

Analysis of Construction Cost Variation of Construction Manager General Contractor (CM/GC) Project

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Cost overrun is prevalent in the construction industry. Usually, an owner sets a budget at the preliminary phase of a project which changes over time. Past studies are focused on analyzing the cost growth of design-bid-build projects during construction. Limited efforts have been made to analyze details of projects delivered with the Construction Manager General Contractor (CM/GC) method. This study tracks and analyzes the construction cost variation of a project from the conceptual phase to the design completion phase. The analysis is presented with a case study of a new stadium construction project. It identifies that the changes in the scope and design of the project due to the change in available budget were a major reason for variation in the cost estimates over time. Further, this study identifies a) trades with the highest variation in subcontractors' bids, b) trades that were most overestimated, and c) trades that were most underestimated. The findings of this study is expected to aid owners, designers, and contractors of future projects in improving the preparation, planning, and estimating of future projects; reducing cost variation within trades; and optimizing the amount of contingency required to ensure the successful completion of similar projects.

Key Words: cost-growth, cost-overrun, estimate, cost-variation, cmgc, construction-manager-general-contractor, stadium-construction

Introduction

Owners and/or their representatives estimate the costs of a construction project from the conceptual design phase to the final design completion. Once the design is completed, contractors will produce their own estimates after careful analysis of the project's scope, materials, and schedule and submit their bids accordingly. During this estimating period, the project can experience several design changes as a result of variations in owner's requirements and available of funding. Such design changes are likely to result in fluctuations among the construction cost estimates. Further, various factors such as site conditions, weather delays, and design errors can result in additional fluctuations of the construction costs. Despite the owner's desire to ensure that estimates remain constant, this cost fluctuation among construction projects is unavoidable. When there is a cost overrun, it might be particularly more problematic from the owner's perspective if the owner has a limited budget to complete the project. Unfortunately, cost overruns are very widespread in construction projects (Al-Hazim et al., 2017). Identifying and understanding the potential causes of a cost overrun is important from the contractor's perspective as these cost overruns can result in reduced profit and even losses for contractors when contracts specify a Maximum Allowable Construction Cost (MACC) and oblige the contractor to be liable for any costs above the MACC.

This study investigates the variation of construction cost estimates over time for a football stadium construction project for a university. The construction of the football stadium started on February 2016 and was completed on September 2017 with a final budgeted cost of $33,358,006.

Literature Review

Accurate cost estimation is an important component for the successful execution of construction projects. From the owner's perspective, an accurate estimate ensures that they get the projects on budget. From the contractor's perspective, it ensures that they can make profit from the projects. However, computing accurate cost estimates is a challenging task especially during the early stages of the project design phase as situations related to cost estimation can change unexpectedly. Depending on the study in question, both cost overruns and overestimations are prevalent in the construction industry. Al-Hazim et al. (2017) noted that 76% of projects are overestimated, and 24% are underestimated. The study further finds that delays associated with factors such as land acquisition, utility relocation, and unforeseen conditions often lead to added costs. Several other studies support this relationship between delays and cost overrun (Aibinu & Jagboro, 2002, Kaliba et al., 2009, and Assaf & Al-Hejji, 2016). Al-Hazim et al. (2017) conclude by stating that the most critical factors for projects are terrain conditions, weather conditions, change orders, and unavailability of labors. Moreover, they stress the importance of proper planning, scheduling, and cost evaluation to ensure the success of any construction project. Other potential causes of cost overruns include design mistakes, government requirements, environmental requirements, and decision making delays. Further, the lack of understanding of labor productivity and time estimation can also result in inaccurate estimates (Shiner, 2013).

Another study by Riddell (2016) indicates that only 30% of contractors deliver projects on budget due to the increasing complexity of today’s construction projects. The study also notes the difficulties brought about by the shrinking size of qualified laborers in construction along with the generational gap between the veterans of the industry and the few incoming new employees. The silver lining to this problem is the constantly improving technology and the growing demand to improve worker productivity and reduce the number of necessary bodies in the field.

