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Develop A Decision-Making Strategy for Sustainable WWTP Locations Using FAHP: Baghdad a Case Study

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ABSTRACT

Population growth and urban development have posed challenges for wastewater treatment plants (WWTPs) locations in large cities such as Baghdad since they fail to meet sustainability criteria due to outdated planning and the lack of an approved strategy to determine the appropriate location for a WWTP in it. This study aims to develop a decision-making strategy for sustainable sites for WWTPs by using the Fuzzy Analytic Hierarchy Process (FAHP) and applying the strategy to evaluate the locations of the major WWTPs in Baghdad. Nine factors affecting decision-making regarding WWTP locations were categorized into three groups based on environmental, economic, and social sustainability requirements. A questionnaire method was used to collect data and calculate weights for each factor from the opinions of 12 experts. Seven factors had weight values greater than zero, while two had zero values and were excluded. A second questionnaire calculated the distance distribution for each factor, with experts agreeing on the ratings. Three equations for calculating main group weights and one for total weights have been developed using the weighted factors. The equations were applied to evaluate the locations of Baghdad's major WWTPs, Al-Karkh, Al-Rustamiya Southern, and Al-Rustamiya Northern. The results showed that the three locations were unsuitable due to limitations in distance from population settlements, main and secondary roads, and surface water bodies at Al-Rustamiya Southern and Northern WWTP locations.

Keywords: Decision-making, FAHP, Sustainable location, WWTP location, Baghdad.

1. INTRODUCTION

Planning a sustainable site entails analyzing current conditions, mapping out the local environment, and establishing a development strategy that preserves the local natural

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features **(Alibašić, 2022).** This method prioritises short- and long-term costs, human safety, and natural ecosystems to ensure that residential areas coexist with the land's natural characteristics and processes. To guarantee optimal operation, regulatory compliance, and minimal impact on the environment and community, choosing a sustainable location for a wastewater treatment plant is a crucial choice that needs to be carefully considered. The location of the site should be near significant sources of wastewater generation or existing sewage lines for best collection efficiency and to reduce the expense of constructing and maintaining a network of sewer pipes. The location of the treated effluent should be near a suitable body of water in order to reduce the risk of contaminating recreational and drinking water sources. This is especially important if the plant's effluent is not being treated for reuse. Additionally, sites close to natural reserves, wetlands, and other vulnerable ecosystems must be avoided. The site selected for the plant should have sufficient area to support future expansion of plant capacity, as well as prospective modifications and technological advancements if the community it serves is likely to grow in the future **(Singh et al., 2023).**

In metropolitan cities like Baghdad, due to population growth and urban expansion, the old planning of the location of wastewater treatment plants (WWTPs) has made the location of these plants within these cities' boundaries unable to meet sustainability requirements **(Al-Zuhari, 2008)**. Hence, it is necessary to develop a strategy to evaluate the existing sites and propose alternative options for those that fail to fulfil sustainability criteria. This will guarantee the establishment of these plants in line with their acceptable standards, thereby minimizing costs and maximizing positive impacts on the environment and surrounding communities **(Hermawan et al., 2023)**.

In the necessity of making a decision related to the location of a complex infrastructure project like a wastewater treatment plant (WWTP), a number of sustainable key groups of factors should be considered, such as environmental, economic, and social factors **(Hama et al., 2019; Zhou et al., 2022).** Firstly, several environmental factors influence where a WWTP is located in order to make sure that it runs efficiently and sustainably. Here are some key environmental aspects that affect WWTP locations: current and future population densities should be considered to ensure that the facility can sufficiently handle the wastewater generated by the community it serves **(Abbasl and Jassim, 2019; Taghilou et al., 2019; Awad and Shleha, 2020; Liu et al., 2022; Zhou et al., 2022)** preserving the protected habitats, or wildlife reserves should be considered to minimize the impact on ecosystems and biodiversity **(Taghilou et al., 2019; Majed and Ghafour, 2022)**; as well as, ensure a safe distance between the WWTP and water wells to preserve groundwater, regulators set buffering distances **(Taghilou et al., 2019; Majed and Ghafour, 2022)**.

Secondly, crucial economic aspects have to be conducted for the location of WWTPs can be concluded by the most significant ones. WWTPs typically should be located close to water sources, that meet the limitations of environmental regulations, in order to decrease the costs and energy needed for water to transport the treated wastewater that discharges into them **(Abdullahi et al., 2016; Taghilou et al., 2019; Asefa and Mindahun, 2019; Majed and Ghafour, 2022; Zhou et al., 2022**). The site should be adjacent to major roads to make it accessible for transporting materials, tools, workers, and sewer main inflow lines, which facilitate construction and maintenance activities **(Abbasl and Jassim, 2019; Taghilou et al., 2019; Asefa and Mindahun, 2019; Agrawal et al., 2019; Liu et al., 2022; Majed and Ghafour, 2022; Zhou et al., 2022)**. The topography of the location can influence the design and construction of a WWTP on level terrain, facilitating construction and maintenance, while steep slopes could increase the cost of construction and require further engineering solutions **(Sammy, 2018; Asefa and Mindahun, 2019; Majed and Ghafour, 2022).**

Finally, the determination of the site of WWTPs must prioritize the most important social factors. Proximity of a WWTP to educational institutions, historical and regional places, and healthcare care facilities **(Awad et al., 2014; Abd Hasson, 2017; Zhou et al., 2022)** can result in negative impacts such as exposure to noxious odours emitted during the treatment processes and the visual impact of its large industrial structures, which can negatively affect the aesthetics of the surrounding area **(Demircan, 2018).** Consequently, this can have a detrimental impact on the overall environment and comfort inside the facilities of social interest. Considering these factors during the site selection process helps in establishing a WWTP that is not only effective in treating wastewater but also sustainable and environmentally responsible.

Decision-makers must consider the above environmental, economic, and social characteristics and should be using Multiple Criteria Decision Analysis (MCDA) to carry out a thorough exploration of the ideal locations **(Yuan et al., 2022).** MCDA is an effective decision-making tool frequently used in project management to manage complex decisions that incorporate several criteria and alternatives. MCDA techniques assist decision-makers in prioritizing and making informed choices by organizing the decision problem into a hierarchical framework and using pairwise comparisons to measure subjective judgments **(Cinelli et al., 2020).** Analytical Hierarchy Procedure (AHP) is one of the MCDA techniques that was developed by Thomas L. Saaty in 1980 **(Saaty, 1980).** It is commonly utilized for decision-making in different sectors, such as project management. The process entails decomposing a complicated choice problem into a hierarchical framework comprising goals, criteria, sub-criteria, and options. Decision-makers evaluate pairings of items at each hierarchy level using a scale of relative importance or preference, typically ranging from 1 to 9. Saaty's eigenvector approach is used to calculate priority weights for each criterion and option by synthesizing pairwise comparisons. Consistency checking is the final step to verify the trustworthiness of the decisions made by the decision-maker **(Al-Dhaheri and Burhan, 2022).** An extension of AHP that incorporates fuzzy logic is the Fuzzy Analytical Hierarchy Procedure (FAHP) to handle uncertainty and vagueness in decision-making. Within the FAHP method, linguistic expressions such as very important, important, and moderately important, are substituted by fuzzy sets defined by membership functions. Decision-makers offer language assessments that are transformed into fuzzy integers to represent the level of fuzziness, rather than clear-cut pairwise comparisons **(Chang,1996).** Aggregation methods like the fuzzy weighted average or fuzzy arithmetic operations are used to determine the total priority weights **(Alcantud, 2023).**

FAHP can be a useful tool to determine the location of an infrastructures project as it enables decision-makers to evaluate multiple criteria at once and assign significance to them based on the project's goals and limitations **(Wang et al., 2019; Hamlat et al., 2022; Al-Dhaheri and Burhan, 2022; Al Mohamed et al., 2023; Lefta and Hamdan, 2024).** WWTPs are one of the more complicated types of infrastructure projects, and FAHP has been commonly employed for site decision-making in previous studies **(Anagnostopoulos and Vavatsikos, 2012; Shahmoradi and Isalou, 2013; Auadh et al., 2014; Awad and Shleha, 2020; Majed and Ghafour, 2022; Hamlat et al., 2022; Lefta and Hamdan, 2024).** The previous studies have not identified an approved strategy for evaluating the location of a WWTP or selecting alternate locations in Baghdad. Therefore, this research aims to develop a strategy for making decisions about sustainable sites for WWTPs using FAHP method. The city of

Baghdad will be used as a case study to demonstrate the application of this strategy and evaluation the existing major WWTPs location in it.

