Indicators of biological treatment process [10].

Dimensions	Indicators
Technical indicators	COD
	Ammonia nitrogen
	TN
	Volatile phenol
	Sulfide
	Cyanide
	Oil
	Other contaminants
Economic indicators	Infrastructure Investment cost
	Land requirement
	Operating and Maintenance cost
Environmental indicators	Odor
	Foam
	Capacity of sludge disposal
	Potential for wastewater reuse
Administrative indicators	Flexibility in operation
	Maturity
	Difficulty of rebuilding and enlargement

The priority ranking of criteria were computed using AHP and the outcomes for the level of criteria in Figure 3 are demonstrated in the Figure 4 below. Technical indicator which contains many standards as in Table 6 shows highest weightage (48.4%). This is followed by the economic indicators with 28%, the environmental indicators with 16.8%, and the administrative indicators with 6.8%. Therefore, in terms of selecting a CW biological treatment approach under the requirements of the national discharge standards, technical indicators recorded the greatest score.

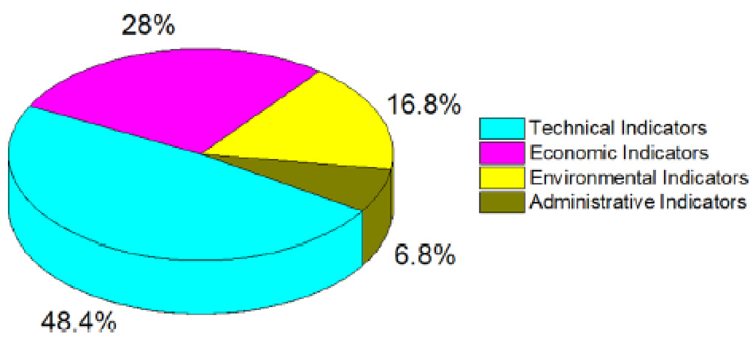

Figure 6. Results of coking wastewater treatment plants (CWTP) [10].

3. Conclusion

In this paper we have reviewed the work conducted by various experts in applications and developments of areas in AHP to strategize in available information. AHP can be used in design, energy power plants using renewable energy source, plastic waste collection system, hydropower plant, and coking wastewater plant’s biological treatment. Different criteria and sub-criteria are arranged. Biological processes employed in CWTP may be determined using a comprehensive method of AHP analysis, which has been developed and proven to make decision-makers' choice of technology less challenging [10]. The AHP is an efficient approach to solving the complex issues of MCDM [8].

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