ANALYZING CAUSES OF CHANGE ORDERS IN KOREA ROAD PROJECTS

Kang-Wook Lee[1], Wooyong Jung[2], Seung Heon Han[3] and Byeong-Heon Yoon[4]

[1] Combined Master's and Doctoral Program Student, Yonsei University, Seoul, Korea
[2] Ph.D. Candidate Yonsei University, Seoul, Korea
[3] Associated Professor, Yonsei University, Seoul, Korea
[4] Assistant director, Ministry of Land, Transport and Maritime Affairs, Gwacheon-si, Korea

Correspond to celebrity3@yonsei.ac.kr

ABSTRACT: The Korean government implemented 259 road projects from 2004 to 2007, valued at $18.4 billion. Change orders of these road projects occurred 8,973 times and, subsequently, caused significant increases in the cost of the projects, approximately up to $4.2 billion (22.8% of the initial budget). These significant problems of huge change orders require a more workable control system for budget management whereas the effectiveness of the government's control is still not satisfied. However, previous approaches and studies mostly limited their analyses to simply classifying the causes of the change orders. This paper investigates the real frequency and cost impacts incurred by each cause of a change order, primarily based on 218 road projects in Korea. The paper then identifies the attributes of change orders through a survey of 204 project participants in that those sources were inevitable or avoided if properly managed. The causes of the change orders are further analyzed with analysis of variance (ANOVA) in connection with contract volume, bid award rate, the contractor's capacity to perform, and the design company's capacity. This study found that if the contract volume is smaller, then the possibility of change orders is higher. Interestingly, if the bid award rate is less than 67.5%, it signifies the highest rate of change orders. In addition, the contractors whose construction ability is assessed as the top-ranked group showed the lowest change order rates. With these results, this paper provides the preventive guidelines for reducing the likelihood of change orders.

Keywords: Causes, Road Projects, Change Orders

1. INTRODUCTION

Change orders are, to large extent, inevitable in most construction projects due to the uniqueness of each project, unexpected conditions, and the limited resources of time and money associated with planning, executing, and delivering the project [8]. Nevertheless, since change orders are among the largest source of cost overruns [13], this necessitates an effort to reduce the frequencies of change orders. For example, construction change orders in the United States are estimated to range from $13 to 26 billion per every year [8]. In the case of Korea, change orders of public road projects are summed up to $4.2 billion from 2004 to 2007, which is estimated to be 22.82% of the initial budgets. This huge increase requires investigating the root causes of cost increases so as to minimize the possibilities of unnecessary or avoidable change orders.

A number of research papers, however, highlight the impact of change orders [4], [5], [6], [7], [8], [10], [12], [13], [14], rather than focus on the causes of the change orders. Developed countries typically assume change orders are natural or unavoidable during the construction phase. But this is not the case in developing or less developed countries where many parts of change orders have occurred due to incorrectly designed processes, poor design quality and error, opportunism, poor control system, and a lack of coordination, just name a few.

This paper investigates the causes, frequencies, and cost increases by change orders for 218 road projects completed from 2004 to 2007 in Korea. The paper then divides the causes of change orders into three groups and describes the risk attributes of change orders through a survey of 204 project participants. In addition, this study analyzes the detailed causes in connection with contract volume, bid award rate, contactor's capacity to perform, and design company's capacity by analysis of variance (ANOVA).

2. LITERATURE REVIEW

There are three streams of research about change orders. One analyzes the impact of change orders, and another deals with the legal aspects and disputes regarding change orders. The third category explores the causes of change orders. The previous studies mostly focused on the first subject. For example, Hanna analyzed and suggested various methods for estimating the impact of change orders not only on large projects but also on small and medium projects [4], [5], [6], [7], [8]. In addition, Stock introduced the 'functional analysis concept design (FACD)', which was applied to United States Navy projects and was estimated to reduce the number of change orders [14]. Lee suggested decision tree approaches to classify and quantify the impact of change orders occurred by loss of productivity [10], and Moselhi evaluated the impact of change orders on labor productivity. In the second stream, Thomas studied legal aspects of orally committed change orders [15], and Hanna suggested contractor strategies and owner strategies from the legal views when change order risk occurs [9]. Finally, some studies deal with the causes of change orders. However, most of them simply classified the type of causes and studied the causes of change orders in less detail. Riley divided 598 change orders in 120 construction projects into owner-directed causes and unforeseen causes [13]. He also suggested that the design-build delivery system created fewer change orders than the design-bid-build (DBB) delivery system. Gunhan investigated 6,585 change orders in a school project and categorized five causes such as owner-directed changes, code compliance issues, error/omissions, discovered or changed conditions, and others [3]. This study also suggested that, if preventive measures such as choosing the right CM firm are taken, the number of change orders could be reduced.

