Quantifying and Modeling the Cumulative Impact of Changes Order for the Projects in Iraq

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Abstract. This research investigates the change orders projects of hospital construction in Iraq, for several reasons. Because these types of projects have a relatively long duration, which leads to a change in some requirements or the emergence of new developments with the owner or gets a new technical development in this field, also these projects contain a large number of documents, specifications, plans, bill of quantities, and a large number of engineers with various specializations participate in preparing them, which makes the probability of change possible due to the large work and poor coordination between those specializations or the development of new government regulations. This current research is based on a database of eleven projects for hospitals. The researcher used combined methodology: the qualitative method represented by interviews of many construction professionals, and the quantitative method represented by questionnaire surveys and gathering data through a survey the documents of change orders for the projects. In this study, we adopted the analytical statistical approach by used F-tests and then used a one - way ANOVA analysis. The researcher managed to reach mathematical models that can predict the added cost of change requests that occur through the planning or implementation phase for the project, to avoid or minimize project changes. A series of statistical model selection criteria were applied to carefully identify the best models, for ease of use of search results and to obtain a tool that can be used by the parties to the project.

Keywords: Modeling, causes of the change order, projects, and quantitative.

1. Introduction

The term "demand change" has always received a bad reputation among the builders of the construction industry. Changes in construction projects are very common and likely to occur from different sources, various causes, at any stage of a project, and may have considerable negative impacts on items such as costs and schedule delays. A critical change may cause consecutive delays in the project schedule, re-estimation of work statement, extra demands of equipment, materials, labor, and overtime, this leads to additional cost. Changes if not resolved through a formalized change management process, can become the major source of contract disputes, which is a severe risk contributing to project failure. In project management, a change order (variance order) is a component of the change management process, where changes in the scope of work or project activities by the owner, contractor, and consultant are common in most projects [1], especially in large and complex projects. After the scope is formed, contract requirements, the total price to be paid and the specific work to be completed, the owner may decide that the original plans do not represent the best definition of the final project [2].

Accordingly, the owner will propose an alternative method [3]. Researchers at Choy have expressed concern about the negative impacts of project change orders [4]. The change order is defined as "a written authorization by the Engineer or approval to change each of the original plans, specifications or other contract documents, as well as the change in cost", and with appropriate signatures, the change
order becomes a legal document. “Change is defined as any an event resulting in an adjustment to the
cost of action” [5]. Any additions, deletions or other revisions to the
project objectives and scope are considered changes, whether they increase or decrease the cost,
schedule or quality of the project [6].

2. Types of Changes
Classifications of changes in general terms apply to changes in the construction domain. “Based on time,
the change could be anticipated or emergent, proactive or reactive, or pre-fixity or post-fixity. Based on
need, the change could be elective or required, discretionary or nondiscretionary, or preferential or
regulatory. Based on effect, the change could be positive, neutral, or negative” [7]. Changes can be
classified in many different ways depending on the basis and the purpose of classifications. In this
review, the most common classifications will be presented:

- According to the cause that forced them [1].
- Changes according to the net impact on the scope [8, 9].
- Changes according to the procedure used to introduce them [8, 9]. This classification is important
  in discussing the legal aspects of changes.

3. Ripple Impact or Cumulative Impact
Ripple impact is a term used in the construction industry to describe a cascade of changes [10]. High
ripple projects are ones with a high number and monetary amount of successive changes because of a
previous change, whereas low ripple projects are the ones with a low number and monetary amount of
successive changes because of a previous change. For high ripple projects, the ripple effect can have a
substantial impact on cost and schedule growth [11].

3.1. Data Collection
Previous researches have included many studies on residential, educational, commercial, and industrial
projects. Health sector projects (hospitals) were selected to study because of the complexity of this type
of project. The study community consists of 11 hospitals distributed in the provinces of Iraq and different
clinical capacities as shown in Fig. 1. These projects included architectural and civil works, works
sanitary, electrical works, mechanical works, and medical devices. The percentage of changes for civil
and architectural works was 47% of the cost of all changes, sanitary works was 22% of the cost of all
changes electrical works was 14% of the cost of all changes, mechanical works was 12% of the cost of
all changes and medical devices was 5% of the cost of all changes as shown in Fig. 2. The cost of
changes can be calculated by the following formula [11].

