CORRELATION BETWEEN CONTINGENCY ALLOWANCE AND CHANGE ORDERS

A Thesis

by

LISHAN LI

Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Chair of Committee,	Kunhee Choi
Committee Members,	Julian Kang
	Yu Xiao
Head of Department,	Joseph P. Horlen

August 2014

Major Subject: Construction Management

ABSTRACT

With escalating demand for improvement of construction project performance, alternative project delivery methods and innovative project contracting methods are implemented depending on various work types and project sizes. Contingency generally refers to initial contingency amount estimated before bidding and will be included in original contract. Premium cost also will be issued to pay non-value additional works. As a result, additional works, which also refers to change orders, are paid mainly by initial contingency, supplemental agreements and premium cost.

This paper mainly aims to compare initial amount of contingency to later investment paid for change orders by means of supplemental agreements or premium cost. If estimation of initial contingency is rather precise, even the initial contingency is high and will increases the original contract amount, it might still be beneficial to projects because it eliminates the cost-related influence caused by unforeseen additional works paid by fund prepared as contingency in advance. This paper is designed to testify correlation between initial contingency and cost overrun, moreover, to compare this correlation to the ones between supplemental agreement amount, premium cost and cost overrun, with which it could demonstrates whether initial contingency is less costly than amount issued by supplemental agreements or premium cost. Based on the results of correlation analysis, initial contingency is proved to be less expensive than paying change orders by supplemental agreements and premium cost.

DEDICATION

I would like to dedicate my thesis to my mother Yuelan He, all beloved families, my research committee and my friends, thank you for all of your support along the way.

ACKNOWLEDGEMENTS

I would like to express my special appreciation and kindest gratitude to my committee chair, Dr. Kunhee Choi, for being so supportive and providing me guidance throughout my research. I would like to thank my committee members, Dr. Julian Kang and Dr. Yu Xiao, for their guidance and support. Without persistent support and feedbacks offered by my research committee, this thesis would not have been possible.

Thanks to my family and friends who support me all the time. It is their encouragement and support that helped me get this far. It is their consistent faith in me which empowers me to face all the challenges in my life.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 Background

Contingency is one of the risk management tool extensively preparing owner for unexpected cost occurrence and additional cost caused by time extension for unforeseen site condition changes, design errors and emissions, design changes initiated for inaccuracy of site inspection, escalation of product price and so on. Uncertainty becomes the determinant factor that is considered into the estimation of contingency amount. Contingency put in project is a predicted amount and anticipated to be adequate to pay for unforeseen cost overrun, increasing as the inspected project uncertainty goes up. [1] Change order amount is prevalently associated with project performance evaluation and tied to each of alternative project delivery for a conclusion that one of all innovative project delivery methods can excel in project control and it should be encouraged to use under specific conditions for certain types or scales of projects. Beyond project delivery methods, contracting methods also would be so intensively influential to change orders and effect how much contingency the owner reasonably or intentionally put into project, as to that neither of delivery method not contracting method should be excluded from this analysis that contingency allowance amount has significant correlation with change order amount.

One of the assumption is that contingency allowance amount is calculated so contingently by predicting uncertainties during construction, based on experience on errors and omissions and information collected by site inspection and relative analyses, that it should be consistent to any predictable risks. While, standing on the other

respective, higher probability of risk occurrence it is with, more change order amounts are expected. However, Construction industry is always a people-oriented business, therefore, more contingency might imply more prepared the project team is to control risks so that change order will be lessened, which could lead to an opposite result of this paper.

1.2 Change Orders

Change orders are issued in forms of supplemental agreement, time extension agreement, contingency work order, and for the use of completing the project by positively accepting project changed requirement and site condition. According to the description given by FDOT, reasons for change orders are categorized as the Table 1:

Table 1 Reasons for Change Orders, FDOT

Reasons for Change Orders (FDOT)	
CEI action/inaction	Minor Changes
Changed Conditions	Partnering
Claim Settlement	Plans Modification
Contingency SA	Specification Modification
Cost Savings Initiative	Tropical Weather Related
Defective materials	Value engineering change proposal
Holiday Time Extension	Weather related
Industry Wide Material Shortage	Weather delays

Within these change orders, some of them are unavoidable, for example, weather related, delays and holiday time extension, while some are partly avoidable depending on case by case such as changed conditions, plans modification and CEI action/inaction. [2]

1.3 Innovative Contracting Methods by FDOT

1.3.1 Conventional Contraction Method, DBB

Conventional contracting methods used for transportation construction projects also refers to Design-Bid-Build (DBB), implemented through a process of competitive bid solicitation and with pre-qualified contractors' participations. [3] Usually, unit price is the format contractors use to place a bid and the bidder with the lowest price will be a winner.

1.3.2 Design Build

DB is an alternative project delivery method that emphasizes project team communication and concurrency of design and construction. Design and construction will be procured by a single responsible entity that also refers to Design Builder. The design-builder is typically selected via some type of qualification process or best-value based selection method. This selection approach is distinctly different from the conventional low bid selection in the DBB method. Experience in Florida has shown that DB projects are delivered faster at a slightly higher cost. [3]

1.3.3 Incentive/Disincentive

Incentive/disincentive is an alternative contracting method that takes project completion as the priority to evaluate the project management performance. I/D contract usually

explicitly demonstrates how time extension and saving influence the contract price. Earlier completion can earn contractor incentive payment from owner, while late completion will cause compensation from contractor to owner. [3] In this contracting method, owner has extensive control over schedule and money compensation can repay the loss caused by time overrun. On the other hand, contractor, taking in charge of project management and control, can set goal for earlier completion by applying operational management philosophy to accelerate project schedule.

1.3.4 A+B Bidding

A+B is a contracting method, within which A refers to cost and B refers to time. By applying A+B, contractor will place a bid on both pay item prices and a project completion duration. FDOT will set up a dollar value for each contract day. For the time bid, days required for completion is given by each bidder and by multiplying dollar value per contract day to days required for completion, price for time bid can be estimated. [3] The sum up of price of time bid and cost bid is the bidding price for total construction cost. Lowest bid price provider will be awarded a contract.

1.3.5 Lump Sum

Contractors will place bids with a lump sum price. In this contracting method, to owner's perspective, the budget could be limited to expected amount, however, because of the uncertainty for contractor's cost, the bidding price will be increased to a level adequately covering foreseen uncertainties. Lump Sum also has negative incentive to contractor that contractor might intend to lower the project quality within the allowable range to trade off more benefits. [3]

1.3.6 No Excuse Bonus

FDOR will set a bonus completion date. By meeting these preset date, contractor will be awarded with bonus payment. Bonus completion date can be a completion milestone date or a project completion date.

1.3.7 Lane Rental

Lane Rental is similar to A+B contracting method that considers both time and cost when a decision is made for biddings. The contract price consists of standard bid price and total lane rental days, which means both are influential to bidding result. [3]

1.3.8 Liquidated Savings

Liquidated savings is a contracting technique that provides incentive payment to contractor, encouraging earlier project completion. [3]

1.4 Contingency and Contract Price

Initial contingency is included in original contract, as an effective risk management tool to pay for unforeseen additional works. When the project spends more than 50% of initial contingency, supplemental agreement is another way to add up contingency and pay for change orders. Unilateral payment also is used to pay change orders. Comparing from supplemental agreement, projects will use unilateral payment when contractor and department fail to consent on a supplemental agreement and this additional work has to be completed immediately. [4] Components that consist in project contract price are shown as the Figure 1.

