Identifying Moderation Effect between Project Delivery Systems and Cost Performance

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Abstract –

This study was performed to identify the theoretical attribution of project type that moderates the impact of project delivery systems on cost performance. Previous studies have used direct relationship analysis to evaluate the project performance (e.g., the relationship between PDS and its cost performance, or the relationship between project type and cost performance). These analyses can cause inconsistent results and need to be analyzed in a single model. To combine the relationships between influential factors on cost performance, a causal model (i.e., moderation model) was suggested. The objective of this study is to develop a moderation model and test the statistical significance of moderation effect between PDS and cost performance. As a preliminary study, we established a simple moderation model and examine the moderation effect of project type. To test the model, 134 public sector projects completed between 1998 and 2013 in South Korea were utilized. The dataset consists of both Design-Build and Design-Bid-Build projects which are the most prevalent delivery systems. Even though the preliminary test results were not statistically significant, we can suggest the better way to understand the causal relationship moderated by project type between PDSs and their cost performance. This study is expected to provide the theoretical basis of the mechanism by which PDS impact cost performance, help project participants to select PDS by considering moderating effects in specific project types, and evaluate PDS appropriately in terms of cost performance.

Keywords –

Cost management; Project delivery system; Design-build(DB); Design-bid-build(DBB); Cost performance; Change order; Project type; Moderation effect

1 Introduction

Evaluating project delivery system (PDS) in terms of cost performance has been conducted by comparing two prevalent methods: design–build (DB) and design–bid–build (DBB) [1-5]. Until the end of 1990s, most studies had concluded that DB outperforms the traditional DBB delivery systems in all aspects (e.g., cost, time, quality, safety and so on) [1-3]. However, adverse results have emerged in terms of cost performance since the early part of 2000s [4-7]. They found that DB is superior to DBB in terms of project schedule, however, cost performance is uncertain and debatable up to date. According to the previous studies, the reason why the comparison results are inconsistent depends on project type and dataset [7-8]. The explanation about the inconsistent results have been arbitrary without any theoretical basis.

To deal with this problem, causal model that explains the mechanism by which PDS cost effects operate should be needed. In research design, mediators and moderators are necessary to solve complex and unsettled problems in theory development [9]. Identifying and quantifying the mediators and moderators are useful in making contributions to the body of knowledge and both variables are the focus of research design in many situations [10]. Moderation is a causal model that postulates “when” or “for whom” an independent variable most strongly (or weakly) causes a dependent variable, while mediation is explains the process of “why” and “how” a cause-and-effect happens [10-12].

For the first step applying these theoretical basis, we [13] identified and quantified a mediation effect between project delivery systems and cost performance through bidding characteristics (e.g., bid price, the number of bidders). The study suggests that the previous studies of evaluating PDS cost performance could be improved when the bidding characteristics are considered. As a second phase, we explored a moderation effect that affect the causal relationship

between PDSs and their cost performance.

The objective of this study is to develop a moderation model and test the statistical significance of moderation effect. As a preliminary study, we developed a simple moderation model and the test of the significance. The goal of this study is to identify the theoretical attribution of project type that moderates the impact of project delivery systems on cost performance. We use the same dataset as in the previous study [13], also the same cost performance metric (i.e., change order rate) is used. With the results, the current study can provide the theoretical basis on the reason why the cost performance comparison of PDSs is inconsistent.

2 Related Work

This section describes literature reviews related with the moderation effect and the influence of project type on the causal relationship between PDSs and their cost performance. Moderators is defined as a third variable that modifies a causal effect, an association between two variables X and Y is said to be moderated when its size or sign depends on a third variable of set of variables [14-15]. Moderation is also known as interaction. Moderation analysis is typically examined by testing for interaction between moderator and X in a model of Y [15]. In construction management discipline, studies on moderation effects have been rarely conducted [9, 16-17].

Yang et al [17] tested the moderating effect of project type by conducting a two-way ANOVA when examining the relationship between knowledge management and project performance. A number of studies indicate that project type affects cost performance [2, 7, 8, 18-21]. We assume that PDS cost performance varies depending on the project type.

3 Preliminary Moderation Model

As a preliminary model, we postulated a simple moderation model

Models were categorized to conceptual and statistical diagram. Conceptually, the moderation model is depicted in the form of a conceptual diagram in Figure 1. The diagram represents a process in which the effect of PDS on change orders is influenced or dependent on project type, as reflected by the arrow pointing from project type to the line from PDS to change order.

