University of Baghdad
College of Engineering
JOURNAL OF ENGINEERING

Journal of Engineering

journal homepage: www.joe.uobaghdad.edu.iq
Number 11 Volume 24 November 2018

Civil and Architectural Engineering

Evaluation of the Project Overhead Costs in Iraqi Construction Industry using Fuzzy Analytic Hierarchy Process (FAHP)

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ABSTRACT

This research investigated the importance and priorities of the project overhead costs in Iraq via a questionnaire using the fuzzy analytic hierarchy process technique (FAHP). Using this technique is very important in the uncertain circumstances as in our country. The researcher reached to frame an equation through the results of the priorities of weights include the percentages of each of the main items of the project overhead costs. The researcher tested this equation by applying it to one of the completed projects and the results showed suitability for the application. The percentages of the (salaries, grants, and incentives) and (fieldwork requirements) in equation represent approximately two-thirds of project overhead costs. So the contractors should deal with the project overhead costs carefully during estimate the bid.
Keywords: project Overhead, Costs, FAHP, Construction Industry

تقييم التكاليف الادارية للمشروع في الصناعة الانشائية العراقية باستخدام عملية التحليل الهرمي الضبابية

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الخلاصة

تحرى الباحث اهمية واولويات الكلف الإدارية للمشروع الانشائي في العراق بواسطة الاستبيان باستخدام تقنية عملية التحليل الهرمي الضبابية. استخدام هذه التقنية مهم جدا في ظل الظروف غير المؤكدة كما هي الظروف في بلدنا. الباحث توصل الى صيغة معادلة من خلال نتائج اولويات الاوزان تتضمن النسبة المئوية لكل الفقرات الرئيسية للكلف الادارية للمشروع. قام الباحث باختبار هذه المعادلة من خلال تطبيقها على أحد المشاريع المنجزة وتبين ملائمتها للتطبيق. النسب المئوية للرواتب والمنح والمكافآت وكذلك متطلبات العمل الحقلية في المعادلة تمثل تقريبا ثلثي الكلف الادارية للمشروع. كذلك المقاولين يجب ان يتعاملوا بعناية مع الكلف الادارية للمشروع عند تخمين عطاءاتهم.
الكلمات الرئيسية: التكاليف الادارية للمشروع، التكاليف، عملية التحليل الهرمي الضبابية، الصناعة الانشائية

1. INTRODUCTION

The costs of any construction project can be divided into three main parts, the direct costs, indirect costs (overhead costs) and the profit. Before starting any project, the construction costs

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Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2018.11.06

Article received: 5/12/2017
Article accepted: 22/1/2018

are planned, the exact costs will be known after the end of the project. Overhead costs are very important costs while estimating building, overhead costs increase continuously and do not decrease. Indirect cost or overhead costs of projects plays a large role and clear influence on the construction industry performance, **Kumar, and Kumar**, **2016**.

2. OVERHEAD COSTS

Direct cost can be defined as the costs directly assignable to a particular product or process. Indirect costs or overhead costs can be defined as the costs not directly assignable to a specified cost object**, Kumar, and Kumar, 2016.**
Project overhead costs which are also called job site are all a part of the expenses which are spent by the contractors in managing a project at the site, **Assaf, et al.**, **1999.**

3. RESEARCH AIMS

The specific aims of this research are:
1. To identify prioritize the project overhead costs items during the costs estimation when pricing the bid.
2. To identify the best percentage of the project overhead costs which may be estimated when pricing the bid.
3. To conclude equations formulas for calculating the percentages of each project overhead costs items.

4. FUZZY ANALYTIC HIERARCHY PROCESS (FAHP)

One of the many useful ways of decision-making is a multi-criteria decision-making (MCDM) method. When testing the criteria in method of analytic hierarchy process (AHP), which play important role in selecting alternatives in addition to determine the weights, it uses understanding and knowledge without need to specific data but it deals with experts ratings by conventional numbers (crisp) ranging from 1 to 9 and it does not deal with the uncertainty of experts ratings. In order to overcome these shortages, the fuzzy logic was integrated with (AHP) method. The combination between (AHP) method and fuzzy logic gives greater flexibility in taking decisions and ratings. The fuzzy analytic hierarchy process (FAHP) reflects the human approach of thinking when dealing with approximate and uncertain information to make decisions. It also maintains the basic characteristics of (AHP) method, facilitates dealing with the quantitative and qualitative data, uses a hierarchical structure, pair comparisons, reduces conflict, and get weights ray, **Ibrahim, et al., 2011.**

5. STUDY METHODOLOGY

The following steps summaries the methodology of this study:
1. Perform the questionnaire containing the items of project overhead costs which have high or very high importance and neglect the items which get medium or less importance as was reached by **Rashed and Al-Dhaheri, 2017**, and performing the pairwise comparison matrix.
2. Distribution the questionnaire for nine experts who have more than 10 years in construction projects. Experience of the experts was in the site management, pricing the bid and engineering consulting offices in the private and public sector company to identify the relative importance for the items (every item with itself and others) from their perspective.