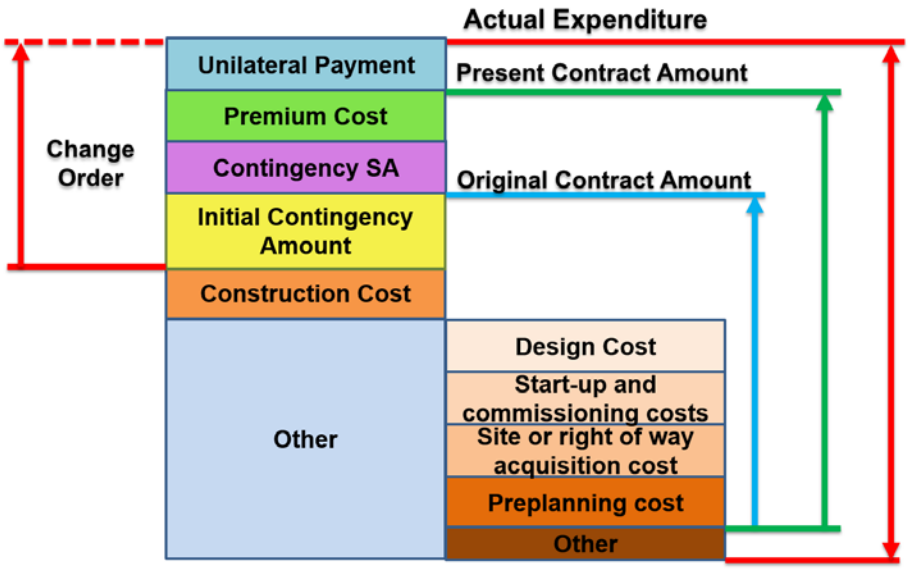


Figure 1 Components Consisting of Contract Price

2. PROBLEM STATEMENT

2.1 Gaps in Knowledge

Numerous researches are discussing over how the time overrun is related to cost overrun, also how is the project performance in each project delivery method so that they can provide suggestions on which one project delivery method is most efficient. However, very few researches concern on the correlation between contingency put in project and change order amount. Contingency is predicted and premeasured through inspections and risk evaluation tools, and should be increased as uncertainties within high up, because that's why contingency is prepared. Within the progress of predetermining contingency amount, efficiency of premeasuring risks is reflected by how precisely the contingency can pay for risk-initiated payment which also is called change order. For this interpretation, effective accurate prediction of contingency contributes to eliminate risk extension and support project completion on time. Fund paying for change orders could be consisted of initial contingency, supplemental agreement amount and premium cost. On the other hand, not many researches have been done for comparison of contingency between contracting methods, instead, for project delivery methods, conventional (DBB) and Design Build (DB), DBB usually have more contingency prepared in advance. [5]

2.2 Data Resources

Data is collected from Florida Department of Transportation and formatted as performance evaluations for alternative project delivery methods. This data consist of contract amount, original and present, amount of contingency paid item, related numbers

of project schedule and project completion date, original and present, also, change order types and the Supplemental Agreement (SA) amount within. Based on data, time extension and cost overrun can be calculated, what's more, for better use of this data to run a convincing regression model, time extension and cost overrun are both evaluated respectively by two indicators. Also, DOT estimate amount is given so that it will be used to assess how the accuracy of DOT's estimation on project cost is.

2.3 Research Assumption and Objectives

This paper is set to discover the correlation between initial contingency and change order. Correlation analysis is completed to interpret whether contingency is an effective risk management tool and how the performance of cost control is. Moreover, because the sum of change orders usually is the major component of cost overrun and change orders are generally paid by initial contingency, supplemental agreements and premium, how would the cost overrun changes when SA amount and premium cost increase? The research assumption is that initial contingency is estimated in the original contract before construction begins and is one of the main approaches to eliminate damages caused by unforeseen risks, therefore, it should be less costly than later investment by means of supplemental agreements or initiated as premium cost. The central objective is to testify the assumption. If the assumption is supported by data analysis, initial contingency should be encouraged to have an appropriately high percentage of contract amount.

3. LITERATURE REVIEW

3.1 Change Orders

According to the Architect's Handbook of Professional Practice, as to the root reason for contingency allowance included in project contract by which the unpredictable changes can be largely covered, contingency aims to serve three occurrences: [1]

1) Errors and Omissions in construction documents

2) Project scope change

3) Unknown conditions

3.2 Contingency Allowance

3.2.1 Benefits of Construction Contingency

Contingency should be regarded as a reserve of money and correlate to level of risk and uncertainty in projects. It is an effective risk management tool. Contingency allowance too often bases on an historical percentage of the total cost [6]. Numerous methods are available for the calculation and allocation of contingencies. It proposed a two-tiered contingency allocation approach for project cost, consisting of an engineering allowance and a management contingency utilizing a probabilistic framework. Contingency normally excludes major project scope changes, extraordinary events, management reserves, escalation on product prices and currency effects. Historical data and survey questionnaire are evaluated and determining contingency allowance amount, which is a normal method to decide contingency amount while traditional percentage, one of the alternative contingency estimating methods, also bases on past experience, intuition and

historical data. [5]Variables considered in traditional percentage estimating method consist of phase of project, level of project scope recognition and identification, type of work and project size.

Contingency mostly separates into two types in construction projects, construction and design contingency. Contingency amount cited in this paper refers to construction contingency. Normally, contingency has specific purposes, for examples, design or document errors and omissions requiring changes within scope or any necessary construction changes found on site during construction; unknown or unforeseen conditions like escalating product prices or any other probably unforeseen changes. In other words, change orders are issued by supplementary agreements, at the same time, contingency will not cover all change orders. [6]Supplementary agreement is one of the essential approaches to adjust original contract amount to present contract, corresponding to changes in specifications.

3.2.2 Construction Contingency in DBB and DB

Construction Contingency provides flexibility supporting to project completion, thereby it should not be regarded as cost lost but a risk management tool. In conventional project delivery method, Design Build Bid (DBB), low bid price is often used as the most determinant factor to award construction contract during bidding process. For projects which use low total contract cost as the only or most essential criterion to award contract, contractors would like to lessen the contingency amount included in contract price, whatsoever, some owners will request to exclude contingency amount from bidding contract price in order to avoid bidders placing inadequate contingency amount

for wining a project. Inadequate contingency amount initiates extensive budget overrun because of lack of financial preparation. As to a DB project, a range of 5% to 10% is acceptable, that should reflect the level of risk, difficulty and complexity the contractor project for the project. Comparing to DB, because of the bidding process and multiparty involvement, DB has more control to manage contingency.

3.2.3 Timeline of Previous Studies on Contingency Estimating Methods

Contingency is a predetermined amount with consideration over numerous variables, thus techniques are required to predict required contingency amount

Table 2 Timeline of Previous Studies on Contingency Estimating Methods

Contingency Estimating methods	Previous studies, arranged by time
Method of Moments	Diekmann 1983; Moselhi, 1997, Yeo 1990
Factor Rating	Hackney 1985, Oberlander & Trost 2001
Range Estimating	Curran 1989
Regression Analysis	Merrow & Yarossi 1990; Aibinu & Jagboro 2002
Traditional percentage	Ahmad 1992, Moselhi 1997
Fuzzy Sets	Paek, Lee, & Ock, 1993
Individual risks – expected value	Mak, Wong & Picken 1998; 2000
Influence Diagrams	Diekmann & Featherman 1998
Monte Carlo Simulation	Lorance & Wendling 1999, Clark 2001
Artificial Neural Networks	Chen & Hartman 2000; Williams 2003

Alternative estimating methods are utilized to calculate construction contingency variously case by case, within which traditional percentage is widely known and understood by comparatively. [7] Vary bidding selection methods and procedures could lead to different determination over contingency amount and contingency management. Also, level of risk is considered by owner. Timeline is as shown in Table 2.

3.2.4 Contingency Estimating Method: Traditional Percentage

Using traditional percentage, contingencies are calculated as an across-the-board percentage addition on the base estimate. This method is to predetermine contingency amount based on historical data, past project experience and intuition, what's more, project nature also would be considered, including work type, project phase and level of work scope definition. Thompson and Perry's observation indicates that "all too often risk is either ignored or dealt with in an arbitrary way: simply adding a 10% 'contingency' onto the estimated cost of a project as typical". With traditional percentage estimating method, a certain percentage will be considered according to the degree of uncertainties and risks with no appropriate adjustments. Whatsoever, project varies case by case and degree of uncertainties is extremely discrete, making this method imprecise. [8]

3.2.5 Contingency Estimating Method: Individual Risks – Expected Value

Expected value considers probability of risk occurrence and its maximum cost of each occurrence, similar to an anticipated value of cost of risk occurrences. There are two types of risks: fixed risk and variable risk. At first, known scope of uncertainties is

estimated and identified with its expected value. For variable risks, various estimating methods will be used depending on project size and type. [9]

Expected Value= probability of risk occurrence * cost of each risk occurrence

3.2.6 Contingency Estimating Method: Monte Carlo Simulation

Monte Carlo Simulation is a statistical technique testing what uncertainties will actually happen by establishing many trails of a project. It is a risk analysis tool, providing an approach to decide contingency value within project cost estimation. Results from MCS shown in Table 3 are calculated from a probability distribution analysis of total project cost. [10] This approach mostly can yield a low percentage of contingency for well-defined projects, arranging from 0%-5%. Conclusions derived from Monte Carlo Simulation for construction contingency are summarized as the followings:

Table 3 Results of Monte Carlo Simulation for Construction Contingency

Contingency Amount	Results
Low	High probability of cost overrun
	Driver for creative solutions
	Probably concessions on quality/safety
High	High probability of cost under run
	Project is probably less feasible；
	Negative impact on cost efficiency
	Cost under run may be used for other purposes
Correct Amount	Probability of over- or under- run estimate is 50%

Project size is extensively influential to the estimated contingency amount, since the probability degree of risk is ranging from 80% to 90%.

