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What effects do construction contractors experience when conforming to contractual cash flow constraints?

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What effects do construction contractors experience when conforming to contractual cash flow constraints?

by

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Program of Study Committee:
Jennifer Shane, Major Professor
Kaoru Ikuma
Cristina Poleacovschi

The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this creative component research report. The Graduate College will ensure this creative component research report is globally accessible and will not permit alterations after a degree is conferred.

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DEDICATION

This research endeavor is dedicated to my mother and brother who represent a true trailblazing mentality when it comes to the pursuit of higher education within our family. You have served as role models and motivators for achievement, not only within the confines of an educational framework, but in a broader sense, by demonstrating the realization of success. It has never been clearer that the true measure of success is not represented by our outward achievements in education and employment, but by our ability to satisfy from within, lead by example, and provide solid foundations for our families. Thank you.

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NOMENCLATURE

AGC	Associated General Contractors of America
APR	Annual Percentage Rate
CMAA	Construction Management Association of America
HR	Hour
IRB	Institutional Review Board
ISU	Iowa State University
P3	Public Private Partnership
SOV	Schedule of Values

ACKNOWLEDGMENTS

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In addition, I would also like to thank my wife, Sarah Mae, whose love and support continues to help me pursue and achieve my educational and professional goals. Finally, I would like to thank the department faculty and staff for making my time at Iowa State University an enlightening experience.

ABSTRACT

Cash flow constraints on construction projects play a key role in determining how to manage project financing. The ability to work within the contractual constraint requirements is equally as important to achieve both financial and overall success at completion of the project. Parties to construction contracts rely on contract documents for requirements in regards to the managing of cash flow. Stochastic financing analysis and finance-based scheduling for construction projects have both been discussed at length in previous literature, however, there appears to be little research on the effects experienced by the effort required to meet contractual requirements for cash flow constraints. (Lee, Lim, and Arditi 2012; Elazouni and Gab-Allah 2004) The findings of this research provide decision makers and organizational members, including project managers, construction managers, and contract administrators with insight geared toward better understanding the implications of and efforts required to successfully manage cash flow within required constraints on construction projects.

CHAPTER 1: INTRODUCTION: PROBLEM AND PURPOSE STATEMENTS, AND RESEARCH QUESTION

Problem Statement

Cash flow during a construction project is viewed by both contractors and project owners as critical. The working definition for this paper for cash flow is the movement of money in to, or out of, a business entity. To contractors, consistent cash flow and appropriate project planning around the anticipated cash inflow from the project owner, allow for little or no financing from the contractor's bank, thus minimizing project costs and maximizing profit from the project. To project owners, consistent cash flow and accurate cash flow projections throughout the execution of the project, allow for adequate project financing to be provided or maintained and also allows for less reworking of periodic budgets. However, in the event that one or more parties to the construction contract encounter financial difficulties stemming from cash flow constraints, project success may be at risk (Lee, Lim, and Arditi 2012).

Purpose Statement

The purpose of this research is to examine the effects of contractually required cash flow constraints through a quantitative inquiry which is to include an examination of relationships through the use of stochastic modeling. The research will be undertaken as an in-depth case study by performing an analysis of a stochastic model of a wastewater infrastructure construction project performed in the western United States. The design of the study was intended to allow for a thorough examination of the potential experiences observed during performance of a construction contract requiring cash flow constraints. The results of this quantitative research study are geared toward informing engineering and construction

academics and project professionals about the potential effects of contractual cash flow constraints on construction projects.

Research Question

The question that this research proposal will seek to address is, “What effects do construction contractors experience when conforming to contractual cash flow constraints?”

CHAPTER 2: LITERATURE REVIEW: HISTORICAL PERSPECTIVE, KEY CONCEPTS, AND EPISTEMOLOGY

Historical Perspective

For the past fourteen years, research has indicated that there is a lack of effective finance-based analysis tools that adequately provide construction contractors the ability to examine effects of cash flow or resource constraints on construction projects. Liu and Wang (2008) present and discuss their research into the topic of profit maximization considering cash flow through the lens of multiple applied constraints to project scheduling in their research article titled, "Resource-constrained construction project scheduling model for profit maximization considering cash flow." The co-authors present a brief review of known researchers, their findings, and existing models used to perform schedule analyses. They explain that, while the body of knowledge on resource constrained project scheduling has grown considerably over the past decade, there remains a lack of research and useable models that allow a user to adequately analyze such schedules from a profit maximization perspective.

Liu and Wang (2008) describe in their research that the existing models provide mechanisms for optimizing resource allocation and resource leveling in project schedules within specified constraints. They continue on to discuss the role that cash flow plays in a project's overall success and present examples of models that have been developed to allow for finance based scheduling. The correlation between resource constraints and profit maximization is then established by Liu and Wang (2008) who present their methodology of constraint programming, model formulation, and model validation which is used in performing their experiment.

The identified void in the body of knowledge described by Liu and Wang (2008) has also been studied and reported on by Lee, Lim, and Arditi in their 2012 paper titled, "Stochastic Project Financing Analysis System for Construction" and by Houseini, Andalib, and Gatmiri in their 2015 paper titled, "Stochastic Framework for Cash Flow Forecasting Considering Owner's Delay in Payment by Use of Monte Carlo Simulation." The researchers explore and develop a system that integrates project scheduling and financing analysis, noting that such a system would aid contractors in maximizing net profit from a project. Lee, Lim, and Arditi and Houseini, Andalib, and Gatmiri agree with Liu and Wang that there are existing finance-based scheduling models that may be effective project management tools but the researchers also appear to agree that the existing systems cannot effectively analyze variability (constraints) in cash flow (Houseini, Andalib, and Gatmiri 2015, Lee, Lim, and Arditi 2012; Liu and Wang 2008). While it is not the intention of this research study to improve an existing analysis system or to develop a novel approach to finance-based project scheduling, the intention is to use available stochastic modeling software coupled with an existing project schedule and raw cash flow data based on monthly applications for payment to determine a set of plausible effects resulting from contractual cash flow constraints.

