

AC 2007-3039: CHANGE ORDERS IMPACT ON PROJECT COST

Engy Serag, San Diego State University

Amr Oloufa, University of Central Florida

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ABSTRACT

Change orders occur frequently in most construction projects. Changes occur not only because of errors and omissions, but also for other reasons such as scope of work changes, or changes because of unforeseen conditions encountered on the site; a problem which is very common in most heavy construction projects. Several studies have attempted to quantify the impact of change orders on the project cost. Almost all of the studies in this area were sponsored by contractors' organizations, where statistical model used to quantify the impact of the change orders on the project cost was based on data supplied by the contractors; a situation that lead to owner-contractor disagreements related to the quantification method used. Also, resulting change order models didn't rely on the actual plans, specs, daily productivity and changes of the project; rather they relied on the reply of the contractor filling survey.

The study addresses the need for a statistical model to quantify the increase of the contract price due to change orders from verifiable site data such as owner's daily reports, change orders, drawing, and specifications. A model is developed and validated to quantify the percent increase in the contract price due to the change orders. This model will provide the owner with an estimate of the cost of the changed work, where it can be used for forward pricing or retrospective pricing of the change orders

INTRODUCTION

Change orders are frequently encountered in any construction project. Contract modifications that increase the contract value from 5 to 10% are expected in most construction projects¹. The

value of construction work put in place in 2003 was \$ 870 billion according to the US Census Bureau. A 5% change rate on this \$ 870 billion means that just the direct costs of change approach \$44 billion per year. In addition there are other indirect costs such as higher insurance rates, delayed completion of projects; and lost opportunity of bidding in other projects due to extended completion; and so forth. The major variable risk item in any construction project is the labor as they are frequently the most variable cost for the contractor. The main areas of labor cost increase include schedule acceleration, changes in the scope of work, project management, project location and external characteristics².

The main objective of the research is the following: (1) Analyze the change orders issued by the owner and their effect on project cost. (2) Develop a model to assist the owner to quantify the increase in the contract price resulting from change orders.

DATA PREPARATION

The most important step is to define the projects criteria under study; which is achieved through running multiple interviews with several claims consultants that handled construction claims for both the owner and the contractor. **Figure 1** summarizes the data collection steps. After collecting the data from the projects, the data is prepared to start the model building step by: (1) determining the dependant variable; and (2) determining the predictor variables.

Dependant Variable (Response):

The main objective of this study is to quantify the percent increase in the contract price due to change orders. It will be referred to in this study as the dependant variable.

$$\% \text{ Inc. due to change} = \frac{\text{Cumulative Cost of the Change Order to Date}(\$) \times 100}{\text{Original Cost of the project}(\$)} \dots\dots \text{Eq. 1}$$

Predictor Variables

Eleven predictors are applied to analyze and quantify their effect on the price increase of the contract due to change orders; they will be referred to in this study as the independent variables:

Timing of the Change Order: Practically, the cost of change increases as the project moves toward completion³. The time factor is evaluated by the following equation:

The “Timing of the Change Order” factor is measured in % as:

$$Time(\%) = \frac{(Date\ change\ order\ resolved\ * - Notice\ to\ proceed)(Days)}{Original\ contract\ duration(Days)} \times 100 \dots \dots \dots Eq. 2$$

****Date CO resolved:*** the earlier of the issuance of the Change Order date or the clarification date of a request for information (RFI) that led to changed work with a directive from the owner to construct the change till CO is issued.

Reason for the Change: There are several reasons for the owner to issue a change order. The most common reasons for design changes are: A) To provide for major quantity differences, B) To provide for unforeseen work, grade changes or alterations in the plans, C) To change the limits of the construction to meet field conditions D) To make the projects more functionally operational, and E) Deterioration or damage to the project after design.

The Party Implementing the Change Order: A study of the party implementing the change order whether it is the contractor or the subcontractor is important. This variable is measured as: A) Contractor, and B) Subcontractor.

Work Stoppage: It is not uncommon that the contractor has to stop the work when a change order is issued. This is a binary variable of whether there was a work stoppage or not.

Change Order Expended as Rework/ Credit (either addition or deletion)/ Idle: This variable is to check how the way the change order is expended affects the cost of the change order. This variable is measured as A) Rework, B) Credit, and C) Idle.

The Way the Change Order is Compensated: When the contractor is preparing a cost proposal for the changed work, it is important to include all the costs, overhead and profit. The change order can be compensated as: A) unit price, B) Time and material basis, or C) Lump sum amount negotiated between the contractor and the owner.

