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Adopting a Method for Calculating the Impact of Change Orders on the Time it Takes to Complete Bridge Projects

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ABSTRACT

If the employer believes that changing the shape, quality, or quantity of the work or some part of it is appropriate, he has the authority to order the contractor to do so. These instructions would extend the time it takes to accomplish the task and, as a result, the project's completion time. In the majority of situations, the employer and the contractor couldn't agree on how to compute the extra time the contractor was provided as a result of change orders. The aim of this research is to find a mechanism to determine the additional time required to carry out these works, which will vary based on the type of work, the increase in quantity for any work within the contract, etc.. Modify the nature, quality or type of any work, change the levels, lines, position and dimensions of any part of the work, and perform any additional work necessary to finish the works. A field visit and survey will be conducted on the various bridge projects as part of the research to determine the types of change orders and the additional time required for each of them, in addition to the most important reasons for not using the relative change length and how each project differs from the other. A mathematical software can be enhanced to reliably calculate the additional time for each form of change order. Most of the works expected to appear in variation order are steel and concrete works, and asphalt cladding works, with a frequency of each of them (25 percent), followed by excavation works, which have a frequency of (16.66 percent) in bridge projects.

1. Introduction

For a variety of reasons, the world is experiencing a massive building movement, which is followed by several failures, one of which is adjustments during the project's execution. Construction projects are prone to change for a number of causes such as the long duration of these type of building project compared to the time it takes to complete it, and thus leads to increase in certain demands, or the development a new ideas to the continuation of work, or the occurrence of new technical developments in this field.

Bridge projects also involve a large number of papers, including specifications and bills of quantities, produced by many engineers from different disciplines, making them difficult to adapt. This is referred to as the

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issuance of change orders, which are used to monitor and limit these changes, as well as specify their conditions and timelines for use, and are provided as a separate item within the project framework.

Numerous studies have been conducted by different researchers using different methodologies to identify and evaluate the causes of various changes in construction A review of various literature has shown that project stakeholders such as the owner, consultant and contractor may have the direct cause of the occurrence of construction change orders, and many of studies by many researchers using different methods and methodologies to assess and identify the causes of different construction changes (Ssegawa et al., (2002)).

The reasons for change orders accompanying construction projects are: 1. Owner, 2. Contractor, 3. Consultant, 4. Other parties (Arain et al., 2006). There are many studies that have been conducted in order to understand and know the impact of change orders and to assess the main causes and effects of building changes. Where the impact of change orders was divided into several categories, the most important of which is the effect on the project completion time or project schedule (Al-Hamms et al., 2010).

It was also found that the real cost is directly affected by the time difference it takes to implement all the work of project and the pre-prepared time that is required to finish the project, as shown in formula (1).

Failure to complete the project within the schedule is described as a failure to complete activities from the specified completion date of the contract, and it can be described as a late completion or late start of works (Ebbs et al., 2007).

change order schedule (%)=(total time used estimated time)/(estimated time)*100% … (1)…(Ibbs. etl., 2007).

Changes in procurement and logistics, such as specialized expertise, new equipment, and supplies, can cause delays (Arain et al., 2006).

Change orders have a clear impact on the delay in the time of project completion, as it represents only (29%) of the deviation in time for the contractual duration and outputs due to variation orders, while it was found that the largest percentage of the variation period to the total variation in administrative projects is 64.0% (Hassan et al., 2013).The findings revealed a clear connection between the probability of change orders and project delays. Change orders were found to have increased project durations by (22-200) percent, which is considered troubling (Mahmoud et al., 2019).

2. Methodology.

This study's methodology can be summarized as follows:

1- Choosing bridge projects in the cities of Tikrit for the purpose of study by reviewing their files and identifying and sorting the most common works in them that lead to the emergence of change orders. Then study a number of research related to the topic for the purpose of finding the gap with the current research and arriving at a solution to the research problem.

2- Field surveys for these projects, as well as file analysis and review, are utilized to gather information on change orders bridge projects.

3- Finding the relationship between the different works and the factors referred to in each work item of the change order for the studied bridge projects, then use the statistical package program (spss25) to calculate the impact of the cost of the work of the above paragraphs on the project time.

3. Field survey and information aggregation

Bridge projects in cities of Tikrit were identified as a sample for the study. The total cost of the project and the time for its full completion before the change order occurs are the basic values that are found in the original project files. According to the change order, there are works that will be developed for the purpose of completing the project within the required specifications. These works contain the cost of each work in the original contract and the time for completion of the work as well, which are prepared in advance, and there are some of them that have not been calculated and are therefore not included in the change order

The study comprised eight projects spread across the Salah al-Din Governorate's various cities and areas. The information gathered from bridge projects is presented in the table (1) below.