Key Concepts

In their research Liu and Wang (2008) present a comparison of their findings juxtaposed against known findings from prior research, highlighting that their model was effective in maximizing project profit. A similar approach was undertaken in this study as a quantitative analysis was performed and conclusions then drawn from a stochastic financial model of a project performed with contractual cash flow constraints. Results of this study are presented as a discussion of the findings of the quantitative research component with

recommendations for improvements to cash flow constrained contract requirements, administration, and execution.

Several key concepts for this study are defined as follows: cash flow refers to the movement of money in to, or out of, a business entity; financial success (profitability) refers to outperforming the breakeven point for a given project; and stochastic model refers to a probability density distribution resulting from an iterative analysis of randomly generated variations on designated variables.

Epistemology

This researcher's epistemology is constructionism with a theoretical lens of inductive logic based inquiry for propositional generalization as described by Creswell and Stake (Creswell 2014; Stake as cited in Creswell 2014). The methodology used in the study includes action research through examination of a singular case study and stochastic modelling of collected raw data from a cash flow constrained project. The results of the quantitative analysis have been analyzed to complete the research endeavor.

CHAPTER 3: INVESTIGATION: SIGNIFICANCE, ADDITIONAL RESEARCH QUESTIONS, AND SIGNIFICANCE OF THE STUDY

Significance

The aforementioned literature review performed for this research endeavor lends itself to the conclusion that contractual limitations on cash flow during the performance of a construction project are not a common budget control mechanism for project owners. The imposition of such constraints may lead to additional challenges faced by contractors operating in such a contractual environment and are identified below.

Information presented in this research will allow for better financial planning on behalf of project owners and contractors thus improving budget management and improving the likelihood of achieving profit maximization. While constraints on cash flow during construction may be one strategy to manage a project owner's capital improvements budget, there may be other alternatives that warrant additional consideration from project owner's decision makers including delaying projects until additional funding is available, financing projects through bond issuance, and public private partnerships (P3s), among others. Similarly, contractor's intending to bid on construction projects in which contractual cash flow constraints will be in place may want to consider additional financial management and scheduling strategies in order to improve the likelihood of a financially successful project.

Additional Research Questions

The overarching research question that this study will seek to answer is, "What effects do construction contractors experience when conforming to contractual cash flow constraints?"

The hypothesis is that budget and schedule maintenance, and financial project success is possible if appropriate project scheduling, financing, and cash flow constraints are

contemplated during the project's bid period and control measures are employed throughout the execution of the project. Current assumptions regarding the ability of the above hypothesis to align with the associated research question include the sentiment that limiting the available amount of funding during a given time period on a construction project will present challenges in a contractor's ability to estimate labor, material, and financing costs for a project, and may also impinge upon a contractor's ability to perform the work in the most timely manner possible. The importance of the above elements cannot be overstated, as a contractor's estimation of the aforementioned elements and its timely completion of a construction project are paramount to the contractor's financial and overall success. This assumption aligns with the findings of Liu and Wang (2008) and Lee, Lim, and Arditi (2012) as indicated in their research of stochastic project financing and finance-based scheduling.

Sub-questions stemming from the overarching research question posed above include: "What role does major equipment procurement play in managing project cash flow?", and "What role does labor resource allocation and expenditure play in managing project cash flow?" It is further hypothesized that major equipment procurement, defined as purchase of permanent equipment which is critical to completion of the project, and labor resource allocation and expenditure have a financially significant impact on project cash flow. Assumptions accompanying these sub-questions are identified by a position that poorly executed procurement strategies and underestimation of labor resource needs will undoubtedly have negative schedule, financial, and labor resource availability impacts for the contractor during project execution.

In summary, this research hypothesizes that, provided appropriate measures to account for contractual cash flow constraints are taken during the assembly of the

contractor's estimate, bid, and preliminary schedule, financially successful completion of projects with contractual cash flow constraints can be expected. Appropriate steps, at this time, are deemed to include adequate project planning and scheduling, sufficient labor resource and financial budgeting, and thorough contingency, estimate, and bid development.

Significance of the Study

The analysis and resulting information presented in this paper allow for better financial planning on behalf of project owners and contractors. While constraints on cash flow during construction may be one strategy to manage a project owner's capital improvements budget, there may be other alternatives that warrant additional consideration from decision makers including delaying projects until additional funding is available, financing projects through bond issuance, and P3s, among others, as previously noted. Similarly, contractor's intending to bid on construction projects in which cash flow constraints will be contractually required may want to consider additional financial management and scheduling strategies in order to improve the likelihood of a financially successful project in which profits are maximized.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY

Quantitative Research Design

The research design follows a quantitative analysis approach. A quantitative design approach was selected for several reasons including a desire to analyze what potential effects may have been experienced for a subject wastewater infrastructure project located in the western United States which has been executed with contractual cash flow constraints. This study is limited to examination and analysis of a project that has been executed with contractual cash flow constraints and the management techniques employed and potential effects experienced when conforming accordingly. Constructionism with a theoretical perspective of critical inquiry provides grounded epistemology to inform the study while action research guides the identified methodology.