2. RESEARCH METHODOLOGY

To meet the study aims, the procedures that follow outline the methodology employed in the present research shown in **Fig. 1**.

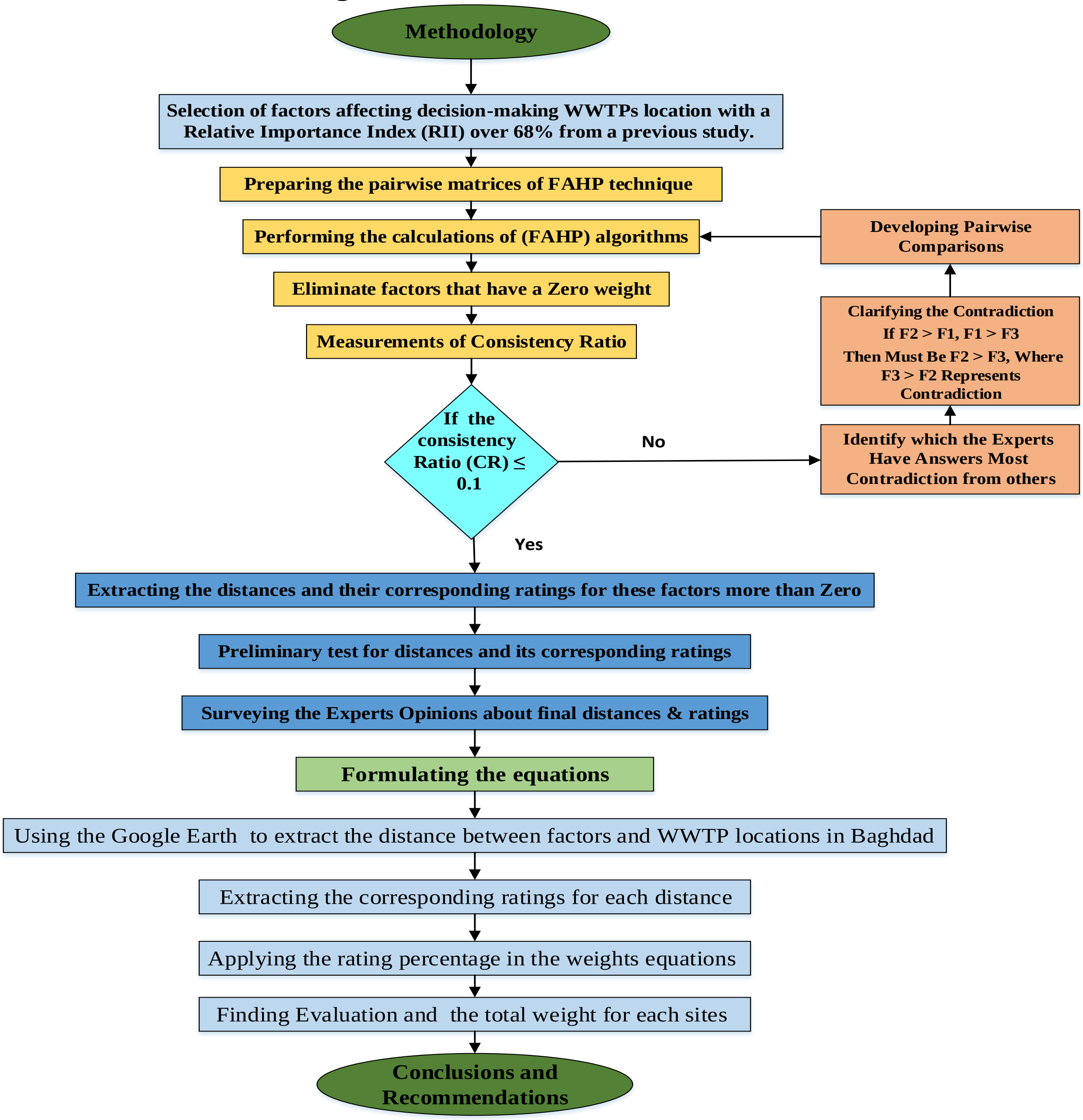

Figure 1. Research methodology.

2.1 Factors Affecting Selection

This study will adopt the findings of the study by (**Mahmood and Hatem, 2024a),** which identified the significant factors influencing the decision-making process for the most suitable site for a WWTP. Factors with relative important index values greater than 0.68 will be selected **(Rashed and Al-Dhaheri, 2018)** and classified into three main groups: environmental factors, economic factors, and social factors, as shown in **Table 1**.

Table 1. Factors influencing a decision-making sustainable location of WWTPS **(Mahmood and Hatem 2024a)**.

Main Groups	Factor symbol	Sub-Factors	RII
Environmental (Env.)	Env.1	Distance from the population settlements (m)	0.971
	Env.2	Distance from wells or groundwater (m)	0.877
	Env.3	Distance from protected areas (m)	0.852
Economic (Eco.)	Eco.1	Topography (m.a.s.l)	0.755
	Eco.2	Distance from surface water bodies(m)	0.852
	Eco.3	Distance from main and secondary roads (m)	0.794
Social (Soc.)	Soc.1	Distance from educational places (m)	0.729
	Soc.2	Distance from historical and religious areas (m)	0.865
	Soc.3	Distance from Health places (m)	0.816

2.2 Fuzzy Analytical Hierarchy Process (FAHP)

The multiple-criteria decision-making analysis technique(MCDM) is an effective decision-making method. When using the analytic hierarchy process (AHP) approach to evaluate criteria, certain aspects are deemed crucial for picking alternatives and setting their weights. These characteristics are based on understanding and knowledge rather than precise data. However, it is vital to emphasize that the foundation for these characteristics is negative and detrimental to the AHP technique. The method involves specialists grading conventional numerals (crisp) on a scale of 1 to 9. It does not account for any uncertainty in the expert assessments **(Al-Dhaheri and Burhan, 2022)**. To address the issue, the AHP technique was used in conjunction with fuzzy logic. Using the AHP in conjunction with fuzzy logic improves adaptability. The AHP combined with fuzzy logic improves adaptability in decision-making and evaluation. The fuzzy analytical hierarchy technique (FAHP) is a method for making decisions based on approximate and imperfect information in the same way that humans do. Furthermore, it maintains the core characteristics of the AHP methodology. It streamlines the handling of quantitative and qualitative data, uses a hierarchical structure, performs pairwise comparisons, resolves conflicts, and assigns weights **(Mahdi and Erzaij, 2024)**.

