



Factors Influencing Change Orders in Horizontal Construction Projects: A Comparative Analysis of Unit Price and Lump Sum Contracts

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Abstract

Change orders (COs) are a common occurrence in construction projects, leading to increased costs and extended durations. Design-Bid-Build (DBB) projects, favored by state transportation agencies (STAs), often experience a higher frequency of COs compared to other project delivery methods. This study aims to identify areas of improvement to reduce CO frequency in DBB projects through a quantitative analysis. Historical bidding data from the Florida Department of Transportation (FDOT) was utilized to evaluate five factors—contracting technique, project location, type of work, project size, and duration—on specific horizontal construction projects. Two DBB contracting techniques, Unit Price (UP) and Lump Sum (LS), were evaluated using a discrete choice model. The analysis of 581 UP and 189 LS projects revealed that project size, duration, and type of work had a statistically significant influence on the frequency of change orders at a 95% confidence level. The discrete choice model showed significant improvement in identifying the appropriate contract type for a specific project compared to traditional methods used by STAs. By evaluating the contracting technique instead of project delivery methods for horizontal construction projects, the use of DBB can be enhanced, leading to reduced change orders for STAs.

Keywords: Discrete Choice Modeling; Lump-Sum Contracting and Unit Price Contracting

Introduction

Construction projects invariably experience changes during the design or construction phases, resulting in the need for change orders (COs) [1,2]. COs can stem from the project owner's requests for modifications to the original contract or arise from field conditions and conflicts encountered during construction [3,4]. These changes can have adverse effects on project performance, leading to increased costs and delays [5]. Researchers have suggested that the chosen project delivery method or contract type directly affects the size and frequency of these COs. Previous research suggests that the selection of project delivery methods and contract types directly influences the frequency and magnitude of COs [6-8]. Among the various project delivery methods used by

State Transportation Agencies (STAs), Design-Bid-Build (DBB) is one of the most prevalent procurement techniques in the United States (9). Since more than 70 percent of STAs projects were procured through DBB, this was the method selected for the analysis of this study [10,11]. DBB involves the owner, often an STA, developing the project design internally or through the engagement of an engineer, while the construction is awarded through a separate agreement [9,12]. The DBB method can be customized like any other method to fit specific projects' needs based on the project's different administrative and management aspects [13]. The compensation for general contractors in DBB projects can take different forms, such as Unit Price (UP), Lump Sum (LS), or

Cost Reimbursable contracts [11]. This study focuses on analyzing DBB projects, specifically those utilizing UP and LS contracting techniques, with the aim of understanding the factors influencing the frequency of COs. By utilizing bidding data from the Florida Department of Transportation (FDOT) between January 2015 and March 2017, the research examines the impact of contracting technique, project location, type of work, project size, and duration on the frequency of COs in horizontal construction projects. The research employs a discrete choice model to predict the frequency of COs and compare the effectiveness of UP and LS contracts in managing change orders. The findings of this research contribute to enhancing the understanding of COs.

Background

In UP contracts, contractors are paid a fixed cost per unit of each item, such as per cubic yard of excavation or linear foot of guide rail, based on the actual measured units constructed on the project [14]. On the other hand, LS contracts involve a fixed amount of money for performing the specified work outlined in the bid documents [15,16]. LS contracts aim to simplify the payment process and reduce contract administration costs, focusing more on quality rather than individual pay items [17,18], Minchin Jr, Chini et al. [19,20]. While UP is the primary contracting technique used by State Transportation Agencies (STAs) for DBB projects, LS contracts are employed in select cases, particularly for simpler projects with well-defined scopes and minimal risk of unforeseen conditions and changes (FDOT 2017). The advantages of LS contracts include reduced contract administration costs, simplified payment processes, and a focus on quality [17,21]. However, managing and negotiating COs can be more challenging under LS contracts due to the absence of unit prices and difficulties in pricing and identifying changes in the scope of work [14]. Contractors may include higher contingencies in their price proposals to mitigate potential risks. Previous research has mainly focused on comparing different delivery methods such as DBB and Design-Build (DB), rather than examining different forms of DBB contract methods [22,23]. Studies have indicated that DBB projects may have a higher frequency of COs compared to DB projects [23]. Another study suggested that Lump Sum DB contracts may outperform DBB contracts in terms of schedule and cost [24]. The causes of COs in construction projects include client-related issues and a lack of national information and databases on soil conditions and services [25].

