Evaluation of the factors affecting for selection the optimal site for construction & demolition waste recycling

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Abstract. Iraq suffers from a large proportion of construction and demolition waste (C&DW) not exploited and causes a lot of environmental and health problems, therefore it is necessary to recycle this waste. The researcher used five point Likert scale to find out the degree of influence for the concluded factors on choosing an optimum site for recycling (C&DW) in Baghdad Governorate. The researcher received 40 of (44) distributed questionnaire. The results showed that all factors have a high (RII). The sequences of the main and sub- factors in terms of the importance were environmental: (distance to surface water, distance to reserves and natural attraction areas, distance to natural and national parks, distance to airports, distance to the military bases), economical: (the distance to the secondary sorting sites for (C&DW), the distance to the sanitary landfill of (C&DW), the distance from the highway taboo, land ownership, the distance to the rail network, the distance to the areas which constructed more than 50 years ago, the distance to the quarries in the region, the degree of inclination or slope of the land), social: (distance to the population groupings, distance to cultural and religious milestones, distance to historical monuments), technical: (available land area, land type).

Keywords: Factor, Site, Recycling, Construction, Demolition, Waste.

1. Introduction
C&DW means the waste resulting from construction, demolition, renewal, extension, repair of buildings, roads, bridges such as concrete, brick, wood, glass, aluminum, iron, Plastics, asphalt, These wastes differ from one facility to another, but the benefits of their reduction, reuse and recycling give additional efficiency[1]. Sites of recycle the (C&DW) are recycling the (C&DW) by special sites and represent reasonable substitutes to existing treatment methods which are unsustainable, like landfills and fly-tipping. These existing methods represent two popular practices for poor C&DW disposal in many countries, especially developing countries such as Iraq. Landfills of the C&DW have several disadvantages, from this disadvantages:
1. They consume large area.
2. They produce prejudicial chemical precipitate
3. Air pollution produced by anaerobic degradation
4. Landfill gas produced by organic waste
5. Other contaminants
These disadvantages contribute in toxic effects on the surface water, ground, and the soil putrefaction [2][3].
Many countries have succeeded in producing construction materials play the same role as traditional construction materials by recycling (C&DW) in order to provide the exploitation of natural resources and achieving the principle of sustainability for future generations.

The process of selection for the optimal site of (C&DW) recycling is a difficult problem because making such a decision depends on many factors affecting the feasibility of establishing it [4]. The Mayoralty of Baghdad adopts only two factors to choose a site of recycling (C&DW) according to the instructions of the environmental determinants for constructing projects and monitoring the safety of their implementation No. (3) for the year 2011 [5], which determined the lowest distance for crushers factories from population groupings and the taboo of highway, although there are many other important factors that are taken into consideration in other countries.

The Baghdad Municipality owns four crushers. The crushers are transferred to random places in which the residents and perhaps the municipal departments throw the (C&DW), as the availability of large quantities of (C&DW) in any place is considered a basic factor for transporting crushers to that site for carrying out the process of recycling those waste.

2. Problems statement:
The research problem assumes the following:
   1. All sites for recycling the construction and demolition waste in Baghdad governorate are temporary and irregular, and they are chosen on the basis of the availability of a stack of construction and demolition waste.
   2. Iraqi legislation adopted only two factors affecting the choice of a site for recycling construction and demolition waste, and did not take into account many of the factors adopted

3. The quantities generated from construction and demolition waste in Baghdad Governorate:
To establish fixed site for recycling (C&DW), it is necessary to know the quantities and distribution of these wastes within the study area. The quantities of construction and demolition waste are calculated annually for the Baghdad governorate and in addition to other governorates at the end of each year by the Ministry of Planning - Central Bureau of Statistics - Department of Environmental Statistics [6] as shown in Table (1).

| S | Year | Quantity of C&DW in Baghdad Governorate t/y |
|---|------|---------------------------------------------|
| 1 | 2015 | 598,892                                     |
| 2 | 2016 | 98,701.8                                    |
| 3 | 2017 | 177,190.4                                   |
| 4 | 2018 | 167,776                                     |

4. Research Methodology
4.1. Data collection
The researcher made several field visits to the Mayoralty of Baghdad for the purpose of examining the factors and determinants approved by them in selecting an optimal site for recycling construction and demolition waste. The researcher found that the factors approved by them are only two according to the instructions of the environmental determinants for constructing projects and monitoring the safety of their implementation No. (3) for the year 2011 [5], which determined the lowest distance for crushers factories from population groupings and the highway taboo.

