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Decision Support System for Proper Selection of Wastewater Treatment Plants Using Analytic Hierarchy Process (AHP)

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ABSTRACT: *The wastewater treatment services are crucial, especially their economic impact in developing countries. This study's objective is to develop an approach for selecting the most appropriate wastewater treatment plant for different population level. Different stages are required in wastewater treatment. This study focused on the secondary treatment stage which is crucial for the selection of treatment plant. Seven plant alternatives are included in the study. A survey was conducted to identify factors influencing the selection process depending Delphi method. Structured interviews with engineers had experiences more than 15 years in wastewater treatment were conducted to identify the optimum alternative for population of different income levels (low, average and high income). The results of survey and interviews were analyzed using SPSS© and EXEL© programs to identify the relative importance of selection criteria. The alternatives were evaluated using analytical hierarchy process (AHP). The implementation of evaluation system developed in this research revealed that the optimum alternative in case of low income is Up Flow Anaerobic Sludge Blanket Reactor (USBR). In addition, the optimum alternative in case of the average income also (USBR) and the optimum alternative for high income is compact unit Moving Bed Biofilm Reactor (MBBR).*

Keywords: *WastewaterTreatmentPlant;Delphimethod; AnalyticHierarchyProcess and DecisionSupportSystem..*

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I. INTRODUCTION

About 2.5% of the water is fresh water that does not contain significant levels of dissolved minerals or salt and two third of that is frozen in ice caps and glaciers. Only 0.01% of the total water of the planet is accessible for consumption. Unfortunately, more than one in six people still lack reliable access to clean water in developing world (CPCB's report, 2004). Wastewater management or sanitation is a basic human requirement; its main purpose is to separate human waste from human settlements in order to prevent disease. Developing countries are in a continuous need to improve access to sanitation and its benefits, as demonstrated by the findings of the World Health Organization (WHO) which state that poor sanitary conditions and practices cause 85 to 90% of diarrheal diseases in developing countries. Such diseases subsequently contribute to the deaths of 1.6 million children under the age of five each year (Flores, Buckley &Fenner, 2008). The world is still a long way from providing this basic need for all. An estimated 2.5 billion people still lack improved sanitation facilities, and 768 million people still do not have access to an improved drinking water source (UNICEF's Division of Policy and Strategy, 2014). The importance of wastewater treatment increases with the increase of the population's healthcare awareness and environmental pollution avoidance. In addition, wastewater treatment is becoming crucial to recover water for further consumption, including agricultural purposes especially when there is an increase in water consumption with a limited water source. The problem becomes worse when the water demand exceeds the supply. The gap between water demand and supply creates the need to develop water sources by utilizing the wastewater via proper treatment. According to Vandeweerd *et al*. (1997), more than 90% of sewage in the developing world is discharged directly into rivers, lakes, or seas without any treatment. Anestimated 50 million Congolese- which is 75 percent of the population by 2011-do not have access to safe water, and approximately 80-90 percent do not have access to improved sanitation (AMCOW's Report, 2011). The key bottleneck that impedes progress in the DRC's water and sanitation sector is the limited implementation capacity. While 65% of Zambians have access to improved water, this leaves over 500,000 people (35% of the population) in the country without access to improved water. Only 43% of people are able to access improved sanitation, which is a very low percentage of the overall national population, resulting in over 800,000 people without access (Republic of Zambia's Report, 2015). In large cities of developing countries, there are serious disposal problems of sewage, industrial effluents and domestic solid waste, as they generate large quantities but have no facilities for their treatment and/or proper disposal. The problems are getting worth in ruler areas and villages, where there almost no wastewater treatment system. Worldwide in 2004, 2.7 billion people still required improved sanitation services (IDAW's Report, 2010). Generally, developing countries have large pieces of flat land are not always available, enormous sanitation deficit, shortage of financial resources, lack of qualified operational personal, and need of low cost figure, sustainable and simplified wastewater treatment systems, soil characteristics are many times inappropriate for large natural systems, such as ponds and constructed wetlands, reuse still in early stages.