On top of the uncontrollable reasons for excess costs, there are bureaucratic factors to consider. Swei et al. (2017) estimated an average cost overrun for projects to be as high as 30%. The study states that sometimes, estimators might deliberately produce overly optimistic estimates to attract potential clients (Swei et al., 2017). Looking from the other side, state representatives and politicians promoting public projects may inflate expectations from such tight budgets (Singh, 2009). Further, the mismanagement of resources in publicly funded projects can result in delays and costs overruns. The study found that cost overruns soar as project size increases. The study concludes the organization and management of construction planning are crucial in optimizing efficiency in time and cost.

Different attempts to improve cost estimation and mitigate cost overruns have been made in the past. Juszczyk (2017) talks about utilizing artificial neural networks in early estimates because of its ease for generalization. However, collecting the data necessary for implementing the technology can prove to be a challenge on its own (Juszczyk, 2017). Another study by Jain et al. (2015) utilized existing bid data for highway construction projects to improve future estimates by accounting for spatiotemporal variation of unit prices of various bid items. The study utilizes Inverse Distance Weighted (IDW) method developed for Geographical Information System (GIS). The study presents a significant improvement over existing cost estimation methodologies as the current methodologies often ignores the spatiotemporal fluctuation of construction costs. However, such comprehensive bid dataset required to utilize such methodology may not available to the owners such as universities that execute a small number of projects every year.

While most studies have pointed out various reasons for cost overruns or presented methodologies to improve accuracies of cost estimates, most of them are focused on cost growth of design-bid-build projects during construction. Although Kamanga and Steyn (2013) list several delay factors related to design phases in construction projects, there is a limited effort to investigate Construction Manager General Contractor (CMGC) projects in detail to explore the cost variation during the design phase. This study overcomes this gap in knowledge by focusing on analyzing the cost variation of a CMGC construction project during the design phase.

Research Goal

The overall goal of this study is to understand the cost variation of CMGC projects. Specifically, it analyzes the cost overruns of a stadium construction project. To accomplish this goal, there are two objectives of the study: a) to analyze project cost estimate variations over time and b) to quantify the cost variability of different trade divisions used in the project. The results of this study are intended to aid owners, designers, and contractors to improve their estimates for future projects, reduce cost variability, and reduce the amount of contingencies required to ensure the successful completion of future projects.

Data and Methodology

This study collects and analyzes the engineers' estimates prepared by the owner's representative along with available budgets for the stadium construction project over time during the design phase of the project. It further collects and analyzes the bids from subcontractors for various trade divisions (i.e. concrete, steel, mechanical, framing, etc.) of the project.

The engineers' estimate and available budget are plotted in a chart to understand their variation over time and the relationships between them. The subcontractors' bids are analyzed to identify the subcontracts with the highest variations. These variations are quantified using two statistical techniques: a) coefficient of variation and b) relative difference. The coefficient of variation measures the variation in bids from subcontractors. A higher coefficient represents a higher variation.

Coefficient of Variation = Standard Deviation*100/Mean ……….……………………………..……………… (1)

The relative differences are computed to compare the engineers' final estimates and bids from the winning subcontrators. A lower relative difference indicates a higher accuracy of the estimate.

Relative Difference = (Estimated Value – Actual Value)*100/Actual Value …………………………………….. (2)

Results

The results are divided into three sections: a) budget progression, b) relative difference between engineers' estimates and subconractors' estimates, and c) coefficient of variation of bids from multiple subcontractors.

Budget Progression

Figure 1 shows the changes in the overall budget of the project over time. It shows the estimated construction costs, MACCs, the total project cost (stadium construction, supervision cost, associated smaller projects, etc.), and the available budget for the project. Analysis on August 28, 2013 shows that the total project cost was higher than allocated budget. As a result, various efforts were made to reduce its cost until early 2015. Later, additional fundings were secured and hence the project's scope was increased to utilize the available budget. On July 14, 2015, updated analysis showed that the project cost exceeded available budget again. As a result, several design changes were made to reduce the scope of the project. This eventually resulted in the lower estimated cost within the available budget. The difference between the available budget and the project cost is the allocated contingency cost.