For application, the comparison pairwise between parameters has used the crisp numbers of Saaty scale in **Table 1** to simplify the answer operation from experts.

3. Performing the calculations of (FAHP) algorithms for the experts' opinions to conclude the weight of every item. The researcher use excel program for the (FAHP) algorithm calculation and two for the consistency ratio to reach for the results.

4. Forming the equation terms from the weights for main and sub-items.

5. Applying the case study on the equation term of the main project items of the overhead costs.

6. FAHP ALGORITHM

The next step after listing and converting the pairwise comparison matrix for each expert to the fuzzy form using fuzzy numbers of Saaty scale in **Table 1**, and finding the integrated fuzzy comparison matrix for the experts group by using the geometric mean to obtain the final matrix, is to apply the extent of FAHP used in four steps, **Chang**, **1996,** as follows:

M^{1}_{gi} , M^{2}_{gi} , M^{m}_{gi} , i= 1,2,…..,n
Where, all of the M^{j}_{gi} (j = 1, 2, …, m) are TFNs.

Step 1: The value of a fuzzy synthetic extent with respect to the ith object is defined as:

$$S_i=\Sigma^{m}_{j=1} M^{j}_{gi} * [\Sigma^{n}_{i=1} \Sigma^{m}_{j=1} M^{j}_{gi}]^{-1} \quad (1)$$

To obtain the $\Sigma^{m}_{j=1} M^{j}_{gi}$, we perform the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\Sigma^{m}_{j=1} M^{j}_{gi} = \{ \Sigma^{m}_{j=1} lj, \Sigma^{m}_{j=1} mj, \Sigma^{m}_{j=1} uj\} \quad (2)$$

Obtaining the $[\Sigma^{n}_{i=1} \Sigma^{m}_{j=1} M^{j}_{gi}]$ we perform the fuzzy addition operation of M^{j}_{gi} (j=1,2,3,…….m) values such that

$$\Sigma^{n}_{i=1} \Sigma^{m}_{j=1} M^{j}_{gi} = \{ \Sigma^{m}_{i=1} li , \Sigma^{m}_{i=1} mi , \Sigma^{m}_{i=1} ui \} \quad (3)$$

Compute the inverse of the vector above, such that :

$$[\Sigma^{n}_{i=1} \Sigma^{m}_{j=1} M^{j}_{gi}]^{-1} = \{ {}^{1}/_{\Sigma^{n}_{i=1} ui} , {}^{1}/_{\Sigma^{n}_{i=1} mi} , {}^{1}/_{\Sigma^{n}_{i=1} li} \} \quad (4)$$

Step2: As $\tilde{M}1$= (L_1,M_1,U_1) and $\tilde{M}2$= (L_2,M_2,U_2) are two TFNs, the degree of possibility of $M2 = (L_1,M_1,U_1) \geq M1 = (L_2,M_2,U_2)$ is defined as:

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

Or

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

0, *otherwise*

Step3: The possibility degree for a convex fuzzy number to be greater than k convex fuzzy numbers can be defined by:
M_i (i=1,2,k)
$V(M \geq M_1, M_2, \ldots\ldots M_k) = V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and} \ldots\ldots [(M \geq M_k)] = \min V(M \geq M_i)$, i=1,2,3,…k (7)

Assume that $d(A_i) = \min V(S_i \geq S_k)$ for k = 1,2,…..,n , k≠i , the weight vector is given by :
$W' = (d'(A1), (d'(A2), \ldots\ldots (d'(An))^T$ (8)

To compare M1 and M2, we need of both the values of V (M1≥M2) and V (M2 ≥ M1)

Step4: the normalized weight vectors would be:
$W = (d(A_1), (d(A_2), \ldots\ldots (d(A_n))^T$ (9)
Where W is a non-fuzzy number.

7. CALCULATION OF CONSISTENCY RATIO IN FAHP METHOD

The harmonic of the comparisons of every expert must be certain, to identify if the comparisons are harmonic or absonant to be certain of the consistency and validity of experts' answers, inconsistency ratio is calculated by using Gogus and Boucher method for this purpose.
This method showed in the steps below, **Buckley, 1985**.
Stage1: The integrated fuzzy triangular matrix is divided into two matrices of middle numbers and the geometric mean of upper and lower limits of triangular numbers.
Stage2: The weight vector of each matrix is calculated by Saaty method as following:

$w_i^m = 1/n \left[\sum^n{}_{j=1} (a_{ijm} / \sum^n{}_{i=1} a_{ijm})\right]$ that $w^m = [w_i^m]$ (10)
$w_i^g = 1/n \left[\sum^n{}_{j=1} \{(a_{iju} * a_{ijl})^{1/2}\} / \{\sum^n{}_{i=1} (a_{iju} * a_{ijl})^{1/2}\}\right]$ that $w^g = [w_i^g]$ (11)

Stage 3: The biggest eigenvalue for each matrix is calculated by the following equation:

$\boldsymbol{\lambda}^{\mathbf{m}}_{\mathbf{max}} = 1/n \left[\sum^n{}_{i=1} \sum^n{}_{j=1} a_{ijm}(w_j^m / w_i^m)\right]$ (12)

$\boldsymbol{\lambda}^{\mathbf{g}}_{\mathbf{max}} = 1/n \left[\sum^n{}_{i=1} \sum^n{}_{j=1} (a_{iju} * a_{ijl})^{1/2} (w_j^g / w_i^g)\right]$ (13)

Stage 4: Then, consistency index is computed by the following equation:

$CI^m = (\boldsymbol{\lambda}^{\mathbf{m}}_{\mathbf{max}} - n) / (n-1)$ (14)
$CI^g = (\boldsymbol{\lambda}^{\mathbf{g}}_{\mathbf{max}} - n) / (n-1)$ (15)

Stage 5: Finally, to compute the consistency rate (CR), the CI index is divided by the random index (RI) as illustrated in **Table 2.** If the value is lower than 0.1, the matrix is consistent and validated.

8. CALCULATIONS RESULTS OF THE MAIN AND SUB ITEMS.

After integration experts' opinions by the geometric mean, the rest steps of FAHP algorithm applied to the integration results to finding the items weights as explained in the **Tables 4 to 10**.
Example: The empirical example below shows the application of FAHP algorithm steps on the Sub Items of (POH) Related with Dispatch, Transportation & Communication which showed in **Table 8.**

- Integrating the experts opinions by the geometric mean(G.M.):

G.M. for (DTC1- DTC2)=$\{(3,4,5)^2*(2,3,4)^2*(1,2,3)^3*(1,1,1)*(1/3,1/2,1)\}^{1/9}$
= **(1.318, 2.0263, 2.8065)**
G.M. for (DTC1-DTC3)=$\{(6,7,8)*(3,4,5)*(2,3,4)*(1,2,3)^3*(1,1,1)^2*(1/4,1/3,1/2)\}^{1/9}$
= (1.2765, 1.8245, 2.3469)
G.M. for (DTC2- DTC3)=$\{(6,7,8)*(3,4,5)*(2,3,4)*(1,2,3)^2*(1/3,1/2,1)*(1/4,1/3,1/2)^3\}^{1/9}$
= **(0.8303, 1.2252, 1.7807)**
G.M. for (DTC2- DTC1) = Reverse (power of -1) for **G.M.** of (DTC1- DTC2) =
1/(2.8065, 2.0263, 1.318) = **(0.3563, 0.4935, 0.7587)**
G.M. for (DTC3- DTC1) = Reverse (power of -1) for **G.M.** of (DTC1- DTC3) =
1/(2.3469,1.8245, 1.2765) = **(0.4261, 0.5481,0.7834)**
G.M. for (DTC3- DTC2) = Reverse (power of -1) for **G.M.** of (DTC2- DTC3) =
1/ (1.7807, 1.2252, 0.8303)= **(0.5616, 0.8162, 1.2044)**

The result of integrated fuzzy comparison matrices (with geometric mean) are shown below:

	DTC1			**DTC2**			**DTC3**		
DTC1	1	1	1	1.3180	2.0263	2.8065	1.2765	1.8245	2.3469
DTC2	0.3563	0.4935	0.7587	1	1	1	0.8303	1.2252	1.7807
DTC3	0.4261	0.5481	0.7834	0.5616	0.8162	1.2044	1	1	1

Step 1: Calculating (Si) by the following mathematical processes:

Finding the sum of each integrated row:
Sum of integrated rows for DTC1= (1+1.3180+1.2765),(1+2.0263+1.8245),(1+2.8065+2.3469)
= **(3.5945,4.8508,6.1534)**
Sum of integrated rows for DTC2= (0.3563+1+0.8303),(0.4935+1+1.2252),(0.7587+1+1.7807)
= **(2.1866, 2.7187, 3.5394)**
Sum of integrated rows for DTC3= (0.4261+0.5616+1), (0.5481+0.8162+1),(0.7834+1.2044+1)
= **(1.9877,2.3643,2.9878)**

The result of Collect each column of the results for the Sum of each integrated row above is:
(7.7688, 9.9338, 12.6806)

The reverse (power of -1) for the collect of each column above is:
(0.0789, 0.1007, 0.1287)
S_i for DTC1 = (0.2835, 0.4883, 0.7921)