II. WASTEWATER TREATMENT OVERVIEW

Many researchers provided an overview of wastewater disposal and treatment such as (Matthias andOliver,2015; John, *et al*,2015; Matthias, 2015; Antonio *et al*,2015; ArunMitt, 2011; Flores, 2008; Reyhani, 2007 and Frank,2003). They explained that wastewater treatment is a process to convert wastewater, which is water that is not needed or suitable for its most recent use, into an effluent that can be either returned to the water cycle with minimal environmental issues or reused. It originates in homes, businesses, schools, hospitals and industries, and is ultimately discharged back into the environment. While many industries treat wastewater on-site, it is not unusual for a publicly in an industrialized city to treat wastewater comprised of up to 40 % industrial wastewater. Untreated wastewater generally contains high levels of organic material, numerous pathogenic microorganisms, as well as nutrients and toxic compounds. It thus entails environmental and health hazards and, consequently, must immediately be conveyed away from its generation sources and treated appropriately before final disposal. The ultimate goal of wastewater treatment is the protection of the environment in a manner that commensurate with public health and socio-economic concerns, (Celia M., *et al*. 2009).

III. WASTEWATER TREATMENT METHODS

Physical, chemical and biological methods are used to remove contaminants from wastewater. In order to achieve different levels of contaminant removal, individual wastewater treatment procedures are combined into a variety of systems, classified as primary, secondary, and tertiary wastewater treatment. Sludge resulting from wastewater treatment operations is treated by various methods in order to reduce its water and organic content and make it suitable for final disposal and reuse. Physical unit operations are applied to remove contaminants. Chemical unit operations are always used in conjunction with physical unit operations and biological processes. In general, chemical unit processes have an inherent disadvantage compared to physical operations in that they are additive processes. This can be a significant factor if the wastewater is to be reused [17]. Biological unit operations are used to convert the finely divided and dissolved organic matter in wastewater into flocculent settle, organic and inorganic solids. Biological processes are usually used in conjunction with physical and chemical processes, with the main objective of reducing the organic content and nutrient content of wastewater. They include: Activated sludge process, aerated lagoon, trickling filters, rotating biological contactors, pond stabilization, anaerobic digestion and biological nutrient removal.

IV. APPLICATION OF TREATMENT METHODS

Preliminary treatment processes consist of physical unit operations, namely screening and comminution for the removal of debris and rags, grit removal for the elimination of coarse suspended matter, and flotation for the removal of oil and grease. Primary treatment involves the partial removal of suspended solids and organic matter from the wastewater by means of physical operations such as screening and sedimentation. It produces a liquid effluent suitable for downstream biological treatment and separating out solids as a sludge, which can be conveniently and economically treated before ultimate disposal. The secondary treatment is used to remove of soluble and colloidal organics and suspended solids that have escaped the primary treatment. This is done through biological processes, namely treatment by activated sludge, fixed-film reactors, or lagoon systems and sedimentation. Tertiary treatment goes beyond the level of conventional secondary treatment to remove significant amounts of nitrogen, phosphorus, heavy metals, etc. It includes chemical coagulation, flocculation and sedimentation, followed by filtration and activated carbon.

Wastewater Treatment Plants Alternatives

Wastewater treatment plant size depends on the population serviced. Population may group as illustrated in Table 1. In this research, the secondary treatment process for low population from (p1) to (p5) will be investigated. Consequently, data concerning the secondary treatment alternatives are considered. Seven alternatives, for secondary treatment process, for low population, are introduced as following:

Activated Sludge Process (Asp) - [Alternative1: A1]

A widely used system for biological wastewater treatment is the activated sludge process (ASP), (Fikar, Chachuat, and Lati, 2002). Activated sludge process is used during secondary treatment of wastewater, (UN-DESA's Report, 2015, and Li J. *et al*., 2008). For small size plants, i.e. less than 20,000 populations equivalent, the basic activated sludge process consists of several interrelated components (PETERSEN, *et al.* 2015). Accordingly, the main advantages of the **Activated Sludge Process**include: Low installation cost; Good quality effluent; Low land requirement; Loss of head is small; Freedom from fly and odor nuisance, and high degree of treatment. In addition, the main disadvantagesinclude: Low degree of flexibility in this method (If there is a sudden increase in the volume of sewage or if there is a sudden change in the character of sewage, there are adverse effects on the workability of the process and consequently the effluent obtained is of bad quality). As well as, operation cost is high; sludge disposal is required on large scale; this process is sensitive to certain industrial wastes and skilled supervision is required to ensure that the returned sludge remains active

Trickling Filter (TF) -[Alternative2: A2]

