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ORIGINAL

Factors affecting the decision-making of appropriate sites for WWTPs

Factores que afectan a la toma de decisiones para las EDAR

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ABSTRACT

The aim of this research was to examine the factors associated in decision-making processes for the selection and evaluation of optimal sites for wastewater treatment plants (WWTPs). The data for this study was collected by an established questionnaire, which received responses from a total of 62 engineers with various specialties These engineers are employed in both the public and private sectors. The reliability and validity of the questionnaire were investigated with the use of Cronbach's Alpha, which showed that the results were consistent with acceptable standards. The Relative Importance Index (RII) technique was employed to evaluate the responses for the 31 factors. The study's findings indicate that the distance from population settlements had the highest level of importance according to the RII scale. This was followed by the distance from wells or groundwater, and then the distance from historical and religious areas. The temperature factor had the lowest RII score in this research.

Keywords: Decision-Making; Wastewater Treatment Plants (Wwtps); Site of Wwtps; Relative Importance Index(RII); Factors Affecting.

RESUMEN

El objetivo de esta investigación era examinar los factores asociados a los procesos de toma de decisiones para la selección y evaluación de los emplazamientos óptimos de las estaciones depuradoras de aguas residuales (EDAR). Los datos para este estudio se recogieron mediante un cuestionario establecido, que recibió respuestas de un total de 62 ingenieros de diversas especialidades Estos ingenieros trabajan tanto en el sector público como en el privado. La fiabilidad y validez del cuestionario se investigaron mediante el alfa de Cronbach, que demostró que los resultados se ajustaban a normas aceptables. Se empleó la técnica del Índice de Importancia Relativa (IIR) para evaluar las respuestas correspondientes a los 31 factores. Los resultados del estudio indican que la distancia a los asentamientos de población tenía el mayor nivel de importancia según la escala RII. Le siguieron la distancia a pozos o aguas subterráneas y la distancia a zonas históricas y religiosas. El factor temperatura obtuvo la puntuación RII más baja en esta investigación.

Palabras clave: Toma de Decisiones; Estaciones Depuradoras de Aguas Residuales (EDAR); Emplazamiento de EDAR; Índice de Importancia Relativa(IIR); Factores que Afectan.

INTRODUCTION

Supporting decision-making is essential for planning for construction complex infrastructure projects.[1] The previous evidence shows that infrastructure project planning is delicate and dependent on numerous factors, the majority of it have been developed and influenced by project stakeholders.[2] For Planning to meet long-term sustainability, this impacting factors should be addressed. Municipal infrastructures, such as, landfills, construction & demolition waste recycling plant, hospitals and power plants, have all been the subject of several studies.[3,4,5,6] However, wastewater treatment plants (WWTPs) placement selection follows a distinct theoretical model than that of other forms of metropolitan infrastructure. Location decisions for WWTPs are complicated by their unique characteristics; in addition to demand and site quality, planners must take into account prohibited development zones mandated by legislation. As well as, identifying an appropriate site for a wastewater treatment plant (WWTP) can be a difficult and time-consuming endeavor for the relevant government agency due to the interplay of multiple geographical considerations.[7]

There are many factors that can be identified from the literature and the experts that affect the selection of the optimal location for the WWTPs; consequently, it is difficult to consider all of them, so it is necessary to choose the most significant factors to be adopted by the planners and apply the tools to review the most suitable location to construct WWTPs. To determine the most significant factors, Relative Importance Index (RII) method that widely using to analyze the result of survey that has been built according to Likert scale.[8,9,10,11] Prior academic research has made beginning attempts to present decision-making tools for managers to utilize during the site selection process. These decision-making aids rely on specific parameters and consider the data's availability.[12,13,14,15] However, only a limited number of research have focused on identifying the key factors that determine the appropriate location for WWTPs.[12,14,16,17] Therefore, this paper attempt to study the factors affecting on decision-making for selecting and evaluating the optimal location for wastewater treatment plants by using the RII technique.