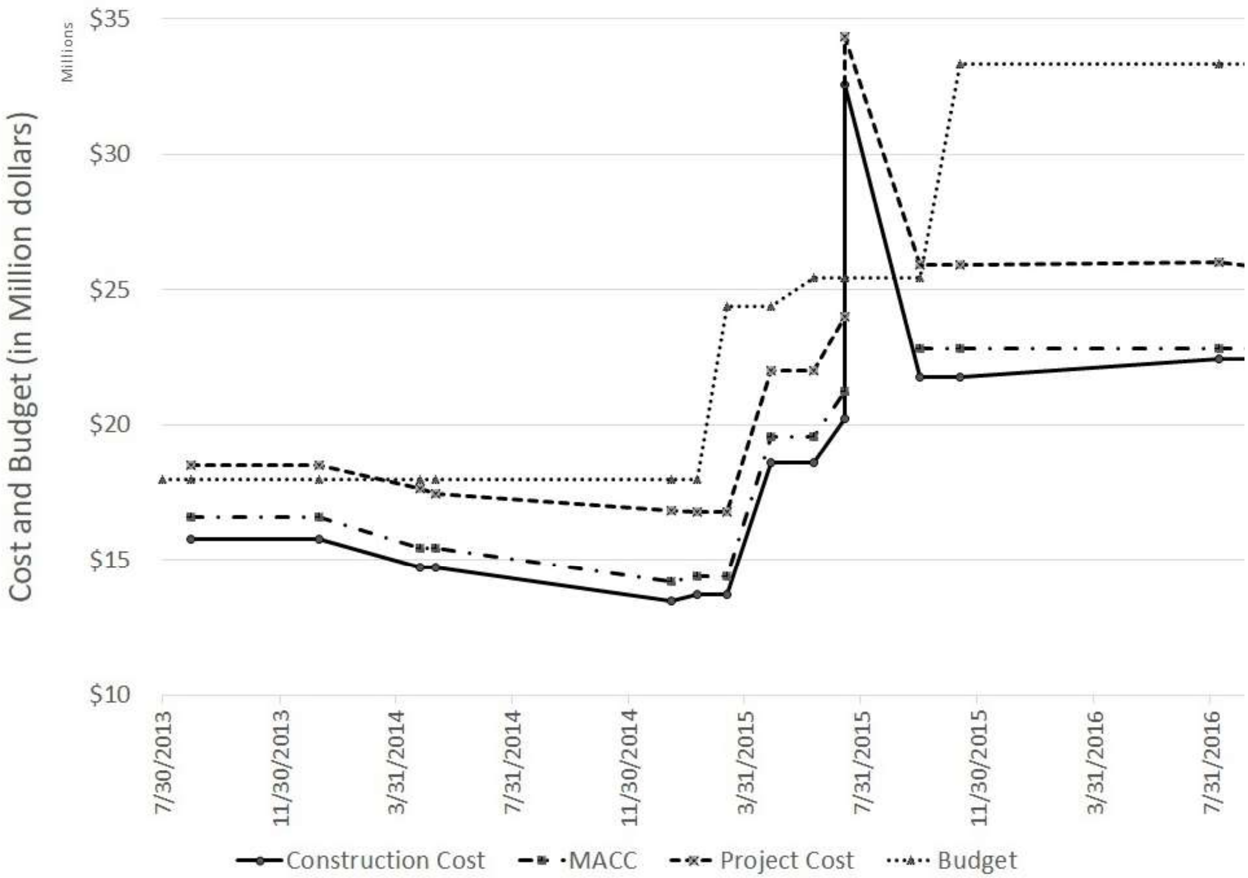

Figure 1: Changes in construction cost, MACC, and budget

Relative Difference Between Engineers' Estimates and Subcontractors' Estimates

The engineers' estimates that were used to budget the project cost were compared with the winning subcontractors' bids. Table 1 lists the largest trade divisions in dollar values and the relative difference between the engineers' estimates and subcontractors' bids. In this paper, if the subcontractor's bid is higher than the budget, the budget estimate is considered to be underestimated. In reality, the budget estimate might be more accurate and subcontractors might have overpriced the bids. However, since subcontractors' estimates determine the actual project cost, their estimates are considered to be more precise. Six of the 10 divisions were underestimated. Further, the items underestimated had higher relative differences than the items that are overestimated.