3.3 Determine Risk and Set Contingency

Washington State Department of Transportation publishes a report of process activity for determining risk and how to set contingency amount. Steps for setting contingency would conclude evaluation of level of risks and base cost estimate. Detailed steps are shown below. WDOT, as shown in Table 4, has a series of instructions on how to determine level of risk analysis: review project-related factors such as location, size, participants, type of work involved, general risks involved and their consequences and previous experience; review " A Policy for Cost Risk Assessment"; Communicate the level of risk analysis and management requirements to the project team. [11]

Table 4 Determine Risk and Set Contingency, WSDOT

Inputs	Estimate Package: 1) Base Cost Estimate, 2) Estimate Basis and Assumptions Previous project risk analysis
Steps to set contingency	1) Determine Level of Risk Analysis
	2) Identify Risks
	3) Perform Qualitative and/or Quantitative Risk Analysis
	4) Determine Total Project Cost

4. DATA ANALYSIS AND METHODOLOGY

4.1 Objectives of Correlation Analysis

Original contract is signed with a certain amount of contingency, in which the contingency amount can be predicted based on several estimating methods.[1] Supplemental agreement will be issued with the same purpose as initial contingency that change orders can be paid timely and damages will be eliminated to the least level, which implies supplemental agreement is an approach to add up contingency to the contract under preset conditions within the original contract. Take FDOT projects as examples, as the initial contingency is spent out over 50%, supplemental agreement is required to pay for change orders. For unforeseen additional works could add up both value and non-value works, premium cost is specially paying for only non-value work. Premium cost, in other words, is another approach to pay change orders so that it is initiated with similar purposes as that of the initial contingency and increased contingency consent through supplemental agreement. As a summary, these three kinds of payments to change orders can be categorized into two, one is pre-prepared amount, the initial contingency, indicating how much uncertainties and risks are expected, by which the efficiency of estimating contingency is extremely critical; the other one includes both supplemental agreement amount and premium cost, functionally similar as initial contingency paying for change orders but only initiated as required. [6] By comparing results from correlation analysis between %SA amount, %Premium cost, % Initial contingency to Cost Performance Ratio, it can conclude that comparing to initial investment of contingency, later added funds paid for change orders is less cost-

effective. But how pre-determined and contingent amount issued for change orders correlate to Cost Performance Ratio might not be consistent. From one research paper, projects with lager amount of contingencies have higher probabilities of cost under run so that a negative correlation between %Initial Contingency and CPR is highly anticipated. [5]

4.2 Hypothesis of Correlation Analysis

%Initial Contingency is negative correlated to CPR; %SA amount and %Premium cost are positively correlated with CPR. In other words, comparing to supplemental agreement amount and premium cost, initial contingency is rather cost-effective proved by negative correlation between %initial contingency and CPR.

4.3 Data Resources

Data analyzed in this paper is provided by Florida Department of Transportation.

Data used and collected originally as:

1) Amount included in Original for Contingency Pay Item: Contingency amount placed in project.
2) Actual Expenditure (Does not included Innovative Contract Adjustment Payments): the final project expenditure amount that excludes innovative contract adjustment payment.
3) CRS Present Contract Amount: along with supplementary agreements, CRS original contract amount will adjusted to an agreed amount regarding to the CRS Original Contract.

4) Original Contract Days: Consented project completion days, demonstrated on the CRS original contract.
5) Supplemental agreement (SA) amount: supplemental agreement is an approach used to collect and allocate funds to pay change orders beyond initial contingency. The SA amount is the sum of invested amount of SA.
6) Premium Cost: premium cost is the amount paying for non-value additional works. Premium cost in this database is under different categories of change orders. The correlation analysis is using the sum of all categories of premium cost.
7) DOT Original Estimate: Total construction cost estimated by DOT engineers, different from the original contract amount and usually more expensive than contract price.

4.4 General Data Analysis

Before establish hypothesis for possible conclusion, general analysis of all data and filtering data into different project contracting methods and project work types are both extremely critical to reach a probably convincing conclusion.

4.4.1 Analysis by Project Delivery Methods

The below comparison in Figure 2 is between Conventional and Design Build, also between DOR Original Estimate, CRS Original Contract Amount and CRS Present Contract Amount. The difference between DOT Original Estimate and CRS Original Contract Amount of DB is about 0.361 million and the one of DBB is 0.353 million. These two numbers are close and the average difference is about 0.357. But if

considering project size and contract amount, DB has less ratio of difference between estimated and original contract amount, which is 5.39% and the one of DBB is 10.52%.

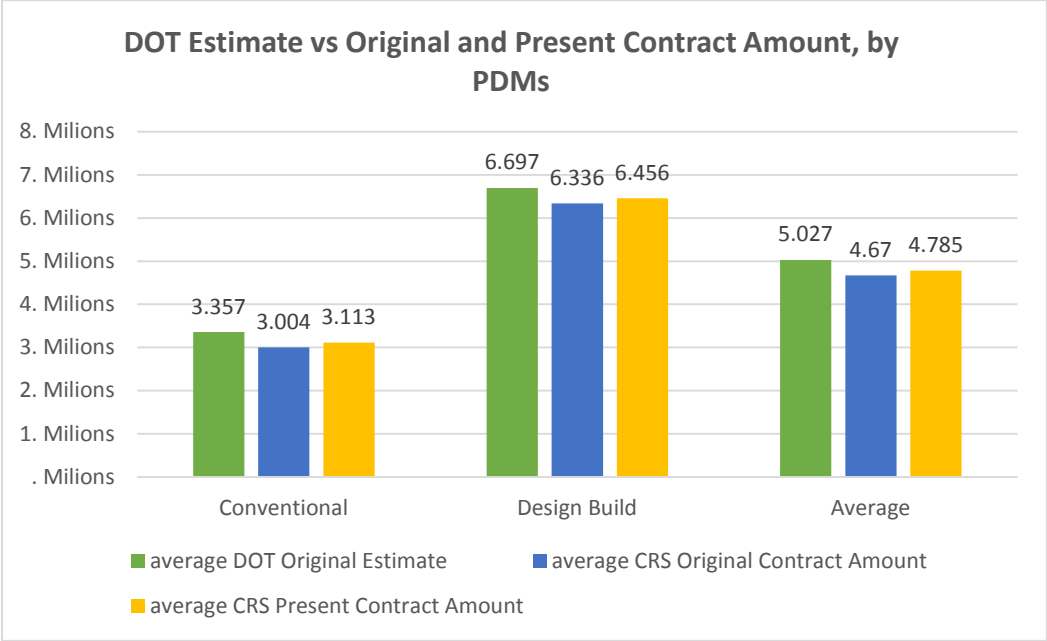


Figure 2 Comparisons between Estimated, Original and Present Contract Amount, by Project Delivery Methods

4.4.2 Analysis by Project Contracting Methods

From Figure 2 and 3, A+B Bidding projects have the largest average difference, 1.674 millions, between DOT original estimate and original contract amount, while incentive/ disincentive projects have the least, 0.183 million.

