Master of Science in Engineering

Cost Performance Comparison of Design-Build and Design-Bid-Build Focusing on Mediator Effect

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Abstract

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According to previous research, the reason why Design-Build(hereinafter referred to as “DB”) outperforms Design-Bid-Build(hereinafter referred to as “DBB”) in terms of cost is due to less change orders. However, if biddropping was low for DBB resulting into change orders, and little difference between completion cost and budget cost, then it would be wrong to conclude that DB is superior due to less change orders. Therefore, in order to confirm such misjudgment, the attempt to comprehensively analyze biddropping, change order and delivery method were made as previous methods had analyzed either the relationship between delivery method and change order, or

biddropping and change order. This research uses a path analysis, which simultaneously compares effect sizes on change orders according to delivery method and biddropping based on the project type, and validated the mediator effect. The research proved that validating DB is superior to DBB due to less change orders cannot be validated as biddropping caused a mediator effect by intervening between the delivery method and change order for specific project types. Therefore, the mechanism of delivery method acts on change orders through biddropping was established. Also, the identity of biddropping was investigated in a different approach from previous research. Based on this result, this research is expected to help determine a delivery method by considering the mediator effect of specific projects and evaluate performance of the selected delivery method.

Keywords: Mediator Effect of Biddropping, Delivery Method, Design-Bid, Design-Bid-Build, Cost Performance, Change Order

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Chapter 1. Introduction

1.1 Research Background and Objective

The procurement phase of a construction project is when various stakeholders are involved. It can also be said that selecting the delivery method is the first step for a successful project. This is because the selection of an inappropriate delivery method can lead to considerable loss in terms of cost and cause a great confusion throughout the project. The performance evaluation of a delivery method in terms of cost has been carried out in two different approaches. The first method evaluates the average cost change rate of the contract price or the average cost growth from change order according to the delivery method, where the lowest value is determined to be superior. The other method evaluates the correlation between the change order and biddropping.

Most previous research, which compared and evaluated the performance of a delivery method, concluded that Design Build (DB) is superior to Design-Bid-Build (DBB) in terms of cost. However, there are few opinions stating that such conclusion is debatable, and there can be a relation between biddropping and change order (Riley, D. R. et al. 2005; Perkins, R. A. 2009; Hale D. R. et al. 2009; University of Seoul 2006; Williams, T. P. 2005; Sung, J. Y. 2015; Yoon, B. H. 2008; Lim, P. J. 2014; Jun, H. C. 2007). However, both research approaches reached at an inconsistent conclusion as one research states that less change orders is superior and the other research states that low biddropping leads to increased change orders.

Comparing cost performance of both DB and DBB method is debatable as the causal relationship cannot be fully explained between delivery methods and change orders. This implies that influence factors such as biddropping exist in the relationship. Therefore, it is necessary to compare the two types of research, which analyzed the relationship between change order and delivery method, and biddropping and change order, utilizing identical data. Comprehensively analyzing the relationship among delivery method, biddropping and change order is also necessary.

The purpose of this study is to analyze synthetically the difference of previous studies that are inconsistent in evaluating change order generated in construction phase and validate mediator effect of biddropping intervening between delivery method and change order. To do so, this research utilizes project data of 234 completed facility cases in Seoul to conduct an empirical comparison of DB and DBB method by project type in terms of cost. Then, difference of perspective of the previous research is identified. Simultaneously, the relationship of factors that have effects on cost performance utilizing the path analysis method is determined. Also, the mediator effect by biddropping is validated and the identity of biddropping as a mediator is investigated from a different perspective. As a result, this research will help evaluate performance of the delivery method and select a delivery method with less impeding effect on cost performance.

1.2 Research Scope and Process

The scope of this research is to limit delivery method and their performance index. Types of delivery method were limited to DB and DBB which are mainly used to compare performance of delivery methods. Although performance of a delivery method is analyzed with various indexes such as cost, time, quality and safety, cost performance was compared and analyzed as it was the controversial subject for this research. Previous research used project cost change or change order as the cost performance index of a delivery method. However, as the adjustment of cost change due to price escalation is not related to the performance of a delivery method, change order excluding the price fluctuation from the altered cost change was used as the index (Lee, Y. S. et al. 2013). This research was intended for contract and construction phase which caused biddropping and change orders during the project life cycle.

The process for this research is the following:

(1) Defining issues with previous research by analyzing preliminary studies related to cost performance evaluation of a delivery method and extracting factors that have an effect on cost performance for DB and DBB.

(2) Defining factors related to cost performance in consideration of the extracted factors (biddropping and change order) and establishing a research hypothesis on the relationship of the factors

(3) Extracting the cause for inconsistent result by gathering data within the research scope and analyzing according to the previous research methods

(4) Simultaneous analyzing the relationship between delivery method and the extracted factors (biddropping and change order) and testing the hypothesis mediator effect of biddropping.

(5) Based on the test results, suggesting items to consider when evaluating cost performance and selecting DB or DBB delivery method

The flow diagram of research process is shown in the following Figure 1-1.

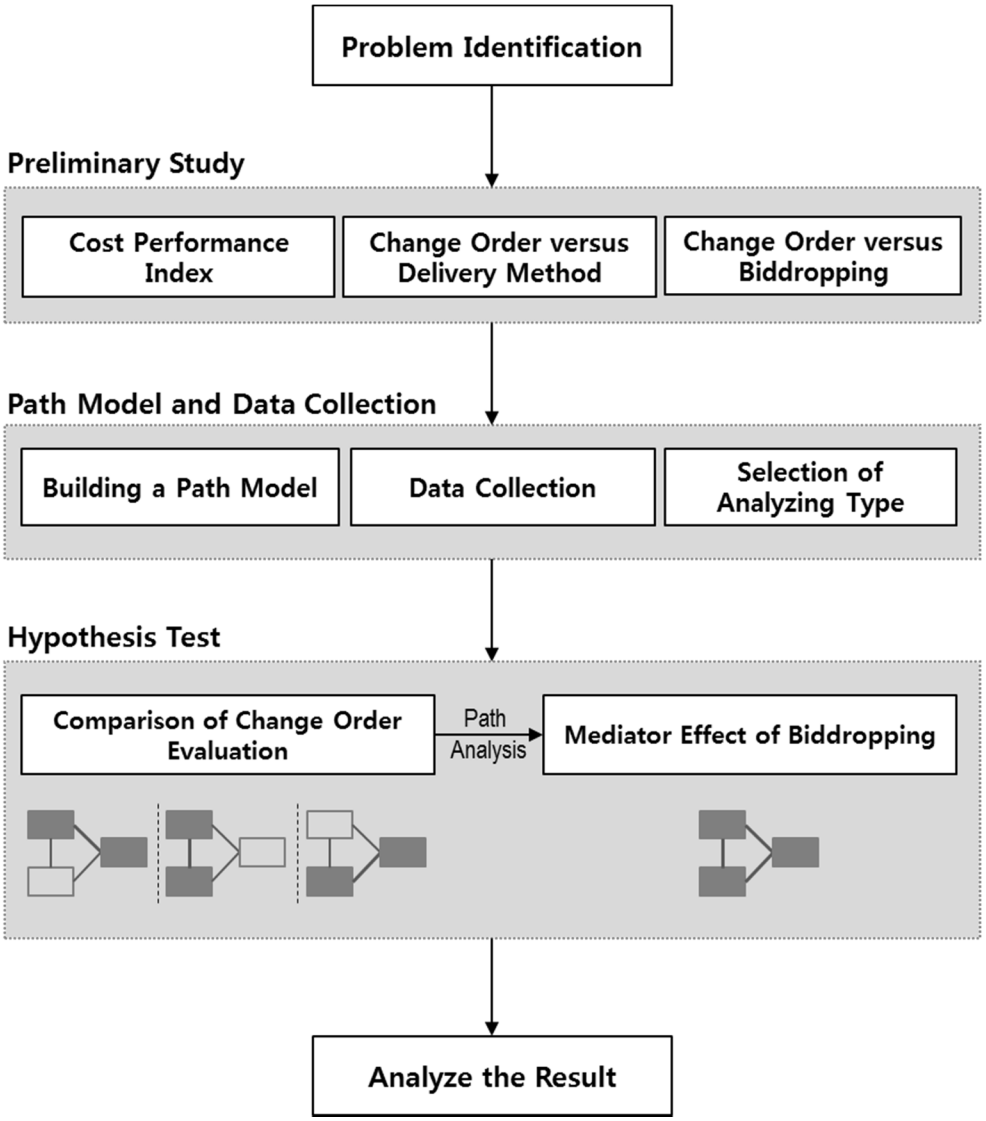


Fig. 1-1 Research Process

Chapter 2. Preliminary Study

This chapter begins by defining delivery method, which is classified into DB and DBB method, and its characteristics for the construction project procurement are compared. Also, cost performance evaluation ways of delivery methods are analyzed from the literature review to extract driving factors that have an effect on cost performance.

Limitations of previous research are discussed focusing on different point of view. To deal with the limitations of past research on methodologies and inconsistency of research conclusions, relationship of extracting factors for research hypothesis are established. And methodologies for this study are introduced.

2.1 Project Delivery Method

Delivery method is defined as the procurement method which includes the project scope, organizational structure, contract and award (Gordon, C. M. 1994). The two prevalent methods among various delivery methods are DB and DBB. In DB is a project delivery method that design and construction services are carried out by a single entity with one contract. DBB is a project delivery method that design and construction services are carried out separately with different companies (Hale D. R. et al. 2009).