To meet these objectives a quantitative analysis of a subject project executed with cash flow constraints was performed with stochastic modeling allowing for a spectrum of variables to be randomly varied in an iterative fashion. The stochastic analysis involves statistical methods for varying selected variables based on their standard deviations and means, plotting the results in a probability density distribution, and selecting a best-fit curve to the resultant data. The analysis includes establishment of a confidence interval to which all results will be required to fall within.

The literature review provides an analysis that leads to general conclusions regarding documented effects with correlations then drawn to the quantitative analysis of the subject project. The process followed for this research is similar in nature to the research performed by Liu and Wang (2008) which presents a comparison of their findings juxtaposed against

known findings from prior research, highlighting that their model was effective in maximizing project profit.

Selection of Sample

The subject project was selected based on experience as a Resident Engineer during construction of the project. The project was executed with cash flow constraints contractually identified and enforced and provided an opportunity to work through and observe the challenges faced by both the contractor and project owner. Selection of the subject project was guided by hands-on experience and interaction, ease of data collection, and an interest in examining the effects of cash flow constraints experienced by the contractor during the project which has stemmed from prior completed coursework that included extensive construction project and business finance topics.

Delimitations

The boundaries of the study are to be strictly potential effects experienced by a contractor who has performed a construction contract for a projects in which cash flow constraints were contractually required. The effects may include financing, billing, payment procedures, procurement, staffing, scheduling, and project execution, to name a few.

The results and conclusions of the study are useful to project owners and contractors considering to either let, or bid on, a project in which cash flow constraints were or are to be a contractual requirement. The study is also useful to construction and engineering academics seeking a detailed examination of projects facing similar constraints.

Instruments and Procedures

Instruments and procedures are limited when considering the scope and methods involved in the study. Data collection for the quantitative component of the study occurred over a period of years as monthly applications for payment containing 264 line items corresponding to specific project work activities were submitted by the contractor for review, approval, and payment by the project owner. The applications for payment are organized in tabular form and take the same form month after month, which minimizes the effort required to organize the data.

An add-on to Microsoft Excel, titled @Risk and published by Palisade, is the primary tool used to perform the quantitative analysis for the study. @Risk allows for stochastic analysis of multiple variables to be performed by Monte Carlo simulation, in which an iterative simulation is performed by the software add-on. A probability density distribution results from the simulation and leads to statistical analysis and best curve-fitting tools for data evaluation. @Risk was selected as the primary software analysis due to familiarity from prior experience with the software and the availability of an inexpensive one-year student license. It is anticipated that the quantitative research will vary the price of major equipment used on the subject project, examining the effects of both high and low price points on procurement strategy, as well as effects on overall project spending and timing of cash outflows. Similarly, the annual percentage rate (APR) at which the contractor borrows money from a banking institution will be varied to analyze the impacts observed on the contractor's potential profit for the project.

Analysis of Data

The analysis of the quantitative data was completed using Monte Carlo simulation, in which an iterative stochastic process involving multiple variables that are simultaneously randomly varied and results then plotted on a probability density distribution and analyzed for impacts or benefits. The standard deviations of the material pricing and APR interest rate data were used to select an appropriate confidence interval within which the data will be varied. Determinations and conclusions were made by further sensitivity analyses performed on sets of varied data organized into least, worst, and most possible scenarios regarding the contractor's financing elections and overall project execution in regards to pace of completion and timing of cash outflows.

CHAPTER 5: LIMITATIONS: RESEARCHER ROLE AND POSITIONALITY, ETHICS, AND VALIDITY

Researcher role and positionality

It must be acknowledged that while the stochastic quantitative analysis was performed on actual project data, the outcomes and conclusions may be tenuous, at best, due to the nature of the analysis performed. Nevertheless, it remains the focus of this research to examine the data and present conclusions in an informative and concise manner. As noted prior, this researcher's assignment to the project by his employer has provided the opportunity to experience project execution in an environment with required cash flow constraints. It is here that the observer-participant continuum plays a significant role in this study. With exposure to the real-life execution of the project, it was a challenge to remain neutral in the analysis of possible alternate effects caused by the project constraints. Regardless of previous exposure to real outcomes, maintaining an open minded approach to the analysis through diligent contemplation of variable variation and thoroughly examining the associated outcomes, reasonable conclusions are expected at the conclusion of the study.

Biases and assumptions stemming from the observation and involvement with the subject project in real time were organized and captured accordingly in the research proposal. These items have been discussed and were then set aside while the study was performed; the conclusions resulting from the research have been compared to the biases and assumptions and analyzed for interfering impacts and adjustments to the study have been appropriately made. Preliminary biases currently include an observation that the contractor exceeded the available annual financing from the project owner (cash flow) and as a result had to obtain outside financing from their bank (the contractor stated that financing costs were not

included in their bid price), an observation that the contractor procured major equipment earlier than planned due to escalation in material pricing, and an observation that the project owner offered to increase the available annual financing in exchange for the addition of liquidated damages to the construction contract (the offer was declined by the contractor).

Ethics

Ethical risk has been removed from the study as much as possible by removing any identifying information. The anonymization includes removal of the project name, location, and participants; additionally, discussions were held with the project owner and the project contractor regarding the intentions of the research. The results are generalized and have been made available to all parties upon request.

Validity, trustworthiness, and credibility

The comparative approach to the observations resulting from the quantitative analysis stands to provide balance and bolster credibility for the study by discussing conclusions drawn from the analysis performed on the first-hand subject construction project and the importance of several strategies required for project success.