2.3 FAHP Algorithm

The FAHP approach was employed after converting each expert's pairwise assessment matrix to fuzzy form utilising numbers that were fuzzy from Saaty's scales, see **Table 2,** and creating the combined fuzzy comparative matrix for the group of experts by determining the geometric mean to arrive at the final matrix. According to the study **(Chang, 1996; Rashed and Al-Dhaheri, 2018)**, the FAHP approach is divided into four steps:

Step 1: The fuzzy synthetic range value of the ith object is referred to as:
$M^1_{gi}, M^2_{gi}, M^m_{gi}, i = 1,2,\ldots..,n$
Where, all of the M^j_{gi} (j = 1, 2, …, m) are TFNs.

$$S_i = \sum_j^m = 1M_{gi}^j * \left[\sum_j^n = 1\sum_j^m = 1M_{gi}^j\right]^{-1} \quad (1)$$

To find the $\Sigma^m_{j=1} M^j_{gi}$, The fuzzy addition operation involving m extent analysis values is carried out for a specific matrix in such a way that these conditions are met:

$$\sum_{j}^{m} = 1M_{gi}^{j} = \{\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} mj, \sum_{j=1}^{m} u_j\} \quad (2)$$

For calculating the **[** $\sum^{n}_{i=1} \sum^{m}_{j=1} M^{j}_{gi}$ **]** the fuzzy addition operation of M^{j}_{gi} will be performed (j=1,2,3,…….m) values such that

$$\sum_{j}^{n} = 1 \sum_{j}^{m} = 1M_{gi}^{j} = \{\sum_{i=1}^{m}, l_i, \sum_{j=1}^{m} mi, \sum_{j=1}^{m} u_i\} \quad (3)$$

Compute the inverse of the vector above, such that:

$$\left[\sum_{j}^{n} = 1 \sum_{j}^{m} = 1M_{gi}^{j}\right]^{-1} = \left\{\frac{1}{\sum_{i=1}^{m} u_i}, \frac{1}{\sum_{i=1}^{m} mi}, \frac{1}{\sum_{i=1}^{n} li}\right\} \quad (4)$$

Step2: Since $M1= (X1, M1, U1)$ and $M2= (X2, M2, U2)$ are two TFNs, the degree to which $M2 = (L1, M1, U1) \geq M1= (L2, M2, U2)$ is defined as:

$$= \begin{cases} 1, & m1 \geq m2 \\ 0, & l1 \geq u2 \\ \frac{l1-u2}{(m2-u2)-(m1-l1)} & otherwise \end{cases} \quad (5)$$

$$= \begin{cases} 1, & m2 \geq m1 \\ \frac{u2-l1}{(u2-m2)+(m1-l1)} & if\ l1 \leq u2 \\ 0, & otherwise \end{cases} \quad (6)$$

Step 3: The probability that a convex fuzzy number is bigger than k convex numbers that are fuzzy can be stated as:
M_i (i=1,2,k)

$V(M \geq M_1, M_2,..M_k) = V[(M \geq M_1)$ *and* $(M \geq M_2)$ *an….*$[(M \geq M_k)] = \min V(M \geq M_i)$, *i=1,2,3,…k* (7)

When that assumes $d(A_i) = \min V(S_i \geq S_k)$ for k = 1, 2, …..,n, k≠i, the weight vectors can be obtained:

$$W' = d'(A_1), d'(A_2), \ldots (d'(A_n))^T \quad (8)$$

For comparing M1 and M2, the both values of V (M1≥M2) and V (M2 ≥ M1) are needed

Step 4: The following would be the normalised weight vectors:

$$W = d(A_1), d(A_2), \ldots (d(A_n))^T \quad (9)$$

where W: non-fuzzy number.

Table 2. The scales of pairwise comparisons **(Saaty, 1980; Buckley,1985; Al-Dhaheri and Burhan, 2022).**

The level of preference (intensity of significance) for one activity over another (linguistically scale)	**The preference degree**			
	Digital value	**Descriptions**	**Fuzzy digital value**	**Invert of the fuzzy value**
Equal significance	1	Both activities contributed equally to the purpose.	(1,1,1)	(1,1,1)
Intermediate significance between (Equal and moderate)	2	One activity holds a level of importance that is considered to be moderate in comparison to another.	(1,2,3)	(1/3,1/2,1)
Moderate significance	3	Experience and judgment a little prefer a certain activity over another.	(2,3,4)	(1/4,1/3,1/2)
Intermediate significance between (Moderate to strong)	4	One activity has a moderate to significant advantage over another.	(3,4,5)	(1/5,1/4,1/3)
Strong significance	5	Experiences and judgments strongly favor one action over another.	(4,5,6)	(1/6,1/5,1/4)
Intermediate significance between (strong and very strong)	6	One activity has a significant to extremely significant advantage over another.	(5,6,7)	(1/7,1/6,1/5)
Very strong significance.	7	A certain activity is very strongly preferred over another.	(6,7,8)	(1/8,1/7,1/6)
Intermediate significance within (Very strong and complete).	8	One activity has a significant to absolute advantage over another one.	(7,8,9)	(1/9,1/8,1/7)
Absolute significance	9	The strongest level of affirmation is the evidence that prefers one activity over another.	(8,9,10)	(1/10,1/9,1/8)

2.4 Measuring the Consistency Ratio Using the FAHP Approach.

It is critical to determine the harmonic of each expert's comparison to determine whether they are harmonic, as well as the consistency and validity of the expert's responses. The initial step in ensuring a low consistency ratio is that each group or matrix, whether sub or main factors, must not exceed nine criteria. It refers to the human limitations on their ability to digest information, as proposed by **(Saaty and Ozdemir, 2003)**.

To be considered acceptable, consistency ratios in both matrices must be less than 10% across all main and subcomponents. This that the experts' evaluations are genuine and constant **(Saaty, 1980)**. The Gogus and Boucher technique, which is described below, is employed to ascertain the inconsistency ratio **(Buckley, 1985**; **Al-Dhaheri and Burhan, 2022)**:

Stage 1: The integrated fuzzy triangular matrix is composed of two matrices containing the middle values and the geometric mean of the upper and lower bounds of the triangular numbers.

Stage 2: The Saaty approach calculates each matrix's weight vector as follows:

$$W_i^m = \frac{1}{n\left[\sum_{j=1}^{n}\left(\frac{a_{ijm}}{\sum_{i=1}^{n} a_{ijm}}\right)\right]} \text{ that } W^m = [W_i^m] \tag{10}$$

$$W_i^g = \frac{1}{n\left[\sum_{j=1}^{n}\frac{\left(a_{iju}*a_{ijl}\right)^{\frac{1}{2}}}{1\left(a_{iju}*a_{ijl}\right)^{\frac{1}{2}}}\right]} \text{ that } W^g = \left[W_i^g\right] \tag{11}$$

Stage 3: The following formula determines each matrix's largest eigenvalue.

$$\lambda_{max}^m = \sum_j^n = 1(a_{ij}^m * w_i^m) = \sum_j^n = 1\ a_{ij}^m \left(\frac{w_j^m}{w_i^m}\right) \tag{12}$$

$$\lambda_{max}^g = \sum_j^n = 1(\ a_{ijU} *\ a_{ijL})^{\frac{1}{2}} * \left(\frac{w_j^m}{w_i^m}\right) = \sum_j^n = 1(\ a_{ijU} *\ a_{ijL})^{\frac{1}{2}} * w_j^g \tag{13}$$

Stage 4: Next, the index of consistency is calculated using the formula that follows:

$$CI^m = \frac{(\lambda_{max}^m - n)}{(n-1)}) \tag{14}$$

$$CI^g = \frac{(\lambda_{max}^g - n)}{(n-1)}) \tag{15}$$

Stage 5: Lastly, as shown in **Table 3**, the consistency rate (CR) is calculated by dividing the CI index by the random index (RI). The matrix is consistent and approved if the value is less than 0.1.

Table 3. Random indicators (RI) **(Goodarzi and Dokht, 2015; Al-Dhaheri and Burhan, 2022)**

Matrix size	RI^m	RI^g
1	0	0
2	0	0
3	0.4890	0.1796
4	0.7937	0.2627
5	1.0720	0.3597
6	1.1996	0.3818
7	1.2874	0.4090
8	1.3410	0.4164
9	1.3793	0.4348
10	1.4095	0.4455
11	1.4181	0.4536
12	1.4462	0.4776
13	1.4555	0.4691
14	1.4913	0.4804
15	1.4986	0.4880

2.5 Preparing the Questionnaires

The study used two questionnaires, the first to evaluate the factors influencing WWTP location decision-making using the FAHP approach that was shown in **Table 1**, and to determine the weight of each component from the perspective of experts. For the purpose of determining the percentage of agreement or disagreement among the group of experts in the management of those facilities, the second questionnaire was designed for the purpose of evaluating the final distances and elevations, along with their ratings, which were picked by the experts.