The benefits of using DB in a large and complex construction project is that management tasks are minimized and responsibilities for the overall construction are definite in the client's perspective as a single entity carries out both design and construction. Also, the contractor benefits as the economic feasibility of the construction can be actively applied during the design stage allowing the project to be carried out efficiently. However, the drawbacks of DB are the lack of quality, excessive cost spent on bidding, and questionable objectivity during the award selection.

On the other hand, DBB benefits from relatively easy quality management, and definite scope of work for the project as the project is awarded by phase making the project easy to carry out. On the other hand, disputes and conflicts concerning the responsibility of the design and construction occur easily resulting in a slow progress (Fernane, J. D. 2011; Park, M. et al. 2009; Kim, S. G. 2006).

Project characteristics and size should be considered beforehand when selecting a delivery method of a project. Also, performance evaluation, which overlooks cost, time quality and other aspects, should be included in the consideration. Especially for public construction projects where the project must be completed within a budget, cost should be reviewed in depth.

2.2 Cost Performance Evaluation of Delivery Methods

2.2.1 Project Performance Evaluations

In the US, performance evaluation of a delivery method is carried out by NCGs (National Construction Goals) and CII (Construction Industry Institute). In the UK, KPI (Key Performance Indicators) is utilized for performance evaluation and the key performance indicators are cost, time, quality, change order, rework, and safety, etc. However, in Korea, although performance evaluation is to be completed after the construction completion according to the 52nd Article of the Construction and Technology Promotion Law, it is not properly carried out due to the lack of evaluation system or available data (Lee, E. J. 2007). Especially, CII has been developing a project performance database by operating a performance evaluation system called BM&M (Benchmarking & Metrics) since 1996, this database is utilized in many research in order to compare the performance of DB and DBB methods.

In terms of cost, performance evaluation was studied by analyzing either the delivery method and change order (change in contract price) or biddropping and change order. This information is shown in Figure 2-1, which represents how two types of research show different perspectives.

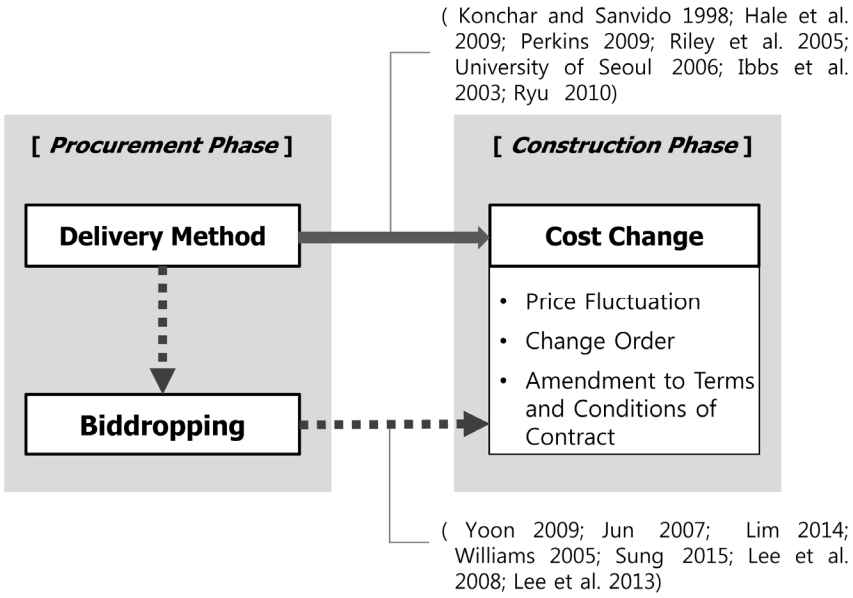


Fig. 2-1 Categorization of Cost Performance Evaluation Methods

2.2.2 Change Order versus Delivery Methods

Majority of the literatures conclude that DB outperforms DBB in terms of cost or time (Konchar, M. and Sanvido, V. 1998; Hale D. R. et al. 2009; Perkins, R. A. 2009; Riley, D. R. et al. 2005; University of Seoul 2006). Specially, Konchar, M. and Sanvido, V.(1998) conducted empirical comparison of nine items such as cost, time, quality and communication speed etc. by 6 facility type. The authors confirmed DB cost change in hi-tech project was lower than other delivery methods. It is meaningful in the way that project type was considered, but the causal factor generates change order by delivery method was not investigated.

By the 1990s, most previous studies concluded that DB outperformed DBB in all aspects. In the 2000s, a few studies have presented different results in terms of cost. Ibbs, C. W. et al. (2003) stated that DB is superior in terms of time but debatable in terms of cost or productivity. According to a report by the US Federal Highway Administration (FHwA), DB outperforms DBB in time but has a larger cost increase (Hale D. R. et al. 2009, re-quote). Also, Ryou, S. S. (2010) concluded that cost increase rate due to change order in a recent turnkey (DB) method is now similar to DBB method.

To sum up, although DB is superior to DBB in terms of time, many researches are pointing out that cost performance between DB and DBB is debatable. Also, these studies have not been tested a causal factor generates change order by delivery method, they just explained qualitative analysis that cost change rate of DB is lower than DBB due to design responsibility.

2.2.3 Change Order versus Biddropping

Biddropping is represented as the ratio between the budget cost calculated by the owner and the awarded cost (contract price) by the bidder. For DB method, biddropping is high due to the risk associated with the design responsibility by the bidder and the weight of the design proposal evaluation other than the bidding price is rather large. On the contrary, as the owner carries out the design for DBB, bidding on construction is based on competitive price resulting in a low biddropping compared to the DB method. Furthermore, if the price competition is high due to a lot of bidders in a lowest price bidding system, there are many cases when it is awarded much lower

than the average. As such, it is assumed that the contractors will induce many change orders to overcome the low-award due to biddropping.

Because biddropping is not directly specified as a cause for change order as stated in the law (Article 19 of Contract Regulation) but rather a hidden agenda by the bidder, it is very difficult to prove the relationship between biddropping and change order. As a result, many research initiated surveys or interviews to prove the relationship between biddropping and change orders. Recently, however, because of quite a number of project database and development of computers, few researches have surfaced proving the relationship between biddropping and change order by analyzing empirical data.

Williams, T. P. (2005) utilized regression model and neural network model to prove that construction cost will most likely to increase when the lowest bid is remarkably lower than other bidding price. Also, Sung, J. Y. (2015) utilized multiple regression analysis to conclude that lower the biddropping is, efforts to raise construction cost through change order will increase. In a research on loss estimation due to change order by Lee, M. J. (2008), 1,433 empirical data was analyzed in an attempt to identify a relationship between biddropping and change order. The research outcome proved no relationship and the statistical experiment was limited as it disregarded the different characteristics of 6 types of projects but rather analyzed the data as a whole.

As a result of the preliminary study, research on cost growth from change order for DB and DBB method, where the lowest value is superior, and

another research on the increase of change order when biddropping is low exist. As the two researches prove inconsistent results, it is necessary to analyze comprehensively.

2.2.4 Comparison of Previous Studies

There coexist two types of studies. One is that method with less change orders is superior, the other is that less biddropping entails more change orders. The former emphasizes that the less change orders the better. The latter admits that a number of change orders are inevitable. Even though these types of research are focused on change orders, they could not compare and analyze relationships between delivery method and biddropping. Because they evaluate change orders with their respective points of view, these differences should be analyzed first, with comprehensive analysis followed on ground of it. With respect to evaluation criteria of change orders in construction phase, literature on delivery method and change orders compares initial contract price of procurement phase with changed final price while literature on biddropping and change orders compares estimated price of planning phase with final price. Figure 2-2 shows the different criteria for change order of previous studies.

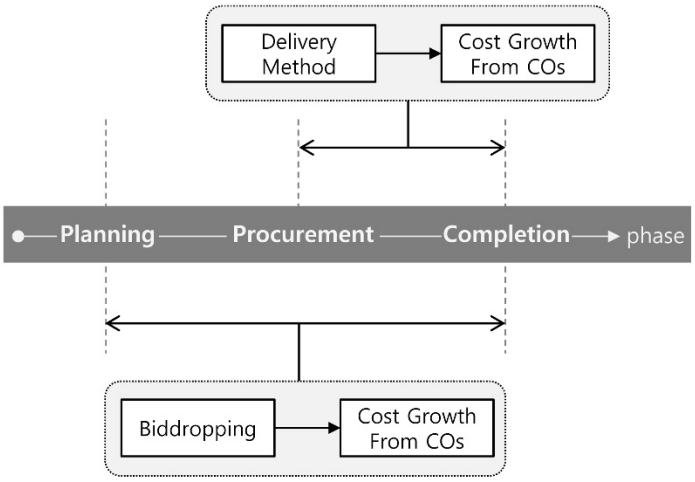


Fig. 2-2 Different Criteria for Change Order (COs)[1] Evaluation

The former concludes that the less ratio of final price to initial contract price, the more superior. The latter draws conclusion that low biddropping leads to cost growth through change orders, reaching near to estimated price. Therefore the former should use the same data in order to understand how it is different to the latter when it employs estimated price as comparison criteria of change orders.

[1] 'Change Order(s)' is usually abbreviated to 'COs' in figures.

2.3 Limitations on Previous Studies and Establishing Research Hypothesis

As previous research methods analyzed only two types of factors which are delivery method and change order, or biddropping and change order, it is difficult to conclude whether delivery method or biddropping has an effect on change order. Also, as there is a relationship between delivery method and biddropping, it is necessary to simultaneously analyze the relationship among delivery method, biddropping and change order.