Alternative explanations for cash flow issues on contractually cash flow constrained projects that may arise from completion of the study include poor project planning and execution, poor contract interpretation, unusually adverse raw material price fluctuations, and unusually high commodity price fluctuations, among countless others. At this time, it is difficult to determine whether the results and conclusions drawn from the completed study are generalizable across the construction industry and across many countries due to the narrow scope of the study, although the single case study approach does allow for greater depth in the analysis. It must be noted that, at least preliminarily, transportation construction

projects recently completed and currently being performed in the United States, have been faced with significant cost and financing issues including inflation and drastic cost overruns, to name a few. As such, it appears that, at this time, such construction projects may not benefit from the analysis and results presented in this paper.

CHAPTER 6: SUMMARY OF PERFORMED RESEARCH AND RESULTS

Introduction

Although several limitations have been identified, diligence in the data collection process and maintenance of sound methodology, as outlined in the paragraphs above, allows for comprehensive results to emerge from this research. This resulting information allows for better financial planning on behalf of project owners and contractors thus improving budget management and the likelihood of achieving profit maximization. Financial success is a critical success factor for all construction contractors (Elazouni, Gab-Allah 2004; Lee, Lim, and Arditi 2012); understanding the potential effects that may have been experienced by contractors on a contractually cash flow constrained project enables better planning and execution for the project, paving the way for achieving financial success.

Summary of Performed Research: Single Case Study

As described above, data collection for the subject project was performed over a period of twenty seven months, with monthly application for payment data gathered incrementally upon submission from the project's contractor. In order to provide monthly application for payment data through the subject project's completion and final payment, the actual collected data was supplemented with an additional seven months of estimated monthly applications for payment due to the on-going construction of the subject project. As a result, the results of the quantitative analysis are considerably more hypothetical than if such an analysis were performed with actual complete project application for payment data. While limited, and despite the hypothetical nature of the performed analysis, the content,

intent, and validity of the research endeavor remains intact, as will be demonstrated in the following paragraphs.

Summary of Methods and Procedures

Monthly Applications for Payment

The quantitative analysis began with the initial step of organizing the actual raw application for payment data in sequential and cumulative order in a comprehensive spreadsheet. As noted above, the final six applications for payment have been estimated; the estimations have been fashioned after applications for payment which have been previously submitted for work elements that mirror the remaining portion of the project. A review and analysis of the comprehensive spreadsheet was then performed with close attention paid to any trends or anomalies in billings. This review and analysis yielded that, due to the project's contractual cash flow constraints, two payments were partially paid when due, and sixteen payments were held until the following calendar year. The amount of time which payments which were held ranged between one and nine months, depending on the timing of the billing and total amount billed. The contractual cash flow constraints implemented during the project are shown in Table 6.1.

Table 6.1 Contractual Cash Flow Constraints

% of Contract Amount	25%	30%	25%	20%
Calendar Year during Project	1	2	3	4
Maximum Annual Billing ($)	2,570,430.14	3,084,516.17	2,570,430.14	2,056,344.11

Following the initial organization and analysis of the raw application for payment data, the contractor's actual submitted projected monthly billings (cash flow) were plotted graphically to show anticipated billings versus time. This series of projected monthly billings was compared to a plot of the actual monthly billings versus time and again analyzed. The graphical output of the first submitted projected monthly billings versus time and the graphical output of the actual monthly billings versus time are shown in Figure 6.1 and 6.2 below.