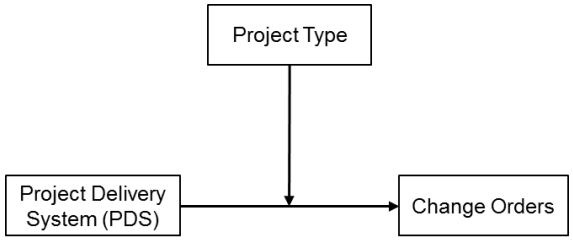

Figure 1. Moderation Model as a Conceptual Diagram

The conceptual diagram is very different in form from its corresponding statistical diagram, which represents how such a model is set up in the form of an equation. As is described in figure 2, the statistical diagram corresponding to this conceptual model requires not two but three antecedent variables, and project type is one of those antecedent.

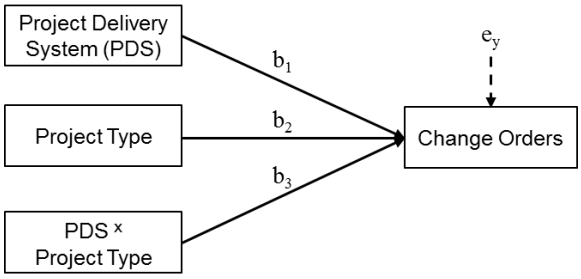

Figure 2. Moderation Model as a Statistical Diagram

Statistically, moderation effect is conducted by testing for interaction between project type(M) and PDS(X) in a model of change orders(Y). With evidence that X's effect on Y is moderated by M, we then quantify and describe the contingent nature of the association or effect by estimating X's effect on Y at various values of the moderator, an exercise known as probing an interaction. Equation (1) shows the standard multiple linear regression model. " b_3 " represents interaction role between PDS and project type.

$$Y = b_{01} + b_1\mathrm{X} + b_2\mathrm{M} + b_3\mathrm{XM} + e_\mathrm{y} \quad (1)$$

The moderation effect is interpreted depending on both the statistical significance and the sign of b_3[22]. If the model result of b_3 is statistically significant. The association between PDS and change orders is various depending on project type (i.e., moderator).

4 Experiment and Results

The developed moderation model is being applied to the construction project of 134 samples from the same dataset of the previous work. Samples are categorized to three project types (i.e., residential building, non-residential building, and road civil work) where the sample sizes are evenly distributed. Table 1 shows the descriptive statistics of change orders according to project types. To examine the effect of moderator, two-way ANOVA was conducted. The results is shown in Table 2.

Table 1. Descriptive statistics of project types

Dependent var.	Project type (M)	N	Mean	S.E.
Change order rate (Y)	Building(residential)	41	13.936	2.753
	Building(non-residential)	49	10.304	2.236
	Civil(road)	44	19.151	2.919

Table 2. Results of two-way ANOVA

Variable	Sum of Squares	df	Mean Square	F	p
PDS (X)	349.185	1	349.185	1.431	.234
Project type (M)	1415.473	2	707.736	2.901	.059
PDS*Project type (XM)	725.054	2	362.527	1.486	.230
Error	31231.363	128	243.995		

According to the test results, the interaction effect (XM) of PDS and project type is not significant (p value > 0.05). Figure 3 shows the moderation effect (i.e., interaction effect) of PDS and project type on change orders.

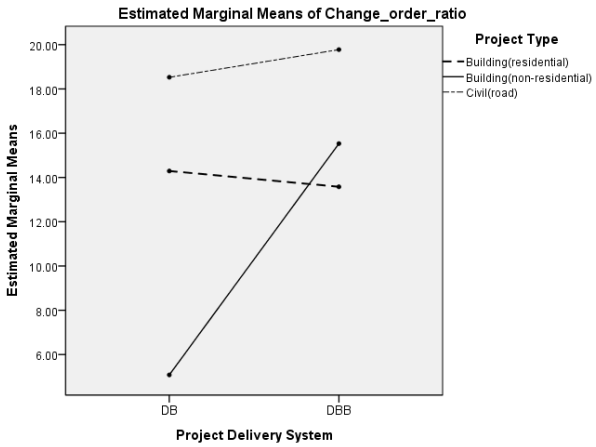

Figure 3. Moderation effect of PDS and project type on change orders

The slopes of non-residential building and civil projects intersect each other in a cross, then the main effect of PDS appears wherever it is, and wherever it is

reversed. That is, the main effect of the independent variable (i.e., PDS) does not consistently appear, and other results appear depending on mutual combinations with other variables. In this case, the model results show the dis-ordinal interaction.

5 Conclusions

A simple moderation model as a preliminary study was proposed to examine that project type moderates the impact of PDSs on their cost performance. This study is expected to provide a better understanding of the mechanism by which PDS impact cost performance, help project participants to select PDS by considering moderating effects in specific project types, and evaluate PDS appropriately in terms of cost performance. The academic contribution of the current study is to theoretically identify project type as a moderator using empirical data.

Regarding the limitations of this study, partial projects were selected from the original database, various combinations of project type should be applied to validate the moderation model. Also, value engineering costs for improvement were not considered because of data limitations.

