The Reasons for Rework Occurrence in Construction Projects and Prioritizing Them by Using AHP Method

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Abstract

Identifying and prioritizing the effective factors on rework plays a great role in decreasing the costs and conflicts existing in construction projects. Moreover, rework reduction helps with sustainable development. Because less materials will be used, which covers the environmental aspect of sustainable development, and additional costs will be decreased. Identifying the effective factors on rework, classification, evaluation, and prioritizing them is a difficult job. Therefore, AHP method is used in the current study. Analytical Hierarchy Process is one of the most comprehensive designed systems for decision making with Multiple Criteria. One of the advantages of this technique is that it is related to personal experience for hierarchical planning of a problem in one way, and it is related to logic, perception, and analysis for decision making and final judgment in other way. Different available options are compared to each other based on the considered criteria, and the priority of selecting each of them is determined. In the present study, some collected and separated information regarding the parameters and causes of rework in construction projects is gathered based on ranking system questionnaires given to employers, consultants, and contractors in Iraq, and then, the information gathered from questionnaires is analyzed by using Multivariate Decision Making Process (AHP) in order to prioritize the factors of rework in projects.

Keywords: Reconstruction, Analytical Hierarchy Process, Multivariate Decision Making, Construction

1.Introduction

Construction industry, as one the most important industries, provides infrastructures to improve people's life conditions, and it is one the largest polluters of environment. A huge amount of money is spent every year in Iraq for construction projects in forms of civil, non-civil, and private projects. Lack of a specific system for recording actual costs is one of the flaws of the construction management of this country. Project cost management is a process which provides forecasting, planning, controlling, costing, analyzing, and evaluating. Cost management is clearly understood when the early impacts of lack of money appears in all aspects of the project due to poor management. Therefore, managers can be effective for the

prevention of rework, and also using efficient management is meant for the reduction of effects which have important impacts on project performance and productivity. Rework means: Unnecessary efforts to redo an activity because the first time it was not done right [2]. Briefly, its factors are divided into four sections.

1- Factors related to customer
2- Factors related to design
3- Factors related to contractor
4- Unpredictable events

In some cases, the level of rework in construction projects is related to external factors, such as very high work capacity and market conditions meaning that the increase of flaws and poor performance of the people might be the result of limitations based on the lack of subcontractors' access to good manpower, or it might be the result of additional and unwanted pressures for early completion of the project [4]. And it can also be the result of some internal factors, such as: Mistakes and errors, neglect, changes, poor communication between sections and weak coordination (5).

Previous studies indicate that rework by poor project management could cost up to 25% of the contract value and 10% of the total project costs [6] and [7]. For instance, according to collected data, more than 30% of construction work is related to rework. According to estimations made by America Manufacturing Industries Institute, the annual lost amount of money in construction projects because of rework is up to $15 million [8].

Rework also increases the complaints because of the additional costs. For instance, contractors claim different types of possible compensations and this results in imposing more costs on the project [9].

2- Problem Statement and Research

In the present study, some information regarding the factors of rework in construction projects is gathered based on ranking system questionnaire given to employers, consultants, and contractors in Iraq, and then the information gathered from questionnaires is analyzed by using the Multivariate Decision Making Process (AHP) in order to prioritize the factors of rework in projects. The questionnaires included 33 questions and they were distributed in the form of four main sections (owners, contractors, consultants, and unpredictable events) among 32 engineers and owners of 8 construction companies in Karbala City. Each of the four sections of owner, consultant, contractor, and unpredictable events included 6, 11, 10, and 6 questions in order. At first, each section was examined separately and then all four sections were compared to each other so that the main causes of delays in construction projects of Karbala can be identified. In Table 1, a sample of the questionnaire is presented.

3- Results

As shown in Table 1, 6 questions related to factors related to the employer are compared with each other individually so that the obtained information can be analyzed by AHP method. In Table 1, numbers 1 through 5 are used based on comparison system. For example, the lack of employer sufficient capital to continue the project and the lack of employer's sufficient

experience regarding the project have the same impact on the rework of the project. Because number 1 is chosen in the questionnaire.