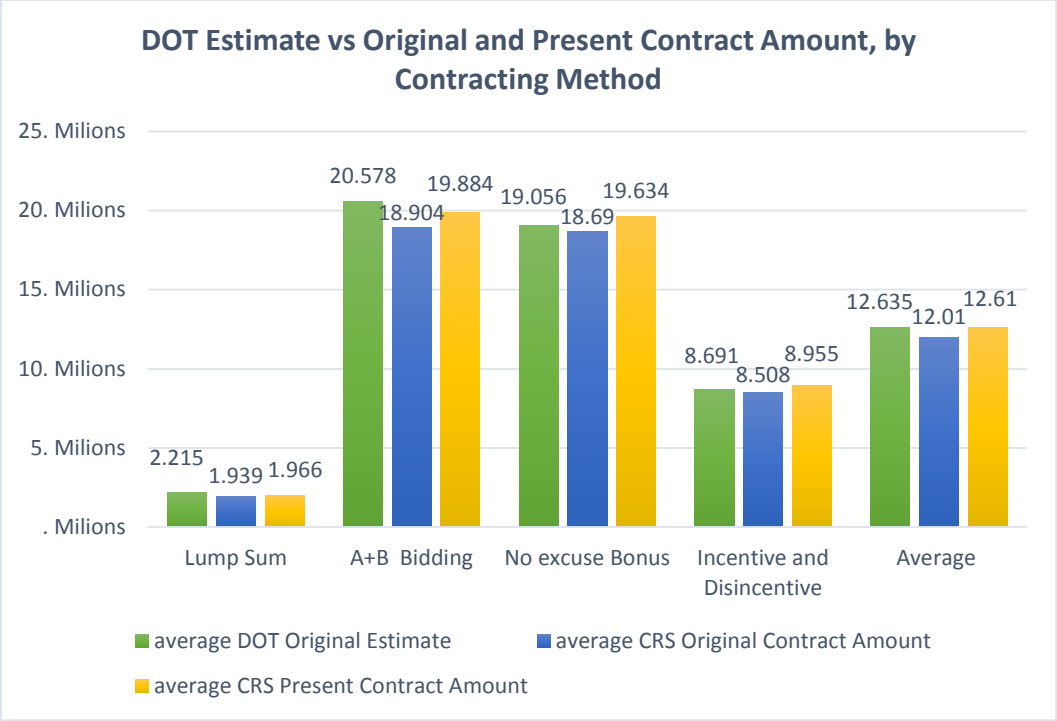


Figure 3 Comparisons between Estimated, Original and Present Contract Amount, by Project Contracting Methods

4.4.3 Deviation, DOT Estimate and Contract Amount, Original and Present

As to the limited data resources, this paper will mainly discuss with two project delivery methods and three innovative contracting methods, some of that are prevalently used by FDOT now and the others might be lessen to use because of their unsatisfying performance. They are respectively Conventional (DBB), Design Build (DB), A+B Bidding, No Excuse Bonus, Incentive and Disincentive (I/D).

In order to discover whether the accuracy of DOT's estimate on project cost will increase as the project cost decrease, compare difference between DOT project estimate

amount to both CRS original contract amount and CRS Present contract amount. Set indicators as followings:

Indicator 1:

Average difference, between estimated and original contract amount = DOT estimate amount-CRS Original Contract Amount

Indicator 2:

Average difference, between estimated and present contract amount = DOT estimate amount-CRS Present Amount

Table 5 Distribution Analysis of Indicator 1 and 2

Comparison	Indicator 1: Average difference, between estimated and original contract amount		Indicator 2: Average difference, between estimated and present contract amount	
Distribution Analysis	Mean	Standard Deviation	Mean	Standard Deviation
Conventional(DBB)	$352,309	$1,056,953	$243,320	$1,071,731
Design Build (DB)	$361,025	$1,474,120	$240,898	$1,586,996
Lump Sum	$276,453	$757,679	$249,065	$752,640
A+B Bidding	$1,673,186	$4,243,633	$693,924	$4,647,045
No Excuse Bonus	$365,126	$7,677,250	($578,857)	$82,721,524
Incentive and Disincentive	$182,342	$2,187,691	($264,811)	$2,663,432
All	$276,453	$757,679	$256,055	$752,640

Indicators set above are used to indicate how much the original and present contract amount exceed the estimated project amount. Assess which project delivery method or contracting method can acquire more competitive bidding price by means of comparing indicator 1 in each delivery and contracting method. Differentiated from indicator 1, indicator 2 is to measure whether and how present contract amount exceeds DOT estimate, by means of which higher indicator 2 implies better performance over cost control. Less standard deviations for indicator 1 and 2 present more similarity in the data of each project delivery and contracting method, moreover, the corresponding mean value of each indicator interprets data more precisely.

From Table 5, indicator 1, the mean value of difference between DOT estimate and original contract, of DBB projects is less than the one of DB projects, which means the average cost of DBB project is less than its expected budget. As to innovative contracting methods, A+B Bidding has extensively largest indicator 1, 1,673,186, while the Incentive/Disincentive projects has the least, concluding to that an extremely competitive project price can be acquired through A+B Bidding contracting method.

Indicator 2, the average differences between estimated project cost and present contract amount, of Conventional and Design Build are approximately as the same. Among four alternative contracting methods, No Excuse Bonus projects have the least indicator 2, -578,857, demonstrating the worst performance over cost control. A+B Bidding apparently has the most excellent performance of cost control by having the highest indicator 2. Besides, both no excuse bonus and incentive/disincentive have negative number of indicator 2, by which it states an excess from the present contract price over

the estimated project cost. If only considerate indicator 2, the worse cost control performance should belongs to No Excuse Bonus projects.

4.5 Correlation Analysis

4.5.1 Methodology of Correlation Analysis

Construction contract mostly will be adjusted and signed for project changes during construction, without regards to whose responsibilities are for those changes. While contingencies are initiated to pay change orders, they are separated into original and additional depending on when they are included into original contract. Initial contingency amount is estimated and calculated into original contract.

As part of the original contract, contingency also could be competitive while a project is procured with conventional project delivery method or any alternative methods in which total project cost is the critical or only criteria to select and award contract to a bidder and contingency amount is embedded into bidding price. Low contingency amount might be applied as an advantage, however, is as low as contingency could be a benefit to the project and to the owner? If based on the definition and purposes of construction contingency, a conclusion could be drawn that it provides protection over unforeseen risks instead of increasing the actual expenses.

Moreover, contingency financially prepares project to bear risks with flexibility. Conventional project delivery method extends project procurement duration because of its separated partnership and construction has to begin after the design completes so that

one of the integrated delivery methods, Design Build, is evaluated as with better performance.

On the other hand, single contract responsibility largely eliminates defects caused by lack of communications between contractor and owner in DB projects, contributing to an easily effective and manageable outcome.

4.5.2 Evaluation Indicators in Correlation Analyses

(1) Cost Performance Ratio (CPR)

Cost Performance Ratio is to gauge difference between actual expense and original contract amount based on original contract amount, representing how cost-effective and efficient the management over change orders is. Higher CPR implies lower efficiency that the project management has, which means low CPR is highly anticipated for construction projects.

Cost Performance Ratio (CPR) = (Actual Expense- Original Contract Amount)/Original Contract Amount

(2) %SA Amount

Supplemental agreement (SA) amount herein is the additional contract amount that has similar function with contingency as a repayment for change orders after the initial contingency amount is spent out at least 50%. [4] It will be initiated and included into contract amount as part of present contract amount, as to that %SA amount is associated with present contract amount rather than the original. It is calculated to evaluate how much SA amount contributes to present contract amount. By this ratio, higher %SA amount indicates greater amount of change orders.

%SA amount=Total SA amount/Present contract amount

(3) %Premium cost

Premium cost pays for non-value additional works, for examples, additional payment for project delays and inefficiency, different from quantity increase and/or price escalation which are usually paid by initial contingency and supplemental agreement. [4]

%Premium cost= premium cost/original contract amount

(4) %Initial contingency

Contingency amount herein is the original contingency amount put in the original contract so the calculation of %Initial Contingency bases on original contract amount, assessing how much investment of contingency put in original contract preparing is for unforeseen additional works. Initial contingency is quite different from supplemental agreement amount, because it is an estimated amount while comparing to SA amount, SA amount is determined as the change orders spends more than 50% of initial contingency.

%Initial contingency=initial contingency amount/ original contract amount

4.6 Correlation Analysis, Conventional and Design/Build

4.6.1 Conventional Delivery Method (DBB)

Correlations

Table 6 shows the matrix of correlation coefficients for conventional projects.

Table 6 Matrix of Correlation Coefficients, Conventional

	Cost Performance Ratio(CPR)	%SA amount	%premium cost	%Initial Contingency
Cost Performance Ratio(CPR)	1.0000	0.6495	0.2788	-0.3998
%SA amount	0.6495	1.0000	0.3607	-0.0565
%premium cost	0.2788	0.3607	1.0000	-0.0817
%Initial Contingency	-0.3998	-0.0565	-0.0817	1.0000

From the Table 6 matrix of correlation coefficients, %SA amount and %premium cost have positive correlations to CPR, which are 0.6495 and 0.2788. Initial contingency has negative correlation coefficient, -0.3998 to CPR.

CI of Correlation

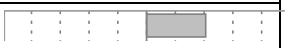
Table 7 Correlation Coefficients and Confidence Intervals, Conventional

Variable	by Variable	Correlation	Lower 95%	Upper 95%
%SA amount	Cost Performance Ratio(CPR)	0.6495	0.6169	0.6798
%premium cost	Cost Performance Ratio(CPR)	0.2788	0.2279	0.3282
%Initial Contingency	Cost Performance Ratio(CPR)	-0.3998	-0.4445	-0.3531

With 95% confidence, correlation coefficient is from 0.6196 to 0.6798 between %SA amount and CPR, and the 95% confidence interval between %premium cost and CPR is from 0.2279 and 0.3282. From Table 7, it has 95% confidence that the correlation efficient between %Initial contingency and CPR is from -0.4445 to -0.3531.

