CCC 2018

Proceedings of the Creative Construction Conference (2018)
Edited by: Miroslaw J. Skibniewski & Miklos Hajdu
DOI 10.3311/CCC2018-086

Creative Construction Conference 2018, CCC 2018, 30 June - 3 July 2018, Ljubljana, Slovenia

Qualitative analysis of electrical-related change orders on university projects

Wesley Collins[a], Robert Bugg[a], Alex Layson[b]

[a]*Auburn University, Auburn, Alabama, USA*
[b]*Henkels & McCoy, Inc. Philadelphia, Pennsylvania, USA*

Abstract

Electrical construction is ubiquitous on building construction projects. Quantitative change order analysis on building construction projects at two American universities showed that electrical change orders were disproportionately high (11-16%) as compared to general contracting (5-10%) or mechanical (5-8%) construction-related change orders, on a percentage of contract value basis. The purpose of the research described herein was to qualitatively analyse electrical change order descriptions on completed building construction projects to discern why this variation exists. The descriptions for 1,214 change orders (associated with 215 projects completed over a seven-year period) were collected and categorized based on the 20 separate reason codes. The reason codes associated with access control/security, interior lighting, circuitry, and low voltage wiring were found to have the highest prevalence. Also, the analysis showed that many electrical change orders were related to work items accounted for by the project team during preconstruction, but not contracted for during the initial tendering stage. Hence, these additional costs, which account for approximately half of the electrical change orders (as a percentage of contract value) were changes to the electrical scope of work as originally contracted, but not changes to the project itself. The results of this analysis show the value of qualitatively tracking (through codes or other methods) change orders, as opposed to purely tracking costs.

Peer-review under responsibility of the scientific committee of the Creative Construction Conference 2018.

Keywords: Change orders; public construction; electrical construction

1. Introduction

The usage of change orders to address unexpected occurrences, owner desires, and project realities is commonplace on almost every construction related undertaking. Change orders are rarely seen in a positive light; considered a necessary evil at best. Changes after the start of construction commonly lead to project cost and schedule overruns, as well as the heightened possibility of litigation between project stakeholders.

The limited availability of funds for capital investment requires owners to maximize the effectiveness of every dollar spent on construction-related expenditures, especially public owners such as school districts, municipalities, departments of transportation, and public universities. Understanding the prevalence and root causes of changes in an owner's construction program are the first steps to proactively mitigate the quantity and impact of change orders on future projects, as project planning and budgeting activities can be focused towards problem areas. This paper discusses a study of electrical construction-related change orders associated with a set of capital projects completed at a public university in the United States. The research methodology and results are discussed. Results of the study uniquely contribute to the existing body of change order research knowledge through a reproducible methodology for examining change orders on a specific and ubiquitous scope of work (i.e., electrical construction) found on almost all building construction projects.

Corresponding author: Author email: wes.collins@auburn.edu

2. Literature Review

O'Brien (1998)[1] defines a "change order" as a formal change to a construction contract that includes a change in work, cost of work, or time to perform work. These scope, cost, and schedule changes are typically additions to the originally contracted scope of work but may be deletions. Sun and Meng (2009)[2] provides a broader definition, stating that a change is "an alteration to design, building work, project program or other project aspects caused by modification to pre-existing conditions, assumptions or requirements." Many authors assert that changes (i.e., change orders) are a certainty or inevitability on all construction projects [1, 3, 4, 5, 6]. Hanna et al (2007)[5] posits that for a project to not have any changes, the design, coordination, and communication on the project would have to be perfect, which is simply not possible.