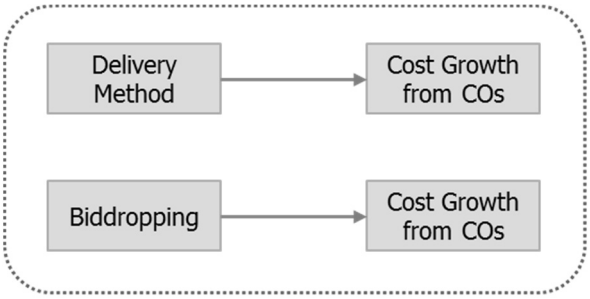


Fig. 2-3 Relationship Analyses of Previous Researches

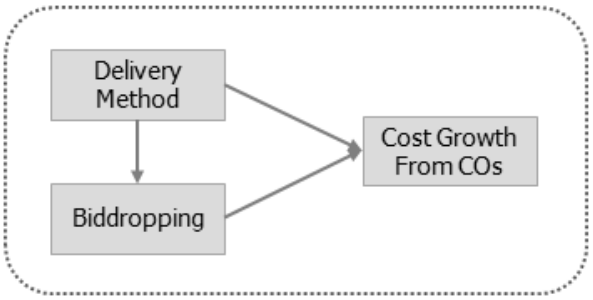


Fig. 2-4 Relationship Analysis for This Study

As a result, the cause for inconsistent results between the two types of researches is found by utilizing empirical data to analyze using the past research method. Then, the process to identify how the delivery method has an effect on biddropping and change order using path analysis method is necessary. To do so, the causal relationship was applied to the time flow where the relationship of delivery method → biddropping → change order was set up for the factors. Then research hypothesis on the mediator effect of biddropping was established and validated.

2.4 Research Methodologies

Statistical analyses by past researches were used to compare the samples and determine if one project delivery method is better than the other. Also they were used to determine if the correlation between biddropping and change order exists, so it leads to a conclusion that DB and DBB are similar in cost growth from change orders. The confidence level selected for analyses were set at 95%, because the statistical analysis done within this range is considered to be acceptable in the construction industry (Hale, D.R. et al. 2009). Independent Samples T Test and correlation analysis were used to compare the two types of past researches. Also, path analysis was conducted to analyze simultaneous relationships between 3 variables (delivery method, biddropping, change order) and validate mediator effect.

Independent Samples T Test

T Test was carried out to determine the difference in means between DB and DBB samples in terms of change order and biddropping. It assumed a null hypothesis that the means of DB and DBB samples were equal. For the null hypothesis is rejected, the p-value must be less than or equal to 0.05. The variable type of delivery methods is discrete, cost change and biddropping are continuous.

Correlation Analysis

To attempt proving the relationship between biddropping and change order, correlation analysis was conducted. It assumed a null hypothesis that the correlation coefficient is zero. For the null hypothesis is rejected, the p-value must be less than or equal to 0.05. Variables' types are both continuous.

Path Analysis

Path analysis which includes multiple regression analysis was used to validate mediator effect of biddropping. It compares the size of direct effect and indirect effect. The direct effect is from delivery method to change order. The indirect effect is from delivery methods to biddropping and biddropping to change order. If the direct effect is small and insignificant while the indirect effect is large and significant, the full mediation of indirect effect is considered to be statistically significant. It means that biddropping intervenes between delivery method and change order.

2.5 Summary

Through the preliminary study on cost performance of delivery methods, past researches were categorized into two types from contents analysis and the different point of view leading to inconsistent results. To deal with the issue, one research method suggested that the cause for inconsistent results between the two types of researches is due to the utilization of empirical data to analyze through past research methods (T-test and correlation analysis). Also there is another issue of biddropping intervening between delivery method and change order. The research hypothesis was established for this issue and is to build a path analysis model in the following chapter.

Chapter 3. Path Model and Data Collection for Cost Performance Comparison

In this chapter, the path model of factors (delivery method, biddropping and change order) that have an effect on the cost performance of a delivery method is suggested. Also, the data within the research scope was gathered and using descriptive statistics, facilities subject for analysis were selected.

3.1 Building a Path Model

3.1.1 A Path Model for Validating a Mediator Effect

A Path Analysis is a method to clarify the relationship between variables which is created by Sewell Wright in 1930's. A causal analysis is executed for path analysis using covariance and correlation coefficient, and it makes easy to distinguish direct, indirect and intent effect which are difficult to be realized from a multiple regression model (Kim, G. S. 2010). Also, a Path Analysis is the member of the Structural Equation Modeling (SEM) family and a path model is a structural model represents hypotheses about effect priority (Kline,R.B. 2011). It allows does not only analyze the effect of the independent and dependent variables but also analyzes the effect between the independent variables. Utilizing this method, the relationship sizes between direct effect and indirect effect are compared. There are two reasons to apply a Path Analysis to this research as following (Figure 3-1):

1) The variable type of delivery method and biddropping are independent variables which relationship is difficult to be analyzed by other methods.

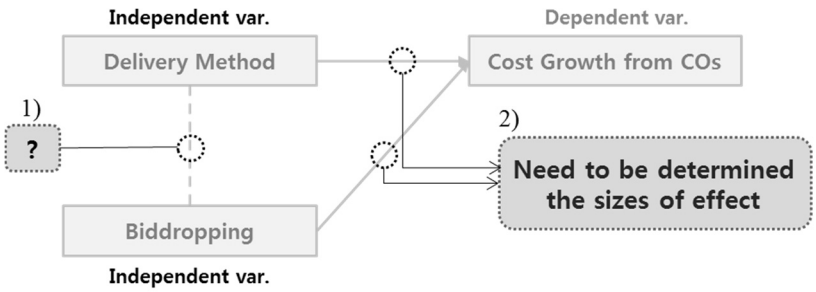


Fig. 3-1 Reasons to Apply a Path Analysis

2) The effect sizes of direct effect from delivery method to change order and indirect effect from biddropping to change order need to be separated and compared.

In align with the research hypothesis mentioned on the previous chapter, variables and their attributes were assigned for subjects as shown in the Table 3-1. In this case, the variable type of biddropping was defined to intervening which was different from preliminary study. Other variables were defined in the same manner as previous research that delivery method was set up as an independent variable, and cost growth form change order was a dependent variable. Such variable types ranged from the procurement to the construction stage depending on time flow, which were then analyzed.

Table 3-1 Variable Definitions

Name	Conceptual Definition	Type of Variables	Type of Scales	
DeliveryMethod	Delivery Method: DB and DBB	Independent	Nominal	Qualitative
Biddropping	Contract cost / Presumed cost (%)	Intervening	Ratio	Quantitative
CostGrowthFromCOs	Percent Growth from Change Orders (%)	Dependent	Ratio	Quantitative

The research model is shown in the following Figure 3-2.

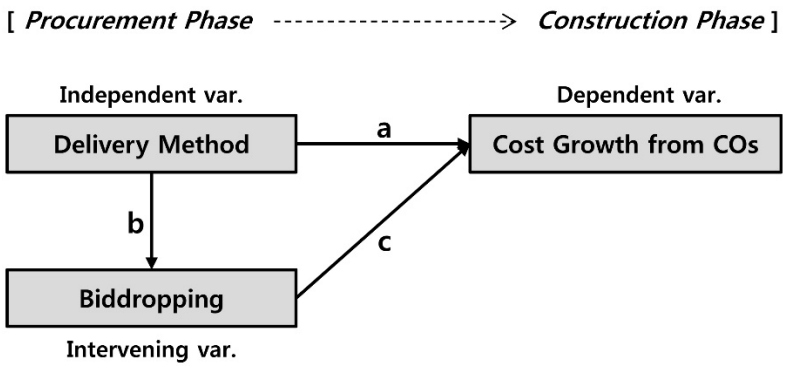


Fig. 3-2 Building a Path Model

The path ‘a’ in Figure 3-2 is a direct effect which shows delivery method effects on variation of change order. The path ‘b → c’ is an indirect effect as a mediator, and it shows that delivery method impacts on change order by mediating of biddropping. There are direct and indirect effect simultaneously between delivery method and change order in this path model, the separation of effect kinds and comparison of effect sizes are needed to be analyzed. Also, depending on the result of path ‘a’, whether ‘b → c’ is a partial mediation or full mediation is determined. The null hypothesis is that there is not a mediator effect between delivery method and change order.

3.1.2 Operational Definitions

To calculate the data, variables can be defined as the following.

Delivery Method

DB = 0 (Turn-key + Alternate)

DBB = 1 (Lowest + Qualification)

Cost Growth from Change Orders(%)

= (change order cost / initial budget) • 100

Change Order Cost(won)

= final cost – initial contract cost – fluctuation price

Biddropping(%)

of DB = (initial contract cost / estimated price) • 100

of DBB = (initial contract cost / projected price) • 100

3.2 Data Collection and Analysis

This research utilized 234 facility samples of large construction projects costing more than 5 billion Won that was awarded by city of Seoul and completed between the dates of Jan 1, 1998 and April 30, 2013.

3.2.1 Delivery Method Categorization and Market Share Analysis

The four types of delivery method acquired in the gathered data were categorized by Turnkey and Alternative as DB, Lowest bidding and Qualification as DBB (Lee, Y. S. 2013). Then, market share analysis according to the contract year is represented in the following Figure 3-3. From 1992, number of DB contracts increased due to governmental policy, and Figure 5 shows how both DB and DBB have similar rise and fall curves.