Nonparametric: Kendall's τ

Table 8 Correlation Coefficients by Kendall's Tau Test, Conventional

Variable	by Variable	Kendall τ	Prob>|τ|	Plot
%SA amount	Cost Performance Ratio(CPR)	0.4166	<.0001*	
%premium cost	Cost Performance Ratio(CPR)	0.2804	<.0001*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.3329	<.0001*	

According to Table 8, with at least 99.99% significant level, correlation coefficients between %SA amount, %Premium cost and CPR are 0.4166 and 0.2804. Whatsoever, %Initial contingency is negatively related to CPR with a coefficient, -0.3329, which has more than 99.99% significant level to reject null hypothesis that %Initial contingency is independent to Cost Performance Ratio.

Nonparametric: Spearman's ρ

Table 9 Correlation Coefficients by Spearman's Rho Test, Conventional

Variable	by Variable	Spearman ρ	Prob>|ρ|	Plot
%SA amount	Cost Performance Ratio(CPR)	0.5639	<.0001*	
%premium cost	Cost Performance Ratio(CPR)	0.3522	<.0001*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.4794	<.0001*	

Results from nonparametric analysis in Table 9, Spearman's Rho, indicates correlation coefficients between %SA amount, %premium cost, %Initial Contingency and CPR. With more than 99.99% significant level, %SA amount and %premium cost are positively related to CPR. The correlated coefficient, 0.5639, between %SA amount and CPR points out that there is a very robust negative correlation. While negative correlation is shown between %Initial Contingency and CPR, as -0.4794. According Table 10, with at least 99.99% significant level, %SA amount, %premium cost and %initial contingency are statistically dependent to CPR.

Table 10 Correlation Coefficients by Pairwise Correlation Test, Conventional

Variable	by Variable	Correlation	Count	Lower 95%	Upper 95%	Significant Prob
%SA amount	Cost Performance Ratio(CPR)	0.6473	1299	0.6145	0.6778	<.0001*
%premium cost	Cost Performance Ratio(CPR)	0.2793	1299	0.2284	0.3287	<.0001*
%Initial Contingency	Cost Performance Ratio(CPR)	-0.3937	1299	-0.4387	-0.3467	<.0001*

4.6.2 Design/Build

Correlations

Table 11 Matrix of Correlation Coefficients, Design Build

	Cost Performance Ratio(CPR)	%SA amount	%premium cost	%Initial Contingency
Cost Performance Ratio(CPR)	1.0000	0.8563	0.0522	-0.2973
%SA amount	0.8563	1.0000	0.0748	0.0563
%premium cost	0.0522	0.0748	1.0000	0.0057
%Initial Contingency	-0.2973	0.0563	0.0057	1.0000

From the correlation Table 11, correlation coefficients between %SA amount, %premium cost and CPR are positive, respectively 0.8563 and 0.0522, with comparison

of which CPR has a more apparently robust coefficient to %SA amount than to %Premium cost. Significantly, %Initial Contingency is negative correlated to CPR with a coefficient -0.2973.

CI of Correlation

Table 12 Correlation Coefficients and Confidence Intervals, Design Build

Variable	by Variable	Correlation	Lower 95%	Upper 95%
%SA amount	Cost Performance Ratio(CPR)	0.8563	0.8134	0.8899
%premium cost	Cost Performance Ratio(CPR)	0.0522	-0.0897	0.1920
%Initial Contingency	Cost Performance Ratio(CPR)	-0.2973	-0.4209	-0.1629

With 95% confidence, correlation coefficients between %SA amount and CPR is from 0.8134 to 0.8899, a robustly positive correlation. But based on Table 12, the interval of 95%confidence between %premium cost and CPR is from -0.0897 to 0.1920, unconvincingly indicating a positive correlation.

Nonparametric: Kendall's τ

Table 13 Correlation Coefficients by Kendall's Tau Test, Design Build

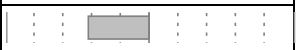
Variable	by Variable	Kendall τ	Prob>|τ|	Plot
%SA amount	Cost Performance Ratio(CPR)	0.4693	<.0001*	
%premium cost	Cost Performance Ratio(CPR)	0.1302	0.0264*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.3044	<.0001*	

In order to measure the association between %SA amount, %premium cost, %Initial contingency and CPR, Kendall's tau is used to provide estimated correlation coefficients. 0.4693 shows medium positive correlation between % SA amount and CPR, with a high probability more than 99.99% to reject null hypothesis that the observed two variables are statistically independent. It is shown in Table 13.

Correlation coefficient between %premium cost and CPR is 0.1302, with 97.36% significance level to prove dependent correlation between two variables. With 99.99% significant level, CPR is negatively associated with %Initial contingency and the coefficient is -0.3044.

Nonparametric: Spearman's ρ

Table 14 Correlation Coefficients by Spearman's Rho Test, Design Build

Variable	by Variable	Spearman ρ	Prob>|ρ|	Plot
%SA amount	Cost Performance Ratio(CPR)	0.5987	<.0001*	
%premium cost	Cost Performance Ratio(CPR)	0.1586	0.0276*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.4201	<.0001*	

Another nonparametric correlation analysis is Spearman's Rho test. With 99.99% significant level, %SA amount is correlated to CPR with a positive coefficient, 0.5987 and %Initial contingency is associated to CPR with a negative coefficient, -0.4201. %Premium cost is negative to CPR with a coefficient, 0.1586, to prove which this result associates to a 97.24% significant level as shown in Table 14 and 15.

Pairwise correlation analysis provides results of correlation coefficients between %SA amount, %premium cost, % Initial contingency and CPR. With 99.99% significant level, %SA amount and %Initial Contingency are dependent to CPR, with correlation coefficients respectively 0.8567 and-0.2980. With about 95%, % premium cost is dependent to CPR and has a positive correlation coefficient, 0.0522.

Table 15 Correlation Coefficients by Pairwise Correlation Test, Design Build

Variable	by Variable	Correlation	Count	Lower 95%	Upper 95%	Signif Prob
%SA amount	Cost Performance Ratio(CPR)	0.8567	193	0.8140	0.8903	<.0001*
%premium cost	Cost Performance Ratio(CPR)	0.0522	193	-0.0897	0.1920	0.4710
%Initial Contingency	Cost Performance Ratio(CPR)	-0.2980	193	-0.4215	-0.1636	<.0001*

4.6.3 Comparison between Conventional and Design Build

To sum up, %SA amount and %premium cost are all positively correlated to Cost Performance Ratio, while %Initial contingency has a negative correlation coefficient to CPR. Comparing to projects completed with conventional delivery method, %premium cost has a comparatively significant correlation coefficient with CPR than DB projects. Initial contingency, SA amount and premium cost have the same purpose to pay for change orders, whatsoever, financially initial contingency should be less costly since it is an anticipated amount considered into contract amount and predicted based on estimations.

Initial contingency amount included into original contract based on which this amount would be within affordable budget. What is different from initial contingency, SA amount and premium cost might be within affordable budget or not, or affordable but

more costly, as a result, the cost of acquiring funds for SA amount and premium cost is more expensive.

4.7 Correlation Analysis between Project Contracting Methods

4.7.1 A + B Bidding

Correlations

Table 16 is to show the matrix of correlation coefficients for A+B Bidding projects. Comparing to DBB and DB projects, A+B Bidding projects have obviously negative correlation between %Initial Contingency and Cost Performance Ratio.

Table 16 Matrix of Correlation Coefficients, A + B Bidding

	Cost Performance Ratio(CPR)	%SA amount	%Premium Cost	%Initial Contingency
Cost Performance Ratio(CPR)	1.0000	0.7601	0.3919	-0.3152
%SA amount	0.7601	1.0000	0.4557	0.0315
%Premium Cost	0.3919	0.4557	1.0000	-0.2046
%Initial Contingency	-0.3152	0.0315	-0.2046	1.0000

CI of Correlation

Table 17 Correlation Coefficients and Confidence Intervals, A + B Bidding

Variable	by Variable	Correlation	Lower 95%	Upper 95%
%SA amount	Cost Performance Ratio(CPR)	0.7601	0.6504	0.8388
%Premium Cost	Cost Performance Ratio(CPR)	0.3919	0.1912	0.5612
%Initial Contingency	Cost Performance Ratio(CPR)	-0.3152	-0.4981	-0.1054

Correlation coefficients between %SA amount, %premium cost, % Initial contingency and CPR are 0.7601, 0.3919 and -0.3152. 95% confidence interval of correlation coefficients between %SA amount and CPR is from 0.6504 to 0.8388.