After that the researcher reviewed many of declared paper, thesis and books to collect the factors affecting on selecting the optimal site for construction & demolition waste recycling, the collected factors from this theoretical studies reached (22) factor including the two factors approved by the Mayoralty of Baghdad and (10) factors suggested and added from the researcher, all factors became (32) distributed on groups, each group shares with particular features put under a key factor, the main factors which conducted are (4) as shown in Table (2).
Table 2. All factors before filtering them by experts.

| S   | Factor                                                                 | Source               |
|-----|------------------------------------------------------------------------|----------------------|
| 1   | Distance to the surface water                                         | [7][8]               |
| 2   | Distance to the water source protection area                          | [8]                  |
| 3   | Distance to the nature reserve                                        | [8]                  |
| 4   | Distance to the airport                                               | [8]                  |
| 5   | Distance to the Special Land                                          | [8]                  |
| 6   | Agricultural Land                                                     | [8]                  |
| 7   | Distance to the natural and National parks                             | [7]                  |
| 8   | Distance to the protected land                                        | [7]                  |
| 9   | Distance to the Areas of special protection in the region             | [7]                  |
| 10  | Distance to the cultural attractions                                  | [8]                  |
| 11  | Distance to the natural attractions                                   | [8]                  |
| 12  | Distance to the historical relics or Natural monuments                 | [7][8]               |
| 13  | Distance to the urban residents (settlements)                          | [7][8]               |
| 14  | Distance to the rural residents                                       | [8]                  |
| 15  | Distance to the Railway Network                                        | [7]                  |
| 16  | Industrial land                                                       | [7]                  |
| 17  | Special Projects of Regional Interest                                 | [7]                  |
| 18  | Slopes degree (%)                                                     | [7][8]               |
| 19  | Altitude                                                               | [8]                  |
| 20  | Distance to the main roads                                            | [7][8]               |
| 21  | Distance to the potential demolished buildings in the next 20 years or | [8]                  |
|     | Geographical distribution of construction waste (Distance from C&DW    |                      |
|     | sources)                                                               |                      |
| 22  | Land price                                                             | [8]                  |
| 23  | Distance from construction sanitary landfill sites                     | [Researcher]         |
| 24  | Type of (C&DW) in the area                                            | [Researcher]         |
| 25  | The nature of virgin construction materials available in the region   | [Researcher]         |
| 26  | Prices of virgin construction materials available in the region        | [Researcher]         |
| 27  | The location of the site relative to the municipal departments in the  | [Researcher]         |
|     | governorate or to secondary sorting sites                             |                      |
| 28  | The size of the construction market in the region                     | [Researcher]         |
| 29  | Available land area for the factory                                   | [Researcher]         |
| 30  | Existence of legislations imposes the use of recycled materials in the | [Researcher]         |
|     | area                                                                   |                      |
| 31  | Existence of legislations imposes taxes or fees on extracting virgin   | [Researcher]         |
|     | material from quarries in the area                                     |                      |
| 32  | Acceptance the customers in the area to use recycled construction      | [Researcher]         |
|     | materials                                                              |                      |

4.2. Preliminary test for the questionnaire data

After reviewing the literature which regard with C&DW recycling and preparation the preliminary questionnaire form, the researcher sent it to a group of experts who have experience in the field of water quality and environmental engineering and practical practice in construction and demolition waste recycling to know their opinion about it and its suitability to the reality of the Baghdad Governorate, the experts have deleted and merged some sub-factors in addition to adding new factors to suit the reality of Baghdad Governorate, Also they transferred some sub-factors from one group to another. The opinion and notes of the experts helped the researcher to formulate the questions and the questionnaire form. The final sub-factors became (18) distributed in (4) groups.
4.3. Conducting combined (closed–open) Questionnaire
The combined questionnaire is one of the methods which used in the researches to collect the information about closed questions which Require specific answers and Selections and open questions which Require free answers to know the opinion of the respondent about many subjects like adding any other affecting factors do not list in the questionnaire which the respondent sees it important. The following steps used to conduct the combined questionnaire:
1. Designing the general frame of the questionnaire and specify lines of questions.
2. Converting the paper questionnaire to electronic
3. Distributing the questionnaire among the study sample electronically to obtain their answers to the questions.
4. Collecting the questionnaire answers and reviews them.
5. Performing the mathematical and statistical analysis by using (SPSS V. 25) program.

5. Selection of the Research Sample
The researcher distributed (44) questionnaires for the private and public sector. The number of questionnaires which received is (40), all of them are valid.