Although the abovementioned studies have all been contributory to understanding the causes of change orders and providing suggestions that can reduce the number of change orders, there exits several limitations; (1) those studies divided the causes of change orders into just a few categories such that they have lacked a practical usage in a meaningful way, and (2) the previous studies mainly considered the sources of responsibility who induced the change orders. On the other hand, in reality, the causes of change order can be varied depending on other diversified viewpoints such as size of a project, level of bid award rate and participants' capability. Given the lack of previous approach, this study investigates the causes of change orders by further detailed categorizations and also shows statistic significance in analyzing the causes of change orders in relation to such factors as contract volume, bid award rate, the contractor's capacity to perform, and the design company's capacity.

3. DATA COLLECTION AND SURVEY

3.1 Data Collection

This study investigated 218 road projects among the total of 259 that were implemented in Korea from 2004 to 2007. This study targeted only national highway projects. All 218 projects were delivered by the DBB (Design-Bid-Build) system and procured by the lowest bidder basis. The total cost of the road projects was $14.7 billion, and the total cost increase of the change orders was estimated at $3.3 billion (22.4% of the initial budgets).

3.2 Survey

A survey was additionally conducted to evaluate each cause of change orders in that those sources were inevitable or can be fully or partly avoided if those causes were suitably controlled by the project teams. The respondents included road project participants such as owners, design companies, contractors, and supervisors. A total of 230 questionnaires were distributed, and 88.7% (204) were returned. Table 1 shows the affiliations of the respondents and their mean experiences.

Table 1. Classification of Respondents

Affiliate	# Respondents	Experiences (Year)
Owner	48	16.3
Design company	35	11.2
Contractor	71	14.2
Supervisor	50	21.2
Total	204	15.9

4. CLASSIFICATION OF CAUSES OF CHANGE ORDERS

4.1 Causes of Change Order by Responsibility

This study divides the causes of change orders in reference to responsibility such as owner, design company, contractor, and other third parties. These classification criteria are similar to Wu's work [16]. Change orders directed by owners have occurred most frequently and accounted for approximately 30% of the total cost impacts of change orders. Whereas those incurred by contractors have occurred least frequently and had a tendency to reduce the total project costs by decreasing the wastes such as soil disposal and change in hauling distance of soil or other materials.

Table 2. Frequency and Cost Increase by Responsibility

Category	Responsibility	Freq.	Cost ($1,000)
Internal Party	Owner	3,327	999,302
	Design firm	2,259	236,815
	Contractor	1,014	-29,555
External Party	Third party	2,373	2,125,409

4.2 Detailed Causes of Change Orders

The causes of 8,973 change orders occurred in 218 road projects were classified into 31 factors. This paper analyzed the frequency and cost impact of each factor as shown in Table 3. Escalation, additional provisions of temporary structures and traffic safety facilities, operation and maintenance cost for existing structures, owner's requirements, and differences between designer's specifications and site conditions were investigated as the main causes of change orders that increased construction costs. In several cases, it was found that change orders decreased the cost; for example, changes in the hauling distance of construction materials rather saved the construction costs as a whole.