The correlation coefficient between %premium cost and CPR is estimated 0.3919 and has 95% confidence interval, from 0.1912 to 0.5612. %Initial contingency is negatively correlated to CPR with a correlated coefficient -0.3152 and has a 95% confidence interval from -0.3152 to -0.1054, shown in Table 17.

Concluding from above, A+B bidding projects are more sensitive to the increase or decrease of contingency amount invested initially. Besides the effect of the change of contingency amount might be relatively apparent than DBB projects.

Table 18 Correlation Coefficients by Kendall's Tau Test, A + B Bidding

Variable	by Variable	Kendall τ	Prob>|τ|	Plot
%SA amount	Cost Performance Ratio(CPR)	0.4608	<.0001*	
%Premium Cost	Cost Performance Ratio(CPR)	0.2091	0.0085*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.2958	<.0001*	

From the results of Kendall's tau test, with 99.99% significant level, they can reject null hypothesis that %SA amount and %Initial contingency are independent to CPR. Besides, with 99.15% significant level, it proves that %premium cost is dependent to CPR. Estimated correlation coefficients between %SA amount, %premium cost, %Initial contingency and CPR are 0.4608, 0.2091 and -0.2658. Only %Initial contingency is negatively correlated to CPR. It is as shown in Table 18.

Table 19 Correlation Coefficients by Spearman's Rho Test, A + B Bidding

Variable	**by Variable**	**Spearman ρ**	**Prob>|ρ|**	**Plot**
%SA amount	Cost Performance Ratio(CPR)	0.6197	<.0001*	
%Premium Cost	Cost Performance Ratio(CPR)	0.2687	0.0146*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.4015	0.0002*	

Spearman's Rho test indicates a high estimated correlation coefficient in Table 19, 0.6197 between %SA amount and CPR, what's more, with at least 99.99% significant level, it proves that %SA amount depends on CPR. With 98.54% significant level, it demonstrates correlation between %premium cost and CPR, which is estimated about 0.2687. As to correlation between %Initial contingency and CPR, it estimates -0.4015, a robust negative correlation coefficient. Besides, with 99.98% probability, correlation is proved.

Pairwise correlations analysis demonstrates significant levels, at least 99.99%, 99.97% and 99.48%, to prove that %SA amount, %premium cost and %Initial contingency are dependent to CPR. The estimated correlation coefficients are 0.7604, 03890 and -0.3059. Robust negative correlation between %Initial contingency and CPR is demonstrated.

Table 20 Correlation Coefficients by Pairwise Correlation Test, A + B Bidding

Variable	by Variable	Correlation	Count	Lower 95%	Upper 95%	Signif Prob
%SA amount	Cost Performance Ratio(CPR)	0.7604	82	0.6508	0.8390	<.0001*
%Premium Cost	Cost Performance Ratio(CPR)	0.3890	82	0.1878	0.5588	0.0003*
%Initial Contingency	Cost Performance Ratio(CPR)	-0.3059	82	-0.4904	-0.0952	0.0052*

Besides, it is proven statistically that %SA amount and %premium cost have significant positive correlations with CPR and %Initial contingency is negatively related to CPR.

4.7.2 No Excuse Bonus

Correlations

Table 21 Matrix of Correlation Coefficients, No Excuse Bonus

	Cost Performance Ratio(CPR)	%SA amount	%Premium Cost	%Initial Contingency
Cost Performance Ratio(CPR)	1.0000	0.8712	0.7219	-0.3168
%SA amount	0.8712	1.0000	0.7616	-0.1019
%Premium Cost	0.7219	0.7616	1.0000	-0.1437
%Initial Contingency	-0.3168	-0.1019	-0.1437	1.0000

CI of Correlation

Table 22 Correlation Coefficients and Confidence Intervals, No Excuse Bonus

Variable	by Variable	Correlation	Lower 95%	Upper 95%
%SA amount	Cost Performance Ratio(CPR)	0.8712	0.8203	0.9085
%Premium Cost	Cost Performance Ratio(CPR)	0.7219	0.6238	0.7976
%Initial Contingency	Cost Performance Ratio(CPR)	-0.3168	-0.4688	-0.1466

Correlation coefficients between %SA amount, %premium cost, %Initial contingency and CPR are 0.8712, 0.7219 and-0.3168. 95% confidence interval between %SA amount and CPR is from 0.8203 to 0.9085 and the one between %premium cost and CPR is from 0.6238 to 0.7976. With a negative coefficient between %Initial contingency and CPR, it has a 95% confidence that it varies from -0.4688 to -0.1466.

Table 23 Correlation Coefficients by Kendall's Tau Test, No Excuse Bonus

Variable	**by Variable**	**Kendall τ**	**Prob>|τ|**	**Plot**
%SA amount	Cost Performance Ratio(CPR)	0.6442	<.0001*	
%Premium Cost	Cost Performance Ratio(CPR)	0.4640	<.0001*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.3003	<.0001*	

Kendall's tau test demonstrates positive correlations between %SA amount, %premium cost and CPR and negative correlation between %Initial contingency and CPR, which are with estimated correlation 0.6442, 0.4640 and -0.3003.%SA amount, %premium cost and %Initial contingency are all proved dependent to CPR with at least 99.99% significant level in which a conclusion on how sensitive the correlation between contingency amount and cost performance.

Table 24 Correlation Coefficients by Spearman's Rho Test, No Excuse Bonus

Variable	**by Variable**	**Spearman ρ**	**Prob>|ρ|**	**Plot**
%SA amount	Cost Performance Ratio(CPR)	0.8235	<.0001*	
%Premium Cost	Cost Performance Ratio(CPR)	0.6010	<.0001*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.4356	<.0001*	

In Table 24, with at least 99.99% significant level, %SA amount, %premium cost and %Initial contingency are all dependent to CPR, with estimated correlation coefficients 0.8235, 0.6010 and -0.4356. Statistically, larger values of %SA amount and %premium cost there are, higher CPR will be correspondingly expected.

Table 25 Correlation Coefficients by Pairwise Correlation Test, No Excuse Bonus

Variable	by Variable	Correlation	Count	Lower 95%	Upper 95%	Signif Prob
%SA amount	Cost Performance Ratio(CPR)	0.8729	121	0.8226	0.9097	<.0001*
%Premium Cost	Cost Performance Ratio(CPR)	0.7255	121	0.6284	0.8004	<.0001*
%Initial Contingency	Cost Performance Ratio(CPR)	-0.2893	121	-0.4448	-0.1168	0.0013*

Based on results from pairwise correlation test in Table 25, the correlation coefficients between %SA amount, %premium cost, %Initial Contingency and CPR are estimated 0.8729, 0.7255 and -0.2893. With at least 99.99% significant level, %SA amount and %premium are statistically dependent to CPR, while with 99.87% significant level, % Initial contingency varies dependently as the CPR changes.

4.7.3 Incentive and Disincentive

Correlations

Table 26 Matrix of Correlation Coefficients, I/D

	Cost Performance Ratio(CPR)	**%SA amount**	**%Premium Cost**	**%Initial Contingency**
Cost Performance Ratio(CPR)	1.0000	0.6990	0.3043	-0.5344
%SA amount	0.6990	1.0000	0.3069	-0.2111
%Premium Cost	0.3043	0.3069	1.0000	-0.1832
%Initial Contingency	-0.5344	-0.2111	-0.1832	1.0000

CI of Correlation

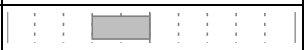
Table 27 is to show the Confidence Correlations for Incentive and Disincentive projects.

Table 27 Correlation Coefficients and Confidence Intervals, I/D

Variable	by Variable	Correlation	Lower 95%	Upper 95%
%SA amount	Cost Performance Ratio(CPR)	0.6990	0.6213	0.7631
%Premium Cost	Cost Performance Ratio(CPR)	0.3043	0.1742	0.4240
%Initial Contingency	Cost Performance Ratio(CPR)	-0.5344	-0.6259	-0.4285

From Table 26 and 27, correlation coefficients between %SA amount, %premium cost, %Initial contingency and CPR are 0.6990, 0.3043 and -0.5344. 95% confident interval between %SA amount and CPR is from 0.6213 to 0.7631; the one between %premium cost and CPR is from 0.1742 to 0.4240. Whatsoever, %Initial contingency and CPR has a 95% confidence interval from -0.6259 to -0.4285.