\[
\text{Cost of changes (\%)} = \frac{\text{Final cost} - \text{Original budget}}{\text{Original budget}} \times 100
\] (1)

The sample selection depends on a few selection criteria. The first selection criterion is that
participants must have experience work in hospital buildings for 10 years minimum. The working profile
of the sample to be selected for data collection must be the contractor, consultants, and owners. The
reason is that these three features are the key in any construction projects and they are at the top of the
pyramid in the construction activities. The researcher found that the most appropriate way to collect
information initially is the questionnaire, so a questionnaire was designed that corresponds to the
objectives of the study. Many owners, consultants, and contractors were asked about the main causes of
change orders, and the impact of change orders in the construction of the hospitals to have a general
preliminary study from their experiences and their point of view, which were used in formulating the
questionnaire Closed-ended questions were chosen because they are easy and quick to answer. It only
requires a short answer in an agreed format or not always, rarely, etc. [12].
4. Analysis of the Data of the Questionnaire Form

Project managers were interviewed and contacted to collect data related to change orders. The researcher distributed questionnaires to a sample of 75 participants, 67 questionnaire forms were retrieved. Then deal with the results using the Microsoft excel package and statistical package for social sciences (SPSS) and give explanations for these results.

4.1. Possible Causes of Change Orders in Construction

Many literature reviews have indicated that the action of the project's stakeholders (e.g. owner, consultant, and contractor) may be the direct causes of the change order in construction [6]. Through a survey conducted by the researcher for the hospitals' projects documents of capacity 400, 300, and 200 beds, the main causes that led to occur changes in these projects, were documented and a questionnaire was conducted for the participants in these projects. Table 1 shows the main reasons that led to changes
in the work. These reasons were linked to the main responsible for the changes. Number 1 was given to
the owner, 2 to the consultant, 3 to the contractor, and 4 to other parties and then analyzed using (SPSS
V. 22). The documents of each project included an increase in quantities and the addition of works to
the scope of the project due to changes in the description of the project, due to poor planning of the
owner and lack of feasibility study of the project as shown in the Table 2.

Table 1. The main responsible for changes.

| No. | Reasons for Changes                                      | First Responsible | Frequency | Percent |
|-----|----------------------------------------------------------|-------------------|-----------|---------|
| 1   | Financial problems                                       | Owner             | 46        | 68.7    |
| 2   | Change in plans or scope of work                         | Owner             | 46        | 68.7    |
| 3   | Replacement of materials or work procedures              | Consultant        | 46        | 68.7    |
| 4   | Change original design                                   | Consultant        | 45        | 67.2    |
| 5   | Detailed designs are insufficient                        | Consultant        | 43        | 64.2    |
| 6   | Detailed designs do not conform to the functional        | Consultant        | 44        | 65.7    |
|     | requirements of the project                              |                   |           |         |
| 7   | Errors and omissions in design                           | Consultant        | 45        | 67.2    |
| 8   | There is ambiguity in the design                         | Consultant        | 45        | 67.2    |
| 9   | No one of the parties to the contract is involved in the | Owner             | 56        | 83.2    |
|     | design                                                   |                   |           |         |
| 10  | Project activities are insufficient                       | Owner             | 46        | 68.7    |
| 11  | Lack of experience.                                      | Contractor        | 55        | 82.1    |
| 12  | Contradictions of contract documents                     | Consultant        | 46        | 68.2    |
| 13  | Unlimited scope of work                                  | Consultant        | 46        | 68.7    |
| 14  | Value Engineering.                                       | Consultant        | 46        | 68.7    |
| 15  | Change technology                                        | Consultant        | 46        | 68.7    |
| 16  | Different location conditions                            | Contractor        | 46        | 68.7    |
| 17  | Lack of knowledge of local conditions                    | Contractor        | 46        | 68.7    |
| 18  | Required work skills are not available                   | Contractor        | 46        | 68.2    |
| 19  | Materials do not meet specifications                     | Contractor        | 45        | 67.2    |
| 20  | Desire to improve financial conditions                   | Contractor        | 46        | 68.2    |
| 21  | New government regulations                               | Others            | 46        | 68.2    |

Table 2. Types of changes (Prepared by the researcher depending on documents of change orders of
the hospitals’ projects issued by the Ministry of Health.