Identifying factors affecting on WWTPs location

Various writers have regarded them to be independent factors for the evaluation and selection of wastewater treatment plant (WWTP) sites due to their adoption of different recommended factors across diverse geographies. Prior studies have found several variables that impact the selection of the most suitable site for WWTPs (table 1).

Table 1. List of the factors that collected form literatures

Factor	Symbol	References
Distance from the population settlements (m)	F1	(12,13,14,15,17,18,19,20,21,22,24,25,26,27,28,31)
Distance from wells or groundwater (m)	F2	(13,16,17,20,23,25)
Distance from protected areas (m)	F3	(16,19,20)
Slope of site area %	F4	(12,14,15,16,17,18,19,20,21,22,24,26,28,29)
Distance from main and secondary roads (m)	F5	(12,13,15,16,17,18,19,20,22,23,24,26,27,28,30,31)
Distance from power transmission line (m)	F6	(20)
Distance from surface water bodies(m)	F7	(12,13,14,15,16,17,18,20,23,25,27,28,29,30,31)
Distance from faults (m)	F8	(24,25,27,28,30,31)
Distance from industrial sites (m)	F9	(20)
Distance from water transmission line (m)	F10	(20)
Distance from oil transmission line (m)	F11	(20)
Distance from Natural gas transmission line (m)	F12	(20)
Distance from agricultural land	F13	(12,17,18,22)
Distance from sewage network	F14	(12,15,24,26)
Distance from historical and religion areas	F15	(12,14,16,20)
Customizing of land use	F16	(12,14,15,16,17,19,21,22,23,24,26,28,29,30)
Distance from educational places	F17	(15)
Geological (Soil & Lithology) nature of the site	F18	(16,17,19,21,11,12,15,19)
Topography	F19	(7,11,12,13,19)
Distance from Railway network (m)	F20	(17,19)
Temperature	F21	(17)
Cost of owned the site ($)	F22	(21)

Technology that used in treatment	F23	(21)
Wind direction	F24	(12,15)
Distance from Airports locations (m)	F25	(13,17)
Location of water supply intake points (m)	F26	(14)
Urban stream direction (m)	F27	(15)
Distance from the flooded Areas (m)	F28	(16)
Distance from the military places (m)	F29	(16)
Distance from Health places (m)	F30	(15)
Depth of subsurface water	F31	(32)

Research objectives

In order determine the factors that warrant consideration and inclusion, and the obtaining factors will be ranked based on their Relative Importance Index values.

Research methodology

The methodology of the current study is briefly described in the following points:

- Collecting key data and information through both theoretical and practical research on the subject of the study, and utilizing a research map to select and evaluate the optimal site for WWTPs.
- Determine the variables by analyzing the available literature, as the majority of studies have focused on the topic being investigated.
- Selecting the study sample and identifying the factors through the use of a closed questionnaire to gather information from the literature review.
- Prioritizing the aspects based on their significance using the RII method, with a scale ranging from 1 (very low) to 5 (extremely high).

Viability assessment for the closed questionnaire form

A preliminary research may be employed to validate and assess closed questionnaires.(15) A pilot study refers to the administration of a questionnaire that involves the evaluation of question design. Its purpose is to analyze the efficacy of different data gathering methods by finding and evaluating the most difficult queries.(33) During this stage, the questions are assessed for their clarity and potential concerns are identified. The closed questionnaire distribution for this pilot project included an evaluation panel that possessed a minimum of 15 years of experience. The closed questionnaire form underwent evaluation and examination by professionals, who verified the validity and appropriateness of its components. The researchers gathered and evaluated all recommendations and comments, and engaged in discussions regarding all proposed improvements and suggestions.(34)

Distribution of closed questionnaire form

Closed questionnaires were distributed to a nominated group of Iraqi engineers who worked in both public and private sectors. Out of the 75 survey forms that were distributed, a total of 66 forms were collected. However, it is important to note that certain samples were removed from the analysis due to insufficient data and information. A total of 62 collected questionnaire forms have been utilized in the analysis.