Table 28 Correlation Coefficients by Kendall's Tau Test, I/D

Variable	by Variable	Kendall τ	Prob>|τ|	Plot
%SA amount	Cost Performance Ratio(CPR)	0.4261	<.0001*	
%Premium Cost	Cost Performance Ratio(CPR)	0.3096	<.0001*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.4073	<.0001*	

In Table 28, with 99.99% significant level, %SA amount, %premium cost and %Initial contingency are dependent to CPR. The estimated correlation coefficients between %SA amount, %premium cost, %Initial contingency and CPR are 0.4261, 0.3096 and -0.4073.

Table 29 Correlation Coefficients by Spearman's Rho Test, I/D

Variable	**by Variable**	**Spearman ρ**	**Prob>|ρ|**	**Plot**
%SA amount	Cost Performance Ratio(CPR)	0.5739	<.0001*	
%Premium Cost	Cost Performance Ratio(CPR)	0.3943	<.0001*	
%Initial Contingency	Cost Performance Ratio(CPR)	-0.5833	<.0001*	

From Spearman's Rho test in Table 29, %SA amount, %premium cost, %Initial contingency and CPR are correlated with estimated coefficients 0.5739, 0.3943 and -0.5833. With at least 99.99% significant level, %SA amount, %premium cost, %Initial contingency are statistically dependent to CPR. Results conclude that higher CPR is expected while %SA amount and %Premium cost increase.

Table 30 Correlation Coefficients by Pairwise Correlation Test, I/D

Variable	**by Variable**	**Correlation**	**Count**	**Lower 95%**	**Upper 95%**	**Signif Prob**
%SA amount	Cost Performance Ratio(CPR)	0.6990	204	0.6213	0.7631	<.0001*
%Premium Cost	Cost Performance Ratio(CPR)	0.3041	204	0.1739	0.4237	<.0001*
%Initial Contingency	Cost Performance Ratio(CPR)	-0.5339	204	-0.6254	-0.4279	<.0001*

As to Table 30, with at least 99.99% significant level, null hypothesis is rejected that %SA amount, %premium cost, %Initial contingency are statistically dependent to CPR. The estimated correlation coefficients between %SA amount, %premium cost, %Initial contingency and CPR are 0.6990, 0.3041 and -0.5339.

4.7.4 Comparison between Contracting Methods

Based on data of projects completed through A+B Bidding, No Excuse Bonus and Incentive and Disincentive, %SA amount, %premium cost and %Initial contingency are all significantly dependent to CPR. %SA amount is more robust correlated to CPR than %premium cost is, by which as %SA amount or %premium cost increase, the corresponding CPR will add up. What these correlation coefficients can demonstrate statistically is that pre-prepared funds of contingency is less costly when comparing to payment for change orders by means of initiating supplemental contracts and premium cost.

5. CORRELATION BETWEEN WORK TYPE AND CHANGE ORDER

5.1 Data Resources

Average % Contingency: refers to an average value of all contingency amount over total CRS original contract amount in each project delivery and contracting method, consist of conventional, design build, incentive and disincentive, A+B Bidding, No Excuse Bonus.

Average % Contingency= Total Contingency Amount of each project delivery (contracting) method/Total CRS Original Contract amount of each project delivery (contracting) method

Probability of Occurrence: refers to probability of occurrence in each work type for each project delivery (contracting) method. Work types include bridge construction, bridge repair, interstate new construction, interstate rehabilitation, maintenance, miscellaneous construction, new construction, other, reconstruction, resurfacing, traffic operation, widening & resurfacing.

% of Occurrence=Number of occurrence of each work type / Total number of projects in each project delivery (contracting) method

% of Contingency to original contract amount at average: refers to an average value for each work type project of contingency amount to CRS original contract amount and no considerations of project delivery or contracting methods are included.

% Contingency to original contract amount at average=Total Contingency amount of each work type/Total CRS original contract amount of each work type

Indicator: is calculated to assess contingency amount in each project delivery (contracting) method for each work type, also considering probability of occurrence in each project delivery (contracting) method for each work type. It is merely an indicator to find out in which project delivery (contracting) method and work type, contingency has the highest ratio.

Indictor= Average % Contingency* Probability of Occurrence*% of Contingency to original contract amount at average*100

5.2 Distribution Analysis

5.2.1 Analysis Objectives

In chapter 4, correlation analyses are established based on different project delivery and contracting methods with no regards to work type. Project work type usually has significant influence to project size and the amount of unforeseen risks during construction, because of that correlation analysis combining considerations of delivery and contracting methods to work types has major contributions to eliminate bias in chapter 4.

5.2.2 Comparisons of Initial Contingency Amount

From Table 31, comparing to Design Build, DBB has an obviously higher number of contingency amount, while in three alternative contracting methods, Incentive and Disincentive has the highest average percentage of contingency over original contract amount. According to the indicators shown below, resurfacing project completed by conventional delivery method has an indicator, 69.44, the highest one in both DBB and

DB, by which resurfacing, DBB project has highest expected percentage of contingency over original contract price. The ranks are shown in Table 32 and Table 33. Incentive/Disincentive projects have highest average contingency percentage 1.0%, comparing to A+B Bidding and No Excuse Bonus projects. Traffic operation projects have the highest average percentage of contingency over original contract mount amount different work types. By considering average %contingency of each project delivery method, probability of occurrence of each work type and average %contingency of each work type, rankings of which project delivery or contracting methods with specific work types are usually invested with high contingency.

Table 31 Indicators and Distribution Analysis of Contingency Amount

Conventional (DBB)												
Average %Contingency: 1.57%												
Work Type	bridge construction	bridge repair	Interstate New Construction	Interstate Rehabilitation	Maintenance	Miscellaneous Construction	New Construction	other	Reconstruction	Resurfacing	Traffic Operations	Widening & Resurf.
Probability of occurrence in DBB	3.08%	12.31%	0.50%	0.29%	0.57%	13.82%	3.36%	17.25%	4.58%	29.28%	10.16%	4.80%
% of contingency to original contract	1.07%	1.38%	0.48%	0.59%	1.14%	1.28%	0.73%	1.27%	0.66%	1.51%	1.76%	0.94%
Indicator 1	5.15	26.67	0.38	0.26	1.02	27.75	3.85	34.39	4.73	69.44	28.12	7.06
Design Build												
Average %Contingency: 0.92%												
Work Type	bridge construction	bridge repair	Interstate New Construction	Interstate Rehabilitation	Maintenance	Miscellaneous Construction	New Construction	other	Reconstruction	Resurfacing	Traffic Operations	Widening & Resurf.
Probability of occurrence in DB	4.52%	4.02%	2.51%	1.51%	0.00%	24.62%	8.04%	22.61%	0.50%	15.58%	9.55%	6.53%
% of contingency to original contract	1.07%	1.38%	0.48%	0.59%	1.14%	1.28%	0.73%	1.27%	0.66%	1.51%	1.76%	0.94%
Indicator 2	4.42	5.08	1.11	0.81	0.00	28.86	5.36	26.30	0.30	21.56	15.41	5.61
Incentive and Disincentive (I/D)												
Average %Contingency: 1.00%												
Work Type	bridge construction	bridge repair	Interstate New Construction	Interstate Rehabilitation	Maintenance	Miscellaneous Construction	New Construction	other	Reconstruction	Resurfacing	Traffic Operations	Widening & Resurf.
Probability of occurrence in I/D	1.91%	4.78%	0.96%	0.00%	0.48%	13.40%	3.35%	16.27%	7.66%	31.10%	7.66%	12.44%
% of contingency to original contract	1.07%	1.38%	0.48%	0.59%	1.14%	1.28%	0.73%	1.27%	0.66%	1.51%	1.76%	0.94%
Indicator 3	2.05	6.61	0.46	0.00	0.54	17.18	2.44	20.70	5.05	47.08	13.52	11.69