S_i for DTC2 = (0.1724, 0.2737, 0.4556)
S_i for DTC3 = (0.1567, 0.2380, 0.3846)

Step2: Comparing S_i with S_k (V ($S_i \geq S_k$))

-When compared S_i for DTC1 with S_i for DTC2 and S_i for DTC3 find that (0.4883 > 0.2737) so with S_i for DTC3 find that (0.4883 > 0.2380)
This mean V ($S_i \geq S_k$) for DTC1 = (1,1)

-When compared S_i for DTC2 with S_i for DTC1 find that (0.2737 < 0.4883) (0.2835 < 0.4556) then apply the third condition (0.4556- 0.2835)/ [(0.4556- 0.2737+(0.4883-0.2835)] = **0.445**
When compared S_i for DTC2 with S_i for DTC3 find that (0.2737 > 0.2380)
This mean V ($S_i \geq S_K$) for DTC2 = (0.445,1)

-When comparing S_i for DTC3 with S_i for DTC1, it was found that (0.2380< 0.4883) (0.2835< 0.3846) then applying the third condition (0.3846 - 0.2835)/ [(0.3846 - 0.2380)+(0.4883- 0.2835)]= **0.288**

-When comparing S_i for DTC3 with S_i for DTC2, it was found that (0.2380 < 0.2737) (0.1724 <0.3846) then applying the third condition (0.3846 - 0.1724)/[(0.3846 - 0.2380)+(0.2737- 0.1724)]= **0.856**
This means V ($S_i \geq S_k$) for DTC2 =(0.288, 0.856)

Step3: Finding the min (V ($S_i \geq S_k$))
The min value for V ($S_i \geq S_k$) for DTC1=1
The min value for V ($S_i \geq S_k$) for DTC2= 0.445
The min value for V ($S_i \geq S_k$) for DTC3= 0.288

Step4: Calculating the weights of each items
W for DTC1=1/ (1+0.445+0.288)= 1/1.733 **= 0.577**
W for DTC2=0.445/1.733 **= 0.257**
W for DTC2=0.288/1.733 **= 0.166**

- Finding the consistency ratio**:**

Stage1: The integrated fuzzy triangular matrix has been done in the example above:
Stage2: The weight vector of each matrix is calculated as below:

$\mathbf{W_i^m}$ =1/3*[(1/2.0416 +2.0263/3.8425+1.8245/4.0497), (0.4935/2.0416+ 1/3.8425+1.2252/4.0497), (0.5481/2.0416+0.8162/3.8425+1/4.0497)]= **(0.4892, 0.2682, 0.2426)**

$\mathbf{W_i^g}$ =1/3*{[(1*1)/2.0977+ (1.318*2.8065)/3.7457 + (1.2765*2.3469)/3.9468),(0.3563*0.7587)/2.0977+(1*1)/3.7457 + (0.8303*1.7807)/3.9468), (0.4261*0.7834)/2.0977+ (0.5616*1.2044)/3.7457+(1*1)/3.9468)] = **(0.4762, 0.2743, 0.2495)**

Stage 3: The biggest eigenvalue for each matrix is calculated as below:
$\boldsymbol{\lambda^m_{max}}$ =1/3 **{**[(1*0.4892)+(2.0263*0.2682)+(1.8245*0.2426)]/ 0.4892, [(0.4935*0.4892)+(1*0.2682)+(1.2252*0.2426)]/ 0.2682, [(0.5481*0.4892)

+ (0.8162*0.2682)+(1*0.2426)]/ 0.2426**}**= **3.0106**

λ^{g}_{max} =1/3 {[(1*1)1/2*0.4762+(1.318*2.8065)1/2*0.2743+(1.2765*2.3469)$^{1/2}$*0.2495]/ 0.4762,[(0.3563*0.7587)$^{1/2*}$0.4762+ (1*1)$^{1/2}$*0.2743+(0.8303*1.7807)$^{1/2}$*0.2495]/ 0.2743, [(0.4261*0.7834)$^{1/2}$*0.4762+(0.5616*1.2044)$^{1/2}$*0.2743+(1*1)$^{1/2}$*0.2495]/ 0.2495**}** = **3.0101**

Stage 4: Computing the consistency index as below:
CI^{m} = (3.0106-3)/2 = **0.0053** **CI^{g}** = (3.0101-3)/2 = **0.0050**
Stage 5: Compute the consistency ratio as below:

CR^{m}= 0.0053/0.4890= **0.0108** **CR^{g}**= 0.0050/0.1796 = **0.0280**

As illustrated in **Table3,** the consistency ratio of all main and sub-items of the POH costs are less than (10%). This means that the experts judgments are valid and consistence.