Quantitative data analysis

The collection and analysis of quantitative data were conducted utilizing a statistical software program, specifically IBM/SPSS V25. The factors were computed for the purpose of ranking through the utilization of the RII technique. The Relative Importance Index (RII) was employed to assess the significance of each recommendation as indicated by the participants.(35) The calculation of the RII the selected factors is performed according to the equation 1:(10,11)

$$RII = \frac{\sum W}{A * N} \qquad (1)$$

Where
RII: is the relative importance index its value ranged from 0 to 1
W: is the weight given to the factors by the responders from 1 to 5 (1 is less significant and 5 is highly significant),
A: is the total number of responses for that factors of option
N: is the highest weight (in case 5)

The relative significance index (RII) is a numerical scale that spans from 0 to 1. A higher RII value indicates a greater level of hazard perception in relation to exposure from construction-related activities. The values of RII have been categorized as follows: High (H) (0,8≤RII≤1), High-Medium (H-M) (0,6≤RII<0,8), Medium (M) (0,4≤RII<0,6), Medium-Low (M-L) (0,2≤RII<0,4), and Low (L) (0≤RII<0,2). These categories are used to define the levels of importance for the examined attributes.[36]

Examination of Reliability and validity

Validity and reliability are widely recognized as crucial factors in the design of research tools. Hence, it is imperative to establish the validity and reliability of the closed questionnaires to doing any statistical analyses on the collected data.

The concept of "reliability" pertains to the assessment of accurate outcomes and the implementation of measures to ensure consistency and fairness. The aspect of reliability is essential in assessing the suitability of a technique for measuring historical building characteristics, although it alone is not adequate. The determination of the value of Reliability can be ascertained by calculating the value of Cronbach's Alpha (α) (equation 2).[37]

$$\alpha = \frac{N * \overline{c}}{\overline{v} + (N-1) * \overline{c}} \qquad (2)$$

Where:
N: number of items
$\bar{c}$: mean covariance between items.
$\bar{v}$: mean item variance

George and Mallery (2003)[36] established a guideline for evaluating the Cronbach's Alpha coefficient for an instrument that uses a dichotomous or Likert scale as it presented in table 2. The Cronbach's Alpha is a statistical measure that ranges from 0 to 1. A higher Cronbach's Alpha value indicates stronger internal consistency of the item within the scale. George and Mallory (2003) [37] state that a Cronbach's Alpha value equal or greater than 0,90 shows exceptional internal consistency, while a value equal or greater than 0,80 and less than 0,9 is considered good, equal or greater than 0,70 and less than 0,8 is acceptable, equal or greater than 0,60 and less than 0,7 is Questionable, equal or greater than 0,50 and less than 0,6 poor, and below 0,50 is considered unsatisfactory.

Table 2. Cronbach's Alpha assessment

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0{,}9$	Excellent
$0{,}8 \leq \alpha < 0{,}9$	Good
$0{,}7 \leq \alpha < 0{,}8$	Acceptable
$0{,}6 \leq \alpha < 0{,}7$	Questionable
$0{,}5 \leq \alpha < 0{,}6$	Poor
$\alpha < 0{,}5$	Unacceptable

In order to determine the validity of an assessment, it is necessary to develop a correlation connecting the assessment and the conduct that it intends to evaluate, surpassing the significance of any individual statistical instrument. Ensuring the validity of the test is of utmost importance in order to accurately utilize and interpret the obtained outcomes. The concept of validity can be quantitatively measured by using the square root of the coefficient of reliability, as indicated by reference(equation 3).[38]

$$V = \sqrt[2]{\alpha} \qquad (3)$$

where
V: is the validity
α: is the reliability.

RESULTS AND DISCUSSION

The decision-making process of the primary assessment standards was conducted utilizing the SPSS V25 software for statistical analysis. After distributing and retrieving of the administered questionnaire forms, the subsequent step procedure involved selecting an accurate statistical and measuring approach to facilitate the computation and interpretation of the collected data. The findings are presented in tables in order to improve both understanding and simplicity.

Reliability and validity for the closed questionnaire

The majority of social scientific research scenarios utilize the Cronbach's alpha coefficient. If the value surpasses 0,7, the consistency index indicates a significant level of reliability, rendering it a satisfactory result.[34] Table 3 presents the reliability and validity of every factor related to decision-making of a suitable location for WWTPs the as obtained from the closed questionnaire. Based on the findings, the questionnaire demonstrates satisfactory reliability (based on the assessment standard that presented in Table 2) for each single factor and for the whole questionnaire with Cronbach's Alpha value about (0,74).

