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CAUSES OF VARIATION ORDERS IN THE EGYPTIAN CONSTRUCTION INDUSTRY: TIME AND COST IMPACTS

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Abstract: Variation orders are of great significance in any construction project. Variation orders are defined as any change in the scope of works of a project that can result in an addition, omission, or even modification (El-Sadek, 2016). This research introduces the main variation orders that could occur during construction in Egypt. The literature review involves a comparison of causes of variation orders in Egypt with Tanzania, Nigeria, Malaysia and the United Kingdom. A classification of occurrence of variation orders due to owner related factors, consultant related factors and other related factors are signified in the literature review. These 19 identified events that lead to variation orders gathered from the literature review are introduced in a survey to obtain their frequency of occurrence, and their time and cost impacts. The survey data is obtained from 87 participants that represent clients, consultants, and contractors. The number of participants in the survey is an acceptable representation of the population. A database of 42 scenarios is created that is used to develop an easy-to-use expert system model to help assist project managers in predicting the frequency of variations and account for a budget for additional costs and minimize delays that can take place. Two additional experts in the construction industry with more than 25 years of experience are given the expert system model to verify that it is working effectively. The model is then validated on a residential compound that was completed in July 2016 to prove that the model actually produces acceptable results.

1 INTRODUCTION

A variation order is a change in the scope of works of a project that can result in an addition or an omission from the overall volume of work. It observes that a change exists without the need to issue a new contract (Hester et al., 1991). This change is issued as an official document stating the associated change and agreed upon between the client and the contractor. Upon agreement, this document becomes part of the project's contract documents.

Variation orders can occur due to many reasons such as changes within the scope of work and contract documents. Variation orders can result in project cost overrun and delays, as well as many other negative impacts such as affecting project performance, quality, health and safety (Arain et al., 2004). Assaf et al. (2006), CII (1995), Hester et al. (1991), Fisk (1997) and O'Brien (1998) have all highlighted about the impact of variation orders on a construction project. These variation orders can have a massive and numerous impacts on an ongoing project.

With the construction industry expanding in Egypt, projects are getting more innovative and complex. The more complex the project is, the more likely it is time and cost sensitive. Since the construction industry covers a wide spectrum of project types, the type and magnitude of the effect of variation is dependent on the nature of the project. This then leads to complications in predicting variations that can occur during a project and its effect on time and cost without a systematic model.

The main objective of this study is to predict the effect of variation orders that could occur during the execution of different types of projects, and their associated time and cost impacts in the Egyptian construction industry through developing an expert system model.

The followed research methodology in this study starts with a literature review of the list of variations that can occur due to client, consultant and other related factors. A database through a distribution of surveys is obtained for different scenarios of different project types, cost, procurement methods and contract type. The proposed expert system model is then developed to address the different scenarios obtained in the database and analysis of variances (ANOVA) for each scenario in the database is conducted. A selection of an alternative scenario will be chosen if the original scenario fails to accept the null hypothesis. The expert system is then verified and validated.

In this paper, causes of variation orders are classified into three main groups: client related factors, consultant related factors and other related factors.

1.1 Client Related Factors

1. Inadequate project objectives: Unclear communication of project objectives can cause difficulties and variations in a project. Project objectives should be understood among all parties in order to avoid numerous changes that can occur during the work process (Ibbs et al., 1995).
2. Change of scope: During the construction of a project, the Client performs various change orders due to his lack of participation in the pre-tender phase and during the execution of the project (Arain et al., 2004).
3. Substitution of material: Change orders for material substitution have impacts on the construction process of the project (Chappell et al., 1996).
4. Financial problem: Financial issues arising from inflation, sudden price changes and unacceptable claims, affecting the client's cash flow, leading to changes in scope as the Client aims to reduce the project cost, impacting the implementation of the project (Clough et al., 1994) and (Ibbs et al.,1995).
5. Change of Schedule: Clients often change the schedule of the project that indicates cost and schedule consequences for the Contractor's resources as a result of the change that occurred during execution of the project (O'Brien, 1998).
6. Unilateral decisions: Clients can perform unilateral decisions without observing the consequences that can go behind these decisions. These decisions can sometimes be difficult to implement, affecting the projects time and cost (El-Sadek, 2016).
7. Clients do not perform decisions in the correct time: Decisions regarding the work process must be made in the correct timing to ensure project achievement (Memon et al., 2014).