9. THE CONCLUDED EQUATIONS FROM WEIGHTS OF THE SUB AND MAIN ITEMS OF THE (POH) COSTS

1. The concluded equation form weights of the Main Items of the **(**POH**)** Costs, which showed in **Table 4.**

POH = SGI + FWR + SR + DTC + TWS + POR (16)
Where:
SGI = (0.338) POH FWR = (0.311) POH SR = (0.094) POH
DTC = (0.083) POH TWS = (0.137) POH POR = (0.037) POH

2. The concluded equation form weights of the sub-items of (POH) related to salaries, grants, and incentives which showed in **Table 5.**

SGI =SGI1 + SGI2+ SGI3 + SGI4+SGI8 + SGI9 (17)
Where:
SGI1 = (0.366) SGI SGI2 = (0.215) SGI SGI3= (0.279) SGI
SGI4 = (0.115) SGI SGI8 = (0.003) SGI SGI9 = (0.022) SGI

3. The concluded equation form weights of the Sub-Items of (POH) Related with Field Work Requirements which is shown in **Table 6.**

FWR = FWR1 + FWR2 + FWR3 (18)
Where:
FWR1 = (0.640) FWR FWR2 = (0.279) FWR FWR3 = (0.081)

4. The concluded equation form weights of the Sub-Items of (POH) Related with Security Requirements which is shown in **Table 7.**

SR= SR1 (19)

5. The concluded equation form weights of the Sub-Items of (POH) Related with Dispatch, Transportation & Communication which is shown in **Table 8.**

DTC = DTC1 + DTC2 + DTC3 (20)
Where: DTC1 = (0.577) DTC DTC2 = (0.257) DTC DTC3= (0.166) DTC

6. The concluded equation form weights of the Sub-Items of (POH) Related with Temporary Works at the site which is shown in **Table 9.**

TWS = TWS1 + TWS2 + TWS3 + TWS4 (21)

Where:

TWS1 = (**0.278)** TWS TWS2 = **(0.374**) TWS

TWS3 = (**0.131**) TWS TWS4 = (**0.217)** TWS

7. The concluded equation form weights of the Su-Items of (POH) Related with Project Office Requirements which is shown in **Table 10.**

POR = POR1+ POR2 + POR3 + POR4 + POR5 + POR7 (22)

Where:

POR1 = **(0.133)** POR POR2 = (**0.149**) POR POR3 = (**0.345**) POR

POR4 = (**0.157**) POR POR5 = (**0.199**) POR POR7 = (**0.018**) POR

10. APPLYING THE CONCLUDED EQUATIONS ON A PROJECT AS CASE STUDY.

The concluded equation of main items of (POH) costs applied on (Haditha diesel power station) project, which is implemented by the General Company for Projects Design and Implementation – Iraqi Ministry of Industry and Minerals. The implementation period was (18) months and the full cost was (14,124,633,843 IQD) as shown in **Table 11**.

Table 11 shows that the percentages of [(salaries, grants, and incentives), (fieldwork requirements), and (project office requirements)] costs in the equation equal or close to a large extent to its actual percentages in the project. While there are no actual costs of [(security requirements) and (temporary works at the site)], and the percentage of the actual costs of (dispatch, transportation, and communications) very large comparative with its percentage in the equation.

Some of the company's specialists mentioned that there was a camp for accommodation and a restaurant in this project, but the caravans often transfer from project to other, while the other costs such as food etc. consider as (dispatch, transportation, and communications) for the project employees. The security requirements were covered by the client, which it is the Ministry of Electricity.

11. CONCLUSIONS

- The two main items of POH most important were the (salaries, grants, and incentives), (field work requirements) formed about two-thirds of the POH costs.
- The two sub-items most effect related with the first main item are (salaries of supervision & project management) and the (salaries of mechanical and electrical engineers) formed more than two-thirds from the sum of (salaries, grants, and incentives).
- The sub-item most effect related with the second main item is (electric generators and required fuel) where formed about two-thirds from the sum of (fieldwork requirements).
- The fuzzy analytic hierarchy process technique (FAHP) helps in decision-making, analysis and assessment of the factors and identifying the priorities weights in more accurate way because it is suitable for uncertain circumstances.
- The expenses of dispatch, transportation in the project of the case study were nearly equal to the costs of salaries, grants, and incentives.

12. THE RECOMMENDATIONS

- Adopting the concluded equation of main items to estimate the POH cost during pricing the bids.
- Take into Consideration the importance ranks and the percentages of the concluded equations of sub items.
- Adopting the new management techniques like the (FAHP) technique as multi-criteria decision-making technique (MCDM) in testing the criteria in Iraq because of its taking the uncertain and fussy conditions which plagued it in the consideration.
- The contractors should deal with the project overhead costs carefully during estimating the bid.