Table 1. Data of Bridge's Change Orders.

Reconstruction of the two bridges of Shishin Valley, south of Tikrit				
Seq.	Type of work in the project	The contract's total Cost of work (IQ)	Cost of work in the change order (IQ)	Duration's work in change order (day)
1	Breaking the damaged concrete joists, 2 count	0	12,000,000	15
2	Supplying the pivot system (anchors)	0	4,800,000	15
3	Maintenance of old sinks	0	15,000,000	30
4	Casting work on the bridge berths	0	42,000,000	20
5	Electricity works and lighting poles	0	15,000,000	10
6	Asphalt cladding with a thickness of 4 cm	0	22,607,000	10
7	Asphalt modified layer brushes	0	14,000,000	7
8	Protective bridge guardrail	0	18,000,000	13
9	Painting works for the bridge	0	6,000,000	15
10	Asphalt maintenance for the damaged floor	0	4,000,000	9
	Total for Created Paragraphs	0	153,407,000	144

4. Analyze the Data as well as Outcomes Obtained .

There is a set of statistical and mathematical concepts and values that help and lead the researcher to guess the mathematical formulas to determine the time of the most common business paragraphs in change orders depending on their cost.

Some mathematical concepts must be grasped since they help in data analysis and give direction on the kind and form of equations that may be used to estimate the duration and cost of bridge work sections (Hussar et al., 2018, & Raposo 2016).They are as follows:

1- **Correlation coefficient value:** It can be defined as a statistical measure that gives the strength and degree of correlation between two variables as a value between (positive 1) and (negative 1). Therefore, the value (positive one) It gives a strong link between the variables that are studied, one in terms of the other.

While the value (negative one) It gives a strong inverse link between the variables being studied, through which it is known that an increase in some quantities by a certain amount leads to a decrease in the rest of the variables associated with the latter in a certain equation. Also, a value of zero (zero) gives that the connection between the two variables can be neglected.

The strength of the correlation between the variables is indicated by the value of the correlation coefficient between them. As an example, the value (0.2) indicates a weak and perhaps inconsequential positive association between the two variables. Although values more than (0.8) show a close relationship between the two variables, values less than (0.8) do not. (Hussar et al., 2018, & Raposo 2016).

2- **Scatter Diagram**: Using an initial technique, the researcher will establish if there is a strong, weak, or non-existent correlation between the two variables, as well as whether the estimated equation is linear or nonlinear, positive or negative. If both variables are quantitative, the "propagation form" is a suitable strategy.

It's vital to keep in mind that this is only a first step in defining sort of relationship.

Where it gives a representation of the points represented by the cost of work for the paragraphs in the studied document and the time period that is intended to be calculated for these works. From the set of points above, which were drawn on the level, he takes the best curved line that passes through these points, which represents them all, and then takes the equation that represents the curve above. (Jia 2014, Cohen et al., 2014).

3- **ANOVA (Analysis of Variance):** It consists of a collection of estimation methods. and processes that let you compare averages from distinct statistical populations by splitting the entire variation observed between them into sections.

According to ANOVA, the study of variance is based on the value of (F), which is a continuous distribution.

This distribution was developed in 1924 by the scientist Fisher.
Therefore, this number is referred to as Fisher's coefficient of variance. The value of (F) is used to choose and compare among several mathematical equations and models (linear, quadratic, cubic, exponential or logarithmic), and through it the predictive equation describes the best curve that passes through the data presented at the level of (Abd El-Ghani et al., 2013, & Magar 2014).
After inputting and evaluating data for bridging projects using (SPSS) software, and after putting together change orders for these projects, which are classified into:

5. A Change Order Time Estimation Model.

The following are the most prevalent established works in bridge project changes:

1. Iron and concrete works for the bridge structure.
2. Earthworks.
3. Asphalt layers cladding works
4. Electrical works.
5. Other works.

5.1. Estimating the Duration of the Bridge Structure's Created Steel and Concrete Work.

The model is chosen by comparing the correlation coefficients of many models (each of which is Defined in mathematical form: equation of first degree, second degree, third degree, exponential, logarithmic, etc.)and choosing the one with the highest coefficient.
This means a greater representation of the sample under investigation. As well as the Sample Scatter Diagram and the Fisher coefficient F (Baldwin 2019, & Roberts et al., 2014).