Analysis of the closed questionnaire forms

The initial phase of a closed questionnaire entails providing an overview of the participants' collective background and overall encounters. The subsequent phase involves an evaluation of the established factors. The participants were instructed to indicate the characteristics they considered significant for decision-making regarding the selection of appropriate locations for wastewater treatment plants (WWTPs) through a closed questionnaire. Relative Importance Indexes (RIIs) were subsequently computed. The subsequent analysis and discussion of the findings will be structured in accordance with the aforementioned components in the two following parts, so enabling a distinct examination and discussion of each part.

1) Part One: Personal Information

The first part encompasses the collection of personal information through the utilization of closed questionnaire forms.

Figure 1 illustrates the frequency distribution of participants according to their scientific qualifications. It reveals that 42 % of respondents hold a bachelor's degree, 31 % possess a master's degree, and 27 % have obtained a doctoral degree.

Figure 2 displays the distribution of respondents' level of experience. It shows that 39 % of respondents have more than 20 years of experience, 26 % have between 16 to 20 years of experience, 21 % have between 11 to 15 years of experience, 11 % have between 6 to 10 years of experience, and only 3 % have less than 5 years of experience. The data on respondents' level of experience indicates that almost two-thirds possess over 16 years of expertise, which aligns with the acceptable standard set by the Iraqi Engineers Union system. According to their regulations, engineers with more than 14 years of practical experience are eligible to obtain consultant licenses.

Figure 3 illustrates the engineering specializations of the questionnaire respondents. The data reveals that civil engineers represent the largest group, accounting for 45 % of the respondents. Environmental and sanitary engineers make up 15 % of the participants, followed by chemical engineers at 13 %, mechanical engineers at 11 %, and both water resources and electrical engineers at 8 % each.

Figure 4 represents the distribution of respondents according to their working sector. It reveals that around 76 % of the respondents are employed in the public sector, while just 24 % work in the private sector.

Table 3. The reliability (Cronbach's alpha) and validity values for the closed questionnaire

Factor symbol	Reliability (Cronbach's Alpha(α))	Validity coefficient (V)
F1	0,735	0,857
F2	0,73	0,854
F3	0,726	0,852
F4	0,741	0,861
F5	0,73	0,854
F6	0,728	0,853
F7	0,73	0,854
F8	0,723	0,850
F9	0,708	0,841
F10	0,718	0,847
F11	0,731	0,855

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F12	0,715	0,846
F13	0,721	0,849
F14	0,732	0,856
F15	0,74	0,860
F16	0,733	0,856
F17	0,722	0,850
F18	0,745	0,863
F19	0,721	0,849
F20	0,704	0,839
F21	0,713	0,844
F22	0,732	0,856
F23	0,747	0,864
F24	0,764	0,874
F25	0,711	0,843
F26	0,717	0,847
F27	0,731	0,855
F28	0,732	0,856
F29	0,741	0,861
F30	0,736	0,858
F31	0,733	0,856