Restricted Access: Sometimes the owner issues a change order and this change lead to restricted access by the contractor labor. This is a binary variable measured as whether there is a restricted access or not.

Change Order Work Season: This is to check the effect of the season of the changed work relative to the planned work at the time of the bid. This is a binary variable measured as whether there is a change in the season or not.

Stacking of Trades: Stacking of trades occurs when worker from different trades work at the same area⁶. Staking of trades can occur due to different causes; rework, scope change, change order, project acceleration, complexity of work, poor planning, and delay in preceding activity (Few data points were collected were stacking of trades was encountered therefore; this factor is eliminated from the study).

Approved Change Order Hours: Approved change order hours will consist of labor and equipment hours, either operating or idle. This variable is measured as:

$$ApprovedHrs = \left(\frac{Approved\ change\ order\ issued\ for\ each\ change\ order}{Total\ approved\ change\ order\ for\ the\ project} \right) X 100 \dots\dots Eq. 3$$

Extension: According to the type of the delay, the change order cost is calculated. This factor checks the relation between the number of days of the extension granted and the increase of the contract price due to the change orders. This factor is measured as:

$$Extension\% = \left(\frac{Days\ of\ extension\ entitled\ to\ the\ contractor\ for\ each\ change\ order}{Orginal\ duration\ of\ the\ project\ in\ days} \right) X 100 \mathbf{Eq. 4}$$

Some of the variables listed above are qualitative in nature. For the qualitative variables, they have to be coded in a certain way to be included in the model. A qualitative variable with k levels, K-1 dummy variables will be created. These variables are not meaningful independent variables as for the case of quantitative independent variable. They are variables that make the model function.

MODEL BUILDING

Data collected are for projects that encountered an increase in the contract price from 0.01% to 15%. Change orders exceeding 15% will be eliminated from the study due to low frequency of occurrence thus are considered outliers.

Figure 2 summarizes the steps that are used for the model building. As shown in **Figure 2**, the decision of whether to keep a variable or not was based on its statistical significance, the significance of the variable from the engineering view point, and its functional form. The main objectives of this approach were to achieve a simple model, to be able to reduce any potential multicollinearity in the model, and to keep the variables that are meaningful to the engineer practitioner.

RESULTS: Change Order Model for Percent Increase More Than 5%

In order to meet the constant variance assumption, transformation of the response variables is performed. Inverse square root transformation for the percent increase is performed. Variable names are explained in Table 1. The model achieved is as follows:

$$\frac{1}{\sqrt{PERCINC}} = 0.343 + 0.000865 X_1 - 0.0539 X_{2A} + 0.0566 X_{2B} - 0.114 X_{2D} + 0.0315 X_3 - 0.00137 X_4 - 0.241 X_6 + 0.0318 X_{7A} + 0.0462 X_{7B} + 0.0580 X_{8A} + 0.106 X_{8B} - 0.00978 X_9 + 0.000501 X_1 X_{2A} + 0.000018 X_1 X_4 + 0.00239 X_1 X_6 - 0.000277 X_1 X_{7A} - 0.000706 X_1 X_{7B} - 0.00111 X_1 X_{8A} - 0.000946$$

$$\begin{aligned}
& X_1 X_{8B} - 0.0513 X_{2B} X_{7A} - 0.0567 X_{2B} X_{8B} + 0.0133 X_{2B} X_9 - 0.102 X_{2D} X_3 + 0.0834 X_{2D} X_7 + 0.0961 \\
& X_{2D} X_{7B} + 0.0629 X_{2D} X_{8A} + 0.0578 \\
& X_3 X_{8B} \dots \dots \dots \text{Eq. 5}
\end{aligned}$$

When the change order increases the contract price by more than 5%, the most significant factors that explain the percent increase in the contract price due to change orders are: 1) Time, 2) Reason of the change (A,B&D), 3) Party performing the changed work, 4) The way change order is compensated, and 5) Extension.

As for the interaction variables, the most significant interaction of variables that contribute to the increase in the contract price due to the change order: 1) Time and (reason of the change (A), approved change order, restricted access, the way the change order is expended, and how the change order is compensated), 2) Reason (B) and (change order is expended as credit, change order is compensated as time and material basis, extension is granted). 3) Reason (D) and (party, way the change order is expended, when the change order is compensated as lump sum).