Table 1: A Sample of a Questionnaire (Factors Related to Employer) Filled in for Being Analyzed by Analytical Hierarchy Process

	Rank									
Parameter *	5	4	3	2	1	2	3	4	5	**Parameter ***
1					●					٢
1		●								٣
1		●								٤
1				●						٥
1			●							٦
2		●								٣
2			●							٤
2				●						٥
2		●								٦
3				●						٤
3					●					٥
3					●					٦
4							●			٥
4			●							٦
5		●								٦

* **The parameters 1 to 6 are determined in table 2.**

3-1- Factors Related to Employer

In order to analyze the results of the questionnaire, the paired comparison matrix should get normalized. This matrix is presented in Table 2. As it can be seen in Table 2, the validity of the received responses is calculated by using the inconsistency rate index of 0.05. Since the amount is lower than the critical point of 0.1, it can be said that the results are reliable.

Based on Analytic Hierarchy Process, any factor with higher average rank is the most effective factor. According to Table 2, "*Lack of Experience, Knowledge and Awareness about the Manufacturing Process*" is the most important and effective parameter in creation of rework in Karbala construction projects, and it is in the group of factors related to the employer.
Also, '*Inadequate Contract and Tender Offer Documents*' has the least impact on the rework of Karbala City construction projects.

Table 2: The Paired Comparisons of Normal Matrix of Effective Factors on Rework Caused by Employer

Factor		1	2	3	4	5	6	Average
Lack of Experience, Knowledge, and Awareness about Manufacturing Process	1	0.30	0.30	0.34	0.30	0.31	0.20	0.29
Lack of Real Capital and Budget Required for Making Policy of Site	2	0.30	0.30	0.36	0.23	0.30	0.26	0.29
Poor Communication with Design Consultants	3	0.08	0.07	0.09	0.14	0.15	0.07	0.10
Employer's Lack of Involvement and Awareness about Project Process	4	0.07	0.10	0.04	0.07	0.05	0.14	0.08
Inadequate Summarization of Work	5	0.15	0.15	0.09	0.22	0.15	0.27	0.17
Inadequate Contract and Tender Offer Documents	6	0.10	0.08	0.09	0.04	0.04	0.07	0.07
Inconsistency Rate		0.05						

3-2- Factors Related to Unpredictable Events

As it was mentioned earlier, 6 effective factors of rework occurrence in construction projects of Karbala City of Iraq were determined, and they were prioritized in Table 3 respectively.

Table 3: The Paired Comparisons of Normal Matrix of Effective Factors on Rework Caused by Unpredictable Events

Factor		1	2	3	4	5	6	Average
Force Majeure Events such as Flood, Earthquake, and Unexpected Bad Weather	1	0.06	0.04	0.04	0.09	0.07	0.06	0.06
Bad Weather	2	0.24	0.17	0.10	0.13	0.26	0.37	0.21
International or Civil Wars	3	0.29	0.33	0.19	0.14	0.14	0.18	0.21
Inconsistency of Government's Policies	4	0.17	0.34	0.38	0.27	0.20	0.18	0.26
Accidents Happening for Human Forces and Equipment	5	0.06	0.04	0.10	0.09	0.07	0.04	0.07
Political Conflicts and Imposing Related Sanctions	6	0.18	0.08	0.20	0.27	0.27	0.18	0.20
Inconsistency Rate		0.06						

Table 3 shows that two factors of 'Bad Weather' and '*International or Civil Wars*' have a significant role in occurrence of rework in construction projects of Karbala City in Iraq.

3-3- Factors Related to Consultant

Regarding the factors related to consultant in occurrence of rework in construction projects of Karbala City, 11 factors were selected and prioritized as in Table 4.

Table 4: The Weight of Rework Occurrence Factors Caused by Consultant in Construction Projects in AHP Method

Rank	Weight	Variable Name
1	۰,۱۸	Lack of Proper Timing/ Enough and Necessary Time for Completing Any Project Activities
2	۰,۱۶	Lack of Details in Design
3	۰,۱۳	Not Assigning Enough Manpower for Completing Required Task
4	۰,۱۳	Poor and Incorrect Planning and Not Considering Proper Time for Each Manpower in Caculating Total Time of Project
5	۰,۱۱	Lack of Coordination between Members of Design Team
6	۰,۰۶	Change in Contractor's Staff During Project Process
7	۰,۰۵	Ineffective Use of Information Technology
۸	۰,۰۵	Type of Organizational Structure of Project
۹	۰,۰۵	Project Being Three or Four Factors
۱۰	۰,۰۴	Inadequate Items Related to Performing Letters and Obligations Determined by Contract Terms
۱۱	۰,۰۳	Ineffective Use of Quality Management Requirements

As it can be seen in Table 4, the factor of '*Lack of Proper Timing'* is the most important factor of rework occurrence in Karbala City of Iraq with the weight of 0.18. The next factor is '*Lack of Details in Design'*, which leads to make mistake in allocating the required time for the implementation of the project, is in the second place with the weight of 0.16.