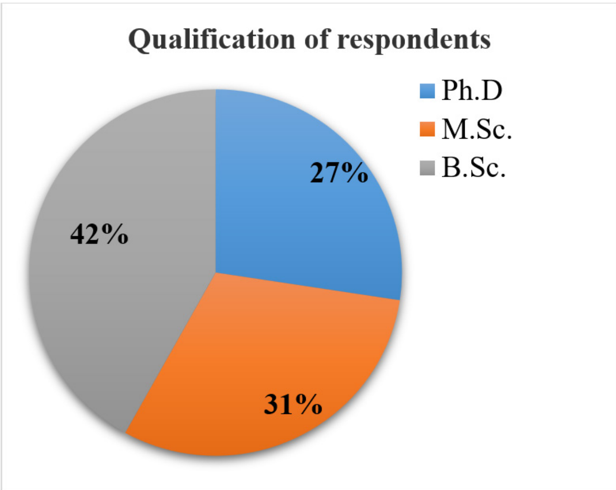

Figure 1. The qualification for the respondents

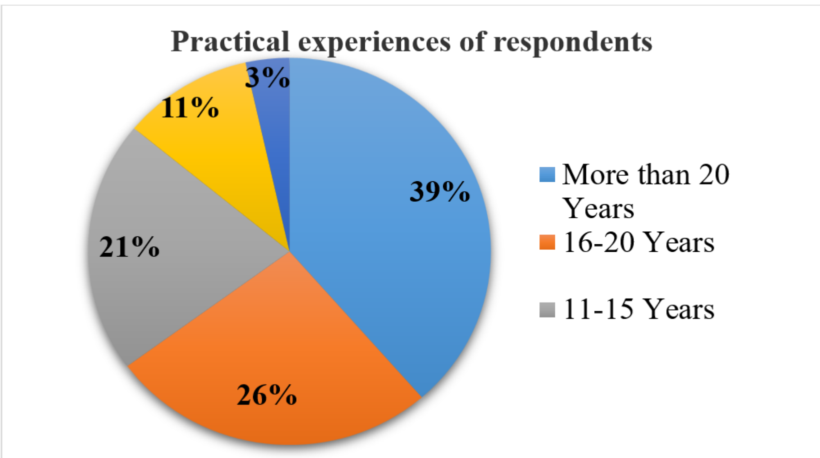

Figure 2. Practical experiences of respondents

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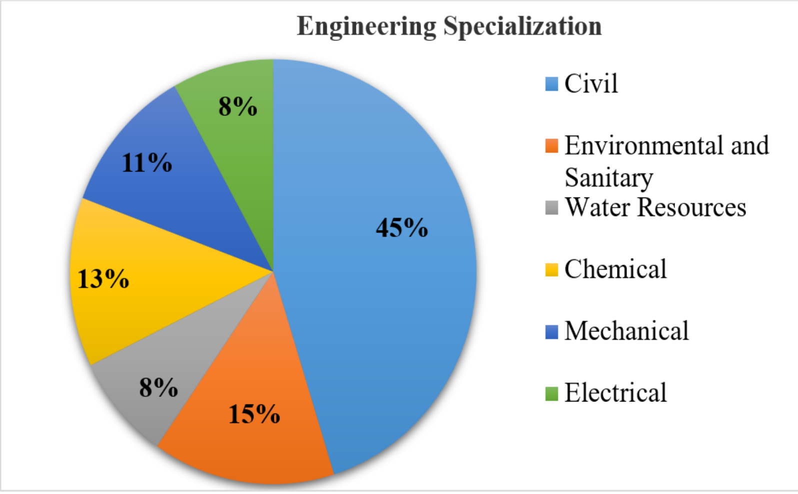

Figure 3. The engineering specializations of the questionnaire's respondents

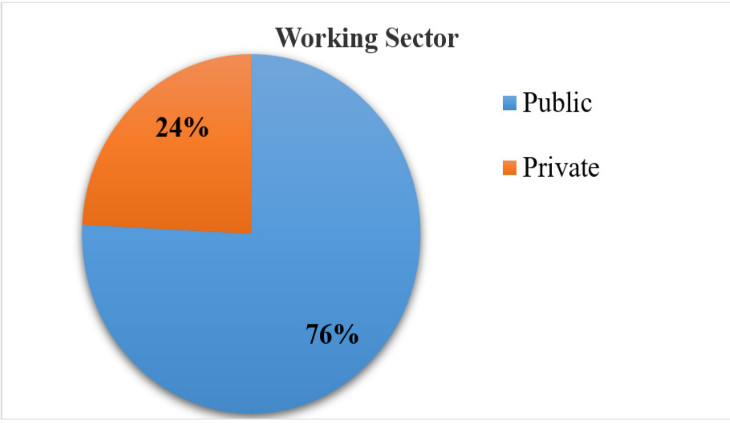

Figure 4. Working sector for the respondents

2) Part Two: Evaluation of the factors

The second part of the study involves the assessment of the decision-making factors utilized by the respondents in determining an appropriate location for wastewater treatment plants (WWTPs). The RII has been applied to assess each factor in order to determine the ranking of factors as it shown in table (4) that presents the assessment and ranking of the factors in descending order of relevance.