1.2 Consultant Related Factors

1. Error and omission: A project having problems with the design or inadequate details in the design would significantly affect the work progress and the project time schedule (Arain et al., 2004) and (Assaf et al., 1995).
2. Design complexity: Design drawings can be often difficult to execute if the project is complex, therefore, a procurement method of Design-Build method should be chosen in order for the contractor to be involved during the design stages (El-Sadek, 2016).
3. Change in design: occurrence of change orders in a project is highly possible due to projects starting before the completion of the final design (Fisk, 1997).
4. Conflicting contract documents: A project having several contract documents may produce misunderstanding in conveying the project scope (CII, 1986).
5. Insufficient design: Insufficient designs can be a common cause for change orders in a construction project, affecting time schedule and leading to a cost increase (Fisk, 1997).

1.3 Other Related Factors

1. Differing site condition: Delays can occur due to physical condition of the project differing from which have been mentioned and stated by the consultants in the contract documents (Assaf et al., 1995)
2. Lack of co-ordination among parties: Lack of co-ordination among consultants, client and contractor leads to misunderstanding of the contractor in selection of equipment, material and labor during the execution of the project (Arain et. al., 2004).
3. New government regulation: project designs should follow specific codes and regulations according to the government organizations at which the project is performed in (Arain et. al., 2004).
4. Weather Conditions: Changing weather conditions can have significant impacts on the project construction specifically productivity as it results in project delays (O'Brien, 1998).
5. Value Engineering: It is a process of replacing the existing materials with an alternative material achieving the same quality, but with a lower cost (Dell, 1982).
6. Safety Considerations: The construction project must be executed in a safe environment following safety regulations and secure working conditions for all employees (Clough et al., 1994).
7. Required labor skills unavailable: Projects that have difficult technology necessities require specific know-how and skills by the labor (Arain et. al., 2004).

2 SURVEY DISTRIBUTION AND DATA COLLECTION

The purpose of the data collection is to create a sufficient database to develop the expert system model. In order for this to happen, the survey is created in a simple way for the user to follow and fill it out. The survey is created in order to obtain the probability of variation types that may occur during the construction of a project and their time and cost impacts in different project types with various costs, procurement types and contract types. The main aim of the survey is to gather as much and as divergent data as possible about different projects to enrich the database with different scenarios. The survey is created in a manner that its responses are used in the model as a database source.

Surveying includes various techniques, one of which is questionnaires. Questionnaires are one of the efficient and most popular techniques as they save time compared to other techniques such as face to face or phone interviews. Questionnaires have a higher reliability especially when conducting it over a divergent sample. Questionnaires can be either performed electronically through Internet or physically through distribution of hardcopies of the questionnaire. Internet is a great option as currently almost every engineer can have access to the Internet; therefore, it is quicker to distribute the surveys. The survey is distributed via email to engineers working in various projects in the construction field. It is collected in the same manner via email.

This survey requires an engineer to fill it out, and particularly an engineer that has worked with variation orders. However, the more experienced the engineer filling out the survey, the more weight will be allocated for the answers in the further development of the database and model. The survey is distributed to people with varying experience in the construction industry in Egypt; Employers, Consultant, and contractors.

The first section of the survey consists of structured questions having number of choices for the user to choose from regarding the background of the engineer filling out the survey. These kinds of questions are simpler for the user to answer and require less time to fill out. The second section of the survey is regarding the two most recent projects the user has worked on. This section is divided into two parts; the first part consists of structured questions regarding the most recent project the user has worked on. The second part is more stimulating as it involves a matrix that involves 19 events that to lead variations related to the client, consultant and other factors that were gathered from the literature review that requires the user to rate his choice. For instance, the frequency of the variation order arising will be a choice between 1-5, where 1 is being the least occurring event and 5 being the most occurring event. The reason those 19 events were specifically selected to be used in the survey is that it was found out through the literature review that these constitute common events leading to variation orders in projects in Egypt. The selection of a number of 19 events to be included in the surveys was totally arbitrary based on previous studies.
The expected outcome of this survey to obtain the probability of variation types that may occur during the construction of a project and their time and cost impacts in different project types with various costs, procurement types and contract types.

The number of surveys distributed was 102 and the total number of people who completed the survey was 87. A sample size equation is used to verify the adequacy of the sample size. It indicates that the sample size that needs to be surveyed is 81 as a minimum. The actual number of respondents is 87; meaning that the sample size is an acceptable representation of the population.