Table 1

Relative differences of top 10 largest divisions

Divisions	Subcontract Bid ($)	Budget ($)	Difference ($)	Relative Difference
Concrete Work	**4,039,785**	**4,014,953**	**(24,832)**	**-0.61%**
Sitework & Utilities	2,115,352	2,086,996	(28,356)	-1.34%
Electrical	**1,976,477**	**1,256,295**	**(720,182)**	**-36.44%**
Mechanical	1,789,164	1,844,876	55,712	3.11%
Steel	1,217,550	1,125,618	(91,932)	-7.55%
Field Turf & Equipment	1,011,068	854,268	(156,800)	-15.51%

Masonry	912,395	918,220	5,825	0.64%
Allowance	510,821	520,610	9,789	1.92%
Asphalt Paving	473,356	386,435	(86,921)	-18.36%
Storefront	416,333	432,786	16,453	3.95%

Table 2 below highlights the top items that were either most underestimated in terms of relative differences. All the trades were undersestimated by more than a third of the subcontract amount. Many of the trades in this list are involved in the finishes of a construction project except for Metal Wall System, Thermal & Moisture, and Electrical. Specifically, Electrical has the highest difference at $720,182 reflecting the programmatic changes made in the project.

Table 2

Relative differences of top 10 underestimated divisions

Division	Bid Estimate ($)	Engineer's Estimate ($)	Difference ($)	Relative Difference
Window Shades	83,320	7,702	(75,618)	-90.76%
Fencing	206,973	22,806	(184,167)	-88.98%
Metal Wall System	189,598	61,617	(127,981)	-67.50%
Landscaping	259,800	104,122	(155,678)	-59.92%
ACT	105,711	58,203	(47,508)	-44.94%
Retaining Wall	55,719	31,278	(24,441)	-43.86%
Millwork & Casework	315,557	183,976	(131,581)	-41.70%
Roofing	148,099	91,691	(56,408)	-38.09%
Thermal & Moisture	171,956	107,980	(63,976)	-37.20%
Electrical	1,976,477	1,256,295	(720,182)	-36.44%

Table 3 shows the top 10 overestimated divisions in this data set. The relative differences for this list are lower than the ones in the previous table indicatating that trades were underestimated more severely than overestimated. This might be a result of the underestimation bias to approve the construction project.

Surprisingly, Mechanical/HVAC has one of the highest budgets and estimates on this list being close to $1.8 million, but its difference is only 3.11% of its bid estimate. This may be explained by the lack of variability within its material cost. In addition, Sitework & Utilities, Concrete Work, and Masonry were very close to having a 0% relative difference – mostly likely because of the same reason (not shown in the table).

Table 3

Relative differences of top 10 overestimated divisions

Division	Bid Estimate ($)	Engineer's Estimate ($)	Difference ($)	Relative Difference
Flooring	183,578	211,595	28,017	15.26%
Doors, Frames, Hardware	118,637	136,049	17,412	14.68%
Stadium Seating	260,823	295,460	34,637	13.28%
Painting	147,059	164,907	17,848	12.14%
Fire Suppression	160,346	175,847	15,501	9.67%
Specialties	157,831	168,339	10,508	6.66%

General Conditions	411,843	435,636	23,793	5.78%
Storefront	416,333	432,786	16,453	3.95%
Mechanical/HVAC	1,789,164	1,844,876	55,712	3.11%
Metal Studs and Drywall	353,460	364,186	10,726	3.03%

Coefficients of Variation of Bids from Multiple Subcontractors

Table 4 shows the 10 most variable trades based on their coefficients of variation. Given that Electrical and Concrete are among the top 10 largest trade divisions (Table 1), they are two specific trades that require the most attention. Their coefficients of variations are also high: 23.10% for electrical and 19.57% for concrete. This could be explained by the complex nature of electrical installation and the variability of concrete cost regarding its transportation and labor cost.