Trickling filters (TFs) are used to remove organic matter from wastewater utilizing microorganisms. The main advantages of the **Advantages** (Brian, 2010) and Martin, 2000)include: Simple, reliable, biological process; Suitable in areas where large tracts of land are not available for land intensive treatment systems; May qualify for equivalent secondary discharge standards and effective in treating high concentrations of organics depending on the type of medium used. As well as, appropriate for small- to medium-sized communities; rapidly reduce soluble BOD5 in applied wastewater; efficient nitrification units; durable process elements; Low power requirements and moderate level of skill and technical expertise needed to manage and operate the system. The main advantages of the **Disadvantages** (Brian, 2010) and Martin, 2000) include:

1. Additional treatment may be needed to meet more stringent discharge standards.
2. Possible accumulation of excess biomass that cannot retain an aerobic condition and can impair TF performance.
3. Requires regular operator attention.
4. Incidence of clogging is relatively high.
5. Requires low loadings depending on the medium.
6. Flexibility and control are limited in comparison with activated-sludge processes.
7. Vector and odor problems.
8. Snail problems.3

Aerated Lagoon (Al) - [Alternative3: A3]

Aerated Lagoons is most common suspended culture biological systems for the wastewater treatment. They are constructed with depth varying from 2 to 5 m. Aerated lagoons are very common in small communities. Energy costs are usually considerably less than other mechanical treatment system. Aerated lagoons require less land area and shorter detention times for wastewater than other lagoons. It was estimated that there were many lagoon-based wastewater treatment systems in Canada, representing almost half of the total number of treatment plants (NGSMI Report, 2004). However, as communities grow and environmental regulations become more stringent, there is often a need to increase capacity or improve performance. Aerated lagoons are an efficient and cost-effective system for primary and secondary wastewater treatment in small communities. The main advantages of the **advantages** (NGSMI Report, 2004) include: Lower capital costs; no extra land requirement; easy to operate; ideal for supplemental use; and ideal for seasonal limits. Accordingly, the main **disadvantages include:** Ineffective below 50^{o}F; potential for clogging & Maintenance; risk of short-circuiting

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Up Flow Anaerobic Sludge Blanket Reactor (UASBR)– [Alternative4: A4]

The up-flow anaerobic sludge blanket reactor (UASBR) is widely accepted for treatment of a wide range of wastewater ranging from domestic sewage to industrial wastewater. UASBR is the most frequently used for the anaerobic treatment of domestic wastewaters, being restricted mainly to countries with a warm climate (Sunny, *et al* 2010). The performance of a UASBR appears to be temperature-sensitive and under psychrophilic conditions, the efficiency of the UASBR system declines significantly (Abdullah and Amtul, 2010). The UASBR has four major components: 1) sludge bed, 2) sludge blanket, 3) gas–solids separator (GSS) and 4) settlement compartment (Akbarpour and Mehrdadi, 2011 &Mohdamed and Kadathur 2004). Accordingly, the main advantages of UASBR ANAEROBIC treatment include:

1. Minimum place requirement, due to compact design.
2. Easy adaptation to change of loadings and no effect from electrical shortage.
3. Less energy and nutrient consumption.
4. 10% less sludge production than aerobic treatment.

5. No odor, noise or aerosol arising due to closed structure.
6. Simple and secure energy production from biogas.
7. Lower maintenance costs
8. Full automatic operation with computerized system.
9. Rapid startup and suitable for seasonable operation.
10. No filling media; Settler self-cleaning system and easy pre-treatment application.

The main disadvantages of UASBR ANAEROBIC treatment however include: this system would be clogged or granules level would be flooded if influent containing high solids concentration were provided or granules rapidly grew due to organic concentration. In addition, the rate of removal of solids in the SGBR should be faster than the rate of input of influent solids in order to operate continuously this system without any trouble. Besides, this system needs periodically backwashing for solids withdrawal out of the reactor. The backwashing process means the additional cost and the instant quality deterioration of effluent.