[1] Sample Size $= \dfrac{\frac{z^2 . p(1-p)}{e^2}}{1+\frac{z^2 . p(1-p)}{e^2 N}}$ (Hulley, 2001)

N = Population size
e = Margin of Error (as a decimal)
z= Confidence Level (as a z-score)
p = Percentage Value (as a decimal)

The sample size corresponds to the completed responses from the survey distribution. The population size (N) refers to the total number of surveys distributed that is 102 surveys. A desired confidence level of 95% was used to determine how reliable the results. Z-score refers to the number of standard deviations a given proportion is away from the mean. The z-score is corresponding to 95% confidence level is 1.96. Margin of error refers to the percentage of expected results in order to reflect the population size. A small margin of error means a closer result to the confidence level; therefore, a 5% margin of error is used. A percentage value of 50% was used to assume a normal distribution in calculation to correspond to an optimum sample size. The sample size that needs to be surveyed was 81. However, the actual number of respondents was 87; meaning that the sample size is an acceptable representation of the population.

The participants that are contributing to the survey are consultants, contractors and clients; where half of the participants are working in a consultant firm and the other half either are working for contracting companies or client firms. More than half of the respondents have experience of more than 10 years (60%). The remaining 40% of the respondents were either juniors or middle management.

3 MODEL DEVELOPMENT, CALCULATION OF TIME AND COST IMPACTS AND ANALYSIS OF VARIANCE

3.1 Scenarios Creation

The database is then used to group each individual project type; project value, procurement method, contract type and project duration in order to create a unique scenario. So for instance, if the user picks the retail as a project type, less than $10,000,000 as project value, design-build as procurement method, less than 24 months as project duration and lump sum as contract type, then this is a unique scenario. However, changing any of previous mentioned data will result in another distinctive scenario. So if the user picks the same previous mentioned data, yet changed the contract type from lump sum to re-measured, it will then result in another scenario. Nevertheless, not all the possible scenarios have been represented as the scenarios are only based on the data gathered via the surveys. Therefore, there is a possibility that there is a scenario that does not exist due to the fact that none of the 87 participants worked on such kind of scenario before. The total number of scenarios created in the database is 42.

3.2 Calculation of Time and Cost Impacts

Each of the scenarios is investigated separately. Every single project within the database involves a survey reference for simplicity when assessing the scenario. The surveys corresponding to each individual scenario are used as an input to determine the average of the frequency of event occurring, average time impact and average cost impact.

The equations for average cost and time score for each variation occurring was:

[2] Average Cost Score = Average Frequency of event occurring x Average Cost Impact

[3] Average Time Score = Average Frequency of event occurring x Average Time Impact

The equations for the total cost and time impacts on the project are:

[4] Total Cost Impact = Project Value x ∑Average Cost Score
[5] Total Time Impact = Project Duration x ∑Average Time Score

Where; project value and project duration are obtained through the user data input.

3.3 Analysis of Variance (ANOVA)

For each scenario of the 42 scenarios, analysis of variances (ANOVA) is used. The terminology “analysis of variance” is based on an approach that uses variances to observe whether the means are the same or vary.

There are three types of ANOVA analysis: one-way ANOVA, two-way ANOVA with replication and two-way ANOVA without replication. In this expert system model, two-way ANOVA without replication is applied. This approach is selected out of the two other approaches due to the fact that the variations being analyzed are independent of one another. Each scenario has three two-way ANOVA without replication being applied for each of the following parameters: frequency of events, cost impact and time impact.

The null hypothesis for the two-way ANOVA without replication tests two tests. The first test states that the means of data grouped by one independent variable are equal. The second test states the means of data for the other independent variable is equal. The main observation is based on the columns as to detect the variances among the submitted surveys corresponding to each scenario. This is conducted to know whether there is a significant difference between the answered surveys of the same scenario or not.

4 DATA ANALYSIS, VERIFICATION AND VALIDATION

4.1 User Input

The user in the expert system model selects a scenario for any project type, project value, procurement method, contract type and project duration for any project he would like to predict the frequency of variations that can occur along with their time and cost impacts. All three parameters mentioned previously have to accept the null hypothesis in order for the scenario the user input gets accepted. However, if the scenario the user inputs is rejected; then an alternative scenario will be selected. The alternative scenario is not the exact same scenario; it is someway similar and closer to the original scenario to what the user wants under the same circumstances. The alternative scenario will include the same project type, project duration and project value; yet will change the procurement type or contract type or both.

4.2 Scenarios Creation

Upon creation of the database, grouping them was the following step. The 144 projects resulted in a total number of 42 scenarios being created. Table 1 shows the 42 scenarios grouped from the database.