Change orders have been widely researched by both academics and practitioners. Sun and Meng (2009)[2] provides a taxonomy of change order research, summarizing 101 journal papers that had been published between the years of 1985 and 2006. The change order research tract has been prevalent most likely because, as stated by Taylor et al. (2012)[8], "change can make life frustrating for project stakeholders, and many projects experience significant performance degradation because of change." These frustrations are due to the propensity of changes to cause time and cost overruns, disruptions, and disputes [2] as well as being detrimental to contractor productivity [5, 7, 9, 10, 11, 12]. Riley et al. (2005)[13] assert that two types of change orders exist; owner generated change orders, which are issued when an adjustment to the project scope, design, or detailing are required by the owner, and field generated change orders, which arise when problems and conflicts are detected in the field that require a re-design or reconfiguration of the design. Sun and Meng (2009)[2] also assert that change orders can be influenced by external factors (e.g., environmental, political, social, economical, technological), organizational factors (e.g., process, people, technology), and project specific factors (e.g., client generated, contractor/subcontractor generated, project structure). Change orders are seen to have many general causes, such as the uniqueness of each project and the difficulty in predicting the future [6], the limited time and money resources available for planning, executing, and delivering projects [9], project complexity, and the inherent uncertainty of financial performance, development funding, and control of costs and schedule on constructed facilities [14]. Specific root causes of change orders are numerous, and can include: design errors, concurrent design and construction, ambiguous design intent, design coordination issues, unexpected site conditions, weather conditions, owner directed changes in scope, project delays/suspensions, project acceleration, hidden site conditions, differing site conditions, premature tender documents, substitution of products from the specifications, force majeure, and contract item overruns [4, 6, 8, 9, 15, 16, 17, 18, 19, 20, 21].

Collins (2012)[22] describes a study of change orders on 215 multi-prime design-bid-build projects completed by a public university in the United States over a 12 year period. The three main prime scopes of work studied were (1) general contracting, (2) mechanical contracting, and (3) electrical contracting. The results of the study are provided in Table 1 below. As shown, 506 total contracts (total meaning the sum of all prime contracts) were let, with a value of over $190 million. Nearly $21 million-worth of change orders were issued on these contracts, averaging 10.61 percent of the contract value. Mechanical contracting had the lowest change order percentage, at 8.55 percent. The most prevalent scope of work, general contracting, had the mid-average change order percentage at 9.96 percent, and the least prevalent scope of work, electrical contracting, had the highest change order percentage, at 16.09 percent. Collins (2012)[22] noted an area of future research to be determining why electrical-related change orders occur at a higher rate than other major prime scopes of work through a qualitative analysis of change order descriptions (i.e., stated reasons for the changes themselves.)

Table 1 – Summary of results from Collins (2012)[22]

	All Contracts	General Contracting	Mechanical	Electrical
Total number of contracts	506	216	150	140
Total value of contracts	$193,869,389	$105,973,492	$54,327,485	$33,568,412
Average contract value	$383,141	$490,618	$362,183	$239,774
Total number of change orders	2,030	951	565	514
Total value of change orders	$20,567,095	$10,522,049	$4,642,867	$5,402,179
Average amount per change order	$10,131	$11,096	$8,217	$10,510
Average change order percentage	10.61%	9.96%	8.55%	16.09%

3. Research Objective and Methodology

The objective of the study described herein was twofold: to (1) duplicate the research methodology described in Collins (2012)[22] on a separate set of construction projects completed by a public university in the United States to compare change order prevalence, and (2) perform a qualitative analysis of electrical construction-related change orders to discern the reasoning for these change orders.

The specific steps of the research methodology for this study consisted of:

1. Collect and compile cost and change order data (through analysis of completed project cost reports) on a set of projects completed by a public university in the United States. The project data would be categorized by the prime scope of work.
2. Analyze the data to determine the total and average contract amounts for each of the prime scopes of work, along with the total and average amounts of change orders attributed to each scope.
3. Collect and compile qualitative data (i.e., change order descriptions) on electrical construction-related change orders, if the analysis described in step two of the methodology showed that electrical construction-related change orders were prevalent.
4. Analyze the qualitative data to conclude what the specific drivers were for the electrical construction-related change orders.

4. Results

4.1 Quantitative Analysis

The authors reviewed historical cost reports for 215 projects completed by a public university in the United States over a seven-year period. The contracts were broken down into the three main scopes of work listed in Collins (2012)[22]. A summary of the results is provided in Table 2.

As shown, 302 total contracts (total meaning the sum of all prime contracts) were let, with a value of over $621 million. Over $35 million-worth of change orders were issued on these contracts, averaging 5.68 percent of the contract value. Mechanical contracting had the lowest change order percentage, at 5.13 percent. The most prevalent scope of work, general contracting, had the mid-average change order percentage at 5.39 percent, and the least prevalent scope of work, electrical contracting, had the highest change order percentage, at 11.4 percent.