Table 3. Classification of Detailed Sources of Change Orders

Factor Affecting Change Orders	Freq.	Cost ($1,000)	Responsibility	Attributes
Escalation	744	1,577,461	External	Inevitable
Additional provisions of temporary structures and traffic safety facilities	1,175	413,532	Owner	Avoidable
Operation and maintenance cost for existing structures	478	218,964	Owner	Avoidable
Owner's requirement	917	197,254	Owner	Reducible
Differences between designer's specification and site conditions	1,384	195,990	Design	Inevitable
Other miscellaneous causes	286	152,541	External	Reducible
Public resistance	356	149,641	External	Avoidable
Workability problem	412	113,941	External	Inevitable
Safety inspection agency's requirement and environmental impact assessment	308	83,858	Owner	Inevitable
Application for retirement fund, insurance bill, and additional tax	244	50,035	External	Avoidable
Change in cost schedule due to insufficient budget	32	38,560	Owner	Avoidable
Local governments or other related organization's requirement	83	27,136	External	Inevitable
Supplement for gardening trees	106	23,888	Owner	Avoidable
Reworks due to defect or mistakes from inspection	311	23,246	Owner	Reducible
Institution and revision of related regulations	130	18,682	External	Inevitable
Preliminary construction	25	17,507	Contractor	Avoidable
Advisory and service cost	19	16,753	Design	Avoidable
Disposal or recycle cost of construction wastes	145	15,976	Contractor	Avoidable
Protection and excavation of cultural properties	14	15,780	External	Inevitable
Review of architect's specification and redesign	124	14,864	Design	Avoidable
Errors in designers' specification	702	13,459	Design	Avoidable
Inevitable accidents	24	10,437	External	Inevitable
Demolition	56	5,225	External	Inevitable
Change in methods of construction	250	4,974	Contractor	Avoidable
Recovery of ecosystem	24	4,530	External	Avoidable
Adjustment in unit price	73	3,887	Contractor	Avoidable
Land surveying	11	1,189	Design	Avoidable
Duplicate calculation	19	-5,440	Design	Avoidable
Soil disposal	45	-6,372	Contractor	Avoidable
Change in hauling distance of soil or other materials	171	-29,252	Contractor	Avoidable
Settlement of accounts	305	-36,275	Contractor	Avoidable

4.3 Causes of Change Orders by Risk Type

The 31 detailed factors were classified into three groups by the degree of controllability based on the responses of the survey. Through the survey, respondents were asked to assess 31 factors; whether these change orders could be predicted or not, and whether they could be prevented or not. Factors that can be not only predicted but also prevented were classified as the avoidable risk group. In addition, factors that cannot be predicted but can be prevented were classified as the reducible risk group. Finally, factors that cannot be prevented, even when it could be predictable, were considered as the inevitable risk group. As a result of surveys, the inevitable group is about 60%, which means that approximately 40% of the total change orders could be partly or fully controlled if properly managed.

Table 4. Frequency and Cost Impacts of Change Order by Degree of Controllability

Types	Freq.	Cost Increase ($1,000)
Avoidable	4,304	910,420
Reducible	1,514	373,041
Inevitable	3,155	2,048,510

5. ANALYZING COST IMPACT OF CHANGE ORDERS

Following the preliminary investigation, this study further analyzed the causes of change orders in association with contract volume, bid award rate, contractor capacity, and design company capacity through a one-way analysis of variance (ANOVA).

5.1 Analyzing Cost Impact Classified by Contract Volume

A total of 218 projects were equally partitioned into 3 groups. The contract volume of the first group (A) exceeded $81 million per a project, group B was between $42 million and $81 million, and group C was less than $42 million. Table 5 shows the ANOVA results of the change order rate in reference to contract volumes.

Table 5. Analysis of Change Order Rate Classified by Contract Volume (ANOVA)

Group	# Projects	Mean	Std. Dev.	Sig. Prob.
A	72	19.9	15.8	0.029
B	73	23.5	24.1	
C	73	34.2	50.0	
Total	218	25.9	33.8	

This result shows that if the contract volume is smaller, the change order rate has a tendency to increase at the 95% significance level (p=0.029). Especially, the mean difference between groups A and C has a significant difference according to the post-hoc test of ANOVA (p<0.05). This is, to some extent, opposed to what is expected from traditional perspectives of change orders; in the following view, the number of change orders tends to decrease as contract volume becomes smaller because a small contract typically has a shorter period with less uncertainty than a big contract [8]. This result implies that each country has a unique aspect on the causes for change orders.

5.2 Analyzing Cost Impact Classified by Bid Award Rate

Figure 1 shows the bid award rate histogram for 218 road projects. As shown Figure 1, the mean bid award rate was 81.33%, while the distribution had a tendency to be concentrated in the range of 67.5-70% and 92.5-95%. Therefore, this study classifies a total of 218 projects into 3 groups considering these two peak points.