Table 1: Database scenarios

Project Type	Value ($M)	Procurement Method	Contract Type	Project Duration (months)	Scenario Number

Commercial/Administrative	<10	Design Build	Lump Sum	<12	1
Commercial/Administrative	<10	Traditional	Lump Sum	<12	2
Commercial/Administrative	<10	Traditional	Unit Price	<12	3
Commercial/Administrative	50-100	CM*	Cost-plus fee	24-36	4
Commercial/Administrative	50-100	Design Build	Lump Sum	2436	5
Commercial/Administrative	10-50	Traditional	Lump Sum	12-24	6
Commercial/Administrative	50-100	EPC**	Unit Price	24-36	7
Commercial/Administrative	50-100	CM*	Lump Sum	24-36	8
Commercial/Administrative	100<	Traditional	Cost-plus fee	>36	9
Commercial/Administrative	100<	Traditional	Lump Sum	>36	10
Healthcare	<10	Traditional	Lump Sum	<12	11
Healthcare	100<	Design Build	Lump Sum	> 36	12
Heavy Construction	100<	EPC**	Lump Sum	> 36	13
Industrial	<10	Design Build	Lump Sum	<12	14
Industrial	<10	Traditional	Lump Sum	<12	15
Industrial	<10	Traditional	Unit Price	<12	16
Industrial	10-50	Traditional	Lump Sum	12-24	17
Industrial	50-100	Traditional	Lump Sum	24-36	18
Industrial	50-100	Traditional	Unit Price	24-36	19
Industrial	100<	Traditional	Unit Price	>36	20
Industrial	100<	Traditional	Unit Price	>36	21
Infrastructure	10-50	Traditional	Unit Price	12-24	22
Infrastructure	10-50	Design Build	Lump Sum	12-24	23
Infrastructure	100<	Traditional	Lump Sum	>36	24
Infrastructure	100<	Traditional	Unit Price	>36	25
Residential	<10	Traditional	Lump Sum	<12	26
Residential	<10	Traditional	Unit Price	<12	27
Residential	10-50	Design Build	Lump Sum	12-24	28
Residential	10-50	Traditional	Lump Sum	12-24	29
Residential	10-50	Traditional	Unit Price	12-24	30
Residential	50-100	Design Build	Unit Price	24-36	31
Residential	50-100	Design Build	Lump Sum	24-36	32
Residential	50-100	EPC**	Lump Sum	24-36	33
Residential	50-100	Traditional	Unit Price	24-36	34
Residential	100<	EPC**	Unit Price	>36	35
Residential	100<	EPC**	Lump Sum	>36	36
Residential	100<	Traditional	Lump Sum	>36	37
Retail	<10	Traditional	Unit Price	<12	38
Retail	10-50	Traditional	Lump Sum	12-24	39
Retail	50-100	CM*	Cost-plus fee	24-36	40
Retail	100<	EPC**	Lump Sum	>36	41
Retail	100<	Traditional	Lump Sum	>36	42

*CM~ Construction Management
**EPC~ Engineer- Procure-Construct

4.3 Calculation of Time and Cost Impacts

For each scenario, averages of frequencies of variation event, time and cost impacts were calculated. The number of surveys being assessed in each scenario differs according to the number of surveys undergoing this specific scenario. This has been repeated for each of the 42 scenarios and results have been calculated. Each scenario had to have a minimum of 3 surveys in order to achieve reliable results. Average frequency scores, average cost scores and average time scores corresponding to each variation occurring are then calculated in order to reach the total predicted cost and time impacts for that scenario as shown, as an example, in Table 2.

Table 2: Total cost and time impact for scenario

Impact	Effect on Project	
Cost Impact	15%	$1.5M (additional)
Time Impact	17%	2 months (additional)

4.4 Analysis of Variance (ANOVA)

Two-way ANOVA without replication has been used to analyze the results of the surveys. It has been used to test whether the null hypothesis has been accepted or fail to accept (rejected).

Table 3: Two-way ANOVA without replication for frequency of events occurring

Summary	Count	Sum	Average	Variance
Inadequate project objectives	3	4	1.33	0.33
Change of scope	3	7	2.33	0.33
Substitution of material	3	6	2	0
Financial problem	3	6	2	3
Change of Schedule	3	6	2	1
Unilateral decisions	3	5	1.67	1.33
Clients do not perform decisions in the correct time	3	9	3	4
Error and omission	3	4	1.33	0.33
Design complexity	3	5	1.67	0.33
Change in design	3	6	2	3
Conflicting contract documents	3	4	1.33	0.33
Insufficient design	3	8	2.67	2.33
Differing site condition	3	5	1.67	0.33
Lack of co-ordination among parties	3	6	2	1
New government regulation	3	9	3	0
Weather Conditions	3	4	1.33	0.33
Value Engineering	3	8	2.67	1.33
Safety Considerations	3	6	2	3
Required labor skills unavailable	3	6	2	3
Survey 14	19	35	1.84	1.14
Survey 18	19	39	2.05	1.61
Survey 21	19	40	2.11	0.88