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Abbreviation	Meaning
SGI	Salaries, grants, and incentives
FWR	Field Work Requirements
SH	Safety & Health
SR	Security Requirements
DTC	Dispatch, Transportation & Communication
TWS	Temporary Works at Site
POR	Project Office Requirements

SGI1	Salaries of Supervision & Project Management
SGI2	Salary of Site Engineer
SGI3	Salaries of Mechanical & Electrical Engineers
SGI4	Surveyor Salary
SGI5	Project Accountant Salary
SGI6	Forman Salary
SGI7	Salaries of Drivers
SGI8	wages of Service occupations (Office Boy, Watchmen, Chef, Generator operator)
SGI9	Cost of Demobilization
FWR1	Electric generators and required fuel
FWR2	Equipment Contingency
FWR3	Bills Of Water & Electricity
FWR4	Sewage Disposal
SR1	Cost of Protection Fence
SR2	The costs of monitoring and guarding requirements (monitoring cameras, etc.)
DTC1	Vehicles of the project and Required Fuel
DTC2	Job Transportation
DTC3	Cost of Equipping Access Roads
TWS1	Site Stores
TWS2	Temporary Accommodation in Site (Sheds)
TWS3	Temporary Utilities(Toilet, Bathroom, Kitchen)
TWS4	Other Temporary Buildings at Site
POR1	Cleaning & Rubbish Removal
POR2	Xerox
POR3	Costs of Field Offices Rental
POR4	Computers & Printers
POR5	Field Offices Furniture
POR6	Videos & Photos
POR7	Stationery & Publications

Table 1. The linguistic scale, which used in pairwise comparisons**, Chun, and Shang, 2013.**

The preference degree (Intensity of the importance) of one activity over another(linguistically scale)	The preference degree			
	Digital value	Explanations	Fuzzy digital value	Invert of the fuzzy value
Equal importance	**1**	Two activities contribute equally to the objective	**(1,1,1)**	**(1,1,1)**
Intermediate importance between (Equal and moderate)	**2**	One activity has (equal to moderate importance) over another	**(1,2,3)**	**(1/3,1/2,1)**
Moderate importance	**3**	Experience and judgment slightly prefer one activity over another	**(2,3,4)**	**(1/4,1/3,1/2)**
Intermediate importance between (Moderate to	**4**	One activity has (moderate to strong) over another	**(3,4,5)**	**(1/5,1/4,1/3)**

strong)				
Strong importance	**5**	Experience and judgment strongly prefer one activity over another	**(4,5,6)**	**(1/6,1/5,1/4)**
Intermediate importance between (Strong and very strong)	**6**	One activity has (strong to very strong) over another	**(5,6,7)**	**(1/7,1/6,1/5)**
Very strong importance	**7**	An activity is preferred very strongly over another	**(6,7,8)**	**(1/8,1/7,1/6)**
Intermediate importance between (Very strong and absolute)	**8**	One activity has (very strong to absolute) over another	**(7,8,9)**	**(1/9,1/8,1/7)**
Absolute importance	**9**	The evidence preferring one activity over another is of the highest Possible order of affirmation	**(8,9,10)**	**(1/10,1/9,1/8)**

Table 2. Random indicators (RI**), Goodarzi, and Dokht, 2015.**

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

Table 3. The consistency ratio for main and sub-items of the POH costs.

N	**The Items Of the POH Costs**	**Number of Items**	m CR	g CR
1	The Main Items of the Project Overhead Costs	7	0.0063	0.0187
2	Sub Items Of Salaries, Grants and Incentives	9	0.0142	0.0419
3	Sub-Items of Field Work Requirements	4	0.0351	0.0838
4	Sub-Items of Safety & Health	3	0.0308	0.0767
5	Sub-Items of Dispatch, Transportation & Communication	3	0.0108	0.0280
6	Sub-Items of Temporary Works at Site	4	0.0138	0.0347
7	Sub Items of Project Office Requirements	7	0.0121	0.0301

Table 4. The main items of the project overhead costs.