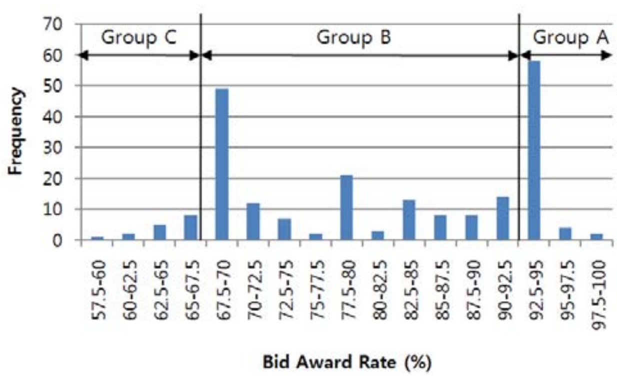

Figure 1. Histogram of Bid Award Rate

Lee [11] suggested that change order rate is not relevant to bid award rate about 559 Korea road projects from 1991 to 2004. However, this study pointed out that the lowest bid award rate group (C) shows a higher change order rate than other groups at the 95% significant level (p=0.025), although those of group A and group B are not statistically different.

Table 6. Analysis of Change Order Rate Classified by Bid Award Rate (ANOVA)

Group	# Projects	Mean	Std. Dev.	Sig. Prob.
A	64	28.6	46.2	0.025
B	137	22.4	24.0	
C	16	45.8	42.0	
Total	217	26.0	33.9	

5.3 Analyzing Cost Impact Classified by Contractor

This study divided contractor's capacity intro three groups as shown Table 7. This classification is based on '2008 Ranking of General Contractors for Construction Ability' that is suggested by 'Construction Association of Korea' [2]. Each group has the same market share of total construction volume. Group A that has a best capacity to perform shows a lowest change order rate. However, interestingly, the group that has an intermediate capacity has the largest change order rate. These results imply that top ranked contractors tend to generate less change orders but, as the contractor's capacity decreases, this is not the consistent case to generalize.

Table 7. Analysis of Change Order Rate Classified by Contractor Capacity (ANOVA)

Group	# Projects	Mean	Std. Dev.	Sig. Prob.
A	15	14.7	9.8	0.006
B	45	39.5	51.2	
C	158	23.1	24.1	
Total	218	25.9	33.8	

5.4 Analyzing Cost Impact Classified by Design Company

Similar to contractor's classification, this study divided design company's capacity into three groups as shown in Table 8. This classification is also suggested by 'Construction Association of Korea' [2]. Surprisingly, group A that has the best capacity shows a higher change order rate at 99% significant level. These results imply that top ranked design company has a tendency to perform more complicated projects. It should be also noted that the current classification does not fit with the actual capacity of a firm because the rankings are determined upon the total revenues of all projects, not the summary of road projects only.

Table 8. Analysis of Change Order Rate Classified by Design Company Capacity (ANOVA)

Group	# Projects	Mean	Std. Dev.	Sig. Prob.
A	30	44.2	64.2	0.006
B	29	24.0	24.2	
C	159	22.8	25.2	
Total	218	25.9	33.8	

6. CONCLUSIONS

This paper investigated the frequency and cost in association with detailed sources and described the attributes of change orders. The causes of the change orders were analyzed by ANOVA from the viewpoint of the contract volume, bid award rate, contractor capacity, and design company capacity. The main conclusions for this study can be summarized as follows:

- Escalation, additional provisions of temporary structures and traffic safety facilities, operation and maintenance cost for existing structures, owner's requirement, and differences between designer's specifications and site conditions were deduced as the main critical factors for change orders.
- Small projects have a tendency to create more cost overruns in association with contract volumes. Therefore, project participants had better take care of design management about small projects such as group C.

- Generally, the bid award rate is not relevant to change order rate. However, this study shows that if the bid award rate is very low (below 67.5%), the change order rate rapidly increases.
- Middle ranked contractors showed the highest change order rates, whereas top ranked design companies have a tendency to make a high change order rate.

The results as mentioned above are expected to be helpful for project participants when they manage the public road projects. And these conclusions imply that the existing institution about delivery and design management process should be improved.

Nevertheless, this paper has some limitations. First, this study cannot distinguish grey area of change orders affected by more than two causes. In addition, the results can be changed by selection of the group classification criteria, especially on design company. Therefore validation of definite criteria to classify the each group is required. Then more reliable results can be achieved.