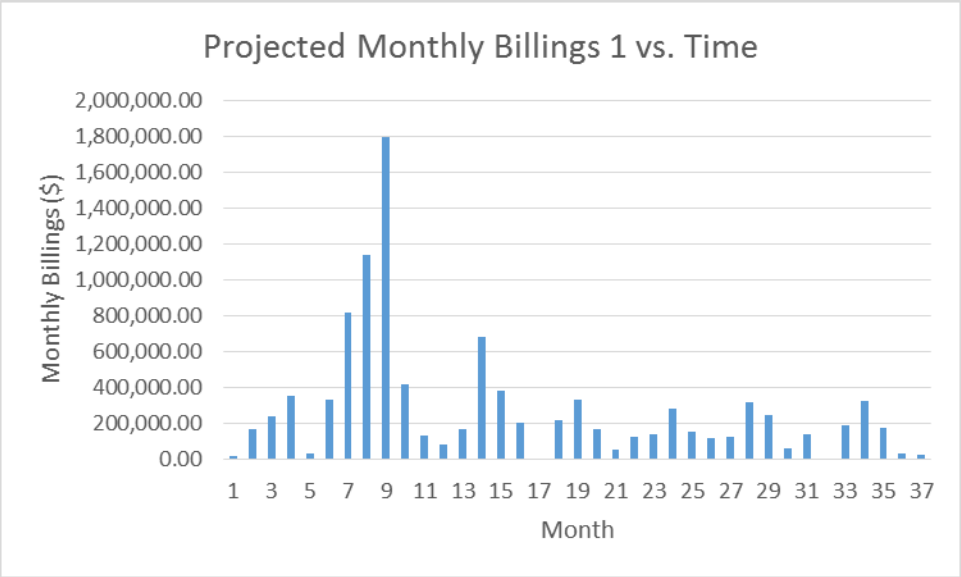

Figure 6.1 Projected Monthly Billings vs. Time

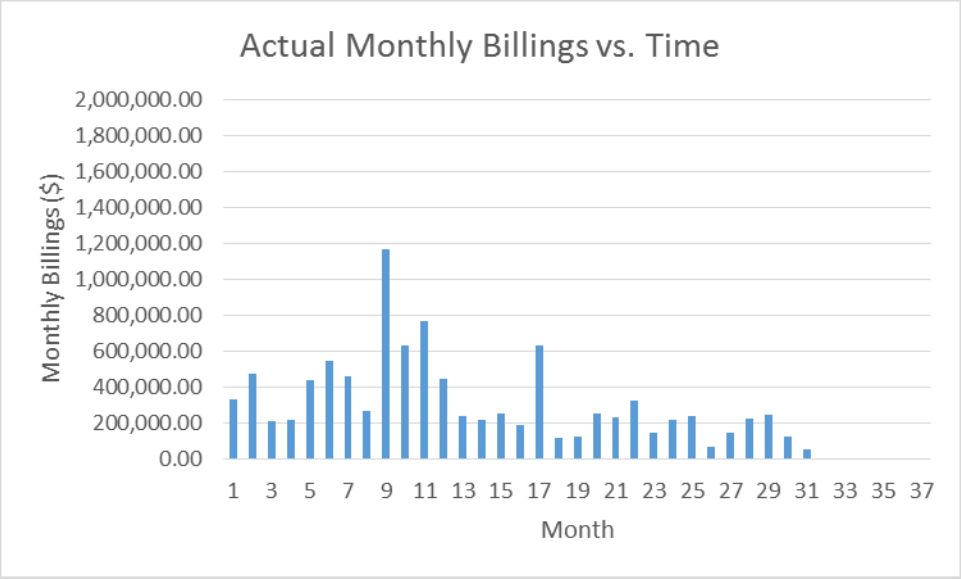

Figure 6.2 Actual Monthly Billings vs. Time

When comparing the as-submitted actual monthly billings to the as-planned projected monthly billings, shown in Figure 6.1 and 6.2, it can be seen that the actual billings differ considerably from those that were projected. Continuing the investigation into the project's cash flow, actual cumulative billing amounts were then organized by project calendar year, and were analyzed to determine the amount and timing of the project billings.

Table 6.2 Cumulative Payments Year 1

Monthly Billings ($)	Actual Monthly Payment to Contractor ($)	Cumulative Payment to Contractor Year 1 ($)
336,005.00	319,204.75	319,204.75
474,473.83	450,750.14	769,954.89
215,589.82	204,810.33	974,765.22
219,922.99	208,926.84	1,183,692.06
445,035.99	422,784.19	1,606,476.25
552,140.52	524,533.49	2,131,009.74
459,906.19	436,910.88	2,567,920.62

Project billings and actual payments to the contractor in project calendar Year 1 were observed to be slightly over the contractual cash flow constraint limitation of 25% of the contract amount and was attributed to an increase in the contract amount in Year 1 due to processing of change orders. Comparatively, billings in project calendar Year 2 were observed to reach the contractual cash flow constraint of 30% of the contract amount at the fifth monthly billing with change orders not included in the contract amount for the Year 2 billing limitation. In accordance with the contractual limitations, no payments to the contractor beyond 30% of the contract amount were made in Year 2. The resulting underpayment required the contractor to obtain financing to cover the associated costs in order to maintain the project schedule.

Table 6.3 Cumulative Payments Year 2

Monthly Billings ($)	Actual Payment to Contractor ($)	Cumulative Payment to Contractor Year 2 ($)
266,931.37	253,584.80	253,584.80
1,172,971.20	1,114,322.64	1,367,907.44
630,813.05	599,272.40	1,967,179.84
773,129.49	734,473.02	2,701,652.85
449,059.30	382,863.31	3,084,516.17
244,988.65	0.00	3,084,516.17
221,099.91	0.00	3,084,516.17
259,305.51	0.00	3,084,516.17
191,940.00	0.00	3,084,516.17
635,036.85	0.00	3,084,516.17
121,673.18	0.00	3,084,516.17
2,036,459.51	0.00	3,084,516.17

Cost Loaded Baseline Schedule

The next analysis performed on the subject project included a review of the accepted cost loaded baseline project schedule. To summarize, the project entailed upgrades in six separate process areas, five of which were nearly identical. Contract constraints indicated that work in Area 1 was required to be fully operational prior to the startup and commissioning of the improvements performed in Area 2; Area 1 and Area 2 collectively comprised Milestone No.1. Additional contractual constraints required that substantial completion of each milestone be achieved prior to beginning work on the subsequent milestone.

The analysis was performed by organizing the approved schedule of values (SoV) into total costs attributed to each project area, as shown in Table 6.4.

Table 6.4 Total Cost Breakdown by Area

Description	Total Cost ($)	Project Calendar Year Scheduled Completion
Project Administrative and Procurement	2,014,567.34	NA
Area 1 (Milestone No. 1)	4,177,982.06	Year 2
Area 2 (Milestone No. 1)	862,499.84	Year 2
Area 3 (Milestone No. 2)	911,799.75	Year 2
Area 4 (Milestone No. 3)	704,285.37	Year 3
Area 5 (Milestone No. 4)	905,502.30	Year 3
Area 6 (Milestone No. 5)	705,083.90	Year 4
As-bid Total:	10,281,720.56	

The review and analysis yielded that SoV costs associated with Milestone No. 1 total $5,040, 481.9 and compare to a maximum cash flow constrained billing amount of $5,654,946.31 for work taking place in project calendar Years 1 and 2. Taking a simplified approach to distributing the project administrative costs equally across the four project calendar years would result in administrative expenditures in the amount of $503,641.84 per

year. As a result, the approximate total billing for project calendar Years 1 and 2 would be $6,662,229.98 and would exceed the aforementioned maximum cash flow constrained billing amount of $5,654,946.31 by $1,007,283.67. Including the Milestone No. 2 costs in the analysis increases the billings further beyond the owner's maximum cash flow constrained billing amount and brings the total billings for work performed and completed in project calendar years 1 and 2 to a total of $7,574,029.73; an overage of $1,919,083.42 thus indicating a need for financing (either internal or external) to cover the accumulated project costs beyond the project owner's contractually constrained progress payments. The analysis performed aligns reasonably well with the contractor's actual billings in excess of the owner's contractual cash flow constraints which totaled $1,934,636.53, not including finance charges and interest. The billings in excess of the contractual cash flow constraints were, in fact, financed through the contractor's bank; these costs are commonly known as carrying costs.