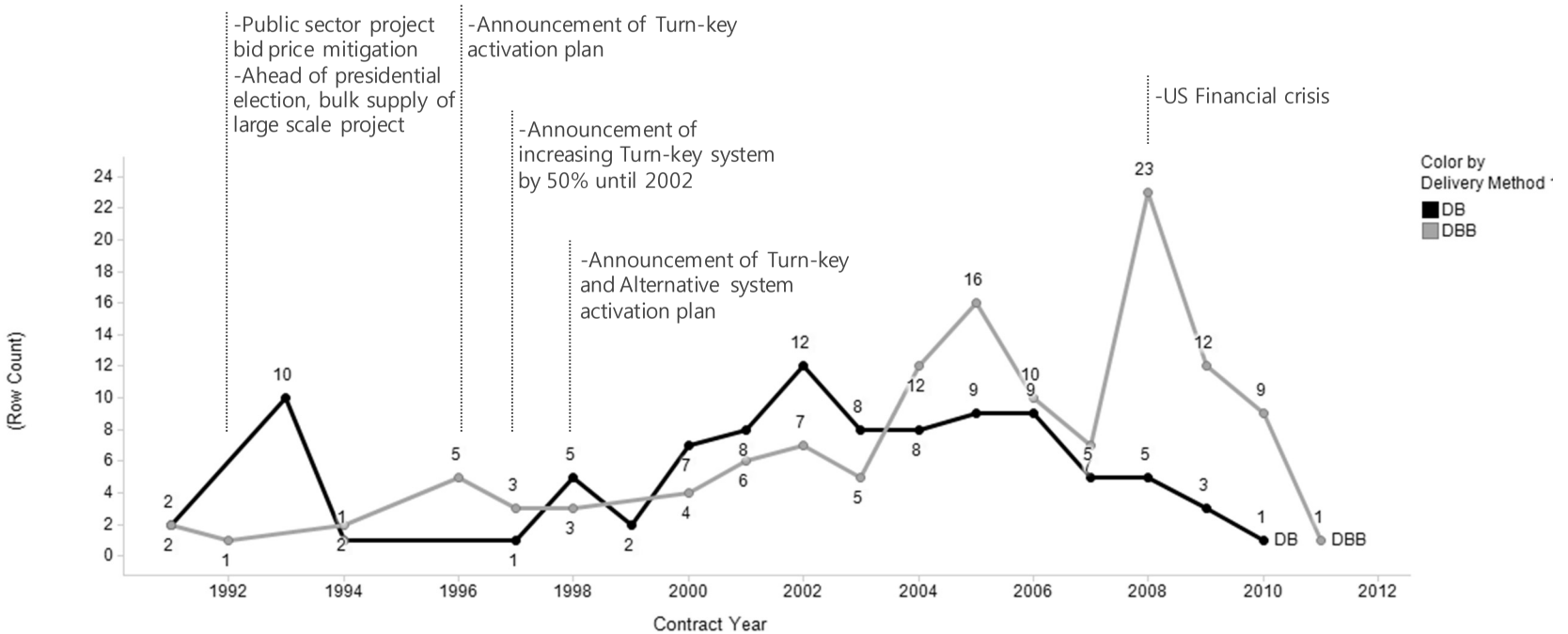


Fig. 3-3 Market Share Analysis of DB and DBB

3.2.2 Analyses of Project Size and Number of Projects

The project size and number according to the delivery method were analyzed as Figure 3-4. DB accounted for 11 trillion Won, DBB accounted for 6 trillion Won. For each project, DB exceeded 100 billion Won, whereas DBB was between 30-70 billion Won. The minimum price was 5.3 billion Won and the maximum was approximately 540 billion Won. The number of projects for DB and DBB were similarly distributed where DB was 97 (41.5%) samples and DBB accounted for 137 (58.5%) samples.

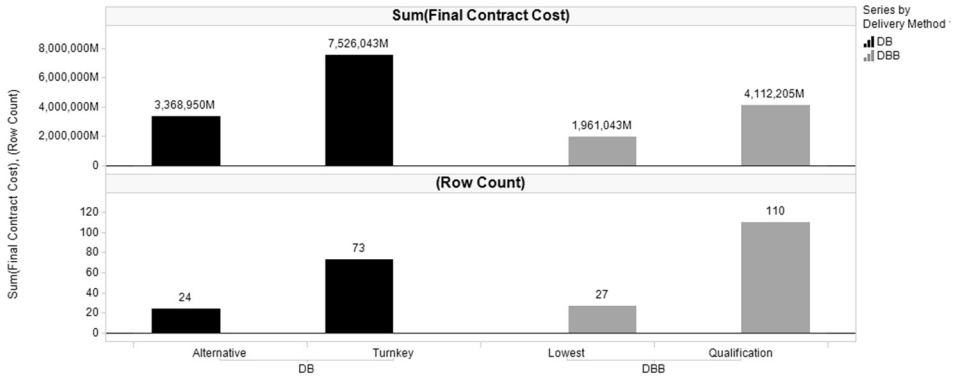


Fig. 3-4 Project Size and Number of Projects

3.2.3 Biddropping and Change Order versus Delivery Methods

In order to compare biddropping due to delivery method and cost growth from change order, factors from the gathered data set were combined and according to the operational definition defined in the previous chapter, the factors were generated. After analyzing the generated factors, DB had a high average for biddropping, and DBB had high average of cost growth from change order, which follows the general trend as mentioned by the previous

chapter. Because this results are attributed only to the action of delivery method, it is necessary to identify and analyze in details whether there are facilities that distort the average due to a block effect. In this case, facility type for a block effect consideration is defined as classification variable.

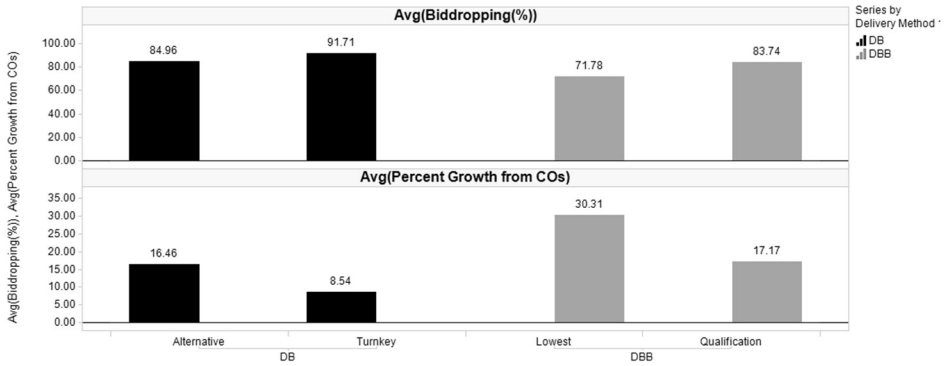


Fig. 3-5 Biddropping and Change Order versus Delivery Methods

By comparing biddropping and rate of change order by project type, it can be seen that DB averages high in all facilities for biddropping as show in Figure 3-6 but Figure 3-7 shows that the distribution for cost growth from change order differes according to the project type. In addition, as project types, such as river work and landscaping, can distort the average, it is necessary to analyze according to the facility rather than the whole.

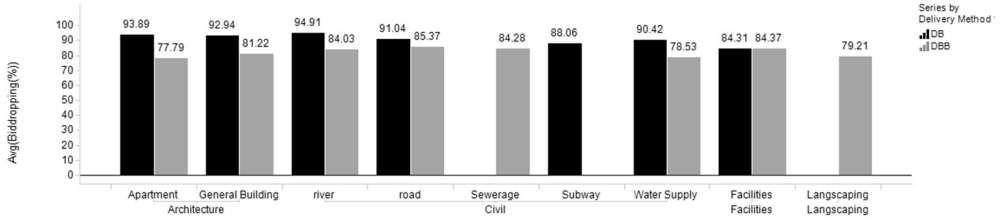


Fig. 3-6 Biddropping versus Delivery Methods by Project Type

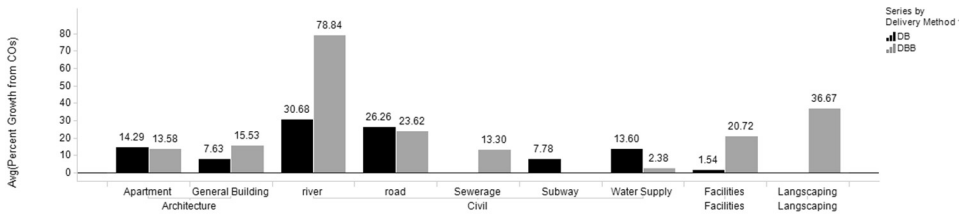


Fig.3-7 Cost Growth from Change Orders versus Delivery Methods by Project Type

3.2.4 Selecting Project Types for Analysis

Apartment, general building, and road were the three facilities selected for analysis as each facility had an even distribution as well as sufficient number of samples for both DB and DBB. As river and water supply facility lacked the number of samples, they were combined as civil work for analysis. As shown in the following Table 3-2, there are a total of 7 types of analysis, which are a combination of architecture, civil, apartment, general building, and road.