2.6 Case Study Description

Baghdad is located on a wide expanse of land that is separated into two parts by the Tigris River. The east part of the river is referred to as Al-Risafa, whereas the west part of it is referred to as Al-Karkh. As the capital city of Iraq, more than eight million people live in an area of around 900 km^2. It is regarded as the most developed and crowded metropolitan area in the whole country. **(AbdulRazzak, 2013; Tawfeek et al., 2020).** The city is divided into 457 distinct "sectors," and sewage systems cover approximately 82% of these regions **(AbdulRazzak, 2013)**. It has three individual and major WWTPs: the Al-Karkh plant, which includes both new and old projects, Al-Rustamiya Southern Plant, which has first and second expansions, and Al-Rustamiya Northern Plant, which has a third expansion, see **Fig. 2 (Ismail, 2013; Mahmood and Hatem, 2024b).** Al-Karkh WWTP is located south of Al-Dora area on the west bank of the Tigris River. This plant was designed to contain six parallel and identical treatment lines. The initial design of the plant allowed for a capacity of 205,000 cubic meters per day, while the current inflow is 625,000 cubic meters per day **(AbdulRazzak, 2013).** The Al-Rustamiya Southern plant, which has been operational since 1963, consists of two interconnected projects: the first and second expansions. It has a designed capacity of 175,000m^3/day, but the actual flow is more than 300,000m^3/day. The plant produces treated wastewater for a population of 1,500,000 on the Al-Risafa side **(AbdulRazzak, 2013)**. The Al-Rustamiya Northern Plant, 3rd Expansion, has been operational since 1984. It was originally designed to treat 300,000m^3/day, but it now receives 450,000m3/day from more than 1.5 million people living on the Al-Risafa side **(Mahmood and Hatem, 2024b).** Both Al-Rustamiya treatment plants treat wastewater on Baghdad's eastern side of Al-Risafa and threeared wastewater is discharged into the Diyala River and then into the Tigris River.

3. RESULTS AND DISCUSSION

3.1 Calculation of the Weights and Rating Levels for the Factors

Two programs using Excil have been built according to FAHP equations to simplify the procedure of extracting the results, one to calculate the priorities of weights, the consistency ratio and the ranking of factors affecting the decision-making of WWTP locations. The program for the priorities of weight calculations has been fed using the data collected from the respondent's opinions of the first questionnaire. After obtaining the weights for each factor, the outcomes of the fuzzy integrating matrix were copied from calculating weights programmes to consistency ratio calculation programs in order to guarantee that the CR was less than 10%, confirming that the findings were appropriate and acceptable. **Tables 4 to 7** display the weights and rankings of the major and sub-factors, as well as the Consistency Ratio for Middle Values (CR^m) and the Consistency Ratio for Lower and Upper Values (CR^g) for each integrated fuzzy comparison matrix. Based on the sum of the weights for all the major factors shown in **Table 4**, the environmental factor has the highest weight (0.581), making it the most important first key element in the experts' decision-making process for where to put the WWTP. The results also revealed that the weight of social factors was 0.277, making it the most influential second main factor, while the lowest one was the economic factor, with a value of 0.142. The consistency ratios for both (middle) and (lower and upper) of the values of the fuzzy integration matrix were less than (10%) with values of CR^m equal to (0.3%) and CR^g equal to (1.03%).

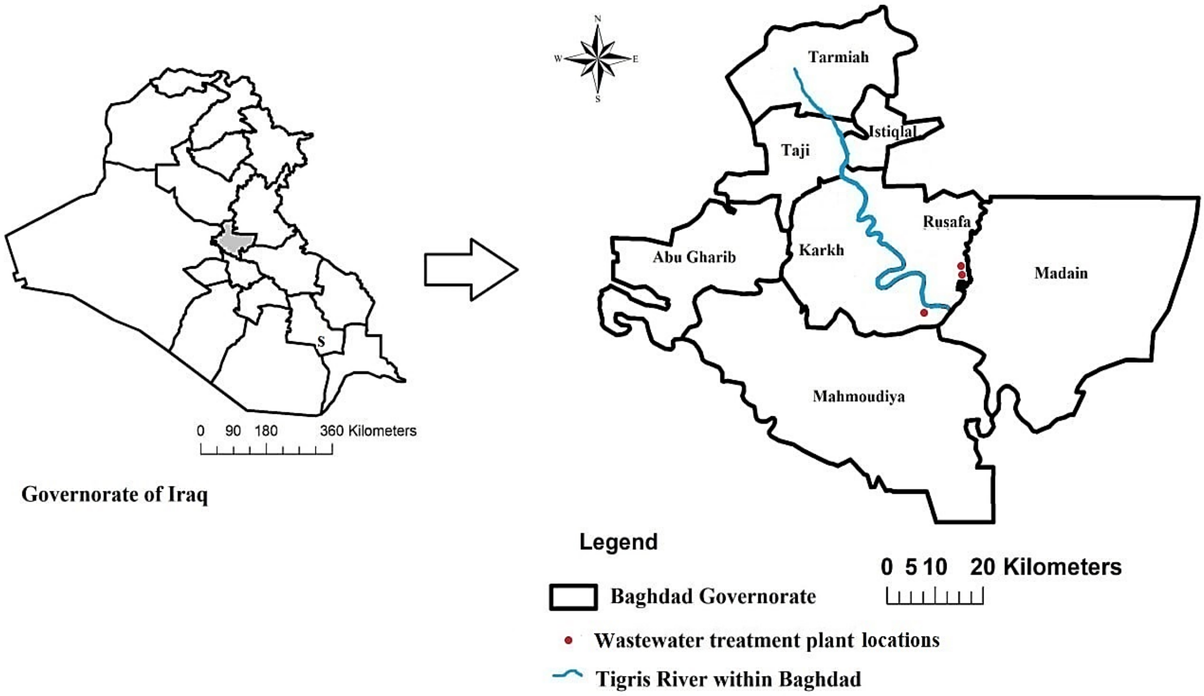

Figure 2. Wastewater treatment plant locations of Baghdad.

Table 4. Main factor calculations

N	Main factors (Main.F)	Group Weight	The Rank	CR^m	CR^g
1	Environmental factors (Env.)	0.581	1	0.3%	1.03%
2	Economic factors (Eco.)	0.142	3		
3	Social factors (Soc.)	0.277	2		

Table 5 shows the weighted total of all environmental factors used in the decision-making process for WWTP locations. Experts consider distance from the population settlement to be the most critical environmental sub-factor. Furthermore, the data indicated that the weight of the distance from protected areas factor was 0.156, making it the most influential second factor, but the factor of distance from wells or groundwater had no weight. The consistency ratios for both the middle and upper values of the fuzzy integration matrix were less than 10%, with CR^m equal 0.20% and CR^g equal 0.64%.

Table 5. Environmental factors calculations

N	Environmental factors (Env.)	Factors Weight	The Rank	CR^m	CR^g
1	Distance from the population settlements (Env.1)	0.844	1	0.20%	0.64%
2	Distance from wells or groundwater (Env.2)	0.000	3		
3	Distance from protected areas (Env.3)	0.156	2		

According to the total weights assigned to each factor of economic factors group in **Table 6**, Topography has the highest weight (0.430), making it the main and critical consideration in the experts' decision-making process for determining the location of the WWTP. The findings also indicated that the factor of distance from surface water bodies had a weight of 0.354, making it the most significant factor in this group of factors. Conversely, the factor of distance from main and secondary roads had the lowest weight, with a value of 0.216. The consistency ratios for the middle values and the lower and upper values of the fuzzy integration matrix were both below 10%. The CR_m value was 0.05% and the CR_g value was 0.08%.