The assessment indicated that the factor with the highest Relative Importance Index (RII) value is the distance from population settlements, with a value of 0,971. The second highest RII value is associated with the distance from wells or groundwater, with a value of 0,877. Additionally, the factor of distance from historical and religious areas ranked third, with a value of 0,865. However, the results indicate that the temperature factor had the lowest RII score, with a value of 0,597. Furthermore, the research findings indicate that out of a total of 31 components, 6 factors were classified as having a high level indicator(H), while 24 factors were assessed as having a high to medium level indicator(H_M). Only one factor was assessed as having a medium level indicator(M). These results were obtained using the RII analysis, using the classification system proposed by Akadiri (2011).[36]

Table 4. The RII analysis ranking for the factors that affect the decision-making process for identifying suitable sites for WWTPs

Factor symbol	Factors	Mean	RII	Indicator
F1	Distance from the population settlements (m)	4,855	0,971	H
F2	Distance from wells or groundwater (m)	4,387	0,877	H
F15	Distance from historical and religion areas.	4,323	0,865	H
F3	Distance from protected areas (m)	4,258	0,852	H
F7	Distance from surface water bodies(m)	4,258	0,852	H
F30	Distance from Health places (m)	4,081	0,816	H

F5	Distance from main and secondary roads (m)	3,968	0,794	H-M
F19	Topography	3,774	0,755	H-M
F17	Distance from educational places	3,645	0,729	H-M
F24	Wind direction	3,371	0,674	H-M
F10	Distance from water transmission line (m)	3,355	0,671	H-M
F22	Cost of owned the site ($)	3,355	0,671	H-M
F14	Distance from sewage network .	3,339	0,668	H-M
F6	Distance from power transmission line (m)	3,323	0,665	H-M
F18	Geological (Soil & Lithology) nature of the site	3,323	0,665	H-M
F31	Depth of subsurface water	3,323	0,665	H-M
F11	Distance from oil transmission line (m)	3,306	0,661	H-M
F20	Distance from Railway network (m)	3,306	0,661	H-M
F25	Distance from Airports locations (m)	3,306	0,661	H-M
F12	Distance from Natural gas transmission line (m)	3,290	0,658	H-M
F9	Distance from industrial sites (m)	3,274	0,655	H-M
F23	Technology that used in treatment	3,274	0,655	H-M
F8	Distance from faults (m)	3,242	0,648	H-M
F16	Customizing of land use	3,242	0,648	H-M
F27	Urban stream direction (m)	3,226	0,645	H-M
F28	Distance from the flooded Areas (m)	3,210	0,642	H-M
F13	Distance from agricultural land.	3,194	0,639	H-M
F26	Location of water supply intake points (m)	3,194	0,639	H-M
F29	Distance from the military places (m)	3,194	0,639	H-M
F4	Slope of site area %	3,081	0,616	H-M
F21	Temperature	2,984	0,597	M

CONCLUSION

This study describes the development of a set of evaluation parameters that influence decision-making in the selection and evaluation of the best optimal location for wastewater treatment plants. This research found a total of 31 factors through a full literature investigation, fieldwork, and discussions with experts from several governorates. The questionnaire's reliability and validity were assessed using Cronbach's Alpha, indicating that the results met acceptable levels consistently. The RII calculation and analysis were employed to prioritise the components based on their level of importance, ranging from the most significant to the least significant. The research conducted a comparison of the perceived importance of the factors by the respondents using these rankings. The examination revealed that the distance from population settlements has the highest Relative Importance Index (RII) value, which is at 0,971. The RII value of 0,877 is the second highest and is linked to the distance from wells or groundwater. Furthermore, the variable of proximity to historical and religious sites was rated third, with a coefficient of 0,865. However, the findings demonstrate that the temperature variable exhibited the lowest Relative Importance Index (RII) score, specifically measuring at 0,597.

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