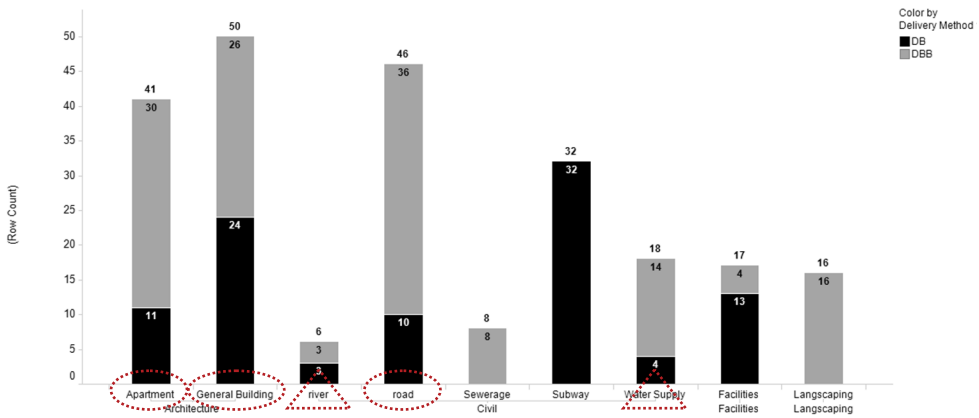


Fig. 3-8 Selection of Project Types

Also, according to a report drafted by Seoul, excessive change orders due to the policy change and social conditions for a total of 3 projects were assumed to be outliers and were eliminated from samples. Therefore, the final number of projects subject for analysis is 157 samples.

Table 3-2 Project Types for Testing

Project Type	Sample Size	Project Type	Sample Size
Architecture, Civil	157	Architecture	90
		Civil (Road, Water Supply, River)	67
Apartment, General Building, Road	134	Apartment	41
		General Building	49
		Road	44

3.3 Summary

To validate research hypothesis, path analysis model was developed first. For the model, variables and their attributes were assigned to the subjects for analysis. Then, the conceptual and operational definitions of the variables were made for both research methods.

Empirical data set of 234 facility samples provided by the city of Seoul was utilized for this research. Project delivery methods of samples were categorized to DB and DBB methods, and 7 project types of 157 samples for hypothesis testing were selected.

Chapter 4. Hypothesis Testing for Cost Performance Comparison and Mediator Effect

In this chapter, the result of the hypothesis validation of 7 types of analysis is suggested. First, the difference between the previous research which compared biddropping based on delivery method and cost growth from change order was analyzed using identical data and the research method suggested in the previous research. Then, utilizing the path analysis model, suggested in this research, hypothesis on the mediator effect of biddropping was validated and a conclusion was derived.

4.1 Testing Results

The following Table 4-1 summarizes the hypothesis validation results of the 7 types of analysis. The result for architecture facility was not consistent with results of previous research method as path analysis method was used for this research. However, a project type which had a meaningful result overall was general building.

To analyze the relationship between delivery method and cost growth from change order in previous research, T-test, and ANOVA's variance analysis or regression analysis were used. Also, correlation and multiple regression analysis were used for biddropping and cost growth from change order. In this research, T-test and correlation analysis were initiated to analyze the difference and relationship of cost growth from change order. In addition, a new analysis method called path analysis model was used to determine the relationship size among the analysis subjects and the mediator effect of biddropping was validated.

Table 4-1 Summary of Testing Results

		Past Researches			This Study
Project Type	Sample Size	**Independent Samples T Test**		**Correlation** (Biddropping– Cost Growth from COs)	**Path Analysis** (Delivery Method - Biddropping– Cost Growth from COs)
		(Delivery Method – Cost Growth from COs)	(Delivery Method – Biddropping)		
Architecture, Civil	157	X	O	X	X
Architecture	90	O	O	O	X
Civil (Road, Water Supply, River)	67	X	O	X	X
Apartment, General Building, Road	134	X	O	X	X
Apartment	41	X	O	X	X
General Building	49	O	O	O	O
Road	44	X	O	X	X

4.2 Comparison of Cost Performance Evaluations

Independent Samples T Test was conducted to determine if the cost growth from change orders(hereinafter referred to as "①") and biddropping (hereinafter referred to as "②") related performance means of the two delivery methods' samples were equal. If the p-value is larger than 0.05, which is typically the standard for determining statistical significance, it cannot be statistically concluded that the samples' means are statistically different (Hale, D. R. et al. 2009). T-test ① and ② are shown in the following Figure 4-1. Also Correlation analysis (hereinafter referred to as "③")was conducted to determine if biddropping and the cost growth from change orders have correlation as shown in Figure 4-1. If the If the p-value is larger than 0.05, which is typically the standard for determining statistical significance, it cannot be statistically concluded that their correlation is statistically significant.

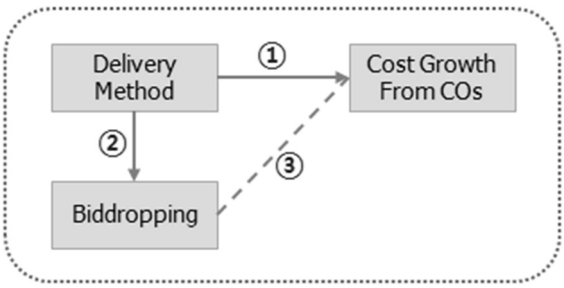


Fig. 4-1 Classification of Hypothesis Testing for Cost Performance Comparison

4.2.1 Mean Difference of Change Order versus Delivery Methods

The hypothesis test for ① was conducted with a 95% confidence interval that means of cost growth from change order due to delivery method are not different. The result of the T-test with a significance level of 0.05 showed statistically significant difference in general building (p value = 0.02 < 0.05). Cost growth from change order means for DB and DBB in general building was respectively 5.07% and 15.53%, and mean difference is 10.46%p. Other facilities but architectural project type did not show any significance. Figure 4-2 shows a box plot of general building, the median is distributed in central position, and the standard deviation (DB=6.99, DBB=13.81) is proper compared with other facilities.

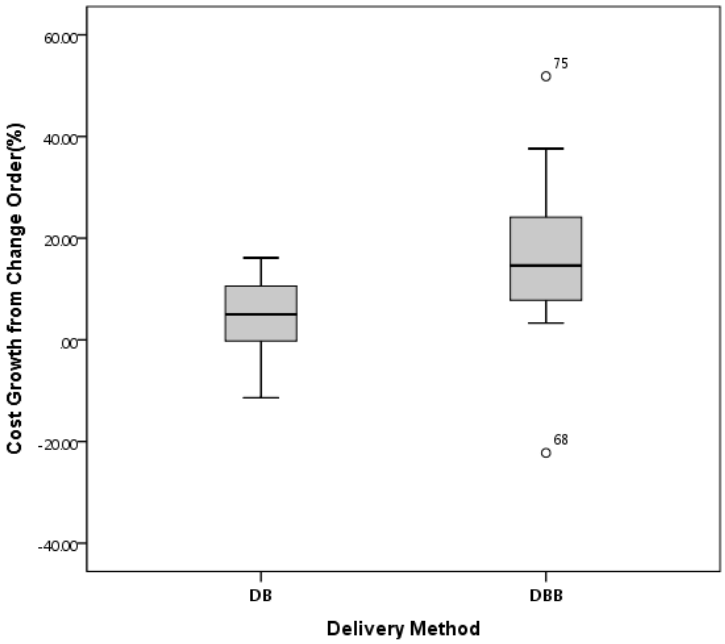


Fig. 4-2 Box Plot of General Building

The significant difference appeared only in the architectural project type and general building, which may be the same context that researchers could not convince of the superiority of the DB delivery method in terms of cost performance depending on the characteristics of each researchers analyzed data as a result of review of the literature.

4.2.2 Mean Difference of Biddropping versus Delivery Methods

All of the biddropping mean differences for the DB and DBB sample projects were statistically significant. The result of ② with a significance level of 0.05, since all the p-values are less than 0.05($p = 0.00 \sim 0.035 < 0.05$) the null hypothesis can be rejected with an almost statistical certainty, which confirm the difference in sample means. The mean of biddropping for DB was large in every category compared to DBB. These results are in agreement with those of previous studies, which can be explained in a qualitative analysis that biddropping of DB is high due to the risk associated with the design responsibility by the bidder and biddropping of DBB is low rather than DB as the owner carries out the design and the bidding is based on competitive price.

In case of general building that demonstrated significant mean difference in previous testing, biddropping mean of DB and DBB was 92.94% and 81.23% respectively, and the mean difference is 11.71%p similar to other cases.

4.2.3 Correlation of Biddropping and Change Order

The result of ③ with a significance level of 0.05, the correlation coefficient of biddropping and change order showed a substantial relevance

(r=0.513) for general buildings as shown in Figure 4-3. Other facilities did not show any relevance. The correlation analysis is for only linear relationship between 2 variables, it doesn't determine causal relationship.