Table 6. Economic factors calculations

N	Economic factors (Eco.)	Factors Weight	The Rank	CR^m	CR^g
1	Topography (Eco.1)	0.430	1	0.05%	0.08%
2	Distance from surface water bodies (Eco.2)	0.354	2		
3	Distance from main and secondary roads (Eco.3)	0.216	3		

Table 7 displays the total weights of all the social factors that are considered in the decision-making process for identifying WWTP locations. Experts consider distance from health places as the most crucial sub-factor within the realm of social factors. Moreover, the data revealed that the distance from educational places factor had a weight of 0.156, making it the second most significant one. However, the factor of distance from historical and religion places had no weight.

Table 7. Social factors calculations

N	Social factors (Soc.)	Factors Weight	The Rank	CR^m	CR^g
1	Distance from educational places (Soc.1)	0.233	2	0.19%	0.14%
2	Distance from historical and religious areas(Soc.2)	0.000	3		
3	Distance from Health places(Soc.3)	0.767	1		

The consistency ratios for both the middle and lower and upper values of the fuzzy integration matrix were below 10%, with CR^m being 0.19% and CR^g being 0.14%.

A new questionnaire has been formulated after finalising the calculation of the weights of the studying factors using FAHP. This questionnaire only included sub-factors with a weight that was over zero and excluded those with a score of zero. It also contained distances and ratings for each factor considered in the decision-making process for WWTP locations. The questionnaire was then given to experienced WWTP project managers. Its goal was to collect their professional judgements on the distances and corresponding ratings. The experts altered several distances as well as associated ratings in accordance with Iraqi guidelines and regulations. The new questionnaire was given to twelve experts with over sixteen years of experience managing WWTP plants. The goal was to determine their level of agreement or disagreement with the designated distances and ratings. After gathering and analysing the expert responds, it was discovered that the vast majority of them agree with the distances and ratings, as shown in **Table 8**.

The data presented in **Table 8** indicated the distances and elevation system levels offered for the location of the WWTP, together with their corresponding ratings. Additionally, the percentage of agreement among respondents in the second questionnaire was also considered. The results indicated that four out of seven factors had a 100% agreement rate, two factors had a 91.7% agreement rate, and two factors had an 83.3% agreement rate. These findings support the suitability of these factors for use in the research.

Table 8. The proposed distances and the elevation system levels and ratings

Groups	Factors	Factor Rating symbol	Standards (m)	Buffer (m)	Rating Level	% of Agree
Environmental (Env.)	Distance from the population settlements (m)	Renv.1	> 6000 >5000-6000 >4000-5000 >3000-4000 >2000 -3000	2000	5 4 3 2 1	91.7
	Distance from protected areas (m)	Renv.3	>3500) >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	83.3
Economic (Eco.)	Topography (m.a.s.l)	Reco.1	L. Elev. - (L. Elev. +0.2 (H Elev. – L. Elev.)) (L. Elev. +0.2(H Elev. – L. Elev.))- (L. Elev. +0.4(H Elev. – L. Elev.)) (L. Elev. +0.4(H Elev. – L. Elev.))- (L. Elev. +0.6(H Elev. – L. Elev.)) (L. Elev. +0.6(H Elev. – L. Elev.))- (L. Elev. +0.8(H Elev. – L. Elev.)) (L. Elev. +0.8(H Elev. – L. Elev.))- H. Elev.	-	5 4 3 2 1	100
	Distance from surface water bodies(m)	Reco.2	>500-1000 >1000-1500 >1500-2000 >2000-2500 >2500	500	5 4 3 2 1	91.7
	Distance from main and secondary roads (m)	Reco.3	>500-1000 >1000-1500 >1500-2000 >2000-2500 >2500	500	5 4 3 2 1	100
Social (Soc.)	Distance from educational places (m)	Rsoc.1	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	100
	Distance from Health places (m)	Rsoc.3	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	100

3.2 Equations for Decision-Making of WWTP Locations

Based on the previous results from applying FAHP that were presented in **Tables 4 to 7**, which determined the weights of main and sub-factors and the concluded the distances and the elevation system levels with it ratings for the factors in **Table 8**, the equations for the decision-making process of sustainable WWTP locations can be concluded as following:

$$TW.WWTP \ = \ 0.581 \ Wenv. + 0.142 \ Weco. + 0.277 Wsoc. \quad (16)$$

where:
TW. WWTP: the total weights of selected wastewater Treatment plant
Wenv.: the weights of environmental factors.
Weco.: the weights of economic factors.
Wsoc.: the weights of social factors.

$$Wenv. = \frac{0.844\ Renv.1 + 0\ Renv.2 + 0.156\ Renv.3}{5}$$

$$Wenv. = \frac{0.844\ Renv.1 + 0.156\ Renv.3}{5} \tag{17}$$

where:
Wenv.: the weights of environmental factors.
Renv.1: the rating of the distance from the population settlements to the WWTP location
Renv.3: the rating of the Distance from protected areas to the WWTP location

$$Weco. = \frac{0.430\ Reco.1 + 0.354\ Reco.2 + 0.216\ Reco.3}{5} \tag{18}$$

where:
Weco.: the weights of economic factors
Reco.1: the rating of the elevation of the WWTP location
Reco.2: the rating of the distance from surface water bodies to the WWTP location
Reco.3: the rating of the distance from main and secondary roads to the WWTP location

$$Wsoc. = \frac{0.233\ Rsoc.1 + 0\ Rsoc.2 + 0.767\ Rsoc.3}{5}$$

$$Wsoc. = \frac{0.233\ Rsoc.1 + 0.767\ Rsoc.3}{5} \tag{19}$$

where:
Wsoc.: the weights of social factors.
Rsoc.1: the rating of the distance from educational places to the WWTP location
Rsoc.3: the rating of the distance from Health places to the WWTP location

3.3 Evaluation of the Locations of the Existing WWTPs in Baghdad

Baghdad has numerous unique and big wastewater treatment plants. These include the Al-Karkh plant, which includes both the new and old projects; the Al-Rustamiya Southern Plant, which includes the first and second extensions; and the Al-Rustamiya Northern Plant, which includes the third extension **(Mahmood and Hatem, 2024b)**. Google Earth was utilised to calculate the actual distance from each factor to WWTP locations included in the calculation of weights and the evaluation was conducted using GIS techniques **(Al-Dhaheri and Burhan, 2022)**. To establish the weight of each wastewater treatment facility in Baghdad, the next step is to identify the ratings that correlate to each distance and then apply those ratings to weight formulae. Through the use of Google Earth technologies, the distances between the nearest locations of the selected factors and three wastewater treatment plant (WWTP) locations in Baghdad are as follows: Al-Karkh WWTP, Al-Rustamiya Southern WWTP, and Al-Rustamiya Northern WWTP. **Tables 9 to 11** present the rating assigned for each factor according to the recommended rating level.

3.3.1 Total Weights of Al-Karkh WWTP Location

The obtained rate for each factors affecting decision-making Al-Karkh WWTP location that shown in the **Table 9** will be used to calculate the weights for the location by using the developed **Eq. 16** to **19.** The weight of each WWTP location has been calculated by applying the developed equations and proposed rating system. The results indicate that the weight of the Al-Karkh WWTP location is 0.3912448. Two factors (the distance from population settlements, and the distance from main and secondary roads) did not meet the limitations of the proposed rating system of this research and the instructions No. 3 for the year 2011 **(Ministry of Environment, 2012).**

Table 9. The distances between the Al-Karkh WWTP location and its elevation with their rating values.