| No. | Type of change orders                                      | The engineers’ opinions (%) | Arithmetic Mean |
|-----|------------------------------------------------------------|-------------------------------|----------------|
|     |                                                            | Always | Frequently | Occasionally | Rarely | Never |                      |
| 1   | Delete any part of the works.                              | 0      | 0          | 46           | 10     | 11    | 2.52                 |
| 2   | Change the description, quality, or class of the works.    | 46     | 21         | 0            | 0      | 0     | 4.52                 |
|     |                                                            | 68.7   | 31.3       | 0            | 0      | 0     |                      |
| 3   | Increase the quantity of any work included in the contract.| 46     | 10         | 11           | 0      | 0     | 4.52                 |
|     |                                                            | 68.7   | 14.9       | 16.4         | 0      | 0     |                      |
| 4   | Decrease the quantity of any work included in the contract.| 0      | 0          | 12           | 44     | 11    | 2.01                 |
|     |                                                            | 0      | 0          | 17.9         | 65.7   | 14.6  |                      |
4.2. Impact of Change Orders on the Construction Projects
Several studies have been conducted to demonstrate the impact of change orders and to identify the main cause of changes in construction and their effects [3,4,8,9]. The impacts of change orders on the construction industry were ranked by using a 5 points scale as the following: never = 1; rarely = 2; occasionally = 3; frequently =4, and always =5. Cost overrun came in the first position with a mean score (4.69), followed by a decrease in productivity which was given a mean score (4.67). Whereas delay in the schedule was ranked the third with a mean score (4.66). Moreover, many of the change orders’ adverse impacts were ranked according to their mean scores as shown in Table 3.

Table 3. Impact of change orders.

| No. | Impact of change order                              | The engineers’ opinions | Arithmetic Mean | Standard deviation |
|-----|-----------------------------------------------------|-------------------------|-----------------|--------------------|
|     |                                                     | Always | Frequently | Occasionally | Rarely | Never |                |                |
| 1   | Delay in the schedule                               | 44   | 23        | 0            | 0      | 0      | 4.66         | 0.478          |
|     |                                                     | 65.7 | 34.3      | 0            | 0      | 0      |                |                |
| 2   | Increase the cost of the Project                    | 46   | 21        | 0            | 0      | 0      | 4.69         | 0.467          |
|     |                                                     | 68.7 | 31.3      | 0            | 0      | 0      |                |                |
| 3   | Decrease in productivity                            | 45   | 22        | 0            | 0      | 0      | 4.67         | 0.473          |
|     | Dispute between the owner and the contractor         | 67.2 | 32.8      | 0            | 0      | 0      |                |                |
| 4   |                                                     | 22   | 45        | 0            | 0      | 0      | 4.33         | 0.473          |
|     |                                                     | 32.8 | 67.2      | 0            | 0      | 0      |                |                |
| 5   | Low in quality                                      | 24   | 43        | 0            | 0      | 0      | 4.36         | 0.483          |
|     |                                                     | 35.8 | 64.2      | 0            | 0      | 0      |                |                |
| 6   | Access to materials and equipment                   | 21   | 46        | 0            | 0      | 0      | 4.31         | 0.467          |
|     |                                                     | 31.3 | 68.7      | 0            | 0      | 0      |                |                |

4.3. Causes of Change and Its Impact on the Cost Factor of Project
The results of the questionnaire reviewed the causes of changes and their impact on the project. According to these results, the researcher selected the impact of the reasons mentioned previously on the cost element, included an increase in quantities and a change in specifications, which had a significant impact on the cost contracted, and it exceeded by up to 25 %, which is a very high percentage of what is allowed in the law of contracts and standard documents in Iraq. So previous studies have been interested in trying to control this factor, and not overtaken to a certain extent.

4.4. One-Way ANOVA
A one - way ANOVA analysis is used to verify the existence of statistically significant differences between more than two groups in one dependent variable. This is done by comparing between the averages of the groups, the available data about three sets of hospitals, 200, 300, and 400 beds, and to conduct this analysis some conditions must be achieving:

- The samples are random and independent.
- The communities of these samples have a normal distribution.
- The homogeneity of the variance of the community from which random sampling was taken.