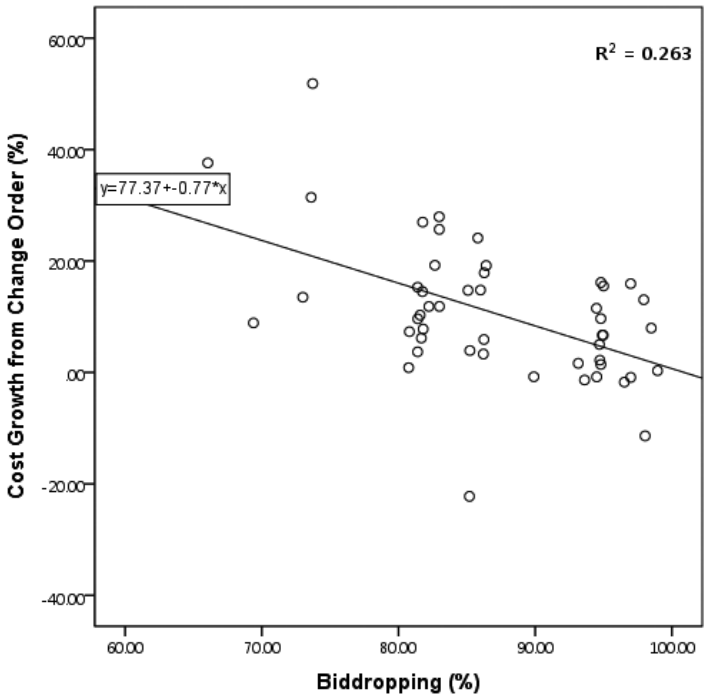


Fig. 4-3 Scatter Plot of General Building

Although previous studies analyze the correlation for Lowest Bidding method low in biddropping, this test was conducted for both DB and DBB methods, which extends the scope of analysis. Also, this study was distinct from Lee, M. J (2007) in that the analyzing according to project types was statistically significant rather than the whole.

4.2.4 Composite of Results (mean difference and correlation)

After comparing the results of the two types of previous research, as shown in the following Figure 4-4, the results in case of general building were not consistent. ① represents the research on the delivery method and cost growth from change order, which proved that DB creates less change orders compared to that of DBB. ②+③ or ③ represents the research on biddropping and cost growth from change order, which resulted in similar cost growth from change order for both DB and DBB.

The reason for inconsistent result of the two types of research was due to the different approach in addressing when in the project stage (budget cost from the planning stage or the contract price in bidding stage) cost growth from change order was focused. As shown in ①, if the cost growth from change order is analyzed using the budget cost during the bidding stage, it is possible to conclude that cost growth from change order for both DB and DBB is similar. However, this analyzes the total effect between the delivery method and cost growth from change order and it is not possible to determine any indirect effects, such as the intervention of biddropping.

As a result, combining research from ①+②+③ and simultaneously analyzing the effect of both delivery method and biddropping on cost growth from change order to determine which factor has a larger effect is necessary.

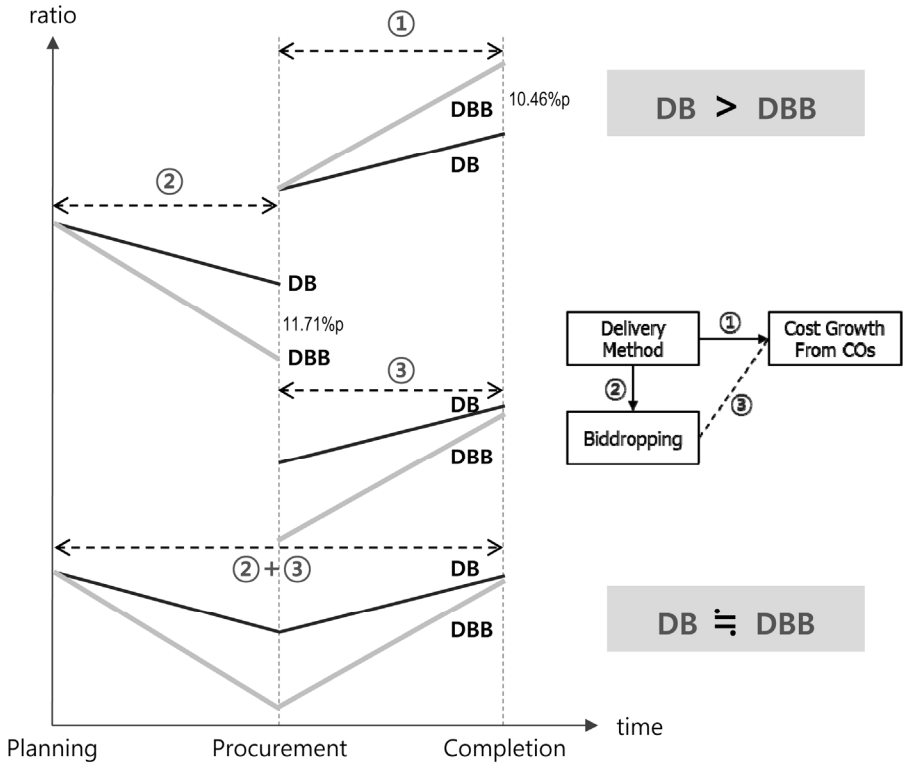


Fig. 4-4 Composite of Testing Results and Analysis

4.3 Testing for Mediator Effect of Biddropping

AMOS (Analysis of Moment Structure, version 20.0, Kline, R. B. 2011) was used to conduct path analysis which is a Microsoft Windows program sold by IBM SPSS, Inc. The name, AMOS is the analysis of mean and covariance structures. Path analysis method does not only analyze the effect of the independent and dependent variables but also analyzes the effect between the independent variables. Utilizing this method, the relationship sizes between direct effect and indirect effect were compared. Hence, the hypothesis of a mediator effect due to biddropping intervenes between delivery method and change order was tested with a significance level of 0.05(α = 5%). The conceptual path model diagram shown as Figure 3-2 was transferred to statistical path model (Figure 4-5) on AMOS. In the following Figure 4-5, path 'a' is a direct effect and path 'b → c' is an indirect effect as a mediator. Depending on the result of path 'a', whether 'b → c' is a partial mediation or full mediation is determined.

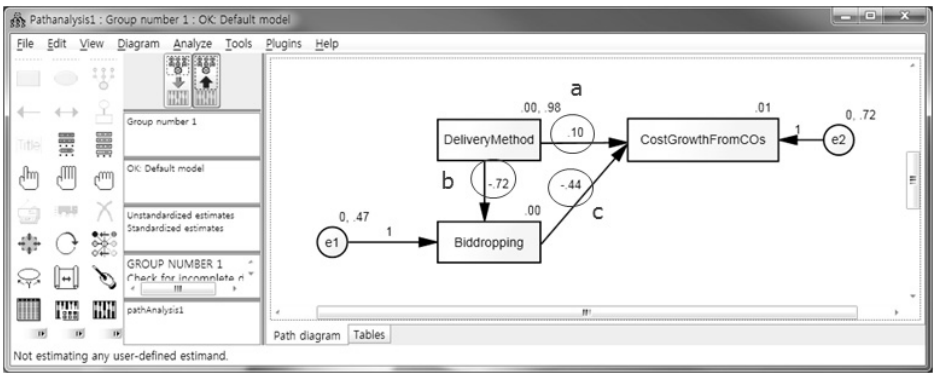


Fig. 4-5 Statistical Path Model and Testing Result of General Building

After conducting path analysis on delivery method, biddropping and change order for 7 project types, only general building among those types had a meaningful result in statistically significance. Each values of path 'a', 'b' and 'c' are called path coefficient (hereinafter referred to as "Estimate") from standardized data, and used to determine their effect sizes. The Estimates of path 'b' and 'c' is 0.720 and 0.441 respectively which is much bigger than the Estimate of path 'a' (0.096) with absolute value comparison as shown in Table 4-2.

Table 4-2 Path Analysis Testing Result of General Building

Regression Weight / Path	Estimate	Standard Error	Critical ratio	p-value	Significant
Delivery Method → Cost Growth from COs (a)	.096	.178	.537	0.591	NO
Delivery Method → Biddropping (b)	-.720	.099	-7.266	0.000	YES
Biddropping → Cost Growth from COs (c)	-.441	.178	-2.479	0.013	YES

Also, since the p value of path 'a' is more than 0.05(p value = 0.591> 0.05), the path 'a' is not statistically significant, so the path 'b → c' can be a full mediation depending on the result of their path significance. Although the p values of path 'b' and 'c' is 0.000 and 0.013(<0.05) respectively and both are statistically significant, the significance of indirect effect (mediator effect) which is made up of path 'b' and 'c' could not tested by AMOS. To deal with

this problem, Sobel Test was conducted through website[2] of Preacher professor (Kim, G. S. 2010). Standard Errors and Estimates of path 'b' and 'c' were used for Sobel Test, Table 4-3 provides the result for significance of the indirect effect by the test. The p value of path 'b → c' (0.019) is less than 0.05 which is the 'α' value of confidence level. As the result, the statistical significance of indirect effect of path 'b → c' was tested, the null hypothesis has been rejected and research hypothesis which biddopping

Table 4-3 Statistical Significance of Mediator Effect by Sobel Test

Parh	Estimate	Standard Error	p-value	Significant
Delivery Method → Biddropping (b)	-.720	.135	.019	YES
Biddropping → Cost Growth from Cos (c)	-.441			

With respect to general buildings of city of Seoul, path 'a', which is direct effect of delivery method on change orders, has small effect size, not being statistically significant. By contrast, paths 'b' and 'c', which are related to delivery method → biddropping → change orders, have great effect size, being statistically significant. Moreover these paths amount to full mediation while path 'a' is not significant as shown in Figure 4-6. Because biddropping has full mediation effect by intervening delivery method and change orders, it

[2] http://quantpsy.org/sobel/sobel.htm

can be interpreted that effort to cover cost loss due to low biddropping would be a good cause for change orders than DB and DBB dropping.