Table 31 Continued

A+B Bidding												
Average %Contingency: 0.75%												
Work Type	bridge construction	bridge repair	Interstate New Construction	Interstate Rehabilitation	Maintenance	Miscellaneous Construction	New Construction	other	Reconstruction	Resurfacing	Traffic Operations	Widening & Resurf.
Probability of occurrence in A+B Bidding	1.19%	3.57%	4.76%	2.38%	0.00%	3.57%	7.14%	21.43%	21.43%	21.43%	7.14%	5.95%
% of contingency to original contract at average, calculated by all data	1.07%	1.38%	0.48%	0.59%	1.14%	1.28%	0.73%	1.27%	0.66%	1.51%	1.76%	0.94%
Indicator 4	0.95	3.68	1.72	1.04	0.00	3.41	3.89	20.33	10.54	24.19	9.40	4.17
No Excuse Bonus												
Average %Contingency: 0.72%												
Work Type	bridge construction	bridge repair	Interstate New Construction	Interstate Rehabilitation	Maintenance	Miscellaneous Construction	New Construction	other	Reconstruction	Resurfacing	Traffic Operations	Widening & Resurf.
Probability of occurrence in Bonus	2.22%	2.96%	2.22%	9.63%	0.00%	9.63%	4.44%	6.67%	18.52%	31.11%	2.96%	9.63%
% of contingency to original contract at average, calculated by all data	1.07%	1.38%	0.48%	0.59%	1.14%	1.28%	0.73%	1.27%	0.66%	1.51%	1.76%	0.94%
Indicator 5	1.71	2.95	0.78	4.07	0.00	8.90	2.34	6.11	8.80	33.93	3.77	6.52

Table 32 Ranking of Contingency Amount by Work Type and Project Delivery Method

Ranking	Indicator	Work Type	Project Delivery Method
1	69.44	Resurfacing	Conventional(DBB)
2	34.39	other	Conventional(DBB)
3	28.86	Miscellaneous Construction	Design Build
4	28.12	Traffic Operations	Conventional(DBB)
5	27.75	Miscellaneous Construction	Conventional(DBB)
6	26.67	bridge repair	Conventional(DBB)
7	26.3	other	Design Build
8	21.56	Resurfacing	Design Build
9	15.41	Traffic Operations	Design Build
10	7.06	Widening & Resurf.	Conventional(DBB)
11	5.61	Widening & Resurf.	Design Build
12	5.36	New Construction	Design Build
13	5.15	bridge construction	Conventional(DBB)
14	5.08	bridge repair	Design Build
15	4.73	Reconstruction	Conventional(DBB)
16	4.42	bridge construction	Design Build
17	3.85	New Construction	Conventional(DBB)
18	1.11	Interstate New Construction	Design Build
19	1.02	Maintenance	Conventional(DBB)
20	0.81	Interstate Rehabilitation	Design Build
21	0.38	Interstate New Construction	Conventional(DBB)
22	0.3	Reconstruction	Design Build
23	0.26	Interstate Rehabilitation	Conventional(DBB)
24	0	Maintenance	Design Build

Table 33 Ranking of Contingency Amount by Work Type and Contracting Method

Ranking	Indicator	Work Type	Project Delivery Method
1	47.08	Resurfacing	Incentive/Disincentive(I/D)
2	33.93	Resurfacing	No Excuse Bonus
3	24.19	Resurfacing	A+B Bidding
4	20.7	other	Incentive/Disincentive(I/D)
5	20.33	other	A+B Bidding
6	17.18	Miscellaneous Construction	Incentive/Disincentive(I/D)
7	13.52	Traffic Operations	Incentive/Disincentive(I/D)
8	11.69	Widening & Resurf.	Incentive/Disincentive(I/D)
9	10.54	Reconstruction	A+B Bidding
10	9.4	Traffic Operations	A+B Bidding
11	8.9	Miscellaneous Construction	No Excuse Bonus
12	8.8	Reconstruction	No Excuse Bonus
13	6.61	bridge repair	Incentive/Disincentive(I/D)
14	6.52	Widening & Resurf.	No Excuse Bonus
15	6.11	other	No Excuse Bonus
16	5.05	Reconstruction	Incentive/Disincentive(I/D)
17	4.17	Widening & Resurf.	A+B Bidding
18	4.07	Interstate Rehabilitation	No Excuse Bonus
19	3.89	New Construction	A+B Bidding
20	3.77	Traffic Operations	No Excuse Bonus
21	3.68	bridge repair	A+B Bidding
22	3.41	Miscellaneous Construction	A+B Bidding
23	2.95	bridge repair	No Excuse Bonus
24	2.44	New Construction	Incentive/Disincentive(I/D)
25	2.34	New Construction	No Excuse Bonus
26	2.05	bridge construction	Incentive/Disincentive(I/D)
27	1.72	Interstate New Construction	A+B Bidding
28	1.71	bridge construction	No Excuse Bonus
29	1.04	Interstate Rehabilitation	A+B Bidding
30	0.95	bridge construction	A+B Bidding
31	0.78	Interstate New Construction	No Excuse Bonus
32	0.54	Maintenance	Incentive/Disincentive(I/D)
33	0.46	Interstate New Construction	Incentive/Disincentive(I/D)
34	0	Interstate Rehabilitation	Incentive/Disincentive(I/D)
34	0	Maintenance	A+B Bidding
34	0	Maintenance	No Excuse Bonus

6. CONCLUSIONS

6.1 Accept Hypothesis

Change order is prevalently regarded as the performance evaluation indicator, reflecting efficiency on project management. On the other hand, change order is the major increase of contract price and usually is the main part of cost overrun. Less the change order is, more satisfying the performance of project management is.

(1) Initial contingency is less expensive than funds retrieved by supplemental agreements and premium cost.

(2) More contingency amount included in original contract there is, less cost overrun is.

(3) More SA amount or premium cost is issued, more expected cost overrun is.

6.2 Correlation between Work Type and Contingency Amount

6.2.1 Project delivery methods

Table 34 Top 5 of High Contingency Amount, from Largest to Least:

Ranking	Work Type	Project Delivery Method
1	Resurfacing	Conventional(DBB)
2	other	Conventional(DBB)
3	Miscellaneous Construction	Design Build
4	Traffic Operations	Conventional(DBB)
5	Miscellaneous Construction	Conventional(DBB)

6.2.2 Project contracting methods

Table 35 Top 5 of High Contingency Amount, from Largest to Least:

Ranking	Work Type	Project Delivery Method
1	Resurfacing	Incentive/Disincentive(I/D)
2	Resurfacing	No Excuse Bonus
3	Resurfacing	A+B Bidding
4	other	Incentive/Disincentive(I/D)
5	other	A+B Bidding

REFERENCES

[1] H. Hart, D. (2007, September). Managing the Contingency Allowance. Retrieved from http://www.aia.org/aiaucmp/groups/secure/documents/pdf/aiap026970.pdf

[2] Florida Department of Transportation. (2014, May.). Reason Codes. Retrieved from http://www.dot.state.fl.us/construction/trnsport/Business%20Rules/Contract_Change_Order_Reason_Code_Descriptions.pdf

[3] Baccarini, D. (2005). Estimating Project Cost Contingency – Beyond the 10% Syndrome. Retrieved from http://cms.3rdgen.info/3rdgen_sites/107/resource/Baccarini-AIPMconf05.pdf

[4] Florida Department of Transportation. (2014, April.). Alternative Contracting. Retrieved from http://www.dot.state.fl.us/construction/AltContract/AltContract.shtm

[5] Sadler, D. (2014, February 17). Coding Contract Changes. Retrieved from http://www.dot.state.fl.us/construction/manuals/cpam/New%20Clean%20Chapters/CodingContractChanges.pdf

[6] Baccarini, D. (2014, March). Statistical Characteristics of Cost Contingency in Water Infrastructure Projects. Retrieved from http://cedb.asce.org/cgi/WWWdisplay.cgi?314875

[7] Baccarini, D. (2004, September). Estimating Project Cost Contingency - A Model and Exploration of Research Questions. Retrieved from http://www.arcom.ac.uk/-docs/proceedings/ar2004-0105-0113_Baccarini.pdf

[8] Autry , A. (2014, March.). Contract Modification Discussion. Retrieved from http://www.dot.state.fl.us/construction/training/ConstAcademy/Presentations/ContractModifications_AlanAutry.pptx

[9] Washington State Department of Transportation. (2014, March.). Process Activity-Determine Risk and Set Contingency. Retrieved from http://www.wsdot.wa.gov/NR/rdonlyres/45B85BFF-6813-439C-B82B-3AE50544A023/23821/DetermineRiskandSetContingency.pdf

[10] U.S. Department of Transportation-Federal Highway Administration. (2006, October). 4. Risk Analysis - Risk Assessment and Allocation for Highway Construction Management | Office of International Programs | FHWA. Retrieved from http://www.international.fhwa.dot.gov/riskassess/risk_hcm06_04.cfm

[11] Florida Department of Transportation. (2013, October 28). Contingency Supplemental Agreements and Work Orders. Retrieved from http://www.dot.state.fl.us/construction/Manuals/cpam/New%20Clean%20Chapters/Chapter7s4.pdf