The number of data points used to create this model is 137 data points. The standard deviation (S) achieved is 0.0253270% , R-Sq = 80.2% and R-Sq (adj) = 75.3%. This means that 75% of the variability in the response variable, percent increase in the contract price due to change orders, is explained by the predictor variables. As shown **Figure 3**, the normal distribution assumption is checked using the normality plot and the histogram of the residuals. As for the constant variance assumption, the data has improved from the first trial (when all the data of the change order are evaluated in one model for PERCIN from 0-15%) and the data are not following any trends.

RESULTS: Change Order Model for Percent Increase Less than 5%

In order to meet the constant variance assumption, transformation of the response variables is performed for the percent increase. Variable names are explained in Table 1. The model achieved is as follows:

$$\begin{aligned} \text{PERCINC}^{0.4} = & 1.56 + 0.00763 X_1 + 0.365 X_{2A} + 0.139 X_{2B} - 0.160 X_{2C} + 0.295 X_{2D} + 0.149 X_3 + 0.00308 X_4 \\ & + 0.354 X_5 - 0.947 X_{7A} - 0.912 X_{7B} + 0.256 X_{8A} - 0.519 X_{8B} + 0.00832 X_9 - 0.00699 X_1 X_{2A} - 0.00535 X_1 X_{2C} - \\ & 0.00535 X_1 X_{2D} + 0.112 X_{2A} X_4 - 0.480 X_{2A} X_5 - 0.385 X_{2B} X_3 - 0.342 X_{2B} X_5 + 0.224 X_{2B} X_{8B} + 0.679 X_{2C} X_{8A} + \\ & 0.850 X_{2C} X_{8B} - 0.263 X_3 X_5 + 0.175 X_3 X_{7A} - 0.401 X_3 X_{8B} - 0.164 X_5 X_{7B} + 0.594 X_{7A} X_{8B} + 0.759 \\ & X_{7B} X_{8B} \dots \dots \dots \text{Eq. 6} \end{aligned}$$

The number of data points used to create this model is 208 data points. The model has a standard deviation (S) of 0.25959, R-Sq = 62.9% and R-Sq(adj) = 57%. This means that only 57% of the variation of the response variable percent increase in the contract price due to change order is explained by the predictors. This is a considerably low value of R-Sq (adj), however as supported by the literature most of construction projects experience change orders up to 5% and more than 5% is where problems of quantification arise.

Most of the variables have a variable of inflation less than 100; a threshold which above multicollinearity is present. The most significant factors that explain the percent increase in the contract price due to change orders are: 1) Time, 2) Reason for the change (A&D), 3) Way the change order is expended, 4) How the change order is compensated.

As for the interaction variables, the most significant interaction of variables that contribute to the increase in the contract price due to the change order are: 1) Time and the reason of the change (A&D), 2) Reason (A) and (approved change order hours), 3) Reason (B) and (the party

performing the change, and when the change order is compensated as time and material basis), 4) Reason (C) and the way the change order is compensated, 5) Party and the when the change order is compensated as time and material basis, and 6) The way the change order is expended and when the change order is compensated as time and material basis. As shown in **Figure 4**, the normal probability plot and the histogram of the residuals the data follows a normal distribution, and the residual versus the fitted value the variance is not following a trend, thus the assumption of constant error is met.

MODEL VALIDATION

The validation data set consists of 29 observations from four projects that were not used in the model building. The actual percent increase in the contract price due to change order is compared to the predicted percent increase from the model. The average percentage of error is 28.61% for the change order model that quantify the percent increase in the contract price due to change orders that exceed 5%, and 43.94% for the change order model that quantify the percent increase in the contract price due to change orders less than 5%. The error value is slightly high for the prediction model for change orders less that 5%, yet usually most of the quantification damage problems occur when change orders are higher than 5%.

CONCLUSION

The study tackled the change orders from verifiable site data. The researchers conducted several interviews with a public owner and claims consultants who work for parties, the owner and the contractor. The change order model provided a tool to the owner to perform a forward or retrospective pricing of change orders. It aids in forecasting the cash flow of the owner and to

make sure that the contingency money available for the project will cover the cost of the change orders. In addition, the research provided a tool to help the owners in heavy construction projects, a trade that was seldom studied, to quantify the cost of the change orders at different period of times during the lifetime of the project. In the presence of the change order model, where both parties agree upon, the process of handling the changes and the quantification of the damage will be easier and hence the owner's and the contractor's time and money allocated for the dispute resolution will be minimized.