6. Calculating the Arithmetic Mean and Relative Importance Index
The analysis of the data obtained from the five-scale Likert and calculate the arithmetic mean require identifying method of evaluation the Answers. The contribution of each of the factors affecting on selecting the optimal site for (C&DW) recycling was examined, and the factors ranked according to their importance as perceived by the respondents was done by use of relative importance index (RII) which was computed using equation (1).The results of the Respondents' answers analysis were listed in the tables 3 to 6. [9][10] [11].

\[
\text{RII} = \sum \frac{W}{(A \times N)}
\]

Where:
\( W \) = The given weight to each factor by the respondents
\( A \) = Highest weight (i.e., 5) in this case.
\( N \) = The total number of respondents.
The equations (2,3) was used to calculate Arithmetic Mean (AM) and Standard Deviation [12].

\[
\text{AM} = \frac{\sum (\text{Weight Value for particular } + \text{number of frequencies})}{\text{Total number of the answers}}
\]

\[
\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (X_i - \mu)^2}
\]

Where:
\( X_i \): An individual value
\( \mu \): The mean /expected value
\( N \): The total number of value
The researcher used the program of statistical package for social sciences (IBM-SPSS V. 25) to calculate the arithmetic mean and standard deviation (S.D.).

7. Results of questionnaire data analysis and discussion
The questionnaire includes two parts; the first part includes the personal data of the respondents, while the second part includes the final factors that were approved by the experts after deleting, adding and merging to the list of factors that the researcher concluded from previous studies and those that he suggested. The final factors are distributed in this part of the questionnaire into four main factors and according to the five Likert scales.
7.1. General data
The result of part one which is general data about Information of the respondent include his scientific qualification and experience years.

7.1.1. Scientific qualification of respondents
The respondents’ scientific qualification was distributed according to the percentages illustrated in Figure (1).

![Figure 1. The result of scientific qualification of respondents](image1)

These percentages in Figure (1) mean that the sample of the study has good academic qualifications that enable them to understand the questions of the questionnaire, which enhances confidence in the information collected by the questionnaire.

7.1.2. Years number of respondents practical experience
The years number of respondents’ practical experience were distributed according to the percentages illustrated in figure (2).

![Figure 2. The result of number of experience years for respondents](image2)
These percentages in Figure (2) reflect that there is previous sufficient experience for the study sample in dealing with the construction & demolition waste, and have the ability to dealing with the questionnaire and package objectively.

7.2. Factors affecting the selection of a site for recycling C&DW
Includes the factors affecting the selection of a site for recycling C&DW and distribution of respondents' responses according to each evaluation of the five Likert scale, the computation of the arithmetic mean, the standard deviation, the relative importance index, and the ranks of the factors as shown in the tables (3, 4, 5, 6, 7).

Table 3. The main factors that influence in selecting the site of C&DW recycling.

| N/S | Main Influencing Factors | No Important | Low Importance | Medium Importance | Important | Very Important | S.D. | Mean | RII | Rank |
|-----|--------------------------|--------------|----------------|-------------------|-----------|----------------|------|------|-----|------|
| 1   | Environmental factors    | 0            | 0              | 2                 | 8         | 30             | 0.554| 4.73 | 94.6| 1    |
| 2   | Social factors           | 0            | 2              | 5                 | 20        | 13             | 0.781| 4.18 | 83.6| 3    |
| 3   | Economic factors         | 0            | 1              | 3                 | 13        | 23             | 0.749| 4.45 | 89  | 2    |
| 4   | Technical factors        | 0            | 2              | 6                 | 17        | 15             | 0.822| 4.13 | 82.6| 4    |

The results in Table (3) showed that the most affecting first main factor in selecting the optimal site for C&DW recycling were the environmental factors. The results showed too that the most affecting second main factor was the economical factor. Social factors came in the third order in terms of the level of influence on selecting the optimal site for construction & demolition waste recycling. While the technical factors came in the last order.

Table 4. Sub-factors related to the environmental factors that influence the selection of a C&DW recycling site

| N/S | Environmental factors                                           | No Important | Low Importance | Medium Importance | Important | Very Important | S.D. | Mean | RII | Rank |
|-----|----------------------------------------------------------------|--------------|----------------|-------------------|-----------|----------------|------|------|-----|------|
| 1   | Distance to surface water (such as seas, rivers, lakes, and other water sources) | 0            | 0              | 5                 | 12        | 23             | 0.714| 4.45 | 89  | 1    |
| 2   | Distance to airports                                            | 0            | 1              | 10                | 16        | 13             | 0.816| 4.00 | 80  | 4    |
| 3   | Distance to natural and national parks                         | 1            | 0              | 4                 | 12        | 23             | 0.868| 4.37 | 87.4| 3    |
| 4   | Distance to reserves and natural attraction areas              | 0            | 0              | 3                 | 18        | 19             | 0.628| 4.38 | 87.6| 2    |
The results in Table (4) showed that the first sub-factor of the environmental factors that have most affecting on selecting the optimal site for C&DW recycling was the distance to surface water (such as seas, rivers, lakes, and other water sources). The results showed too that the most affecting second sub-factor was the distance to reserves and natural attraction areas. Distance to natural and national parks factor came in the third order in terms of the level of influence on selecting the optimal site for construction & demolition waste recycling. While other factors which are (the distance to airports) and (distance to the military bases) came in fourth and fifth orders respectively.