Moving Bed Biofilm Reactor (MBBR) [Alternative5: A5]

The moving bed biofilm reactor (MBBR) is a biological wastewater treatment process, which is used for treating most types of wastewater streams. MBBR was implemented for larger wastewater treatment facilities in the 1990's (Borkar, *et. al.*,2013 and Mostafa, *et. al.* 2015) and accordingly, the main advantages of MBBR include: Compact units with small size; Increased treatment capacity; complete solids removal; improved settling characteristics; Operation at higher suspended biomass; Concentrations resulting in long sludge retention times; Enhanced process stability. In addition to low head loss; no filter channeling; No need of periodic backwashing; Reduced sludge production and no problems with Sludge bulking. But, the main disadvantages of MBBRinclude: high energy consumption; coarse bubble; higher DO; influent screening; tank downtime and media procurement.

Oxidation Pond (Op) [Alternative6: A6]

Sewage oxidation ponds (lagoons) offer economical secondary sewage treatment with relatively low initial cost (Mitchell and Robert 2008). Oxidation ponds are particularly suited to locations with available land and warm climates. Their ability to absorb shock loads and ease of operation and maintenance make them desirable treatment units (Report of OWWDC, (2000) andMasuo, *et al.* 1998). The loading allowed can vary from 125–2000 persons per hectare depending upon the location. The oxidation pond was built as an aerobic and anaerobic pond system in which the sewage treatment occurs naturally without added chemicals. Accordingly, the main advantages of Pond systems (Tobajas et al 2014) include:Low energy consumption compared to more conventional systems; Oxygenation of the upper water layer via movement of air and natural wave action; Solar / powered aeration via algal respiration; Natural pH buffering via carbonate / bicarbonate system; Natural nutrient uptake and reduction; Solar induced disinfection; and biogas generation from anaerobic ponds (where they are covered and gas collected).

In addition, the main disadvantage of POND systems includes:
1. The inability to significantly remove nutrients.
2. Lagoons must be constructed in clay soil or be lined to prevent leakage.
3. It may overflow occasionally during extended periods of heavy rainfall.
4. As with any other open body of water, there is some potential danger.

Oxidation Ditches (Od) [Alternative7: A7]

An oxidation ditch refers to a modified activated sludge biological treatment process utilizing long solids retention times (SRT) to remove biodegradable organics (Blackburne, *et. al.*, 2008). An oxidation ditch is a large circular basin equipped with aerators that is used to remove organic matter and pollutants from sewage through the processes of adsorption, oxidation, and decomposition (Mikosz, *et. al.*, 2000). As a secondary wastewater treatment technology, the oxidation ditch process is suitable in any situation where activated sludge treatment is appropriate. Although this technology requires more land in comparison with conventional treatment facilities, it is shown to be highly effective in small installations, small communities, and isolated institutions. When considering the reactors used, although vertical reactors are generally more expensive than traditional horizontal ones, they require less land area, which can offer a significant reduction in overall capital costs. The cost of an oxidation ditch plant varies depending on treatment capacity size, design effluent limitations, land cost, local construction costs, and other site-specific factors (Gurtekin 2014). Accordingly, the main advantages of OXIDATION DITCHES include:

1. The constant water level and continuous discharge, which lowers the weir overflow rate and eliminates the periodic effluent surge, make the technology reliable over other biological processes.
2. Its long retention time and complete mixing reduces the impact of a shock load or hydraulic surge.
3. Because of its extended biological activity during the activated sludge process, the oxidation ditch produces less sludge compared with other biological treatment processes.
4. The process is energy-efficient. Ensures stable, continuous dissolved oxygen measurement
5. Reduces operating costs and eliminates the need for manual cleaning.

In addition, the main disadvantage includes: Effluent suspended solids concentrations are relatively high compared to other modifications of the activated sludge process; and The process requires a larger land area.

Evaluation Criteria considered for evaluation of wastewater treatment plants:

A review was carried out to identify the different factors that may affect the selection of proper project delivery method. Twenty-eight factors were identified and categorized into eight factor areas and their description of each these factors are shown in Table 2.The identification of the relative importance of these factors was carried out via structured interviews with selected experts. Sixteen interviews were conducted with experts from the construction industry who had at least 15 years' experience in infrastructure construction industry in different public and private sectors. The data collected during of these interviews was analyzed using the AHP analytic tool to determine their relative importance. The result of this analysis is as follows:

Concept of Analytical Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a mathematical theory for measurement. Saaty (1994) developed the mathematical foundations of the analytical hierarchal process (AHP) at the University of Pittsburgh. With the advent of the personal computer during the 1980s and 1990s this decision support tool, as implemented in several software packages, especially Expert Choice developed by Forman, Saaty, Selly and Waldron (Mahdi and Khaled, 2006), has become very popular. Increasingly, AHP_s power has been validated in empirical use, Chang, Ibbs and Crandall (Mahdi and Khaled, 2006) extended by research and expanded by new theoretical insights as reported in series of international symposia devoted to AHP (Mahdi and Khaled, 2006). Since its introduction, AHP has been applied to many types of decision problems in diverse fields as portfolio selection, transportation planning, manufacturing systems design, and artificial intelligence. There are tremendous published papers that use AHP to model diverse problems such as conflict analysis, urban planning and space exploration (Mahdi and Khaled, 2006).

Applications of the Analytic Hierarchy Process can be classified into two major categories:

1. Choice: the evaluation or prioritization of alternative courses of action, and
2. Forecasting: the evaluation of alternative future outcomes.
3. Professional Expert Choice_ (2000) was implemented to develop the proposed decision system for selection of the most appropriate wastewater treatment system in this paper. In Professional Expert Choice, the decision-maker first structures the problem into different hierarchical levels. Top down structuring is best used when the objectives are more known than the alternatives. The model is built from the top starting with the most general objectives, then the more specific (sub-objectives), and finally the alternatives of choice. At the top of the hierarchy the goal of the decision can be clearly stated, which is defined in this paper as the ‘‘Optimum wastewater treatment plant’’. Then, the evaluation criteria and sub-criteria which were called objectives are clearly represented. Eight objectives are included in the first level of hierarchy and seven objectives in the second level, as shown in Table 2.AHP provides measures of judgement consistency, derives priorities among criteria and alternatives, and simplifies preference ratings among decision criteria using pair wise comparisons

Decision Criteria for the selection of Proper Wastewater Plant Alternative using AHP

is applied using expert choice 2000©to develop decision support system for Proper Wastewater Plant selection. The decision-maker structures the problem into different hierarchical levels. The model is built from the top starting with the goal, then the more specific criteria, and finally the alternatives of choice as shown in figure 1. At the top of the hierarchy the goal of the decision in this paper is defined as the ‘‘the proper wastewater treatment plants alternative’’. Then, the evaluation criteriaare clearly represented. Eight criteria are included in the evaluation process, as mentioned above (C1 to C8) as shown in Table 2. Once the hierarchy structure is established, the decision- making process takes place. The decision-maker derives ratio-scale (as shown in Table 3) priorities reflecting the relative importance of criteria via pairwise comparisons with respect to the goal of the problem. Similarly, the decision-maker derives ratio-scale priorities reflecting the relative preference of alternatives relative to each objective. The relative importance of decision criteria is identified based on survey of experts from the industry (structured interviews) and applying Delphi technique (Mahdi and Khaled, 2006). The same group of decision criteria are tested three times according to the size population which served by the wastewater treatment plant and the average income standard. Therefore, they included three levels of income those are low, average and high. The statistical results using Excel © version 16 are shown in Tables 4and Figure 2 demonstrate the relative weights of criteria with respect to the three levels of income populations. The evaluation of wastewater plants alternative with respect to the Decision Criteria in case of Low Population Income (Sample of calculation) according to AHP approach is demonstrated as calculationsexample as shown in Table 5.The survey analysis reveals that the most important factor in determining the proper wastewater plant is C6 (Capital Investment) in low (16.0) income population. C6 represent the third level of importance in the average income population while it represents the lowest level of importance in the high-income population. C7 (Operation and Maintenance Cost) represented the most important factor in deciding the proper wastewater plant in the average income population while it represents the second one in the low-income population, but it represents the one before the lowest level of importance in the high-income population.C5 (Characteristics of waste (Physical and chemical property) represents the most level of importance in deciding the proper wastewater plant in the high-income population. While, C5 represent the 6th order of importance level out of eight factors in low income population and the 3rd order of importance level out of eight factors in average income population.

Wastewater Treatment Evaluation Analysis

Finally, the judgments are further synthesized to provide a ranking of the alternatives for the proper alternative selection. Sensitivity analysis enables the decision maker to see how the final priorities and how it is affected by changes in the relative importance of the evaluation criteria (C1 to C8) according to the level of population income as illustrated in Table 6 and figure 3.Alternative**4**(UASBR) represent the most appropriate wastewater treatment plant in case of low population income and on the basis of the relative importance level of eight decision criteria (C1 to C8) and Alternative**5**(MBBR) represented the second priority level as shown in Table 6 and Figure 3. In addition, the last alternative (7th order) is Alternative**1**(ASP).