FDOT considers LS as a distinct contracting technique for simple projects and utilizes UP contracts for more complex projects (FDOT 2017). FDOT has defined ten types of COs that contractors can request during the construction phase, which have specific impacts on project constraints such as schedule and cost (FDOT 2017). The advantages of LS contracts, as identified in previous

literature, include reduced contract administration costs, simplified payment processes, and greater flexibility in construction means and methods [14]. However, the disadvantages include difficulties in pricing and negotiating COs, identifying changes in the scope of work, and potentially higher contingencies in price proposals [11]. It is challenging to price COs under LS contracts due to the absence of unit prices, leading to contractors including higher contingencies in their price proposals [16]. To mitigate the disadvantages of LS contracts, project selection criteria have been developed, considering factors such as a well-defined scope of work, low risk of unforeseen conditions, low possibility of scope changes, and contractors providing the required quantities of work [19,22]. In this study, we aim to analyze DBB projects utilizing UP and LS contracting techniques, focusing on the factors influencing the frequency of COs. By examining bidding data from FDOT, we evaluate the impact of contracting technique, project location, type of work, project size, and duration on the frequency of COs in horizontal construction projects. Furthermore, we employ a discrete choice model to predict the frequency of COs and compare the effectiveness of UP and LS contracts in managing change orders.

Methodology

The research methodology employed in this study is illustrated in Figure 1. The study began with an extensive literature review to gain insights into the contracting practices of STAs in DBB projects, as well as the processes related to COs. Relevant data and information were then collected, including historical bid data from all projects awarded by FDOT between January 2015 and March 2017. Bid tabulations published by FDOT were used to gather approximately 1,274 projects for further analysis. Among these, 705 projects were UP contracts, and 200 projects were LS contracts, which formed the focus of this study. It should be noted that the selected projects were in different life cycle stages, including executed, work begun, final acceptance, material certified, final payment authorized, and final payment made. From the collected projects, a subset was identified for in-depth analysis based on their life cycle stages. Specifically, the projects in the final payment authorization and final payment made stages were chosen, as these stages indicated that any potential changes in the construction contract had already been finalized. This subset consisted of 581 UP projects and 189 LS projects, as shown in Table 1. Additionally, information on the projects that included CO requests. The analysis focused on understanding the changes that occurred during the life cycle of the selected projects, with the frequency of COs requested serving as the dependent variable. The frequency of COs approved by FDOT in the analyzed projects ranged from zero to 197 COs per project, as depicted in Figure 2. For analysis purposes, the frequency of COs was categorized into three groups: low (≤ 10 COs), medium (11-20 COs), and high (> 20 COs).