For the further studies, conditional process model that integrates mediating effect and moderating effect in a single model could be developed. That is, moderated mediation and mediated moderation model considering project characteristics and bidding characteristics simultaneously need to be applied. Those models are to be expected to enhance the explanation the inconsistent evaluating results of PDS performance comparison.

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References

[1] Bennett, J., Pothecary, E., and Robinson, G. Designing and building a world-class industry: The University of Reading design and build forum report. Centre for Strategic Studies in Construction, Univ. of Reading, UK., Rep. No. ISBN 0704911701, 1996.

[2] Konchar, M. and Sanvido, V. Comparison of U.S.Project Delivery Systems. J. Constr. Eng. Manage., 124:435-444, 1998.

[3] Molenaar, K., Songer, A., and Barash, M. Public-sector design/build evolution and performance. J. Manage. Eng., 15(2), 54–62. 1999.

[4] Ibbs, C. W., Kwak, Y., Ng, T. and Odabase, A. M. Project Delivery Systems and Project Change: Quantitative Analysis. J. Constr. Eng. Manage., 129:382-387, 2003.

[5] Minchin, R. E., Li, X., Issa, R. R., and Vargas, G. G. Comparison of Cost and Time Performance of Design-Build and Design-Bid-Build Delivery Systems in Florida. J. Constr. Eng. Manage., 139(10), 04013007. 2013

[6] FHwA (U.S. Department of Transportation, Federal Highway Administration). Design-build effectiveness study. 2006. Online: http://www.fhwa.dot.gov/reports/designbuild/designbuild.pdf, Accessed: 22/06/2016

[7] Chen, Q., Jin, Z., Xia, B., Wu, P., and Skitmore, M. Time and Cost Performance of Design-Build Projects. J. Constr. Eng. Manage., 142(2):04015074, 2016.

[8] Asmar, M. E., Hanna, A. S., and Loh, W. Quantifying performance for the integrated project delivery system as compared to established delivery systems. J. Constr. Eng. Manage., DOI: 10.1061/(ASCE)CO.1943-7862.0000744, 04013012-1-13, 2016.

[9] Xiong, B., Skitmore, M. and Xia, B. A critical review of structural modeling applications in construction research, J. Automat. Constr., 49 (2015) 59–70, 2015.

[10] Baron, R.M. and Kenny, D.A. The moderator–mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations, J. Pers. Soc. Psychol. 51 (6): 1173-1182, 1986.

[11] Kraemer, H. C., Wilson, G T., Fairburn, C. G. and Agras, W. S. Mediators and moderators of treatment effects in randomized clinical trials. Archives of General Psychiatry, 59, 877–883, 2002.

[12] Frazier, P. A., Tix, A. P. and Baron, K. E. Testing moderator and mediator effects in counselling psychology. Journal of Counselling Psychology, 51, 115–134, 2004.

[13] Moon, H., Kim, K., Williams, T. P., Lee, H., Park, M., Son, B. and Chun, J. Modeling of identifying mediator effects between project delivery systems and cost performance. In Proceedings of the 35th ISARC, pages 578-585, Berlin, Germany, 2018.

[14] Wu, A. D. and Zumbo, B. D. Understanding and Using Mediators and Moderators. Social Indicators Research, 87, 367-392, 2008.

[15] Heyes, A. F. Introduction to mediation, moderation, and conditional process analysis: a regression-based approach, Guilford Press, New York, 2013.

[16] Aibinu, A. A. and Al-Lawati, A. M. Using PLS-SEM technique to model construction organizations' willingness to participate in e-bidding, J. Automat. Constr., 19(2010), 714-724, 2010.
[17] Yang, L., Chen, J. and Wang, H., Assessing impacts of information technology on project success through knowledge management practice, doi:10.1016/j.autcon.2011.06.016, J. Automat. Constr., 22 (2012) 182–191, 2012.
[18] Jahren, C. T., and Ashe, A. M. Predictors of cost overrun rates. J. Constr. Eng. Manage., 116(3):548-552, 1990.
[19] Gkritza, K., and Labi, S. Estimating cost discrepancies in highway contracts: multistep econometric approach. J. Constr. Eng. Manage., 134(12): 953-962, 2008.
[20] Love, P. E. D. Influence of Project Type and Procurement Method on Rework Costs in Building Construction Projects. J. Constr. Eng. Manage., 128(1):18-29, 2002.
[21] Liu, B., Huo, T., Liang, Y., Sun, Y., and Hu, X. Key Factors of Project Characteristics Affecting Project Delivery System Decision Making in the Chinese Construction Industry: Case Study Using Chinese Data Based on Rough Set Theory. J. Prof. Issues Eng. Educ. Pract., 05016003, 2016.
[22] Cohen, J., Cohen, P., West, S. and Aiken, L. S. Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences. Lawrence Erlbaum Associates, Inc., New Jersey, 2002.