The Pearson correlation coefficient = +0.984, as shown in table (2), It is inferred that the strength of the association between the variables is very good, and therefore one can be guessed in terms of the other.

Table 2. ANOVA and Correlation Results For Created Concrete and Iron Works.

Graduation	Correlation of Pearson	Fisher Number F	Significance
Linear	+0.984	187.937	Smaller than 0.01
Quadratic	+0.984	86.794	Smaller than 0.01
Cubic	+0.984	86.794	Smaller than 0.01

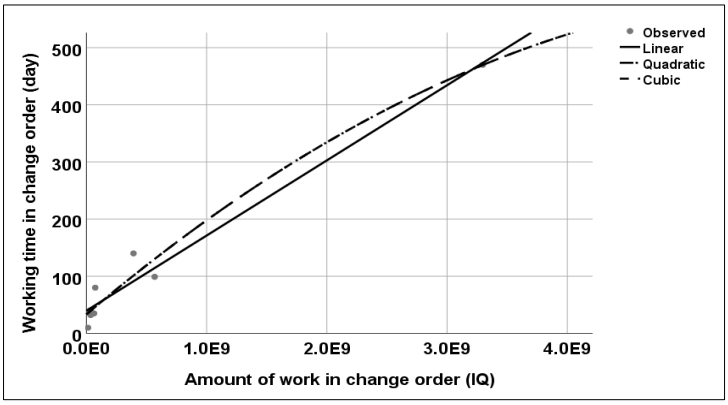

Figure 1. It's time to create a scatter diagram for the Created Concrete and Iron works.

A Linear equation a model is selected from Table (2) and Figure (1) (Baldwin 2019, & Roberts et al., 2014). This is how it's written:

$$y_1 = a_0 + a_1 x_1$$

Where:

y_1 = Time to modify the sequence of created steel and concrete works (D).

x_1 = Cost of Created Concrete and Iron works in variation order (per IQ).

$a_{0,\ and} a_1$ = Constant.

when a detailed analysis, the values $a_{0,\ and} a_1$ are found as follows:

$a_0 = 39.676$, $a_1 = 1.3153 * 10^{-7}$

The equation becomes:

$$y_1 = 39.676 + 11.3153(* 10^{-7})x_1 \quad \text{.....(2),(Researcher).}$$

The table (3), summarizes the work equations that have been created.

Table 3. The Created Work Equations in Simplified Form.

Seq.	Work type	Equation
1	Steel and concrete work .	$y_1 = 39.676 + 1.3153 * (10^{-7})x_1$
2	Earthworks.	$y_2 = 1.7764 * (10^{-15}) + 1.71 * (10^{-7})x_2 + 3.235 * (10^{-14})x_2^2$
3	the cladding of asphalt layers works	$y_3 = 6.803 * (10^{-7})x_3 - 2.426 * (10^{-23})x_3^3$
4	Electrical works.	$y_4 = -2.11 * (10^{-15}) + 7.667 * (10^{-7})x_4 - 6.667 * (10^{-15})x_4^2$
5	Other works.	$y_5 = 3.883 * (10^{-6})x_5 - 1.11 * (10^{-13})x_5^2$

5.2. Calculating the Impact of a Change Order by Modeling a Program.

To make applying the formulas for forecasting time of work for variation orders easier, a system was constructed under (Visual Basic) environment using the see sharp (C#) programming language. When you first open the software, a window appears with the application's entry button, as illustrated in Figure (2). The searcher's passcode is required after clicking on it, as seen in Figure (3).

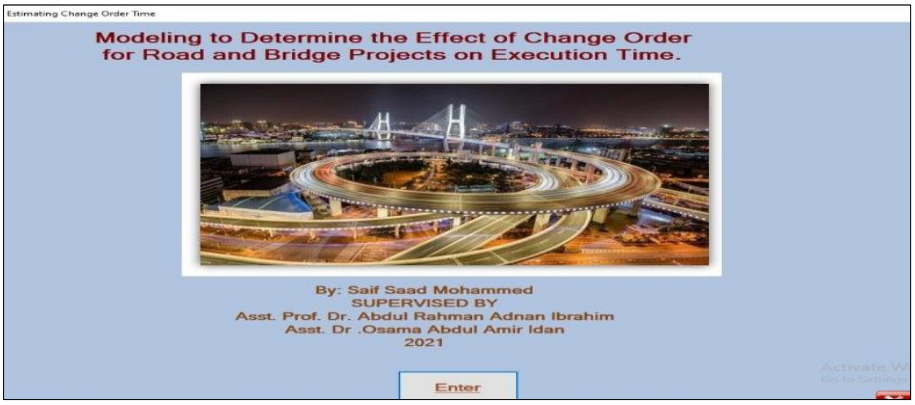

Figure 2. A window holding the program's entry button.