Carrying Costs

To determine the potential impact of the carrying costs associated with the subject project, a sensitivity analysis was performed to compare the interest paid at rates of 3.5% APR, 4.5% APR, and 5.5% APR, which were assumed to be representative of available rates. It must be noted that interest rates vary widely and depend on many factors including company solvency, amount to be financed, the prime interest rate, payback period, and type of financing sought, to name a few. The results of the sensitivity analysis are presented in Table 6.5.

Table 6.5 Carrying Cost Sensitivity Analysis

Interest Rate (APR)	3.5%	4.5%	5.5%
Total Interest Accrued Years 2 and 3 ($)	27,420.08	35,424.71	43,506.27

The carrying costs were calculated based on the contractor's cumulative billings during the period of time when the project owner's cash flow limitations were exceeded, a situation that occurred during calendar Year 2 and again in calendar Year 3 of the project. These costs, if not planned for and included in the contractor's estimate and bid, would reduce the overhead and profit expected to be generated by the project. A sampling of overdraft calculations is presented in Appendix A.

Stochastic Modeling for Price Fluctuations

The research next sought to explore the potential effects of an increase in labor costs, varying major equipment costs, and varying steel and aluminum costs. The @Risk add-in for Microsoft Excel was used to perform Monte Carlo simulations on the desired inputs. In order to examine the effect of an increase in the cost of labor, the SoV line items were organized into material, labor, and combination line items.

The material line items were further organized into major equipment, steel components, and aluminum components for later further analysis. Next the combination line items were separated into a material and a labor component following the assumption that labor accounts for 45% of earthwork, concrete, and site work line items, and accounts for 60% of electrical and mechanical line items. Following the labor breakout, the average burdened labor rate for all craft resources on the project were calculated from the contractual

burdened labor rates. The labor components from the SoV were then divided by the calculated average burdened labor rate to determine the labor hours required for each SoV line item. The U.S. Bureau of Labor and Statistics value for average percentage of fringe benefits of 29.5% was then used to determine the unburdened cost of labor for all SoV line items. The @Risk simulation model was then set to vary the cost of labor between using triangular distribution with a low value of $35.87/hr, a high value of $41.54/hr, and a most likely value of $37.76/hr. The resulting distribution, shown in Figure 6.3, indicates a 90% probability that the labor rate will be between $36.60/hr and 40.50/hr. The stochastic model was then used to randomize the labor rate used to complete the line item activities from the SoV.

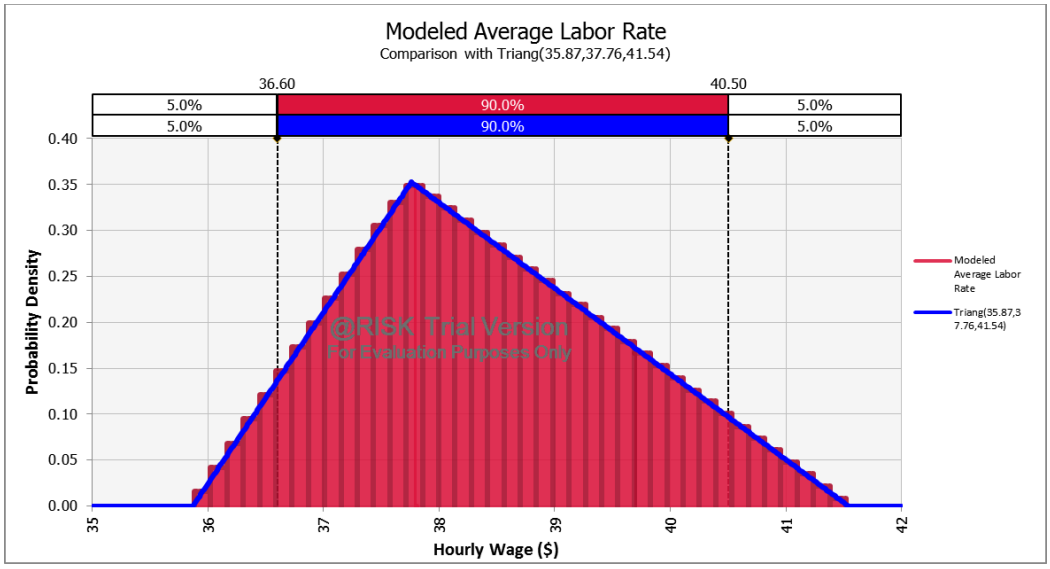

Figure 6.3 Probability Density of Modeled Average Labor Rate

Major equipment was then modeled in a similar fashion in which the @Risk add-in was used to produce a probability density distribution of varying escalation percentages. A key difference to note is that a chi squared distribution was used as the resulting distribution more closely represents the likelihood of increases in the major equipment prices.