Groups	Factors	Standards	Buffer	Rating Level	Close affected place to the WWTP location	Distance or elevation value	Rating of factors
Environmental (Env.)	Distance from the population settlements (m)	> 6000 >5000-6000 >4000-5000 >3000-4000 >2000 -3000	2000	5 4 3 2 1	Bo'aitha Region	10	0
	Distance from protected areas (m)	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	Iraqi Reserve for Rare Birds in Al-Mada'in District	23,884	5
Economic (Eco.)	Topography of Baghdad (m.a.s.l)	≥27 – 32 >32-37 >37-42 >42-47 >47-52	-	5 4 3 2 1	Sea Level	35	4
	Distance from surface water bodies(m)	>500-1000 >1000-1500 >1500-2000 >2000-2500 >2500	500	5 4 3 2 1	Tigris River	1541	3
	Distance from main and secondary roads (m)	>500-1000 >1000-1500 >1500-2000 >2000-2500 >2500	500	5 4 3 2 1	Arab Ajbour-Bo'aitha Road	227	0
Social (Soc.)	Distance from educational places (m)	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	AlHadi University college	2533	4
	Distance from Health places (m)	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	Al Dora Health Center for Family Medicine	2646	4

$$Wenv. = \frac{0.844\ Renv.1 + 0.156\ Renv.3}{5}$$
$$Wenv. = \frac{0.844 * 0 + 0.156 * 5}{5}$$
$$Wenv.Al - Karkh = 0.156$$
$$Weco. = \frac{0.430\ Reco.1 + 0.354\ Reco.2 + 0.216\ Reco.3}{5}$$
$$Weco. = \frac{0.430 * 4 + 0.354 * 3 + 0.216 * 0}{5}$$
$$Weco.Al - Karkh = \frac{1.72 + 1.062 + 0}{5} = 0.5564$$
$$Wsoc. = \frac{0.233\ Rsoc.1 + 0.767\ Rsoc.3}{5}$$
$$Wsoc. = \frac{0.233 * 4 + 0.767 * 4}{5}$$
$$Wsoc.Al - Karkh = 0.8$$
$$TW.WWTP = 0.581\ Wenv. + 0.142\ Weco. + 0.277 Wsoc.$$
$$TW.WWTP = 0.581 * 0.156 + 0.142 * 0.5564 + 0.277 * 0.8$$
$$TW.WWTP\ Al - Karkh = 0.090636 + 0.0790088 + 0.2216$$
$$TW.WWTP\ Al - Karkh = 0.3912448$$

3.3.2 Total Weights Al-Rustamiya Southern WWTP Location

The rates for every factor influencing decision-making for the Al-Rustamiya Southern WWTP location, as presented in **Table 10** will be utilized to compute the weights for the location using the established **Eqs. (16) to (19).** The weight of the Al-Rustamiya Southern WWTP location has been determined using the established equations and the suggested rating system. The findings show that the weight of the WWTP location is 0.361084. Three factors—distance from population settlements, distance from surface water bodies, and distance from main and secondary roads—did not comply with the limitations set by the proposed rating system of this research and the instructions No. 3 for the year 2011 **(Ministry of Environment, 2012).**

$$Wenv. = \frac{0.844\ Renv.1 + 0.156\ Renv.3}{5}$$
$$Wenv. = \frac{0.844 * 0 + 0.156 * 5}{5}$$
$$Wenv.Al - Rustamiya\ S = 0.156$$
$$Weco. = \frac{0.430\ Reco.1 + 0.354\ Reco.2 + 0.216\ Reco.3}{5}$$
$$Weco. = \frac{0.430 * 4 + 0.354 * 0 + 0.216 * 0}{5}$$
$$Weco.Al - Rustamiya\ S = \frac{1.72}{5} = 0.344$$
$$Wsoc. = \frac{0.233\ Rsoc.1 + 0.767\ Rsoc.3}{5}$$
$$Wsoc. = \frac{0.233 * 4 + 0.767 * 4}{5}$$
$$Wsoc.Al - Rustamiya\ S = 0.8$$

Table 10. The distances between the Al-Rustamiya southern WWTP location and its elevation with their rating values.

Groups	Factors	Standards	Buffer	Rating Level	Close affected place to the WWTP location	Distance or elevation value	Rating of factor
Environmental (Env.)	Distance from the population settlements (m)	> 6000 >5000-6000 >4000-5000 >3000-4000 >2000 -3000	2000	5 4 3 2 1	Al-Ameen Region	802	0
	Distance from protected areas (m)	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	Iraqi Reserve for Rare Birds in Al-Mada'in District	23884	5
Economic (Eco.)	Topography of Baghdad (m.a.s.l)	≥27 – 32 >32-37 >37-42 >42-47 >47-52	-	5 4 3 2 1	Sea Level	36	4
	Distance from surface water bodies(m)	>500-1000 >1000-1500 >1500-2000 >2000-2500 >2500	500	5 4 3 2 1	Diyala River	90	0
	Distance from main and secondary roads (m)	>500-1000 >1000-1500 >1500-2000 >2000-2500 >2500	500	5 4 3 2 1	Baghdad-Kut highway	30	0
Social (Soc.)	Distance from educational places (m)	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	Technical Institute of Management/ Middle Technical University	3306	4
	Distance from Health places (m)	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	Al-Ameen neighborhood clinic	3066	4

$TW.WWTP \; = \; 0.581 \, Wenv. + 0.142 \, Weco. + 0.277 Wsoc.$
$TW.WWTP \; = \; 0.581 * 0.156 + 0.142 * 0.344 + \; 0.277 * 0.8$
$TW.WWTP \; Al - Rustamiya \; S = 0.090636 + \; 0.048848 + 0.2216$
$TW.WWTP \; Al - Rustamiya \; S = 0.361084$

3.3.3 Total weights of Al-Rustamiya northern WWTP location

The rates for each factor affecting decision-making regarding the Al-Rustamiya Northern WWTP location, as shown in **Table 11** will be employed to calculate the weights for the location using the defined **Eqs. (16) to (19).** The created equations and the proposed rating method were utilized in order to come at an assessment regarding the weight of the Al-Rustamiya Northern WWTP location. The research has determined that the weight of the WWTP location is 0.3315004. There were three factors that did not meet with the constraints that were established by the proposed grading system of this research and Instruction No. 3 for the year 2011 **(Ministry of Environment, 2012)**. The three factors in question were the distance from population settlements, the distance from surface water bodies, and the distance from main and secondary roads.

$$Wenv. = \frac{0.844\ Renv.1 + 0.156\ Renv.3}{5}$$
$$Wenv. = \frac{0.844 * 0 + 0.156 * 5}{5}$$
$$Wenv. Al - Rustamiya\ N = 0.156$$
$$Weco. = \frac{0.430\ Reco.1 + 0.354\ Reco.2 + 0.216\ Reco.3}{5}$$
$$Weco. = \frac{0.430 * 4 + 0.354 * 0 + 0.216 * 0}{5}$$
$$Weco. Al - Rustamiya\ N = \frac{1.72}{5} = 0.344$$
$$Wsoc. = \frac{0.233\ Rsoc.1 + 0.767\ Rsoc.3}{5}$$
$$Wsoc. = \frac{0.233 * 5 + 0.767 * 3}{5}$$
$$Wsoc. Al - Rustamiya\ N = 0.6932$$
$$TW.WWTP = 0.581\ Wenv. + 0.142\ Weco. + 0.277 Wsoc.$$
$$TW.WWTP = 0.581 * 0.156 + 0.142 * 0.344 + 0.277 * 0.6932$$
$$TW.WWTP\ Al - Rustamiya\ N = 0.090636 + 0.048848 + 0.1920164$$
$$TW.WWTP\ Al - Rustamiya\ N = 0.3315004$$

The weight of each WWTP location has been calculated by applying the developed equations and proposed rating system. The results indicate that the weight of the Al-Karkh WWTP location is 0.3912448, the weight of the Al-Rustamiya Southern WWTP location is 0.361084, and the weight of the Al-Rustamiya Northern WWTP location is 0.3315004. At first look, it may appear that the series of locations can be ranked based on their relevance or the availability of needed distances for each of them. The Al-Karkh site is placed first in the sequence, followed by the Al-Rustamiya Southern location, and finally the Al-Rustamiya Northern location. Although there is no minimum requirement for the calculated weights for the location, it can be noted that the weight value of the three evaluated locations is low. The low value may be due to the three significant factors that got zero weights and some other factors got not high rate. The three factors (the distance from population settlements, the distance from surface water bodies, and the distance from main and secondary roads) did not meet the limitations of the proposed rating system of this research and the instructions No. 3 for the year 2011 **(Ministry of Environment, 2012)**.