Table 4

Top 10 divisions with highest cost variability

Item	Coefficient of Variation
Spray Insulation	29.00%
Sprinkler	27.19%
Stained Concrete	25.23%
Caulking	24.10%
Electrical	**23.10%**
Fluid Applied Flooring	21.41%
Site concrete	**19.57%**
Landscaping	19.41%
Aluminum Plank Seating	14.10%
Roofing	10.12%

Discussions

This study focused on tracking an overall cost growth of a stadium project over time and identifying the divisions which had the highest and lowest cost variabilities. This study did not conduct an in-depth investigation of the factors causing inaccuracies in estimates. The researcher were able to obtain limited information about such factors related to the project under study. Such factors could be identified and investigated in a future study, but some factors that might be common for such projects are discussed here briefly. The factors that can affect cost estimation inaccuracies includes the level of details available at the time of estimating, construction market inflation, experience of the estimators involved, time available to complete the estimates, accuracies of available data, project complexity, project location, and project type. For this stadium construction project under study, efforts were made to accommodate for multiple scope changes, design options, design changes, change orders, and contingencies. The project's scope included additional smaller projects such as recycling center relocation, challenge course relocation, and construction of a roundabout for the stadium. Those were not included in the base construction cost. Being a public university project, any changes in the project had to be approved by several stakeholders. This, in turn, resulted in delays of the project. The project stakeholders noted that there was a severe inflation of the labor prices when the project construction began. This could have been partly avoided if the approval process was faster. Further, during the construction, contractors found that there were massive boulders instead of softer soils. Thus, the level of details available at various phases of the design process would have attributed to some inaccuracies in the estimates. Being a CMGC project with lumpsum subcontracts, most of the risks were transferred to the subcontractors. Ultimately, these subcontractors dictate the cost of the project because it is the subcontractors who will be billing the general contractor directly. It is also their own estimators who present the most expertise in quoting their respective trades. The general contractor and design engineers would have limited experience with detailed estimation for stadium construction project. Further, estimation accuracies are likely to vary with the time available to estimate. Both engineer and subcontractor estimates are liable to human error. This factor can be explored further in a future study.

Finally, the findings of this study cannot be generalized as the results are based on a dataset for only one project. Future studies can further explore multiple projects to strengthen the findings of this study. Given its scope, other university projects and/or stadium projects can be used for future studies. The findings from such study can be used to develop a decision-making-framework for the contractors and owners to identify the trade-divisions that could result in a high cost variability of an overall project cost.

Conclusion

This study tracked and analyzed the changes in the cost of a stadium project over time. While many studies have focused in blaming the construction cost changes to one party or another, this study shows that construction cost changes can, at least in part, be a result of the natural evolution of a project. The study identified the major construction trades that were overestimated and underestimated for the stadium project under study. Electrical and concrete were among the top 10 trades with highest costs and also among the top trades with highest cost variability within the subcontractors' bids. Thus, extra attention should be paid to those trades while computing the estimates. Most of the severely underestimated trades were those required later in the construction process such as finishing and landscaping. Other large trades such as Mechanical/HVAC were estimated with higher accuracies, potentially due to its straightforward and uniform material cost and lower labor costs. Trades that were overestimated included flooring; doors, frames, hardware; and stadium seating. Further, the trades' costs were more severely underestimated than overestimated.

The findings of this study are expected to aid owners of future football stadiums in better preparing their estimates and avoid potential surprises in terms of cost growths by understanding more important trade divisions associated with such cost growths.

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