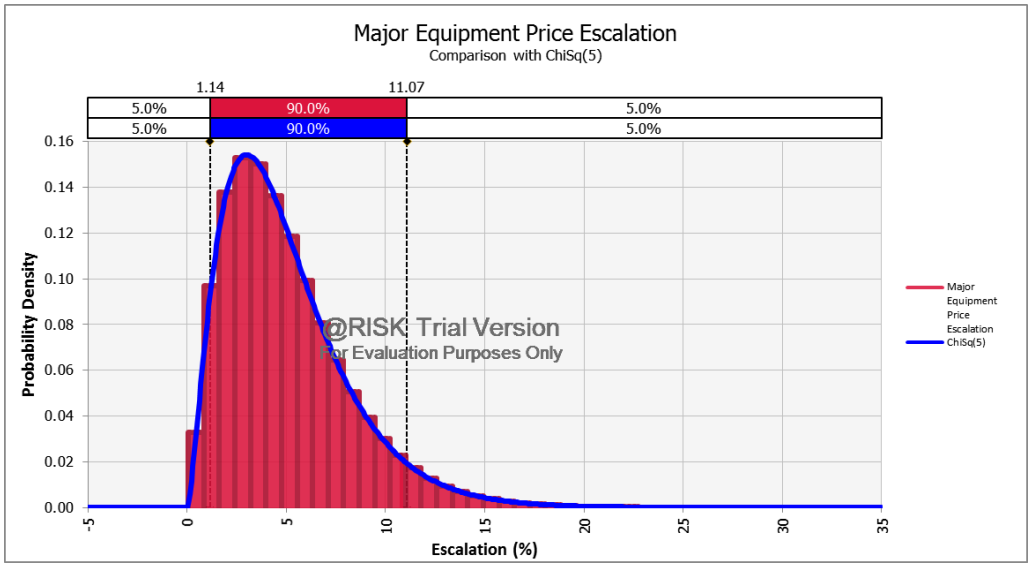

Figure 6.4 Probability Density of Modeled Major Equipment Price Escalation Percentage

Commodity-based iron ore and aluminum raw materials were then modeled in a similar fashion using a log normal distribution probability density function based on historical monthly prices from 2007 through 2017, and the average and standard deviation of those prices. The probability density functions are shown below in Figures 6.5 and 6.6.

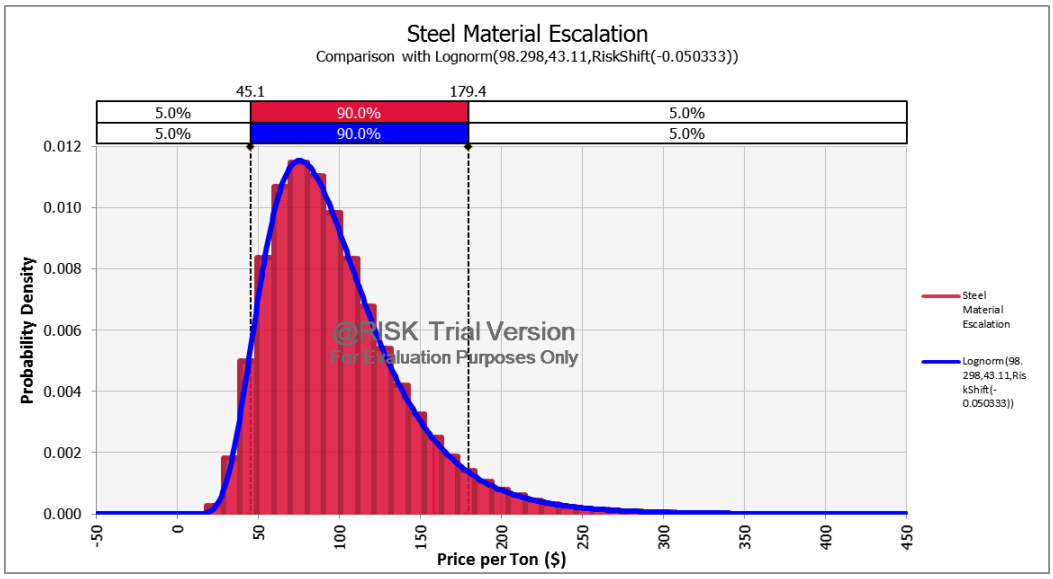

Figure 6.5 Probability Density of Modeled Steel Material Price Escalation

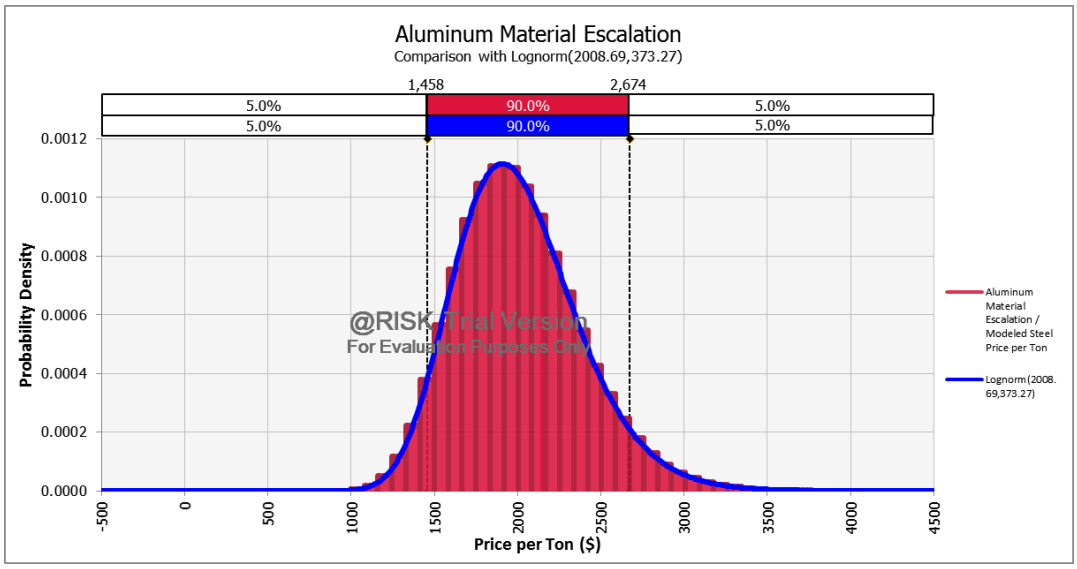

Figure 6.6 Probability Density of Modeled Aluminum Material Price Escalation

The varied cost inputs discussed above play a vital role in the contractor's overall financial success for the project. The overall effects of these inputs will be further discussed and summarized in Chapter 7: Conclusions and Discussion.