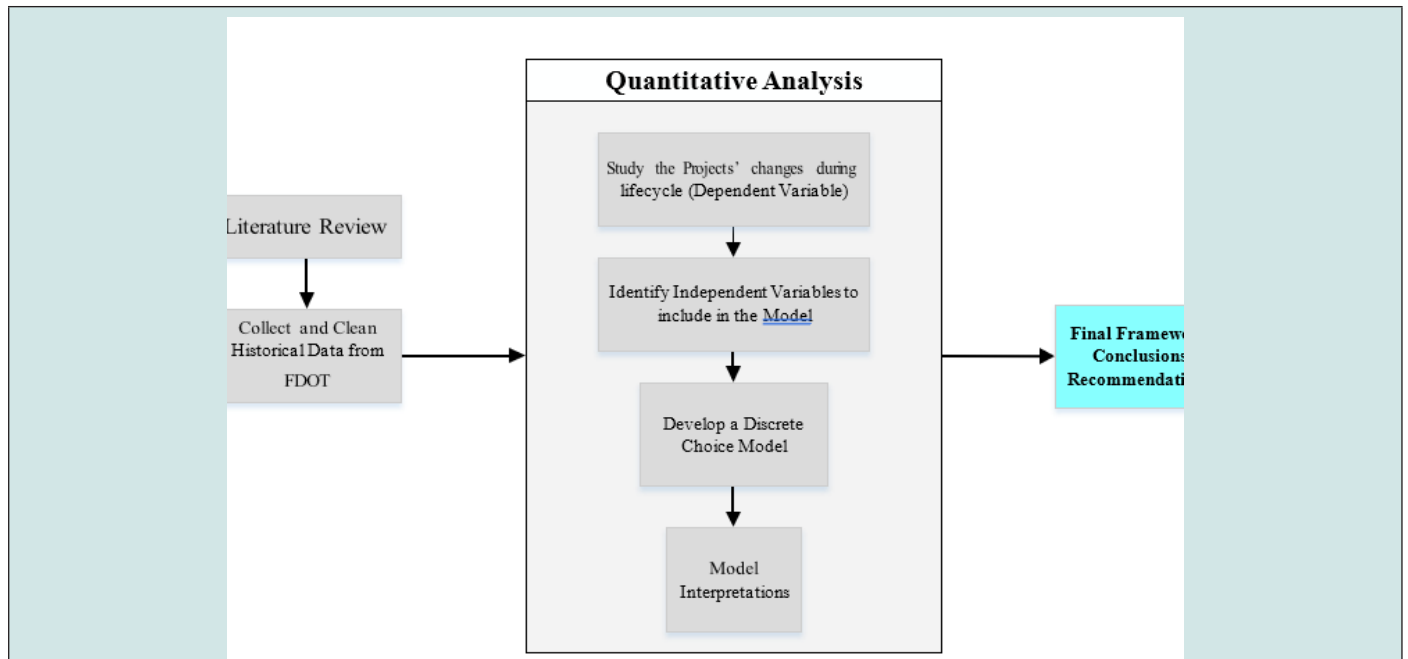


Figure 1: Proposed Research Methodology.