It should be noted that the university projects used in this study were contracted using a single-prime project delivery method, as opposed to a multi-prime project delivery method, as was the case in Collins (2012)[22]. Hence, a majority of the projects are categorized as general contracting, even though mechanical and electrical-related construction was part of that scope of work. The mechanical and electrical contracts listed in Table 2 are for those projects that solely had mechanical and electrical construction.

Table 2 – Summary of results

	All Contracts	General Contracting	Mechanical	Electrical
Total number of contracts	302	208	70	24
Total value of contracts	$621,145,801	$504,462,754	$82,327,320	$34,355,727
Average contract value	$2,056,774.18	$2,425,301.70	$1,176,104.57	$1,431,488.63
Total number of change orders	1,214	812	256	146
Total value of change orders	$35,310,617	$27,172,533	$4,220,067	$3,918,017
Average amount per change order	$29,086.18	$33,463.71	$16,484.64	$26,835.73
Average change order percentage	5.68%	5.39%	5.13%	11.40%

4.2 Qualitative Analysis

The authors determined that performing a qualitative analysis of the electrical change orders was warranted, as the prevalence of electrical construction-related change orders had a similar magnitude to the results of Collins (2012)[22]. The qualitative analysis would be used to determine the reasoning for the electrical change orders (i.e., was there a specific reason or reasons that led to electrical construction-related changes orders being significantly higher than the other prime scopes of work.) The authors developed a set of 20 categories, described in Table 3 (listed in alphabetical order.) The categories were based on specific electrical construction work items and on other necessary category types, such as 'allowances' or 'other.'

Table 3 – Change order categories and their descriptions

Category	**Description**
Access control/security	Video surveillance, security systems, and access control
Allowances	Change to the original contracts resultant from unused unit costs
Audio Visual (A/V)	All audio/visual systems, such as televisions and projectors
Circuitry	Change to circuitry, conduit, or cable pulls
Design changes	Design changes or revisions after the start of construction
Devices	Includes electrical outlets, boxes, switches, and any other electrical devices
Electrical equipment	Electrical equipment such as step-down transformers, main switch gear
Exterior lighting	Site lighting, street lighting, and parking lot lighting
Interior lighting	Wiring and fixtures related to interior lighting
HVAC and elevator	Electrical controls for HVAC or elevator equipment
Life safety	Life-safety inspections, fire alarm systems, radio alarm systems, and emergency communications
Lightning Protection	Changes resultant from lightning protection items
Looking ahead	Changes to a current project to accommodate an anticipated future project
Low voltage	Changes related to telecommunications, data, information technology, and internet/ethernet
Non-electrical	These were non-electrical changes to electrical contracts
Not enough detail	Change orders with descriptions not detailed enough to be put into any specific category
Other	Items not related to any of the other categories
Owner furnished items	Changes associated with items provided by the owner, but installed by the contractor
Primary service	Changes to the main electrical feed, as well as those associated with generators
Sitework	Sitework-specific changes

The authors chose to assess each of the 20 categories based on three components: (1) their rank based on prevalence (i.e., occurrence) as compared to the other categories, (2) their rank based on the total dollar amount of all changes that fell into the specific category, and (3) their rank based on the average dollar amount of all changes that fell into the

specific category. The authors determined that the prevalence of the change order categories should be analyzed along with their cost components to assess the overall magnitude of the changes. For example, many change orders may fall into one category, but the total or average cost of the changes could be minimal. Other changes may not be as prevalent but have a higher attributed total or average cost. The authors completed the analysis using a weighted scheme, where the total score for each change order category would equal three-times the rank of the change order's occurrence, plus two-times the change order's total dollar amount rank, plus one-times the change order's average dollar amount rank. An example of this scoring scheme (for audio visual-related change orders) is provided below in Figure 1. The ranking of each change order category used the methodology of the higher the occurrence, total value, or average value, the lower the rank score. For example, the category with the highest number of occurrences would receive a rank of one, and the category with the lowest number of occurrences would receive a rank of 20. Hence, the lower the total score, the greater the magnitude of the change order category.

Figure 1 – Example of Weighted Ranking System for Audio Visual Category

A	B	C	D	E
Change Order Category	Ranking with respect to total number of occurrences	Ranking with respect to total dollar amount	Ranking with respect to average dollar amount per occurrence	Weighted Ranking = (Column B x 3) + (Column C x 2) + (Column D)
A/V	15	15	9	84

A summary of the rankings for all of the change categories is provided below in Table 4. As shown, access control/security, interior lighting, circuitry, not enough detail, life safety, and low voltage have the lowest scores, meaning that on a weighted basis, those change order categories carried the highest overall magnitude to the projects used in the study.