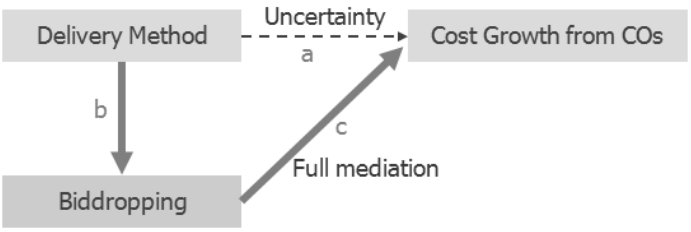


Fig. 4-6 Full Mediation of Biddropping

As previous studies, one of causal factors for frequency of change orders is whether biddropping mediates. If a certain delivery method has few change orders, contrastive one has many change orders through biddropping. Delivery methods have indirect effect on change orders through biddropping, rather than they have direct effect.

Another causal factor for less change orders is laws and decrees concerned. Articles 65, 91 and 108 of ENFORCEMENT DECREE OF THE ACT ON CONTRACTS TO WHICH THE STATE IS A PARTY provide that contract price cannot be adjusted for reasons of omissions or errors because contractors of DB method, who write bill of materials, are responsible for design. A reason why DB method has few change orders is not that design is perfect but that contractors execute change orders on their own, omitting administrative ones. In fact, they are responsible for design errors which account for over 40% of change orders (Jun, H. C. 2007; Ryou, S. S. 2010).

Therefore on the basis of mediator effect of biddropping and laws and decrees concerned, It cannot be argued that one method is superior because number of change orders by delivery methods is small, as previous studies do. On the contrary the mediator effect should be taken into consideration because biddropping affects change orders by characteristics of projects.

Summing up results of analyses, with respect to general building of city of Seoul, superficial number of change orders of DB is small while DBB makes more change orders than DB due to low biddropping, their deviations from estimated price are negligible. As a result, it is demonstrated by mediator effect of biddropping that DB cannot be thought to outperform DBB in terms of cost since it entails less change orders.

4.4 Summary

In this chapter, two research methods were carried out step by step. For the first method, Independent Samples T test and Correlation Analysis were conducted to find out the different point of view of past research on change order evaluation and the comprehensive analysis of cost performance comparison using the methods used by previous studies. From the result of the first method, another method was necessary to compare the relationship size among the analysis subjects. Given that past research methodologies have a limitation on the relationship analysis between independent variables, the new methodology called path analysis was adopted for the second research method. With path analysis model, mediator effect of biddropping between delivery method and change order was validated as a full mediation.

Chapter 5. Conclusions

5.1 Results and Discussion

Based on previous research, it is concluded that the cost of the delivery method for DB outperforms DBB method due to less change orders. Also, there are research that shows DBB has lower biddropping resulting to more change order than that of DB, These two types of research were conducted on different perspectives on the effect of change order during the construction stage, which concluded with inconsistent results. Also, past researches which were conducted to evaluate cost performance of delivery method by measuring change order rate have not investigated the causal factor which generates the value. This study was intended as a comprehensive analysis of different evaluations of change order conducted by past researches and testing a mediator effect of biddropping. The results of this study are the following:

(1) The testing result of a comprehensive analysis of cost performance

Empirical data was collected to analyze the difference of the previous research using the suggested previous research methods. As a result, the reason for inconsistent result of the two types of research was due to the different approach in addressing when in the project stage, so it is possible to conclude that cost growth from change order for both DB and DBB is similar if the same project stage was compared. However, this analyzes the total effect between the delivery method and cost growth from change order and it

is not possible to determine any indirect effects, such as the intervention of biddropping. Consequently, another method called path analysis was needed to compare and test significance the effect sizes on change order.

(2) The testing result of mediator effect of biddropping

The relationship among delivery method, biddropping and change order was investigated utilizing a path analysis, and the mediator effect of biddropping in general building was validated. The results obtained in the testing indicate that less change orders cannot be concluded as being superior as biddropping caused a mediator effect by intervening between the delivery method and change order for specific project types.

So there is need to discuss whether biddropping easy to intervene in any project properties. There is an environment where the biddropping mediator effect will occur depending on the project type. For civil projects, as the materials are simple and mostly predefined, it is difficult to create a change order other than to change the construction method. On the other hand, as architectural projects have more various types of materials involved and large difference in the unit cost compared to civil projects, it is easier to create a change order. Even for apartment of architectural projects, a law prevents change orders when parceling out the units, resulting in the building being built according to the model house; however, it is possible to create change orders for general buildings.

5.2 Contributions

This research proved that previous research that addressed the two factors were comparing the same effect but with different perspectives on the change order resulting in inconsistent conclusions. Also by applying path analysis method, the causal relationship of the factors that have an effect on the cost performance of a delivery method was validated and the existence of a mediator effect was confirmed. In other words, the mechanism that biddropping acts as the causative agent of change order rate due to delivery method was suggested. Therefore, the existence of biddropping was redefined as a mediator, and according to the result, this research is expected to help determine a delivery method by considering the mediator effect of specific projects and evaluate performance.

5.3 Limitations and Further Studies

The limitation of this research is the following. There were difficulties in differentiating the exact type of delivery method used for domestic and international projects. For this research, the delivery method was limited to DB and DBB, as it is widely used globally, to categorize and analyze domestic delivery methods. Performance evaluation of a delivery method should not only consider cost but also time, quality, safety etc. However, this research addressed cost as it was a controversial subject.

Although change order includes improvements, due to lack of data gathered, change order caused by Value Engineering was not considered. Also, it is necessary to compare in terms of LCC, including the maintenance cost for cost performance of a delivery method. LCC cost including maintenance cost is should be considered as less construction cost is not necessarily better

Further Studies will be required that not only cost performance of a delivery method but also project size, time and quality etc. is also needed analysis in various aspects. Next research task would be to identifying other mediator factors that have an effect on performance evaluation other than biddropping and determining which environment is valid for each project type.

Appendices

Appendix A. Descriptive Statistics of Samples

(Section 3.2.3)

Appendix B. Testing Results of Independent Samples T Test

(Section 4.2.1 & 4.2.2)

Appendix C. Testing Results of Correlation Analysis

(Section 4.2.3)

Appendix D. Testing Results of Path Analysis

(Section 4.3)

Appendix A. Descriptive Statistics of Samples (Section 3.2.3)

Project Type	Delivery Method		N	Mean	Standard Deviation	평균의 표준오차
Architecture, Civil	Cost Growth from Change Orders	DB	50	11.74	13.54	1.91
		DBB	107	15.08	17.31	1.67
	Biddropping	DB	50	92.96	6.84	0.97
		DBB	107	81.22	7.19	0.69
Architecture	Cost Growth from Change Orders	DB	34	8.06	9.37	1.61
		DBB	56	14.49	11.28	1.51
	Biddropping	DB	34	93.69	5.64	0.97
		DBB	56	79.39	6.63	0.89
Civil	Cost Growth from Change Orders	DB	16	19.57	17.59	4.40
		DBB	51	15.73	22.24	3.11
	Biddropping	DB	16	91.40	8.88	2.22
		DBB	51	83.24	7.29	1.02
Apartment, General Building, Road	Cost Growth from Change Orders	DB	43	10.25	12.39	1.89
		DBB	91	16.52	17.27	1.81
	Biddropping	DB	43	93.06	6.09	0.93
		DBB	91	81.59	7.38	0.77
Apartment	Cost Growth from Change Orders	DB	11	14.29	10.91	3.29
		DBB	30	13.58	8.67	1.58
	Biddropping	DB	11	93.89	6.77	2.04
		DBB	30	77.79	7.20	1.31
General Building	Cost Growth from Change Orders	DB	23	5.08	6.99	1.46
		DBB	26	15.53	13.81	2.71
	Biddropping	DB	23	93.60	5.19	1.08
		DBB	26	81.22	5.50	1.08
Road	Cost Growth from Change Orders	DB	9	18.53	18.62	6.21
		DBB	35	19.78	23.79	4.02
	Biddropping	DB	9	90.66	7.45	2.48
		DBB	35	85.10	7.23	1.22

Appendix B. Testing Results of Independent Samples T Test (Section 4.2.1 & 4.2.2)

Project Type	Criteria		Levene 의 등분산 검정		평균의 동일성에 대한 t-검정						
			F	유의확률	t	자유도	유의확률 (양쪽)	평균차	차이의 표준오차	차이의 95% 신뢰구간	
										하한	상한
Architecture, Civil	Cost Growth from Change Orders	등분산이 가정됨	.78	.38	-1.20	155	.23	-3.34	2.78	-8.82	2.15
		등분산이 가정되지 않음			-1.31	120.08	.19	-3.34	2.54	-8.37	1.70
	Biddropping	등분산이 가정됨	.05	.82	9.68	155	.00	11.74	1.21	9.34	14.13
		등분산이 가정되지 않음			9.86	100.290	.00	11.74	1.19	9.37	14.10
Architecture	Cost Growth from Change Orders	등분산이 가정됨	.56	.46	-2.79	88	.01	-6.43	2.31	-11.01	-1.84
		등분산이 가정되지 않음			-2.92	79.62	.00	-6.43	2.20	-10.81	-2.04
	Biddropping	등분산이 가정됨	2.61	.11	10.48	88	.00	14.31	1.37	11.59	17.02
		등분산이 가정되지 않음			10.90	78.47	.00	14.31	1.31	11.70	16.92