There are two reasons for this non-meeting : first, the studied WWTP projects had been constructed for more than 40 years (the newest one), and d the huge urban expansion in Baghdad, people's houses became adjacent to the location of them**(Al-Zuhari, 2008)**; second, no regulations have been issued to limit the minimum distance for constructing the

WWTP project from water bodies or public roadways; hence, the WWTP was located in close to rivers and main roads.

Table 11. The distances between the Al-Rustamiya northern WWTP location and its elevation with their rating values.

Groups	Factors	Standards	Buffer	Rating Level	Close affected place to the WWTP location	Distance or elevation value	Rating of factor
Environmental (Env.)	Distance from the population settlements (m)	> 6000 >5000-6000 >4000-5000 >3000-4000 >2000 -3000	2000	5 4 3 2 1	Al-Ameen Region	10	0
	Distance from protected areas (m)	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	Iraqi Reserve for Rare Birds in Al-Mada'in District	21,965	5
Economic (Eco.)	Topography of Baghdad (m.a.s.l)	≥27 - 32 >32-37 >37-42 >42-47 >47-52	-	5 4 3 2 1	Sea Level	36	4
	Distance from surface water bodies(m)	>500-1000 >1000-1500 >1500-2000 >2000-2500 >2500	500	5 4 3 2 1	Diyala River	110	0
	Distance from main and secondary roads (m)	>500-1000 >1000-1500 >1500-2000 >2000-2500 >2500	500	5 4 3 2 1	Baghdad-Kut highway	60	0
Social (Soc.)	Distance from educational places (m)	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	Technical Institute of Management/ Middle Technical University	4102	5
	Distance from Health places (m)	>3500 >2500-3500 >1500-2500 >1000-1500 >500-1000	500	5 4 3 2 1	Al-Ameen neighborhood clinic	1616	3

4. CONCLUSIONS

This study focused to develop decision-making strategy sustainable locations for WWTPs by using FAHP and apply the developed strategy to evaluate the major WWTPs locations in Baghdad. The results showed seven out of nine has got weight more than zero and used to form three equations to determine the total weight for the main groups factors and one main equation to calculate the total weights for the WWTP location. The evaluation of the major WWTPs locations in Baghdad concluded the total weights of Al-Karkh WWTP location was 0.3912448, Al-Rustamiya Southern WWTP location was 0.361084, and Al-Rustamiya Northern WWTP location was 0.3315004. All the plants' locations did not meet the limitation of factors (distance from population settlements, and distance from main and secondary roads) and Al-Rustamiya Southern and Northern WWTP locations of the factor distance from surface water bodies. It was also discovered that combining of FAHP with Google Earth tools to evaluate WWTP locations produces successful outcomes in determining the weight of each location and thus evaluating those sites. Furthermore, the study recommends that Baghdad Municipality authorities look for alternative locations that can be consistent with the developed strategy in this study. The study findings recommend adopting the proposed strategy for decision-making of WWTP location by the competent authorities when deciding to construct a new WWTP, due to the fact that it can be implemented by multiple metropolitan cities, not limited to Baghdad, because it was developed based on sustainability requirements, governmental legislation, and expert opinions from relevant departments involved in the construction and management of wastewater treatment plants in various Iraqi ministries.

Credit Authorship Contribution Statement

Wesam Mahmood: Writing - original draft, review and editing, research and Methodology.
Wadhah Amer Hatem: Supervision, Proofreading, and Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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تطوير استراتيجية صنع القرار بشأن المواقع المستدامة لمحطات معالجة مياه الصرف الصحي باستخدام تقنية FAHP :بغداد، دراسة حالة

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الخلاصة

نظرا للزيادة في النمو السكاني والتطور الحظري تواجه مواقع محطات معالجة مياه الصرف الصحي في المدن ذات الكثافة السكانية العالية مثل مدينة بغداد تحديات كبيرة في تلبية متطلبات معاييرالاستدامة وذلك بسبب التخطيط القديم لها وعدم وجود استراتيجية معتمدة وموثوقة لتقييم مواقعها وتحديد مواقع بديلة لانشاء مشاريع جديدة. تهدف هذه الدراسة إلى تطوير استراتيجية تساعد صناع القرار على تقييم مواقع محطات معالجة مياه الصرف الصحي الحالية و تحديد مواقع بديلة تلبي متطلبات الاستدامة باستخدام تقنية التسلسل الهرمي التحليلي الضبابي (FAHP) و ستم تطبيق الاستراتيجية المطورة لتقييم مواقع محطات معالجة مياه الصرف الصحي الرئيسية العاملة حليا في مدينة بغداد كحالة دراسية .حيث تم اختيار تسعة عوامل مؤثرة على تحديد مواقع المحطات ,بالاعتماد على دراسة سابقة, وتم تصنيفها الى ثلاثة مجاميع رئيسية اعتماداً على متطلبات الاستدامة وهي البيئية والاقتصادية والاجتماعية. تم عمل استبيات وفقاً لمتطلبات تقنية (FAHP) كطريقة لجميع البيانات وتم توزيعه على اثنا عشر خبيراً وبعد جمع اراء الخبراء تم تحليلها وفقة التقنية المعتمدة وتم حساب وزن كل عامل من العوامل المؤثرة. حيث حصل سبعة عوامل على اوزان مؤثرة بينما حصل اثنان منها على قيمة صفر وتم استبعادها. ومن ثم تم عمل استبيان ثاني لتحديد توزيع مسافات كل عامل من العوامل السبعة ذات الاوزان مع تقييم كل مسافة (من 1الى 5) بالاعتماد على نوع المجموعة وتم قبول المسافات وتقييمها من قبل الخبراء بنسبة عالية .وكنتيجة تم تطوير ثلاثة معادلات لحساب اوازن العوامل الفرعية المؤثرة لكل مجمعة ومعادلة رئيسية واحدة لحساب الأوزان الإجمالية لموقع محطة معالجة مياه الصرف الصحي. بعد تطبيق المعادلات المطورة على مواقع محطات معالجة مياه الصرف الصحي الرئيسية في بغداد، الكرخ، الرستمية الجنوبية، والرستمية الشمالية، أظهرت النتائج أن المواقع الثلاثة غير مناسبة بسبب فشلها في تلبية المحددات المعتمدة في الدراسة لكل من المسافة من التجمعات السكانية والطرق الرئيسية والثانوية، بالاضافة الى المسافة من المسطحات المائية السطحية في مواقع محطتي معالجة مياه الصرف الصحي الجنوبية والشمالية في الرستمية.

الكلمات المفتاحية: اتخاذ القرار ، FAHP، الموقع المستدام، موقع محطة معالجة مياه الصرف الصحي، بغداد.

Appendix A

وزارة التعليم العالي و البحث العلمي

جامعة بغداد

قسم الهندسة المدنية - ادارة المشاريع الانشائية

<u>استبيان (2)</u>

يقوم الباحث بإعداد اطروحة الدكتوراه في كلية الهندسة / جامعة بغداد تحت عنوان (استراتجيات مقترحة لادارة مشاريع الصرف الصحي في المدن الكبرى) حيث يستخدم الباحث تقنية التحليل الهرمي الضبابية FAHP لحساب الاسبقيات (الاولويات) للعوامل التي تؤثر في اختيار الموقع الامثل لمحطات معالجة مياه الصرف الصحي , راجين منكم الاجابة الدقيقة والصريحة حول ما تتضمنه استمارة الاستبيان مع ملاحظة ان جميع المعلومات في هذا الاستبيان سوف تستخدم لأغراض البحث العلمي فقط.

مع فائق الشكر والتقدير...