Table 4 – Weighted Ranking of Change Order Categories

Category	Number of occurrences rank	Total dollar amount rank	Average dollar amount rank	Score
Access control/security	6	1	2	22
Interior lighting	3	3	7	22
Circuitry	1	4	14	25
Not enough detail	9	2	3	34
Life safety	2	6	17	35
Low voltage	5	5	10	35
Devices	4	9	15	45
Sitework	7	10	12	53
Exterior lighting	12	8	6	58
Design changes	14	7	5	61
HVAC and elevator	8	13	13	63
Electrical equipment	10	12	11	65
Looking ahead	18	11	1	77
A/V	15	15	9	84
Primary service	16	16	8	88
Owner furnished items	19	14	4	89
Other	13	17	18	91
Allowances	11	20	20	93
Non-electrical	17	18	16	103
Lightning protection	20	19	19	117

5. Discussion of results

The category of access control/security was ranked sixth with respect to total number of occurrences, first with respect to total dollar amount, and second with respect to average dollar amount per occurrence. The authors noticed a recurring theme in the detailed descriptions of change orders in this category, that many of these change orders included incorporating scope packages into the respective projects that could have been included in the original project bid documents but were not for reasons not apparent in the data. For example, the most expensive item from this category was the incorporation of three construction change directives into the project, noted as "Furnish and install all wiring and devices for Access Control and CCTV." The change order is adding a security and access control package to the project after the start of construction. This scope of work is typical for projects completed by the University and would have been included in the total project budget, hence could have been included in the original bid documents.

An analysis of descriptions for change orders in the interior lighting category showed similar results. For example, the two most expensive change orders in this category were attributed to the Owner requesting that the electrical contractor add to their scope of work the lighting fixture package that was originally an Owner-furnished item. Again, the Owner would have included the cost for the lighting fixture package in their total project budget but chose not to include this with the electrical contractor's original scope of work.

The categories of circuitry and low voltage showed more mixed results upon further detailed review. Circuitry change orders were relatively inexpensive when they occurred, but they occurred more often than change orders from any other category by far. The occurrences, as per the detailed descriptions, included adding circuitry to items added to the project (either by the owner or through design clarifications), rough-in of power circuit for future work adjacent to the project at hand, and changes to cover unforeseen conditions realized after the start of construction. Telecommunications circuitry (included in the low voltage category) also required several change orders related to additional work for future projects. Changes related to unforeseen conditions would be expected to be significant, due to the nature of work completed by the University (and most Universities) being renovation in nature as opposed to new construction, but additional work related to future projects would not be expected.

The takeaway from this analysis was that while electrical change orders, from a quantitative perspective, seem disproportionately expensive, most of the largest electrical change orders were from items that would have been accounted for in the Owner's original budget, and were therefore not what would be considered "bad" change orders. The author's estimate that if change orders of this nature were removed from the analysis, the overall change order percentage would drop by approximately half, bringing the overall electrical change order percentage in line with the mechanical and general contracting prime scopes of work. Another main takeaway is the value of complete a qualitative analysis of change orders to complement a quantitative analysis. As shown, a purely quantitative analysis can be deceptive, and not allow Owners to focus towards improving project change performance of items truly in need of addressing on future projects.

6. Conclusions, Limitations, and Future Research

Owners must be diligent with their funds if they are to get the maximum value from their projects. Change orders are pervasive in the construction industry, but as shown, are not always detrimental to an Owner's overall project budget. Many change order items (as least according to the data analysed in the described research project) are a product of Owner's choosing to push-off contracting certain items until after the start of construction or choosing to incur costs on current projects for the betterment of future works. The overall magnitude of such changes can be significant. The analysis also shows the value of qualitative analysis over purely quantitative analysis. It is paramount for decision makers to fully understand the full scope of what may be included in any kind of quantitative analysis, as figure can be misleading.

This study was limited to a set of projects completed by one public university owner in the United States. The results of the study may not be representative of every Owner's construction program. The change orders of general contracting and mechanical scopes of work were also not analysed as part of this project, only electrical construction-related change orders. Future research should seek to again replicate this type of change order analysis with another public university owner, or an owner with a significant construction program that includes a substantial amount of renovation work. Change orders attributed to general and mechanical contracting should also be studied to discern how those changes align with the results of the study described here.