Project Type	Criteria		Levene 의 등분산 검정		평균의 동일성에 대한 t-검정						
			F	유의확률	t	자유도	유의확률 (양쪽)	평균차	차이의 표준오차	차이의 95% 신뢰구간	
										하한	상한
Civil	Cost Growth from Change Orders	등분산이 가정됨	.07	.79	0.63	65	.53	3.84	6.09	-8.33	16.01
		등분산이 가정되지 않음			0.71	31.45	.48	3.84	5.39	-7.14	14.82
	Biddropping	등분산이 가정됨	1.60	.21	3.71	65	.00	8.16	2.20	3.76	12.56
		등분산이 가정되지 않음			3.34	21.72	.00	8.16	2.44	3.09	13.23
Apartment, General Building, Road	Cost Growth from Change Orders	등분산이 가정됨	1.78	.18	-2.13	132	.03	-6.27	2.94	-12.08	-0.46
		등분산이 가정되지 않음			-2.40	110.88	.02	-6.27	2.62	-11.46	-1.08
	Biddropping	등분산이 가정됨	.28	.60	8.86	132	.00	11.47	1.30	8.91	14.04
		등분산이 가정되지 않음			9.49	98.37	.00	11.47	1.21	9.07	13.87
Apartment	Cost Growth from Change Orders	등분산이 가정됨	.78	.38	0.22	39	.83	0.71	3.28	-5.91	7.34
		등분산이 가정되지 않음			0.20	14.88	.85	0.71	3.65	-7.07	8.50
	Biddropping	등분산이 가정됨	.20	.66	6.44	39	.00	16.10	2.50	11.04	21.15
		등분산이 가정되지 않음			6.63	18.89	.00	16.10	2.43	11.02	21.18

Project Type	Criteria		Levene 의 등분산 검정		평균의 동일성에 대한 t-검정						
			F	유의확률	t	자유도	유의확률 (양쪽)	평균차	차이의 표준오차	차이의 95% 신뢰구간	
										하한	상한
General Building	Cost Growth from Change Orders	등분산이 가정됨	3.44	.07	-3.27	47	.00	-10.45	3.19	-16.88	-4.03
		등분산이 가정되지 않음			-3.40	37.97	.00	-10.45	3.08	-16.68	-4.23
	Biddropping	등분산이 가정됨	.11	.74	8.07	47	.00	12.38	1.53	9.29	15.46
		등분산이 가정되지 않음			8.10	46.79	.00	12.38	1.53	9.30	15.45
Road	Cost Growth from Change Orders	등분산이 가정됨	.09	.76	-0.15	42	.88	-1.25	8.56	-18.52	16.02
		등분산이 가정되지 않음			-0.17	15.49	.87	-1.25	7.39	-16.97	14.47
	Biddropping	등분산이 가정됨	.97	.33	2.04	42	.05	5.56	2.72	0.07	11.04
		등분산이 가정되지 않음			2.01	12.19	.07	5.56	2.77	-0.46	11.58

** Significance Level = 0.05

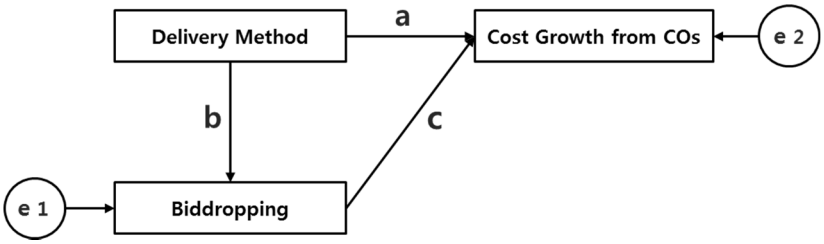
Appendix C. Testing Results of Correlation Analysis (Section 4.2.3)

Project Type	Criteria		Biddropping	Cost Growth from Change Orders
Architecture, Civil	Biddropping	Pearson 상관계수	1	-.050
		유의확률 (양쪽)		.532
		N	157	157
	Cost Growth from Change Orders	Pearson 상관계수	-.050	1
		유의확률 (양쪽)	.532	
		N	157	157
Architecture	Biddropping	Pearson 상관계수	1	-.339**
		유의확률 (양쪽)		.001
		N	90	90
	Cost Growth from Change Orders	Pearson 상관계수	-.339**	1
		유의확률 (양쪽)	.001	
		N	90	90
Civil	Biddropping	Pearson 상관계수	1	.162
		유의확률 (양쪽)		.191
		N	67	67
	Cost Growth from Change Orders	Pearson 상관계수	.162	1
		유의확률 (양쪽)	.191	
		N	67	67
Apartment, General Building, Road	Biddropping	Pearson 상관계수	1	-.098
		유의확률 (양쪽)		.260
		N	134	134
	Cost Growth from Change Orders	Pearson 상관계수	-.098	1
		유의확률 (양쪽)	.260	
		N	134	134
Apartment	Biddropping	Pearson 상관계수	1	-.079
		유의확률 (양쪽)		.623
		N	41	41
	Cost Growth from Change Orders	Pearson 상관계수	-.079	1
		유의확률 (양쪽)	.623	
		N	41	41
General Building	Biddropping	Pearson 상관계수	1	-.513**
		유의확률 (양쪽)		.000
		N	49	49
	Cost Growth from Change Orders	Pearson 상관계수	-.513**	1
		유의확률 (양쪽)	.000	
		N	49	49

Project Type	Criteria		Biddropping	Cost Growth from Change Orders
Road	Biddropping	Pearson 상관계수	1	.128
		유의확률 (양쪽)		.408
		N	44	44
	Cost Growth from Change Orders	Pearson 상관계수	.128	1
		유의확률 (양쪽)	.408	
		N	44	44

**. 상관계수는 0.01 수준(양쪽)에서 유의합니다.

Appendix D. Testing Results of Path Analysis (Section 4.3)



Project Type	Path	Estimate	Standard Error	Critical ratio	p-value	Significant
Architecture, Civil	Delivery Method → Cost Growth from COs (a)	.105	.101	1.036	.300	NO
	Delivery Method → Biddropping (b)	-.614	.063	-9.712	.000	YES
	Biddropping → Cost Growth from COs (c)	.014	.101	.138	.890	NO
Architecture	Delivery Method → Cost Growth from COs (a)	.047	.097	.489	.625	NO
	Delivery Method → Biddropping (b)	-.748	.071	-10.537	.000	YES
	Biddropping → Cost Growth from COs (c)	-.184	.097	-1.904	.057	NO
Civil	Delivery Method → Cost Growth from COs (a)	-.018	.190	-.094	.925	NO
	Delivery Method → Biddropping (b)	-.427	.114	-3.734	.000	YES
	Biddropping → Cost Growth from COs (c)	.217	.185	1.172	.241	NO
Apartment, General Building, Road	Delivery Method → Cost Growth from COs (a)	6.720	3.604	1.864	.062	NO
	Delivery Method → Biddropping (b)	-11.020	1.293	-8.524	.000	YES
	Biddropping → Cost Growth from COs (c)	.039	.193	.203	.839	NO
Apartment	Delivery Method → Cost Growth from COs (a)	-.112	.132	-.844	.399	NO
	Delivery Method → Biddropping (b)	-.842	.129	-6.524	.000	YES
	Biddropping → Cost Growth from COs (c)	-.108	.113	-.958	.338	NO
General Building	Delivery Method → Cost Growth from COs (a)	.096	.178	.537	.591	NO
	Delivery Method → Biddropping (b)	-.720	.099	-7.266	.000	YES
	Biddropping → Cost Growth from COs (c)	-.441	.178	-2.479	.013	YES

Project Type	Path	Estimate	Standard Error	Critical ratio	p-value	Significant
Road	Delivery Method → Cost Growth from COs (a)	.107	.253	.424	.672	NO
	Delivery Method → Biddropping (b)	-.291	.141	-2.068	.039	YES
	Biddropping → Cost Growth from COs (c)	.245	.261	.936	.349	NO

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국 문 초 록

낙찰률 매개효과를 중심으로 한 설계 및 시공 일괄입찰과 분리입찰의 비용성과 실증비교

기존연구에서 설계시공일괄입찰(이하 “일괄입찰”)이 설계시공 분리입찰 (이하 “분리입찰”)보다 비용측면에서 우월하다고 하는 이유는 설계변경이 적기 때문이다. 그러나 만약 분리입찰이 낙찰률이 낮아 이것을 만회하기 위해 설계변경을 발생시켰고, 예정가격 대비 최종 준공금액에 있어서 두 발주방식의 차이가 거의 없다면 일괄입찰이 설계변경이 적기 때문에 우월하다는 것은 잘못된 판단이다. 따라서 이러한 판단의 오류를 확인하기 위해 발주방식과 설계변경, 혹은 낙찰률과 설계변경의 영향관계만 분석하던 두 종류의 연구들을 종합적으로 분석하는 것을 시도했다. 또한 경로분석기법을 통해 프로젝트 타입 별로 발주방식과 낙찰률이 설계변경에 미치는 효과크기를 동시에 비교함으로써 낙찰률의 매개효과를 검증하였다. 그 결과 특정 프로젝트 타입에서는 발주방식과 설계변경 사이에 낙찰률이 개입하여 매개효과를 발생시키고 있으므로, 일괄입찰이 분리입찰보다 설계변경이 적기 때문에 우월하다고 판단할 수 없음을 검증하였다. 이로써 발주방식이 낙찰률을 통해 설계변경에

작용하는 원리를 밝히고, 낙찰률의 정체성을 기존 연구와는 다른 관점에서 규명하였다. 이로써 프로젝트 특성 별로 비용성과를 저해할 수도 있는 매개효과를 고려하여 발주방식에 따른 비용성과 측정과 발주방식의 선정 시 의사결정에 도움을 줄 수 있을 것이라고 기대한다.

주요어: 낙찰률의 매개효과, 발주방식, 설계 · 시공 일괄입찰, 설계 · 시공 분리입찰, 비용성과, 설계변경

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