N	The Main Items of the (POH)	The fuzzy sum of each row			S_i			The priority Si on S_k [$V(S_i \geq S_k)$]						d(Ai)=min V(Si ≥ Sk)	Normalization priorities	Criteria Weights	The Rank
1	Salaries, grants and incentives	11.4024	15.3492	19.5759	0.1447	0.2585	0.4472	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**0.3385**	**0.338**	**1**
2	Field Work Requirements	9.6077	13.9316	18.3468	0.1219	0.2346	0.4191	0.920	1.000	1.000	1.000	1.000	1.000	0.920	**0.3114**	**0.311**	**2**
3	Safety & Health	3.6294	4.5057	5.9957	0.0461	0.0759	0.1370	0.000	0.086	0.662	0.724	0.597	0.862	0.000	**0.0000**	**0.000**	
4	Security Requirements	5.1812	6.6670	8.7951	0.0658	0.1123	0.2009	0.278	0.392	1.000	1.000	0.921	1.000	0.278	**0.0939**	**0.094**	**4**
5	Dispatch, Transportation & Communication	4.7154	6.2514	8.5155	0.0599	0.1053	0.1945	0.245	0.359	1.000	0.948	0.874	1.000	0.245	**0.0830**	**0.083**	**5**
6	Temporary Works at Site	5.1852	7.3546	10.3215	0.0658	0.1239	0.2358	0.403	0.507	1.000	1.000	1.000	1.000	0.403	**0.1365**	**0.137**	**3**
7	Project Office Requirements	4.0564	5.3152	7.2350	0.0515	0.0895	0.1653	0.108	0.230	1.000	0.814	0.870	0.743	0.108	**0.0367**	**0.037**	**6**

Table 5. Sub items of (POH) related to salaries, grants, and incentives.

N	S-b Items Of (POH) Related with Salaries, Grants, and Incentives	The fuzzy sum of each row			Si			The priority Si on Sk [V(Si ≥ Sk)]								d(Ai)=min V(Si ≥ Sk)	Normalization priorities	Criteria Weights	The Rank
1	Salaries of Supervision & Project Management	16.4883	21.5632	27.3505	0.1301	0.2200	0.3671	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.3657	0.366	1

2	Salary of Site Engineer	9.8307	13.8352	18.0607	0.0775	0.1411	0.2424	0.588	0.841	1.000	1.000	1.000	1.000	1.000	1.000	0.588	0.2149	0.215	3
3	Salaries of Mechanical & Electrical Engineers	11.7720	16.5971	21.8541	0.0929	0.1693	0.2933	0.763	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.763	0.2791	0.279	2
4	Surveyor Salary	7.8612	10.4200	13.5570	0.0620	0.1063	0.1820	0.313	0.750	0.586	1.000	1.000	1.000	1.000	1.000	0.313	0.1146	0.115	4
5	Project Accountant Salary	5.2654	6.2332	7.7195	0.0415	0.0636	0.1036	0.000	0.252	0.092	0.493	0.952	0.883	0.455	0.726	0.000	0.0000	0.000	
6	Forman Salary	5.0687	6.5508	8.7444	0.0400	0.0668	0.1174	0.000	0.349	0.193	0.584	1.000	0.939	0.525	0.800	0.000	0.0000	0.000	
7	Salaries of Drivers	5.3988	7.0238	9.3492	0.0426	0.0716	0.1255	0.000	0.408	0.250	0.647	1.000	1.000	0.573	0.864	0.000	0.0000	0.000	
8	wages of Service occupations (Office Boy, Watchmen, Chef, Generator operator)	6.3332	7.6400	9.7860	0.0500	0.0779	0.1313	0.009	0.460	0.296	0.710	1.000	1.000	1.000	0.937	0.009	0.0033	0.003	6
9	Cost of Demobilization	6.4910	8.1706	10.3531	0.0512	0.0833	0.1390	0.061	0.515	0.349	0.770	1.000	1.000	1.000	1.000	0.061	0.0223	0.022	5

Table 6. Sub-items of (POH) related with field work requirements.

N	Sub-Items of (POH) Related with Field Work Requirements	The fuzzy sum of each row			Si			The priority Si on Sk [V(Si ≥ Sk)]			d(Ai)=min V(Si ≥ Sk)	Normalization priorities	Criteria Weights	The Rank
1	Electric generators and required fuel	6.5518	8.7846	11.0651	0.2614	0.4373	0.7059	1.000	1.000	1.000	1.000	0.6401	0.640	1
2	Equipment Contingency	3.8734	5.0530	6.3460	0.1546	0.2516	0.4049	0.436	1.000	1.000	0.436	0.2789	0.279	2

3	Bills Of Water & Electricity	3.1771	3.8521	4.6563	0.1268	0.1918	0.2971	0.127	0.704	1.000	0.127	0.0811	0.081	3
4	Sewage Disposal	2.0718	2.3967	2.9924	0.0827	0.1193	0.1909	0.000	0.216	0.470	0.000	0.0000	0.000	

Table 7. Sub-items of (POH) related to security requirements.

N	Sub-Items of (POH) Related with Security Requirements	The fuzzy sum of each row			S_i			The priority Si on S_k [$V(S_i \geq S_k)$]	d(Ai)=min $V(Si \geq Sk)$	Normalization priorities	Criteria Weights	The Rank
1	Cost of Protection Fence	2.2347	2.4422	2.6273	0.5036	0.5905	0.6825	1.000	1.000	**1.000**	**1.000**	**1**
2	The costs of monitoring and guarding requirements (monitoring cameras, etc.)	1.6145	1.6934	1.8099	0.3639	0.4095	0.4702	0.000	0.000	**0.000**	**0.000**	

Table 8. Sub items of (POH) related to dispatch, transportation & communication.