References

[1] O'Brien, J. J. (1998). Construction Change Orders: Impact, Avoidance, Documentation. New York: McGraw-Hill
[2] Sun, M., & Meng, X. (2009). Taxonomy for change causes and effects in construction projects. International Journal of Project Management, 27(6), 560-572.
[3] Alnuaimi, A., Taha, R., Al Mohsin, M., & Al-Harthi, A. (2010). Causes, effects, benefits, and remedies of change orders on public construction Projects in Oman. Journal of Construction Engineering and Management, 136(5), 615-622.
[4] Doyle, J. T., Molnar, M. J., & Brown, R. B. (2008). Lessons learned on reducing change orders. AACE International Transactions, OWN.02, 1-16.
[5] Hanna, & Swanson, J. (2007). Risk allocation by law—cumulative impact of change orders. Journal of Professional Issues in Engineering Education and Practice, 133(1), 60-66.
[6] Ibbs, W., Nguyen, L., & Lee, S. (2007). Quantified impacts of project change. Journal of Professional Issues in Engineering Education and Practice, 133(1), 45-52.
[7] Hanna, & Gunduz, M. (2004). Impact of change orders on small labor-intensive projects. Journal of Construction Engineering and Management, 130(5), 726-733.
[8] Taylor, T., Uddin, M., Goodrum, P., McCoy, A., & Shan, Y. (2012). Change orders and lessons learned: knowledge from statistical analyses of engineering change orders on Kentucky highway projects. Journal of Construction Engineering and Management, 138(12), 1360-1369.
[9] Hanna, Camlic, R., Peterson, P., & Lee, M. (2004). Cumulative effect of project changes for electrical and mechanical construction. Journal of Construction Engineering and Management, 130(6), 762-771.
[10] Hanna, Camlic, R., Peterson, P., & Nordheim, E. (2002). Quantitative definition of projects impacted by change orders. Journal of Construction Engineering and Management, 128(1), 57-64.
[11] Hanna, Russell, J. S., & Vandenberg, P. J. (1999). The impact of change orders on mechanical construction labour efficiency. Construction Management and Economics, 17(6), 721-730.
[12] Finke, M. (1998). A better way to estimate and mitigate disruption. Journal of Construction Engineering and Management, 124(6), 490-497.
[13] Riley, D., Diller, B., & Kerr, D. (2005). Effects of delivery systems on change order size and frequency in mechanical construction. Journal of Construction Engineering and Management, 131(9), 953-962.
[14] Ford, D. (2002). Achieving multiple project objectives through contingency management. Journal of Construction Engineering and Management, 128(1), 30-39.
[15] Rosenfeld, Y. (2014). Root-cause analysis of construction-cost overruns. Journal of Construction Engineering and Management, 140(1).
[16] Doloi, H. (2013). Cost overruns and failure in project management: understanding the roles of key stakeholders in construction projects. Journal of Construction Engineering and Management, 139(3), 267-279.
[17] Olsen, D., Killingsworth, R. & Page, B. (2012). Change order causation: who is the guilty party? 48th ASC Annual International Conference Proceedings. Birmingham City University. Birmingham, UK.
[18] Anastasopoulos, P., Labi, S., Bhargava, A., Bordat, C., & Mannering, F. (2010). Frequency of change orders in highway construction using alternate count-data modeling methods. Journal of Construction Engineering and Management, 136(8), 886-893.
[19] Günhan, S., Arditi, D., & Doyle, J. (2007). Avoiding change orders in public school construction. Journal of Professional Issues in Engineering Education and Practice, 133(1), 67-73.
[20] Hassanein, A. A. G., & Khalil, B. N. L. (2006). Developing general indicator cost indices for the Egyptian construction industry. Journal of Financial Management of Property and Construction, 11(3), 181-194.
[21] Smith, B. (2005). The validity of oral change orders under construction contracts. ASC Proceedings of the 41st Annual Conference. University of Cincinnati, Cincinnati, Ohio.
[22] Collins, W. (2012). Examination of change orders on building construction projects at Bowling Green State University. Unpublished thesis project. Bowling Green State University. Bowling Green.