RELATION TO THE CURRICULUM DEVELOPMENT:

Change orders and their effect on productivity is an important aspect to our industry and are seldom mentioned in current Construction Engineering and Management programs. This research was the base for the development of two graduate courses. The first one is "Construction Labor Productivity Management". This course focuses on external factors that affect labor productivity on the site and in particular the effect of change orders. The present research opened the door of how to analyze their change orders and quantify their impact on productivity loss. The second course developed from this research is another graduate course called "Construction Claims". In any claim, the most important point is to be able to provide a cause effect analysis to support the entitlement for the claimed amount. The present research showed a methodology to be able to win the claim; a big section that will be taught in this course. In a nutshell, this research provided a baseline for highlighting important concepts that are needed by the industry and is lacked in the curriculum; either for a graduate or undergraduate programs.

REFERENCES

1. Finke, Michael “A Better Way to Estimate and Mitigate Disruption” *Journal of Construction Engineering and Management*, November 1998, 490-497.
2. Shwartzkoph, William” Calculating Lost labor Productivity in Construction Claims” John Wiley & Sons Inc., Canada, 1995.
3. Chick, David “The Time Value of Project Change” *Journal of Cost Engineering*, Vol.41/No.6, June 1999.

LIST OF FIGURES

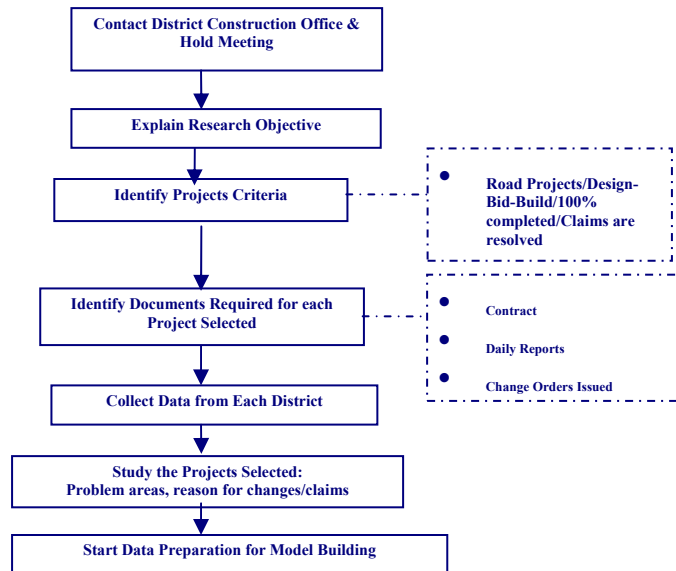


Figure 1: Data Collection Procedures

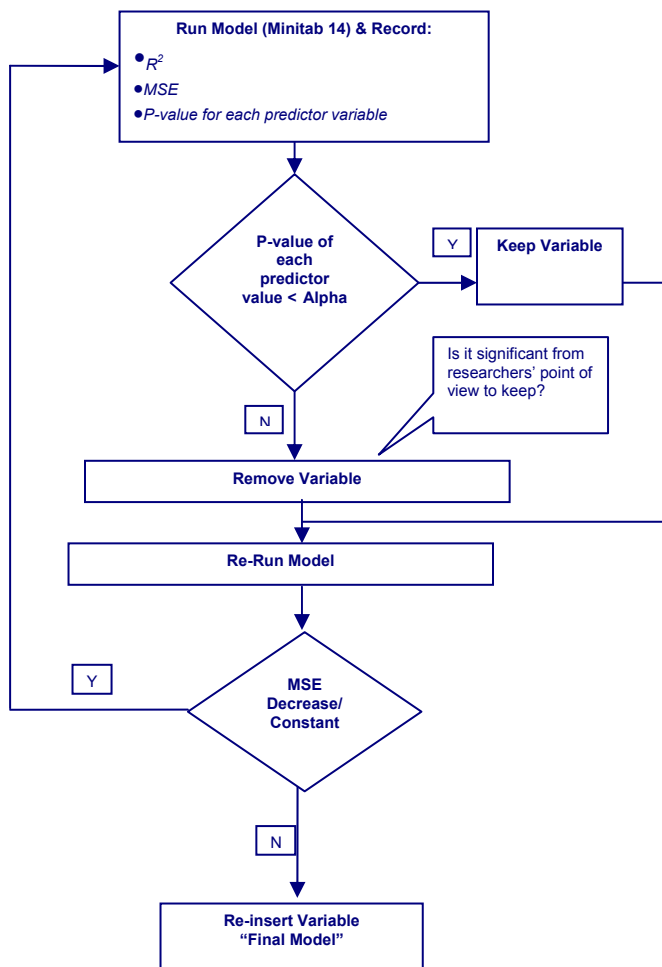


Figure 2: Model Building Procedures

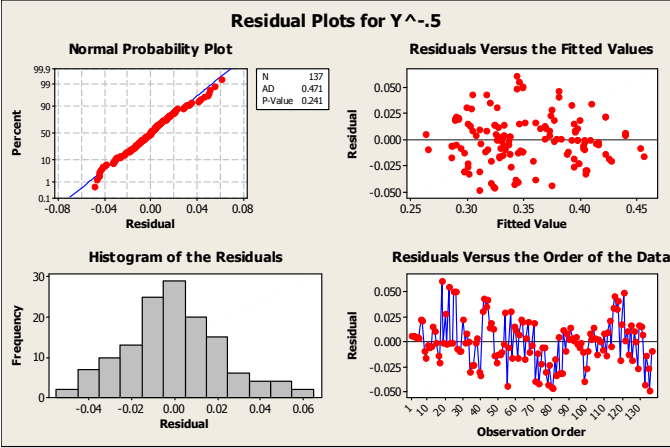


Figure 3: Residual Plots for PERCINC >5%

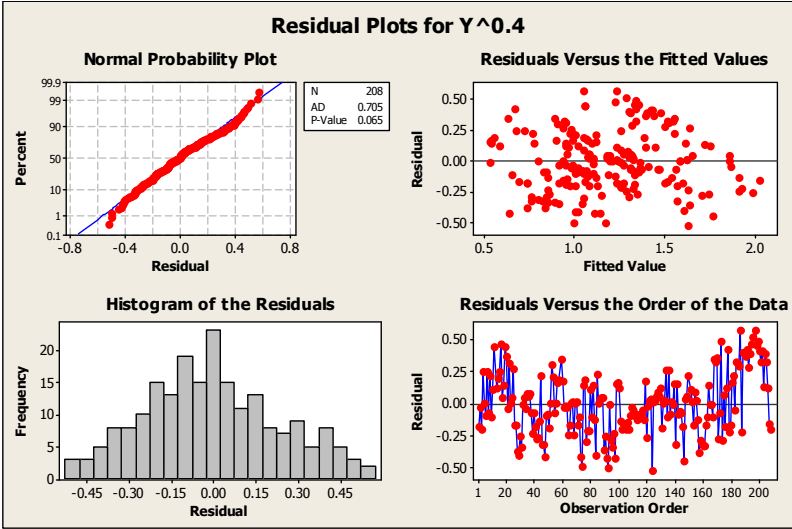


Figure 4: Residual Plot for PERCINC <5%

Table 1: Change Order Case Study Predictor Variables

Variable Name	Variable Reference	Unit	Way of Calculation
% Inc. in contract price	Y	%	Eq. 1
Timing of Change Order	X ₁	%	Eq. 2
Reason for Change Order	X _{2A}	1	A. To provide for major quantity differences
	X _{2B}	0	
	X _{2C}	0	
	X _{2D}	0	
	X _{2A}	0	B. To provide for unforeseen work
	X _{2B}	1	
	X _{2C}	0	
	X _{2D}	0	
	X _{2A}	0	C. To change the limits of the construction
	X _{2B}	0	
	X _{2C}	1	
	X _{2D}	0	
	X _{2A}	0	D. To make the projects more functionally operational
	X _{2B}	0	
	X _{2C}	1	
X _{2D}	0		
X _{2A}	0	E. Deterioration or damage to the project after design due to accidents, weather conditions, and others	
X _{2B}	0		
X _{2C}	0		
X _{2D}	0		
Party	X ₃	1 0	Contractor Subcontractor
Approved Change Order Hours	X ₄	%	Eq. 3
Work Stoppage	X ₅	1 0	Yes No
Restricted Access	X ₆	1 0	Yes No
Way Change Order Expended	X _{7A}	1	Credit
	X _{7B}	0	
	X _{7A}	0	Rework
	X _{7B}	1	
	X _{7A}	0	Idle
	X _{7B}	0	
Way Change Order Compensated	X _{8A}	1	Lump sum
	X _{8B}	0	
	X _{8A}	0	Time & Material Basis
	X _{8B}	1	
	X _{8A}	0	Unit Price
	X _{8B}	0	
Extension	X ₉	%	Eq. 4
Work Season	X ₁₀	1	Same season as bid
		0	Different season than bid
Stacking of Trades	X ₁₁	0	No
		1	Yes