CHAPTER 7: CONCLUSIONS, DISCUSSION, AND NEXT STEPS

Conclusions and Discussion

The study performed on the subject project identified several important considerations that must be given a great deal of attention when assembling an estimate and bid for a construction project in which contractual cash flow constraints will be implemented. Proper planning, from both a scheduling and costing perspective, must be provided. This planning should include a preliminary cost loaded baseline schedule containing sufficient detail to allow for accurate forecasting and analysis of projected monthly billings and project cash flow. The information generated during the initial planning should then be used to determine whether the project's preliminary cost loaded baseline schedule and projected monthly billings can and will conform to the contractual cash flow constraints. If the preliminary cost loaded baseline schedule indicates that projected monthly billings will exceed the cash flow constraints, a detailed analysis of the monthly overdrafts should then be performed to determine the resulting finance charges and total amount required to be financed. These finance charges should be added to the estimate and included in the contractor's bid price. The subject project lends the following example shown in Table 7.1.

Table 7.1 Subject Project OH&P Summary

As-bid Contract Price ($)	As-bid OH&P @ 10% ($)	Total Interest at 4.5% APR ($)	Adjusted OH&P @ 10% ($)	% Reduction in OH&P
10,281,720.56	1,028,172.06	35,424.71	992,747.35	3.45%

Additionally, contingency amounts to cover potential escalation of costs associated with major equipment as well as fluctuations in the cost of commodity based materials should be contemplated through analysis of bid tabulations or historical prices. The

stochastic modeling performed in this research endeavor highlights several key takeaways that are important to take note of including the range of possible values for fluctuations in labor and commodity prices and possible percentage increases in major equipment prices. The subject project again lends the following example shown in Table 7.2.

Table 7.2 Varied Labor and Material Costs

Description	As-bid Cost ($)	Modeled Cost ($)	Cost Delta ($)	% Increase
Labor	4,419,621.98	4,624,691.83	205, 069.85	4.63%
Major Equipment	2,562,743.71	2,762,001.20	199,257.49	7.78%
Steel Materials	624,285.91	924,982.74	300,696.83	48.17%
Aluminum Materials	149,400.00	142,930.69	-6,469.31	-4.33%
		Total Increase:	698,554.86	

If labor and material escalation as shown above were to be realized by the subject project the resulting OH&P for the project would be reduced from $992,747.35 to $294,192.49 and would represent an overall reduction of 71.4% from the original anticipated OH&P amount. Although the above example represents an idealized, hypothetical scenario for labor and material escalation, it appropriately emphasizes the potential risk associated with labor and material components that comprise a project estimate and bid.

The aforementioned hypotheses of major equipment procurement and labor resource allocation and expenditure having a financially significant impact on project cash flow are supported by the findings of this study. From the above observations it can be determined that the procurement strategy implemented on a project must account for timing as well as the potential for price escalation in order to maximize project profitability. Similarly discernable from the quantitative analysis is the importance of labor estimation, including

type, quantity, and cost, prior to bid submission for a project. Careful planning and analysis should be provided to determine optimum procurement strategy, adequate labor budgets, and appropriate project contingency to ensure the highest likelihood of project success.

The observations and conclusions presented in this paper, when comparing to the noted preliminary biases, do not appear to pose any threat to the validity of the results. First, the preliminary biases of observation that the contractor exceeded the available annual financing from the project owner and as a result had to obtain outside financing from their bank and of earlier than planned major equipment procurement due to escalation in material pricing proved to be only a factual occurrence in the course of this study and provided a firm basis for analysis and the ability to highlight the importance of thorough financial and equipment procurement planning during project estimation. Finally, an observation that the project owner offered to increase the available annual financing in exchange for the addition of liquidated damages to the construction contract (which was declined by the contractor) served only to provide an opportunity to assume that the contractor viewed the potential cost associated with liquidated damages as having the possibility of being greater than the forecasted amount of unplanned carrying costs.

In summary, the effects experienced by contractors conforming to contractual cash flow constraints include increased pressure from the risk associated with labor and material escalation as well as a heightened importance of planning and scheduling during the estimating process, with particular importance placed on timing and amounts of projected monthly billings. Additionally, strict control for the timing of material procurement should be incorporated into the project plan because material procurement directly correlates to the timing and amounts of projected monthly billings. Finally, project cash flow should be

projected during the estimating process, with multiple scenarios examined such that periods of overdraft can be anticipated and the accompanying carrying costs included in the estimate and project bid price.

Next Steps

Additional research into contractually cash flow constrained projects would provide the opportunity to provide comparison of success and failure. Furthering the research in such a fashion would help address the limitation of a single case study by allowing for additional supporting case studies to reaffirm the conclusions presented in this paper by providing a broader base for analysis. Furthermore, the research endeavor could be expanded to include analysis of projects that have experienced interrupted or delayed cash inflows which would increase the base for analysis even further.

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APPENDIX A. OVERDRAFT CALCULATIONS @ 4.5% APR