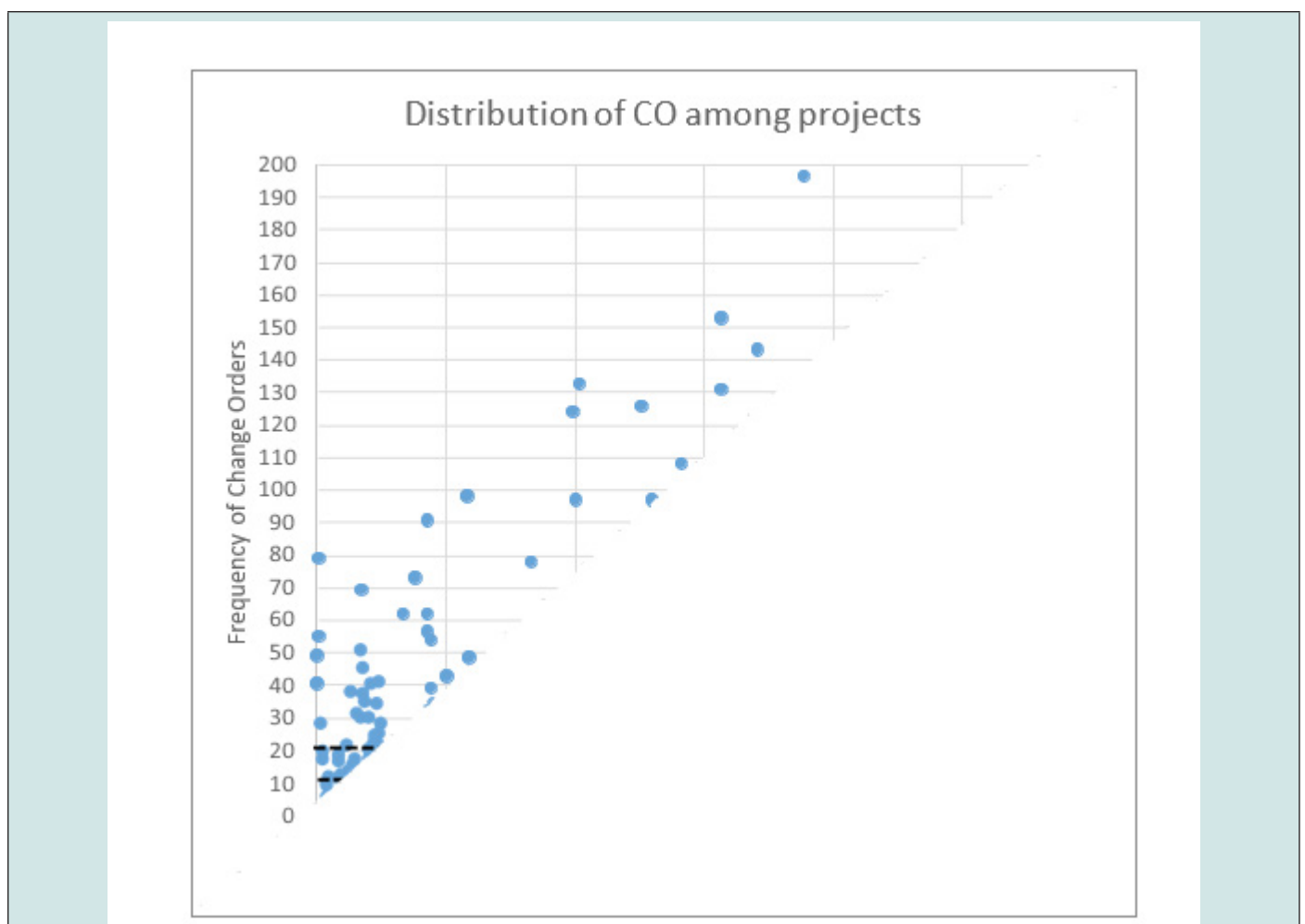


Figure 2: Distribution of Change Orders among Projects.

Table 1: The Total Number of Projects and Projects where CO Requested

Type of Project Work	Total Number of Projects		# Projects Requested COs	
	Unit Price	Lump Sum	Unit Price	Lump Sum
Bridge Construction	26	2	18	2
Bridge Repair	95	4	35	1
Interstate Construction (New)	1	0	0	-
Interstate Rehabilitation	9	0	5	-
Miscellaneous Construction	50	30	29	9
New Construction	9	0	8	-
Other	67	42	25	18
Reconstruction	36	3	33	2
Resurfacing	229	82	125	35
Traffic Operations	24	23	9	5
Widening & Resurfacing	35	3	29	1
Total Projects	581	189	316	73

Several independent variables were considered in the analysis. The first variable was the contracting technique (UP or LS), as the type of contract was expected to influence the occurrence of COs. The second variable was the location of the project, which was divided into eight districts of FDOT. The third variable was the type of work, including Miscellaneous Construction, Resurfacing, Traffic Operations, and Other types. The fourth and fifth variables were the size and duration of the project, respectively, which were determined based on the agency's cost estimate and initially estimated duration before the bidding process.

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Model Development:

Discrete choice models are widely used in various fields to explain and predict decision-making behavior. These models are

Table 2: Case Processing Summary

Category of the frequency of change orders	N		Percentage of Total Data
	Low	Medium	High
Contracting Technique	Lump Sum	176	26.10%
	Unit Price	498	73.90%
	Resurfacing	274	40.70%
Type of work	Traffic Operations	39	5.80%
	Miscellaneous Construction	70	10.40%

Other Types		291	43.20%
Florida District	District 1 - Southwest Florida	99	14.70%
	District 2 - Northeast Florida	104	15.40%
	District 3 - Northwest Florida	122	18.10%
	District 4 - Southeast Florida	62	9.20%
	District 5 - Central Florida	85	12.60%
	District 6 - South Florida	96	14.20%
	District 7 - West Central Florida	90	13.40%
	District 8 - Florida's Turnpike	16	2.40%
Valid		674	100.00%
Missing		96	
Total		770	

Results

The multinomial ordinal logit regression model was employed using IBM SPSS Statistics 25® to analyze the data with a confidence level of 95 percent ($p = 0.05$). Table 3 provides an overview of the case processing involved in the analysis. Models with log-likelihood values close to zero are considered to be the best-fit models. In Table 4, the final new model has a log-likelihood value of 958.63, which is closer to zero compared to the intercept-only baseline model's

value of 1309.73. This indicates that the new model better captures the variance in the outcome and represents an improvement over the original model. The chi-square value of 351.1 indicates that the data is significant, supporting the conclusion that the new model is an improvement. The analysis identified several variables that were not statistically significant at a 95 percent confidence level ($p = 0.05$). With the exception of the size of the project and the type of project (resurfacing), most of the variables were found to be statistically insignificant (Table 5).