N	Sub-Items of (POH) Related with Dispatch, Transportation & Communication	The fuzzy sum of each row			S_i			The priority Si on S_k [$V(S_i \geq S_k)$]		d(Ai)=min $V(Si \geq Sk)$	Normalization priorities	Criteria Weights	The Rank
1	Vehicles of project and Required Fuel	3.5945	4.8508	6.1534	0.2835	0.4883	0.7921	1.000	1.000	1.000	**0.577**	**0.577**	**1**
2	Job Transportation	2.1866	2.7187	3.5394	0.1724	0.2737	0.4556	0.445	1.000	0.445	**0.257**	**0.257**	**2**
3	Cost of Equipping Access Roads	1.9877	2.3643	2.9878	0.1567	0.2380	0.3846	0.288	0.856	0.288	**0.166**	**0.166**	**3**

Table 9. Sub items of (POH) related to temporary works at site.

N	Sub-Items of (POH) Related with Temporary Works at Site	The fuzzy sum of each row			Si			The priority Si on Sk [V(Si ≥ Sk)]			d(Ai)=min V(Si ≥ Sk)	Normalization priorities	Criteria Weights	The Rank
1	Site Stores	3.4721	4.4574	5.7831	0.1583	0.2610	0.4345	0.743	1.000	1.000	0.743	0.2777	0.278	2
2	Temporary Accommodation in Site (Sheds)	4.3775	5.8468	7.3612	0.1996	0.3424	0.5531	1.000	1.000	1.000	1.000	0.3739	0.374	1
3	Temporary Utilities(Toilet, Bathroom, Kitchen)	2.5434	3.0516	3.8312	0.1160	0.1787	0.2879	0.611	0.350	0.798	0.350	0.1310	0.131	4
4	Other Temporary Buildings at Site	2.9166	3.7195	4.9577	0.1330	0.2178	0.3725	0.832	0.581	1.000	0.581	0.2173	0.217	3

Table 10. Sub items of (POH) related to project office requirements.

N	**Project Office Requirements**	**The fuzzy sum of each row**			**S_i**			**The priority Si on S_k [$V(S_i \geq S_k)$]**						**d(Ai)=min V(Si ≥ Sk)**	**Normalization priorities**	**Criteria Weights**	**The Rank**
1	Cleaning & Rubbish Removal	5.6775	7.9035	10.6279	0.0690	0.1292	0.2432	0.942	0.387	0.932	0.824	1.000	1.000	0.387	**0.1334**	**0.133**	**5**
2	Xerox	6.1979	8.5350	11.1694	0.0754	0.1395	0.2556	1.000	0.432	0.989	0.879	1.000	1.000	0.432	**0.1487**	**0.149**	**4**
3	Costs of Field Offices Rental	11.8025	17.5669	23.5128	0.1435	0.2871	0.5380	1.000	1.000	1.000	1.000	1.000	1.000	1.000	**0.3446**	**0.345**	**1**

4	Computers & Printers	6.1774	8.6564	11.5727	0.0751	0.1415	0.2648	1.000	1.000	0.454	0.894	1.000	1.000	0.454	**0.1566**	**0.157**	**3**
5	Field Offices Furniture	6.9912	9.9654	13.6488	0.0850	0.1629	0.3123	1.000	1.000	0.576	1.000	1.000	1.000	0.576	**0.1985**	**0.199**	**2**
6	Videos & Photos	3.0745	3.7292	4.9307	0.0374	0.0609	0.1128	0.391	0.323	0.000	0.319	0.214	0.788	0.000	**0.0000**	**0.000**	
7	Stationery & Publications	3.7796	4.8303	6.7757	0.0460	0.0789	0.1550	0.631	0.568	0.052	0.561	0.455	1.000	0.052	**0.0181**	**0.018**	**6**

Table11. Comparing the main items ratio of POH costs for the case study with its ratio in the concluded equation**.**

Project Name	**The full cost**	**POH Costs**	**POH Costs Items**	**Actual Cost of each item**	**The actual ratio of each item**	**The ratio of each item in the equation**	**difference**
Haditha diesel power station	14,124,633,843 IQD	1,670,698,562 IQD	Salaries, grants and incentives	558,675,672	0.334	0.338	0.004
			Field Work Requirements	509,271,632	0.305	0.311	0.006
			Security Requirements	0	0	0.094	0.094
			Dispatch, Transportation & Communication	550,908,608	0.330	0.083	0.247
			Temporary Works at Site	0	0	0.137	0.137
			Project Office Requirements	51,842,650	0.031	0.037	0.006