Alternative**4**(UASBR) is also the most appropriate wastewater treatment plant in case of average population income but recorded relative weight lower than that recorded in the previous case. Similarly, the 5th alternative (Alt5: MBBR) comes in the second priority level in the average population income as in the previous case as shown in Table 5 and Figure 4. In addition, the last alternative is alternativeAlternative**1**(ASP), but its importance in the average income population more than by about 28%. Alternative**5** (MBBR) comes in the first priority in the high population income. While the 4th alternative (Alternative**4**: UASBR) is coming in the second priority level in case of high population income but recorded relative weight higher than that recorded in the previous two cases. Alternative**4** (UASBR) comes in the second priority level in the high population as shown in Table 6 and Figure 3. In addition, the last alternative (7th order) is alternative Alternative**2**(TF), while its level of importance was recorded the fourth level in low income and sixth level in average income population.

V. DISCUSSIONS AND CONCLUSIONS

Selection of the most appropriate wastewater treatment plant has a great level of importance especially in developing countries which have limited sources of clean water and financial problems. This effort intended to achieve an acceptable treatment level and to choose the appropriate treatment method, according to the social levels of the different community'spopulation. Seven secondary treatment plants were taken for this purpose. Consequently, literature was reviewed in order to identify their strengths, weakness, and threats Moreover, the criteria dominating the choice of the wastewater treatment method, were identified to be eight. Accordingly, structured interviews were conductedwith industry's experts.The respondents' answers analyzed to determine the significant criteria for three population income levels (high, average and low). Accordingly, it was adapted to the obtained assembled results to analyze and discuss them to identify the most appropriate wastewater alternative plant for the different income levels (i.e. low, average and high income). In addition, the relative weight for the seven alternatives and the relative weight for the eight factors were computed implementing (EXCEL©) software applying AHP approaches. This was implemented to identify the optimum alternative for the different income levels. By applying the VE approach, the properalternative in terms of eight decision criteria is identified for each income population level. Alternative**4** (UASBR) is the most appropriate water treatment alternative plant in both cases of population income, low and high. Alternative**5** (MBBR) comes the second one in both cases, while their level of appropriateness is replaced in case of high population income.

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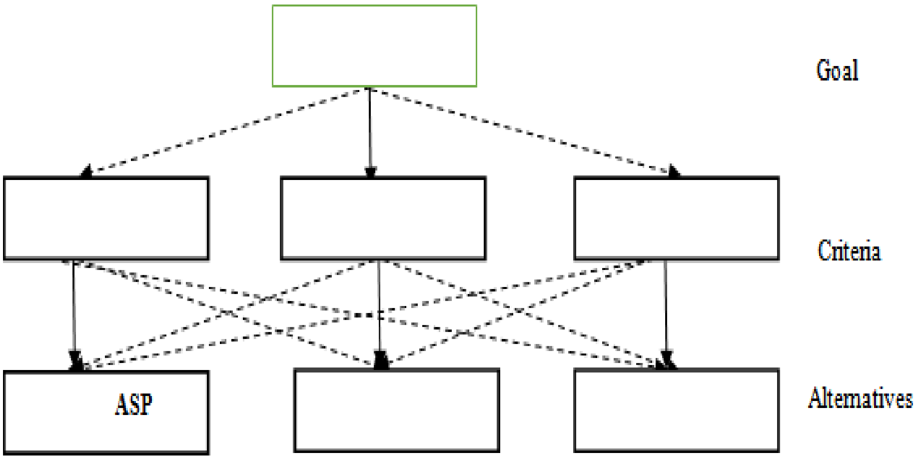

Figure 1: AHP Decision Process (Structure Base According to Saaty, 1988)