الباحث

وسام شاكر محمود

بإشراف أ. د. وضاح عامر حاتم

ملاحظة: 1- يرجى اختيار رقم من القيم في العمود الثاني من الجدول ادناه (من 1الى 9) بعد تحديد درجة الاهمية المقابلة لذلك الرقم والتي ترونها مناسبة لأهمية كل عنصر في الجهة اليمنى (الاعمدة) على العنصر المقابل له في الجهة العليا (الصفوف) لمصفوفات العوامل المؤثرة المدرجة في بقية صفحات الاستبيان.

ملاحظة:2- في حالة العكس اي ان العنصر في الجهة العليا (الصفوف) للمصفوفات اكثر اهمية فيتم تحديد درجة اهميته بالنسبة للعنصر المقابل في الجهة اليمنى (الاعمدة) ويكتب مقلوب تلك الدرجة.

ملاحظة :3- تم وضع رقم واحد في الحقول التي تتضمن مقارنة اي عنصر مع نفسه اي انهما متساويان كما تم تضليل بعض الحقول التي ليس المطلوب ملئها وانما المطلوب ملئ الحقول غير المظللة فقط للمصفوفات لان الحقول المظللة ستأخذ المقلوب الضربي للقيم في الحقول غير المظللة.

درجة الافضلية (الاهمية) لاحد النشاطين على الاخر (مقياس لغوي)	درجة الأفضلية			
	قيمة رقمية	الشرح	قيمة رقمية ضبابية	مقلوب القيمة الرقمية الضبابية
اهمية متساوية	1	النشاطان متساويان في الاهمية	(1,1,1)	(1,1,1)
اهمية متساوية الى متوسطة	2	نشاط له اهمية متساوية الى متوسطة على الاخر (بين 3-1)	(1,2,3)	(1/3,1/2,1)
اهمية متوسطة	3	الخبرة والتقدير يفضلان نشاطا على الاخر بدرجة بسيطة	(2,3,4)	(1/4,1/3,1/2)
اهمية متوسطة الى قوية	4	نشاط له اهمية متوسطة الى قوية على الاخر اي بين 5-3	(3,4,5)	(1/5,1/4,1/3)
اهمية قوية	5	الخبرة والتقدير يفضلان بقوة نشاطا على الاخر	(4,5,6)	(1/6,1/5,1/4)
اهمية قوية الى قوية جدا	6	نشاط له اهمية قوية الى قوية جدا على الاخر اي بين 7-5	(5,6,7)	(1/7,1/6,1/5)
اهمية قوية جدا	7	الخبرة والتقدير يفضلان بدرجة كبيرة جدا نشاطا على الاخر	(6,7,8)	(1/8,1/7,1/6)
اهمية قوية جدا الى تامة	8	نشاط له اهمية قوية جدا الى تامة على الاخر اي بين 9-7	(7,8,9)	(1/9,1/8,1/7)
اهمية قصوى	9	الدليل على تفضيل نشاط على اخر يمثل اعلى درجة ممكنة من التأكيد	(8,9,10)	(1/10,1/9,1/8)

مثال توضيحي :

ت	العوامل الاجتماعية	1. المسافة من المؤسسات التعليمية	2. المسافة الى المواقع التاريخية والدينية	3. المسافة الى المؤسسات الصحية
1	المسافة الى المؤسسات التعليمية	1	3	1
2	المسافة الى المواقع التاريخية والدينية	1/3	1	1/5
3	المسافة الى المؤسسات الصحية	1	5	1

عند مقارنة مدى اهمية عامل (المسافة الى المؤسسات التعليمية) في التسلسل (1) من عمود المصفوفة في الجدول اعلاه مع عامل (المسافة الى المواقع التاريخية والدينية) في التسلسل (2) من صف المصفوفة (الافقي) من الجدول اعلاه, نلاحظ ان القيمة المعطاة من قبل المستبين هي (3) يعني ان عامل (المسافة الى المؤسسات التعليمية) له اهمية اكثر بثلاث مرات (اي له اهمية معتدلة او بسيطة نسبيا) عن عامل (المسافة الى المواقع التاريخية والدينية), وبشكل تلقائي يكون العكس اي ان اهمية عامل (المسافة الى المواقع التاريخية والدينية) مقارنة بأهمية عامل (المسافة الى المؤسسات التعليمية) هي المعكوس الضربي للقيمة (3) اي (1/3) الذي سيدرج من قبل الباحث في الحقل المقابل المضلل.

وعند مقارنة مدى اهمية عامل (المسافة الى المؤسسات التعليمية) في التسلسل (1) من عمود المصفوفة مع عامل (المسافة الى المؤسسات الصحية) في التسلسل (3) من صف المصفوفة (الافقي) يلاحظ ان القيمة المعطاة هي (1) اي ان عامل المسافة الى المؤسسات التعليمية له نفس درجة اهمية عامل المسافة الى المؤسسات الصحية.

وعند مقارنة مدى اهمية عامل (المسافة الى المواقع التاريخية والدينية) في التسلسل (2) من عمود المصفوفة مع عامل (المسافة الى المؤسسات الصحية) في التسلسل (3) من صف المصفوفة (الافقي), نلاحظ ان القيمة المعطاة من قبل المستبين هي (1/5) هذا يعني ان عامل (المسافة الى المؤسسات الصحية) له اهمية اكثر بخمس مرات (اي انه له اهمية كبيرة) عن عامل (المسافة الى المواقع التاريخية والدينية), وبشكل تلقائي يكون العكس اي ان اهمية عامل ((المسافة الى المؤسسات الصحية) مقارنة بأهمية عامل (المسافة الى المواقع التاريخية والدينية) هي المعكوس الضربي للقيمة (1/5) اي (5) الذي سيدرج من قبل الباحث في الحقل المقابل المضلل.

اولا : معلومات المستبين :

1- الموقع الوظيفي ومكان العمل؟....................................

2- المؤهل العلمي والتخصص ؟ ....

3- خبرتكم العملية ؟

□ اقل من 10 سنوات □ من 11- 15سنة □ من 16- 20 سنة □ اكثر من 20 سنة

ثانياً:

العوامل الرئيسية التي تؤثر في اختيار موقع محطات معالجة الصرف الصحي:

ت	العوامل الرئيسية	العوامل البيئية	العوامل الاقتصادية	العوامل الاجتماعية
1	العوامل البيئية	1		
2	العوامل الاقتصادية		1	
3	العوامل الاجتماعية			1

1- العوامل الفرعية المرتبطة بالعامل الرئيسي (العوامل البيئية) التي تؤثر في اختيار موقع محطات معالجة الصرف الصحي:

ت	العوامل البيئية	المسافة الى التجمعات السكانية	المسافة الى الابار والمياه الجوفية	المسافة الى المناطق المحمية
1	المسافة الى التجمعات السكانية	1		
2	المسافة الى الابار والمياه الجوفية		1	
3	المسافة الى المناطق المحمية			1

2- العوامل الفرعية المرتبطة بالعامل الرئيسي (العوامل الاقتصادية) التي تؤثر في اختيار موقع محطات معالجة الصرف الصحي:

ت	العوامل الاقتصادية	طوبغرافية المنطقة	المسافة من مسطحات المياه السطحية	المسافة من الطرق الرئيسية والفرعية
1	طوبغرافية المنطقة	1		
2	المسافة من مسطحات المياه السطحية		1	
3	المسافة من الطرق الرئيسية والفرعية			1

3- العوامل الفرعية المرتبطة بالعامل الرئيسي (العوامل الاجتماعية) التي تؤثر في اختيار موقع محطات معالجة الصرف الصحي :

ت	العوامل الاجتماعية	المسافة الى المؤسسات التعليمية	المسافة الى المواقع الدينية و التاريخية	المسافة الى المؤسسات الصحية
1	المسافة الى المؤسسات التعليمية	1		
2	المسافة الى المواقع الدينية و التاريخية		1	
3	المسافة الى المؤسسات الصحية			1