4.5. Tests of normality
Table 4 shows that the value of each Kolmogorov-Smirnov Shapiro-Wilk is greater than 0.05.
Table 4. Tests of normality.

| Bed capacity | Kolmogorov-Smirnova | Shapiro-Wilk |
|--------------|---------------------|--------------|
|              | Statistic | df  | Sig. | Statistic | df  | Sig. |
| 200 bed      | 0.260  | 2   | .    |            |      |      |
| 300 bed      | 0.260  | 2   | .    |            |      |      |
| 492 bed      | 0.206  | 7   | 0.200* | 0.901  | 7   | 0.343 |

4.6. Homogeneity Test Between Groups
A test was performed homogeneity between three groups of hospitals 200, 300, and 400 beds. Table 5 shows that significance level at 0.362 larger than 0.05 which means achieved the homogeneity.

Table 5. Test of Homogeneity of Variances for Percentage of Change.

|          | Levine Statistic | df1 | df2 | Sig. |
|----------|------------------|-----|-----|------|
|          | 1.175            | 2   | 8   | 0.362|

4.7. One-way ANOVA analysis
After fulfilling the conditions of one-way ANOVA analysis were achieved, the analysis was performed using (SPSS V.22) software. This analysis is based on the F-test attributed to a popular probability distribution F-distribution, which has many applications in hypothesis tests. The researcher tests the existence of differences between the averages of the three groups of hospitals or not. F calculated > F tabulated as shown in Table 6

1. Null hypothesis (H0): \( u_1 = u_2 = u_3 \)
2. The alternative hypothesis (H1): \( u_1 \neq u_2 \neq u_3 \)

Table 6. One-way ANOVA analysis.

| Relation     | Sum of Squares | df  | Mean Square | F    | Sig. |
|--------------|----------------|-----|-------------|------|------|
| Between Groups | 0.004          | 2   | 0.002       | 34.371 | 0.000 |
| Within Groups  | 0.001          | 8   | 0.000       |      |      |
| Total         | 0.005          | 10  |             |      |      |

F tabulated 4.46

5. Model to Quantifying the Cost of the Change of Hospitals Projects Iraq
Many researchers use administrative and engineering programs and use technological development to find solutions to changes that will difficult to predict or control. The researcher used the data of contract cost and data of change orders cost for hospitals 400 beds, to find a relationship between the two variables according to the reasons given for the previously mentioned change orders. These changes were carried out in an indiscriminate and un-studied manner during the implementation of the projects, which negatively reflected on the increased schedule work and the low quality and productivity of the project, which impact on the increased contractual cost of the project. The researcher managed to reach a mathematical model that can predict the added cost of changes that occur through the planning or implementation phase for the project. The mathematical model was selected from among several models each of which represents an equation: (a linear first-degree-second-the third-equation exponential-logarithmic, etc.), by testing the correlation coefficient for it, and select the model has the largest coefficient, which indicates the greater representation of the sample studied.

6. Model for Calculating the Cost of Changing for All Works of the Contracting Cost
After testing the mathematical relationships in the statistical analysis program (SPSS V.22), show that the relationship is the equation of the third degree:

\[ Y = b_0 + b_1 X + b_2 X^2 + b_3 X^3 \]
Where \( Y \): represents the cost of project changes, \( X \): contractual cost of the project, and provided that the value of \( X > 0 \). Through the compensation of those constants is the final form of the equation. The equation that represents this model is:

\[
Y = 1.35 \times 10^{11} - 2.72X - 2.11 \times 10^{-11}X^2 - 4.87 \times 10^{-23}X^3
\]  

(2)

Figure 3. Model for calculating the cost of changing for all works of the contracting cost.

7. Conclusions
Based on the field survey conducted and the results presented the following can be concluded:

- Lack of feasibility study for the project and choose the appropriate type of contract to contract in this type of projects.
- Lack of financial and human resources to manage and follow up on the project.
- Non-contracting with a consultant specialized in this type of project, preparing the initial plans and contracting documents, supervising the contracting procedures, and then participating with the contractor in preparing detailed plans, supervising the worksite, preparing reports, and quantity survey for the site.
- Lack of field experience in this type of projects and lack of specialized staff on the part of the contractor to design, manage and implement the project.

Recommendations
Based on the results of this research, recommendations are made:

- Preferably contracting for this type of projects turnkey.
- Hire experienced workers, engineers, and construction managers to avoid work repetition.
- It is recommended to educate contractors on the negative impacts of change orders.
- Contractors should consider the direct and indirect impact of changes to check feasibility.
- Use updated lists of materials to avoid erroneous material specifications.
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