**Table 5. Sub-factors related to the social factors that influence the selection of a C&DW recycling site**

| N/S | Social factors                          | No Important | Low Important | Medium Importance | Important | Very Important | S.D. | Mean | RII | Rank |
|-----|----------------------------------------|--------------|---------------|-------------------|-----------|----------------|------|------|-----|------|
| 1   | Distance to cultural and religious milestones | 0            | 0             | 3                 | 20        | 17             | 0.622 | 4.35 | 87  | 2    |
| 2   | Distance to historical monuments       | 1            | 0             | 3                 | 17        | 19             | 0.823 | 4.30 | 86  | 3    |
| 3   | Distance to the population groupings   | 0            | 0             | 1                 | 12        | 27             | 0.526 | 4.68 | 93.6| 1    |

The results in Table (5) showed that the first sub-factor of the social factors that have the most affecting on selecting the optimal site for construction & demolition waste recycling was the distance to the population groupings. The results showed too that the most affecting second sub-factor was the distance to cultural and religious milestones. While the distance to historical monuments factor came in last order in terms of the level of influence on selecting the optimal site for C&DW recycling.

**Table 6. Sub-factors related to economic factors that influence the selection of a C&DW recycling site**

| N/S | Economic factors                          | No Important | Low Important | Medium Importance | Important | Very Important | S.D. | Mean | RII | Rank |
|-----|------------------------------------------|--------------|---------------|-------------------|-----------|----------------|------|------|-----|------|
| 1   | The distance to the rail network         | 0            | 1             | 9                 | 20        | 10             | 0.749 | 3.95 | 79  | 5    |
| 2   | The degree of inclination or slope of the land | 0            | 5             | 18                | 14        | 3              | 0.774 | 3.38 | 67.6| 8    |
| 3   | The distance from the highway taboo      | 0            | 2             | 5                 | 22        | 11             | 0.810 | 4.10 | 82  | 3    |
| 4   | The distance to the areas which constructed more than 50 years ago | 0            | 1             | 11                | 15        | 13             | 0.815 | 3.95 | 79  | 6    |
The results in Table (6) showed that the first sub-factor of the economic factors that have the most affecting on selecting the optimal site for C&DW recycling was the distance to the secondary sorting sites for C&DW. The results showed too that the most affecting second sub-factor was the distance to the sanitary landfill of C&DW.

The distance from the highway taboo factor came in the third order in terms of the level of influence on selecting the optimal site for C&DW recycling. While (land price or ownership, the distance to the rail network, The distance to the areas which constructed more than 50 years ago, The distance to the quarries in the region, the degree of inclination or slope of the land) factors came in fourth, fifth, sixth, seventh, eighth orders respectively.

Table 7. Sub-factors related to technical factors that influence the selection of a C&DW recycling site

| S/N | Technical factors                          | No Important | Low Importance | Medium Importance | Important | Very Important | S.D. | Mean | RII | Rank |
|-----|-------------------------------------------|--------------|----------------|-------------------|-----------|----------------|------|------|-----|------|
| 1   | Land type - industrial or other           | 2            | 0              | 11                | 19        | 8              | 0.947| 3.77 | 75.4| 2    |
| 2   | Available land area (vacant land)         | 1            | 0              | 8                 | 19        | 12             | 0.862| 4.03 | 80.6| 1    |

The results in Table (7) showed that the first sub-factor of the technical factors that have the most affecting on selecting the optimal site for C&DW recycling was an available land area (vacant land). While (land type - industrial or other) factor came in the second order in terms of the level of influence on selecting the optimal site for C&DW recycling.

8. Conclusions and Recommendations

All the factors that were included in the questionnaire obtained high evaluation by the respondents, as showed the results that RII for the main factors affecting on selecting the optimal site for C&DW recycling ranges between (82.6-94.8), and showed that RII for the sub-factors related to the
environmental factors ranges between (74.6-89), Also showed that RII for the sub factors related to the social factors ranges between (86-93.6), while showed that RII for the sub-factors related to the economic factors ranges between (67.6-85), finally the results showed that RII for the sub factors related to the technical factors ranges between (75.4-80.6), therefore the study recommends all concerned in the Baghdad Municipality, the Ministry of Environment and the Ministry of Construction, Housing, Municipalities and Public Works to take these factors into consideration and amend the current legislation to achieve this purpose. Moreover, the study recommends those concerned in the Baghdad Municipality to finding sites according to these factors and create legislation that obliges those responsible for construction and demolition operations to hand over C&DW to these sites.

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