Table 3: Model Fitting Information

Model	-2 Log-Likelihood	Chi-Square	Degree of Freedom	P-Value
Intercept Only	1309.734			
Final	958.63	351.104	13	0

Table 4: Parameter Estimates

Variables		Coefficient Estimate	P-Value
Threshold	Low	2.454	0.001
	Medium	3.813	0
Location	Size of the Project	1.34E-07	0
	Duration of the Project	0.009	0
	Contracting Technique		
	∅ Base: Unit Price		
	∅ Lump Sum	-0.503	0.037
	Type of work		
	∅ Base: Other Types		
	∅ Resurfacing	0.895	0
	∅ Traffic Operations	0.401	0.378
	∅ Miscellaneous Construction	0.892	0.007
	Florida District:		
	∅ Base: District 8 - Florida's Turnpike		
	∅ District 1 - Southwest Florida	-0.295	0.678
	∅ District 2 - Northeast Florida	-1.188	0.093
	∅ District 3 - Northwest Florida	-0.349	0.62
	∅ District 4 - Southeast Florida	-0.092	0.899
	∅ District 5 - Central Florida	-0.464	0.523
∅ District 6 - South Florida	-0.999	0.163	
∅ District 7 - West Central Florida	-0.413	0.566	

Table 5: Interpretations from the Model

Variable	Significant	Meaning
Size of the Project	Yes	As the size of the project increases, the number of change orders is more likely to increase.
Duration of the Project	Yes	As the duration of the project increases, the number of change orders is more likely to increase.
Contracting Technique		
Ø Base: Unit Price		
Ø Lump-Sum	Yes	Projects procured through LS are less likely to have COs than Projects procured through UP.
Type of work		
Base: Other Types		
Ø Resurfacing	Yes	Resurfacing projects are more likely to have more COs than other types of projects
Ø Traffic Operations	No	Traffic Operation projects are more likely to have more COs than other types of projects
Ø Miscellaneous Construction	Yes	Miscellaneous Construction projects are more likely to have more COs than other types of projects
Florida Location		
Base: District 8		
Ø District 1	No	Projects in District 1 are less likely to have more COs than projects in District 8
Ø District 2	No	Projects in District 2 are less likely to have more COs than projects in District 8
Ø District 3	No	Projects in District 2 are less likely to have more COs than projects in District 8
Ø District 4	No	Projects in District 4 are less likely to have more COs than projects in District 8
Ø District 5	No	Projects in District 5 are less likely to have more COs than projects in District 8
Ø District 6	No	Projects in District 6 are less likely to have more COs than projects in District 8
Ø District 7	No	Projects in District 7 are less likely to have more COs than projects in District 8

Conclusions And Recommendations

Construction projects often undergo changes in scope, time, or cost during their life cycle, which are managed through the issuance of change orders (COs) by owners. The frequency of COs requested can significantly impact the expected outcomes of projects, with lower frequencies generally leading to better project outcomes. This study aimed to identify the factors that contribute to COs and their effect on the frequency of COs approved for horizontal construction projects. The analysis utilized a multinomial ordinal regression discrete choice model and focused on completed projects undertaken by FDOT between 2015 and 2017, consisting of 581 unit price (UP) and 189 lump sum (LS) contracts. The results of the analysis indicate that project size, project duration, and contracting technique (UP or LS) were statistically significant in influencing the frequency of change orders during the construction life of a project. Specifically, as the size and duration of a project increases, the likelihood of experiencing more COs also increases. Projects procured through the LS contracting technique were found to have a lower likelihood of COs compared to projects procured through UP. Moreover, the data reported for resurfacing and miscellaneous construction projects demonstrated a higher likelihood of having more COs compared to other types of project work. For future research, it is suggested to explore additional factors, such as studying the influence of CO size as a percentage of the project's cost. Developing an objective approach for selecting

projects suited for the LS contracting technique, rather than relying solely on expert judgment, could also be beneficial. Furthermore, future research could focus on developing a framework for selecting projects to be procured through the LS technique. By expanding the understanding of these factors, construction stakeholders can make more informed decisions to minimize the occurrence of COs and enhance project performance.

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