7. ACKNOWLEDGEMENT

This research was supported by a grant from Construction and Transportation R&D Program (06CIT-A03) funded by Ministry of Land, Transportation and Maritime Affairs (MLTM) of Korean government.

REFERENCES

[1] Chen, J. H. and Hsu, S. C., “Early Warning System for Severe Change Orders.”, *Proceedings of the 2005 ASCE International Conference on Computing in Civil Engineering*, pp. 1913-1924, 2005.

[2] Construction Association of Korea, [online], [cited 2009. 1.21], < http://www.cak.or.kr/ >

[3] Gunhan, S., Arditi, D., and Doyle, J., “Avoiding Change Orders in Public School Construction.”, *Journal of Professional Issues in Engineering Education and Practice*, Vol. 133(1), pp. 67-73, 2007.

[4] Hanna, A. S., Russell, J. S., Gotzion, T. W., and Nordheim, E. V., “Impact of Change Orders on Labor Efficiency for Mechanical Construction.”, *Journal of Construction Engineering and Management*, Vol. 125(3), pp. 176-184, 1999.

[5] Hanna, A. S., Peterson, P., Dettwiler, J., Russell, J. S., and Gunduz, M., “Assessment of Global Impact of Change Orders on Electrical and Mechanical Construction. - Delta Approach.”, *Proceedings of Construction Congress VI: Building Together for a Better Tomorrow in an Increasingly Complex World*, pp. 1177-1188, 2000.

[6] Hanna, A. S., Camlic, R., Peterson, P. A., and Nordheim, E. V., “Quantitative Definition of Projects Impacted by Change Orders.”, *Journal of Construction Engineering and Management*, Vol. 128(1), pp. 57-64, 2002.

[7] Hanna, A. S., Lotfallah, W. B., and Lee, M. J., “Statistical-Fuzzy Approach to Quantify Cumulative Impact of Change Orders.”, *Journal of Computing in Civil Engineering*, Vol. 16(4), pp. 252-258, 2002.

[8] Hanna, A. S., and Gunduz, M., “Impact of Change Orders on Small Labor-Intensive Projects.”, *Journal of Construction Engineering and Management*, Vol. 130(5), pp. 726-733, 2004.

[9] Hanna, A. S., and Swanson, J., “Risk Allocation by Law - Cumulative Impact of Change Orders.”, *Journal of Professional Issues in Engineering Education and Practice*, Vol. 133(1), pp. 60-66, 2007.

[10] Lee, M. J., Hanna, A. S., and Loh, W. Y., “Decision Tree Approach to Classify and Quantify Cumulative Impact of Change Orders on Productivity.” *Journal of Computing in Civil Engineering*, Vol. 18(2), pp. 132-144, 2004

[11] Lee, M. J., Park, B. J., Im, K. S., “A Study on the Estimation of Change Orders Impact for the Public Construction.”, *Journal of the Korean Society for Civil Engineer* , Vol. 28(3), 2008.

[12] Moselhi, O., Assem, I., and El-Rayes, K., “Change Orders Impact on Labor Productivity.”, Journal of Construction Engineering and Management, Vol. 131(3), pp. 354-359, 2005.

[13] Riley, D. R., Diller, B. E., and Kerr, D., “Effects of Delivery Systems on Change Order Size and Frequency in Mechanical Construction.”, *Journal of Construction Engineering and Management*, Vol. 131(9), pp. 953-962, 2005.

[14] Stocks, S. N., and Singh, A., “Studies on the Impact of Functional Analysis Concept Design on Reduction in Change Orders.”, *Journal of Construction Management and Economics*, Vol. 17(3), pp. 251-267, 1999.

[15] Thomas, H. R., Smith, G. R., and Wright, D. E., “Legal Aspects of Oral Change Orders.”, *Journal of Construction Engineering and Management*, Vol. 117(1), pp. 148-162, 1991.

[16] Wu, C. H., Hsieh, T. Y., Cheng, W. L., and Lu, S. T., “Grey Relation Analysis of Causes for Change Orders in Highway Construction.”, *Journal of Construction Management and Economics*, Vol. 22(5), pp. 509-520, 2004.