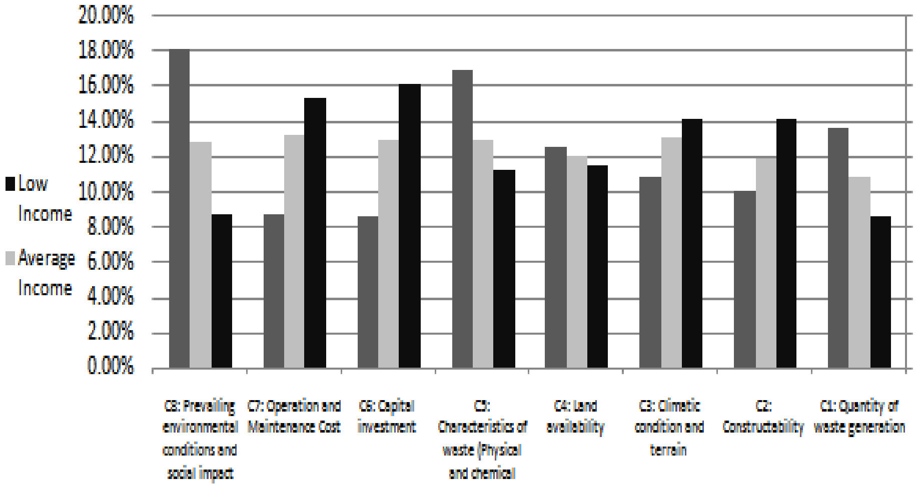

Figure 2: Relative Weight of Criteria for High, Average and Low Income Population

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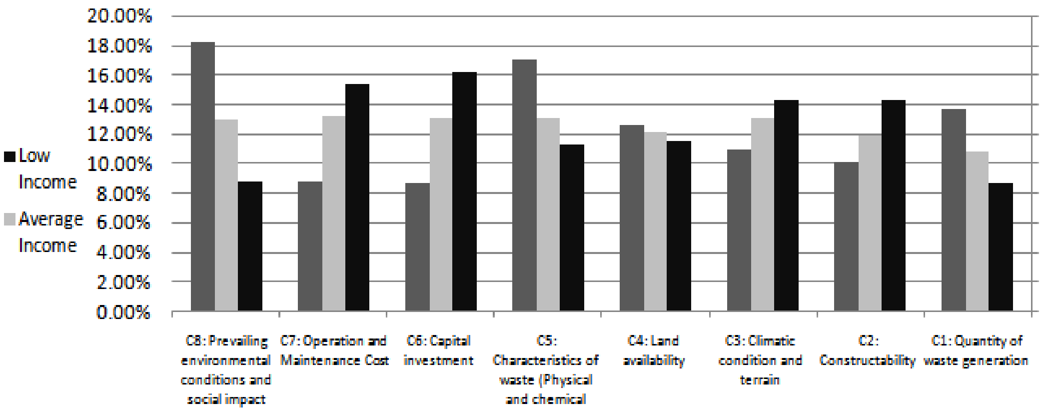

Figure 2: Relative Weight of Criteria for High, Average and Low Income Population

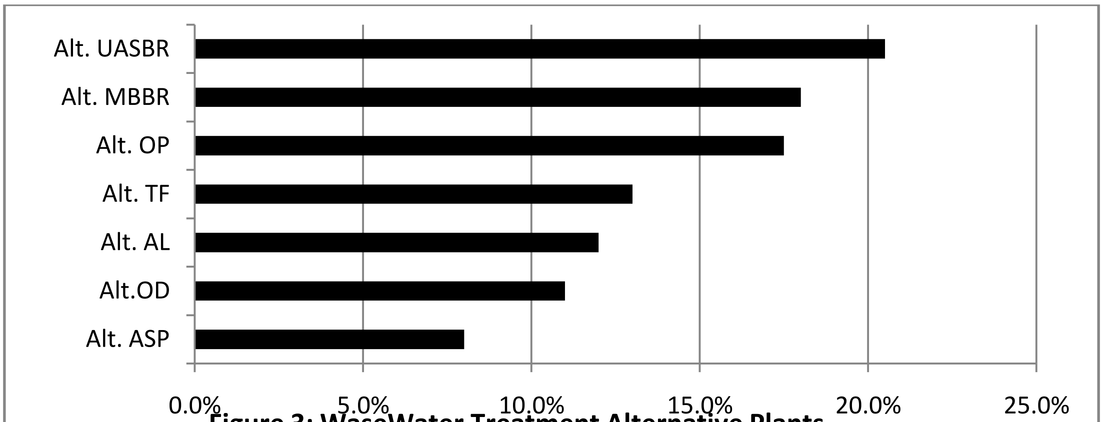

Figure 3: WaseWater Treatment Alternative Plants

Table 1: Count Population (p) Groups (UNICEF Issues No.3 (2014),Arun Mitt, 2011).