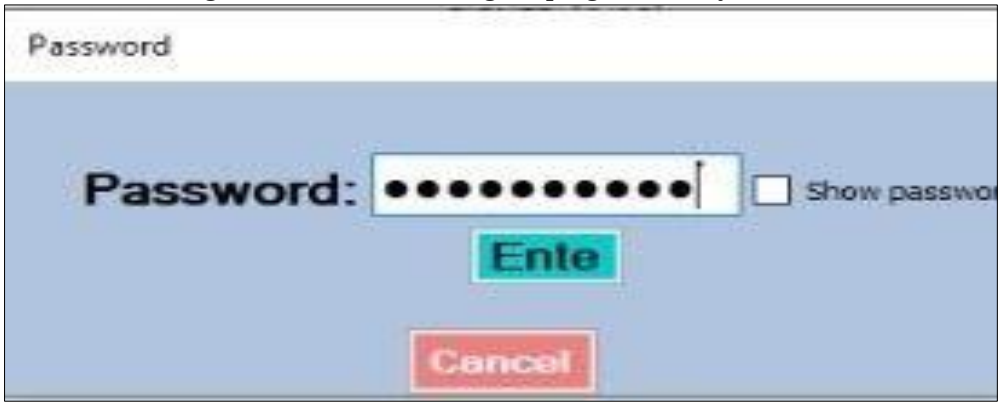

Figure 3. A window with demands for passcodes

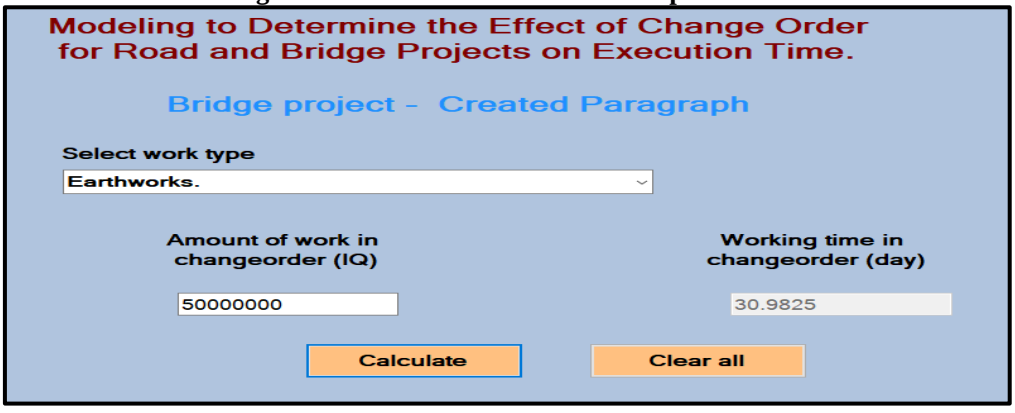

Figure 4. The nature of the task that requires time estimation.

After that, the type of work that will be completed and its duration will be estimated. The value of the time to be estimated is done through the computer program and as shown in Figure (4).

6. Conclusions.

1- Regardless of the type of work, the cost of a change order and the time it takes to accomplish it are closely related (additional work). This may be observed in the correlation coefficient values for the data under consideration (R) The values of (R) for the studied data are close to the value of the positive one, which indicates a close relationship between the costs of known work and the time periods to be calculated.

2- The most common words predicted the time that estimated in the variation order is (iron and concrete works, and asphalt work), each of them has a recurrence rate of (25 percent), followed by earthworks that have a recurrence rate of (16.66 percent) in bridge projects.

3- The conclusions of these mathematical equations are more detailed than those of any other study's equations. Because the latter was derived from a study of the questionnaire results (i.e. the engineers' perspectives). They are less exact than the equations employed in this research, which were derived from real field values of projects change orders for roads and bridges.

7. Recommendations.

1- Variation order should be created by engineers who have highly experienced and worked on projects comparable to the one for which the change order is being written.

2- Predicting and analyzing the cost and timing of change orders paragraphs in current projects using change orders from prior projects as a source of information.

3- Material price must be update, also lists and work in line with current market circumstances, as well as keeping up with new science and technology, such as automation working to lower task execution time.

4-Engineers creating estimates for bridge construction should focus on steel and concrete work, as well as asphalt cladding work, and be cautious when calculating their quantities, since these are the most prevalent in modifying bridge project orders.

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