3-4- Factors Related to Contractor

Table 5 indicates the ranking and the weight of each one of the effective factors on rework occurrence related to contractor in the construction projects of Karbala Governorate. According to this table, from the 12 factors caused by the negligence of the contractor in performance of his tasks and resulting rework in construction project of Iraq's Karbala Governorate, two factors of '*Inadequate Management Skills'* and '*Contractor's Financial Limits in Equipping Workshop'*, with the same weight of 0.014, are the most important factors of rework by the contractor in construction projects of Karbala Governorate in Iraq. The factor of '*Contractor's*

Lack of Careful Study of Contract Document Details' was also the least rework occurrence factor with 0.04 percent. A notable point about contractors is that the weight of the factors related to contractor is close to each other. In this case, the inconsistency rate is 0.06, and since this amount is less than 0.1, it is certain to tell that the results of the research are desirable.

Table 5: The Weight of Effective Factors on Rework Caused by Contractor in Construction Projects in AHP Method

Rank	Weight	Variable Name
1	۰,۱۴	Inadequate Management Skills
2	۰,۱۴	Contractor's Financial Limits in Equipping Workshop
3	۰,۱۲	Weak Workforce
4	۰,۱۱	Not Employing Experienced Executive Forces and Making Several Mistakes
5	۰,۱۰	Lack of Constant Supervision and Control on Designing and Executive Operations
6	۰,۰۹	Constractor's Executive Limits
7	۰,۰۸	Problems Related to Other Subcontractors and Lack of Coordination between Them
۸	۰,۰۵	Mistakes Related to Work
۹	۰,۰۵	Change in Contractor's Staff During the Project
۱۰	۰,۰۴	Contractor's Poor Organizational Structure
۱۱	۰,۰۴	Use of Materials with Poor Qualit
۱۲	۰,۰۳	Lack of Careful Study of Contract Document Details

4- Results of the Study and Comparison of the Main Factors

After determining the main factors of rework occurrence in construction projects of Karbala Governorate of Iraq, and prioritizing them in each group (employer, consultant, contractor and unpredictable events), now we specify the weight of each one of the main four factor.
Table 6 shows the paired comparison matrix of these four factors.

Table 6: The Paired Comparisons Matrix of Effective Factors on Rework Caused by Four Main Factors

factor		1	2	3	4
Employer	1	*1.00*	۰,۴۹	۰,۳۳	۰,۳۳
Unpredictable Events	2	۲,۰۳	*1.00*	۰,۴۹	۰,۹۹
Consultant	3	۳,۰۴	۲,۰۳	*1.00*	۱,۰۱
Contractor	4	۳,۰۰	۱,۰۱	۰,۹۹	*1.00*
Total		۹,۲۲	۵,۴۰	۲,۸۳	۳,۲۸

After this step in Table 7, the normal matrix of the paired comparison Table 6 is calculated. As indicated in Table 7, by dividing the amounts of each item into the amount of each column from Table 6, the normal matrix of the paired comparison is obtained. According to the calculations, first, consultants with 0.36 percent are at the top of the factors which lead to rework in construction projects of Karbala Governorate in Iraq. Second, contractors are in the second place with 0.30 percent. Unpredictable events with significant amount of 23% are in the third place of the quadratic table. The reason for this high percentage of unpredictable events is the unstable political conditions of Iraq.

Table 7: The Paired Comparisons of Normal Matrix of Effective Factors on Rework Caused by Four Main Factors

		1	2	3	4	Average
Employer	1	۰,۱۱	۰,۱۱	۰,۱۲	۰,۱۰	۰,۱۱
Unpredictable Events	2	۰,۲۲	۰,۲۲	۰,۱۷	۰,۳۰	۰,۲۳
Consultant	3	۰,۳۴	۰,۴۵	۰,۳۶	۰,۳۰	۰,۳۶
Contractor	4	۰,۳۳	۰,۲۲	۰,۳۵	۰,۳۰	۰,۳۰
Inconsistency		۰,۰۲				