Table 4: Two-way ANOVA without replication for frequency of events occurring

Source of Variation	Sum of Squares	Degrees of Freedom	Mean of Square	F-Test	P-Value	F Critical value
Rows	15.33	18	0.85	0.61	0.86	1.89
Columns	0.74	2	0.37	0.27	0.77	3.26
Error	49.93	36	1.39			
Total	66	56				

Tables 3 and 4 represent the output of the two-way ANOVA without replication analysis. Table 3 represents the summary of variations that occur during that specific scenario. Table 4 represents the sources of variation for the rows which in that case are all the variations that can take place during the project and the columns which are the surveys submitted for that scenario.

The following conditions need to be satisfied to accept the null hypothesis or in other words, fail to reject the null hypothesis. These conditions state that there is no significant difference among the results.

$F\text{-value} < F_{crit}$
$P\text{-value} > 0.05$

The main focus in this study of two-way ANOVA without replication analysis is on the columns where an assessment of variance on the surveys has been conducted. The following results have been attained:

$F = 0.26 < F_{crit} = 3.26$, and
$P\text{-value} = 0.77 > 0.05$

The above conditions satisfy the acceptance of the null hypothesis, showing that the results are not different from each other. It also indicates that the alternative hypothesis is weak, and therefore, cannot reject the null hypothesis as the means of the results are the same. The following previous conditions of accepting or rejecting the null hypothesis have been assessed for the time and cost impacts as well for each individual scenario.

4.5 Accept/Reject Scenario

Each scenario of the 42 scenarios has three two-way ANOVA without replication analysis conducted for each of the three parameters: frequency of events, cost impact and time impacts. All three parameters must accept the null hypothesis in order for the scenario to be accepted. However, if one of the parameters fails to satisfy this condition, or in other words is rejected, then the scenario as a whole is rejected.

4.6 Verification of the Expert System Model

The model was given to two professionals in the construction industry with more than 25 years of experience to test that the model is working coherently and give comments, if any. The expert selects the scenario that needs prediction for variation orders occurrence and their time and cost impacts. Upon expert selection, the model then predicts the variations that can occur during that specified project along with the time and cost impacts that the expert needs to account for any additional project costs and time delays.

4.7 Validation on Real Case Study

The model is validated on a case study for a residential compound in Cairo that has been completed in July 2016. The original project value is 125 Million Egyptian Pounds ($6,9400,000) and the final agreed amount is 153 Million Egyptian Pounds ($8,500,000). The project had a procurement method of traditional (design-bid-build) and a lump sum contract. The original project duration is 14 months and the original completion date is January 2016. However, the actual completion date is July 2016 with 112 variation orders issued during the project construction phase with an additional cost of 28 million Egyptian Pounds ($1,550,000). The previous data is then used as an input for the model to predict the variations that can occur during the project and compare it to the actual data.

The model predicts that the project can have an approximate of $1.4 Million cost impact and 6 months project delay due to variation orders arising during the construction phase of the project. Comparing this to the actual data of the case study, the results are very near. The total cost of variations generated is extremely high which needs to account a budget for. The time impact as well is worrying as it contributes to almost 40% time delay of the total project duration. Hence, if the project manager had used this model at the beginning of the project, he would have been able to predict the occurrence of variations and their time and cost impacts and account a contingency for these impacts.

5 CONCLUSION

Variation orders are very significant in any construction project. They can affect project duration, cost, productivity, quality as well as many other negative impacts. An expert system model is developed in this research to help predict the variations that can arise during the construction of a project and account for their time and cost impacts. The expert system model is based on gathering 87 surveys of various participants that include clients, consultants and contractors. The surveys consist of 19 events that are obtained from the literature review to determine the time and cost impact corresponding to each event. From the surveys gathered, 42 scenarios are created each having a unique project type, value, procurement method, contract type and project duration. The user inputs these project data and a scenario is selected to produce the output of the model representing time and cost impacts corresponding to the input data entered. The main objective of the model is to help assist clients and project managers in accounting for time and cost impacts that can occur due to variation orders before the commencement of the project. This model could be applied in different country as it depends entirely on the database that is created through the distribution of surveys.

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