population	groups population	Classification residential assembly
p1	less than 5,000	Rural community and Villages
p2	from 5,000 to 10,000	
p3	from 10000 to 20000	
p4	from 20,000 to 30,000	
p5	from 30,000 to 50,000	Small cities
p6	from 50,000 to 100,000	
p7	from 100,000 to 200,000	Medium-Sized cities
p8	more than 200,000	
p9	more than 1,000,000 (Big cities)	Big cities

Table 2: Factors Affecting the Identification of the Proper Wastewater Plant Alternative

Criteria	**Criteria Description**
C 1	Quantity of waste generation
C2	Constructability
C 3	Climatic condition and terrain
C 4	Land availability
C 5	Characteristics of waste (Physical and chemical property)
C 6	Capital investment
C 7	• Market for the products
C 8	Prevailing environmental conditions

Table 3: Linguistic Measures of Importance (Tobajas *et. al.*, 2014)

Intensity of importance	Definition
1	Equal importance
3	Weak importance
5	Strong importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values

Table 4: Relative Weight of Criteria for Different Income

Criteria	Description	Low Income	Average Income	High Income
C1	Quantity of waste generation	**16.2%**	**13.0%**	**8.6%**
C2	Constructability	**15.3%**	**13.2%**	**8.8%**
C3	Climatic condition and terrain	**11.5%**	**12.1%**	**12.6%**
C4	Land availability	**14.2%**	**11.9%**	**10.1%**
C5	Characteristics of waste (Physical	**14.2%**	**13.1%**	**10.9%**
C6	Capital investment	**8.6%**	**10.8%**	**13.7%**
C7	Operation and Maintenance Cost	**8.8%**	**12.9%**	**18.2%**

C8	Prevailing environmental	**11.2%**	**13.0%**	**17.0%**

Table 5: Evaluation of Wastewater Plant Alternative with Respect to The Decision Criteria in Case of Low Population Income (Sample of Calculation**)**

Relative Weight of Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
	16.2%	**15.3%**	**11.5%**	**14.2%**	**14.2%**	**8.6%**	**8.8%**	**11.2%**
Alt1: ASP	5.70% %	5.70%	20.00%	2.80%	2.80	8.60%	8.60%	20.00%
Alt2: TF	14.30%	20.00%	14.30%	14.30%	14.30%	2.90%	5.70%	2.80%
Alt3: AL	22.90%	14.30%	5.70%	8.60%	8.60%	5.70%	14.30%	8.60%
Alt4: UASBR	20.00%	25.70%	22.90%	22.90%	20.00%	22.90%	22.90%	5.70%
Alt5: MBBR	2.80%	2.80%	25.70%	25.70%	22.90%	25.70%	25.70%	25.70%
Alt6: OP	25.70%	22.90%	2.90%	20.00%	25.70%	20.00%	2.90%	14.30%
Alt7: OD	8.60%	8.60%	8.60%	5.70%	5.70%	14.30%	20.00%	22.90%

Table 6: Evaluation of Wastewater Plant Alternative for Decision Criteria with Different Population Income

Alternatives Ranking	**Low Income**		**Average Income**		**High Income**	
Alt1: ASP	**UASBR (A4)***	**20.52%**	**UASBR (A4)**	**20.28%**	**MBBR (A5)**	**21.38%**
Alt2: TF	**MBBR (A5)**	**18.09%**	**MBBR (A5)**	**19.33%**	**UASBR (A4)***	**19.63%**
Alt3: AL	**OP (A6)**	**18.07%**	**OP (A6)**	**16.85%**	**OP (A6)**	**15.11%**
Alt4: UASBR	**TF (A2)**	**12.15%**	**OD (A7)**	**11.82%**	**OD (A7)**	**13.27%**
Alt5: MBBR	**AL (A3)**	**11.71%**	**AL (A3)**	**11.28%**	**Alt3: AL**	**10.60%**
Alt6: OP	**OD (A7)**	**10.87%**	**TF (A2)**	**11.22%**	**ASP (A1)**	**10.24%**
Alt7: OD	**ASP (A1)**	**8.63%**	**ASP (A1)**	**9.25%**	**TF (A2)**	**9.71%**

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