4- Discussion and the Analysis of Results

To determine the overall weight of each one of the effective items on rework in construction projects, the weight of each one of the subgroup factors is multiplied by the total weight of the group. For instance, the factor of *'Weak Workforce'* in the group of factors related to contractor is 0.12 and by multiplying this percentage in the weight of the contractor group, which according to Table 5 is about 0.30%, the amount of 0.036 will be the result. Then, by dividing the result of overall weight of each item into the amount of total weight, the normal weight of each item is obtained. The results are presented in Table 8. Based on this table, the six main factors of rework in projects of Iraq are as follows:

1- Lack of Proper Timing/ Enough and Necessary Time for Completing Any Project Activities
2- Lack of Details in Design: Causing Mistakes in Allocating Enough Time for the Whole Project
3- Not Assigning Enough Manpower for Completing Required Tasks

4- Poor and Incorrect Planning and Not Considering Proper Time for Each Manpower in Calculating Total Time of Project
5- Contractor's Financial Limits in Equipping Workshop
6- Inadequate Management Skills

Table 8: The Paired Comparisons of Normal Matrix of Effective Factors on Rework Caused by Four Main Factors

Criteria	Weight	Normal Weight	Rank
Factors Related to Employer			
Lack of Experience, Knowledge, and Awareness about Manufacturing Process	0.032	0.264	20
Lack of Real Capital and Budget Required for Making Policy of Site	0.031	0.260	22
Employer's Lack of Involvement and Awareness about Project Process	0.011	0.090	33
Inadequate Summarization of Work	0.009	0.072	34
Poor Communication with Design Consultants	0.019	0.155	28
Inadequate Contract and Tender Offer Documents	0.007	0.062	35
Factors Related to Unpredictable Events			
Force Majeure Events such as Flood, Earthquake, and Unexpected Bad Weather	0.014	0.113	32
Bad Weather	0.047	0.391	15
International or Civil Wars	0.049	0.401	14
Inconsistency of Government's Policies	0.059	0.491	10
Accidents Happening for Human Forces and Equipment	0.015	0.126	31
Political Conflicts and Imposing Related Sanctions	0.045	0.370	16
Factors Related to Consultant			
Ineffective Use of Quality Management Requirements	0.018	0.145	29
Ineffective Use of Information Technology	0.030	0.251	24
Lack of Coordination between Members of Design Team	0.075	0.623	7
Lack of Proper Timing/ Enough and Necessary Time for Completing Any Project Activities	0.121	1.000	1

Poor and Incorrect Planing and Not Considering Proper Time for Each Manpower in Caculating Total Time of Project	0.087	0.720	4
Not Assigning Enough Manpower for Completing Required Tasks	0.087	0.721	3
Inadequate Items Related to Performing Letters and Obligations Determined by Contract Terms	0.030	0.251	25
Change in Contractor's Staff During Project Process	0.041	0.338	17
Lack of Details in Design: Causing Mistakes in Allocating Enough Time for the Whole Project	0.107	0.883	2
Type of Organizational Structure of Project	0.034	0.284	18
Project Being Three or Four Factors	0.031	0.256	23
Factors Related to Contractor			
Weak Workforce	0.075	0.619	8
Inadequate Management Skills	0.086	0.712	6
Use of Materials with Poor Quality	0.023	0.192	26
Problems Related to Other Subcontractors and Lack of Coordination between Them	0.049	0.409	13
Lack of Constant Supervision and Control on Designing and Executive Operations	0.059	0.485	11
Mistakes Related to Work	0.032	0.268	19
Constractor's Executive Limits	0.056	0.462	12
Lack of Careful Study of Contract Document Details	0.015	0.126	30
Change in Contractor's Staff During the Project	0.032	0.261	21
Not Employing Experienced Executive Forces and Making Several Mistakes	0.067	0.557	9
Contractor's Poor Organizational Structure	0.022	0.186	27
Contractor's Financial Limits in Equipping Workshop	0.086	0.715	5

4- Discussion and the Analysis of Results

Based on the field research carried out in this paper, the results are as follows:

1- Prioritization of the main factors and details of rework were reviewed and presented (Table 8).

2- The first priority of rework relating to consultant is caused by the lack of proper time allocated to construction projects.

3- The second priority of rework is due to the failure to provide full design details by the consultant.

4- The third main factor of rework in construction projects is due to the lack of knowledge and assignment of necessary number of experts in implementation of the project.

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