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Cost and Schedule Analysis of Highway Projects based on Project Types

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Abstract: Change Orders generally impact cost and schedule performance of highway projects. However, highway projects that do not have any change orders also face cost growth and schedule delays. This study seeks to determine the cost and schedule performance of Texas DOT projects by collecting project data for 120 highway projects completed between 2016 to 2020. For the study, we selected project data that has zero or negative change orders which were then grouped and analyzed based on their Project Types i.e., maintenance works; structural works; restoration and rehabilitation works; and safety works. The study found that performance of Maintenance and Safety type projects had less cost and schedule growth among the data analyzed. Statistical tests also found that even though the projects have no change orders, Rehabilitation and Restoration type projects experienced significant schedule growth compared to others. However, the data did not show any significant cost and schedule growth for the projects when statistical tests were performed on overall data. The study concluded that highway projects are experiencing schedule growth even though the projects had no change orders. Results from the study can help planners, engineers, and administrators to gain better insight on how different types of highway projects are performing in terms of cost and schedule and eventually derive appropriate solutions to minimize cost and schedule growth in such projects.

Key words: Cost growth, Schedule growth, Project performance, Highway project types, ANOVA

1. INTRODUCTION

Successful delivery of a project is generally defined by its cost performance and ability to meet project deadlines. Project cost/budget and schedule are the two major project elements which helps to determine how well the project is progressing or complete. In construction projects, Cost overrun refers to increase in project cost from the original budgeted amount, whereas schedule growth refers to extension of project from its original completion date. Cost and schedule overruns can occur due to variety of reasons. Factors such as poor estimation, design errors, unforeseen site conditions, poor investigation, additional works, and modification of design affect the cost and schedule performance of construction projects[1,2].

Cost and schedule growth are common in construction projects. Particularly, highway projects in the United States mostly experience cost overruns [3]. One of the major reasons contributing to cost and schedule growth of highway projects in the United States is Change Order[4,5]. Change orders are defined as any alterations in the contract made by the owner due to an unplanned change in the project. It is seen that change orders affect cost and schedule performance of US highway projects irrespective of their project size [6]. Due to change orders, various types of highway projects such as road maintenance projects [7], transportation improvement projects [8] and resurfacing projects [9] are experiencing cost and schedule growth.

Most of the studies have identified the negative effects of change orders on cost and schedule but fewer studies have investigated the project performances when there are no change orders. In addition, very less studies have analyzed the project performance for different types of highway projects. To address this gap, this study uses statistical tests to analyze the cost and schedule performances for projects that had no change orders. The authors collected data for 120 projects (maintenance work, structural work, rehabilitation and restoration work, and safety work projects) from TXDOT database for the study. The results from the study will be helpful to better understand the performance of various highway projects with respect to cost and schedule.

2. LITERATURE REVIEW

Shrestha et al. [7] performed statistical study on 614 maintenance projects from Kenya Rural Road Authority and concluded that project level change orders increased the cost of maintenance projects by 13.07%. Furthermore, the correlations between change orders and schedule performance showed that change orders significantly affected the schedule performance of maintenance projects. The researchers concluded that change orders are higher in small maintenance projects compared to large maintenance projects. When analysis was performed for various project activities, culvert installation activity had the highest change orders. For 1,372 transportation infrastructure improvement projects in California, Choi et al. [8]investigated change orders effects on schedule change percentages using three types of contracting strategies i.e. Conventional contracts, pure Cost-plus-Time (A+B projects), and Cost-plus-Time (A+B projects) including Incentives/Disincentives(I/D). The results showed that pure A+B projects have higher impacts of change orders than the other two strategies, whereas in terms of cost impacts, the authors found no significant difference between pure Cost-plus-Time (A+B projects) and Cost-plus-Time (A+B projects) including Incentives/Disincentives(I/D).

Shrestha & Maharjan [5] analyzed data for 615 Florida DOT small highway DBB projects to determine the effects of change orders on their cost and schedule performance and found that projects having zero change orders or negative change orders have better project performance and higher construction intensity compared to projects with change orders. Anastasopoulos et al. [9] used 1,939 Indiana DOT projects data to find out the effect of change order frequencies on highway projects. The results showed that resurfacing and traffic maintenance projects have fewer change orders compared to other project types. The authors concluded that resurfacing and traffic maintenance projects are likely to have fewer change orders because they do not typically involve uncertain conditions like earthwork, and they have straight implementation procedures. Using information on 517 change orders obtained from 27 building renovation projects, kim et al. [10]concluded that change orders due to unforeseen conditions are substantial, and these change orders are responsible for increasing project costs up to 9.04%.

Many studies have investigated the impact of change orders on project performances of highway projects. These studies show that the impact of change orders in cost and schedule performance of highway projects are substantial, and it is important to manage these changes effectively. However, only few studies have analyzed the cost and schedule performance when change orders are zero or

negative. Therefore, this study aims to determine change orders' impacts on highway project performances of various work types when the projects have no change orders.

3. RESEARCH METHODOLOGIES

For the study, analysis of variance (ANOVA) test was conducted to determine whether the mean values of cost and schedule growth differed significantly between the project groups. Before conducting the test, three major assumptions needs to be verified: 1) normality of data; 2) homogeneity of variances; and 3) independence of data [11]. Using normal Q-Q plots can determine if the cost growth and schedule growth data were distributed normally. In addition, to check equal homogeneity of variances across the groups, the Levene's Test of Equality of variances was used. Since the project data was collected from TxDOT, the data is independent from the others.

While conducting statistical tests, if the project groups have equal variances then it is followed by post hoc test; however, if the results from Levene's test have difference in variances, then Welch test can be used to determine the significance difference in the means between these projects [12]. The Welch test determines whether the mean values of cost and schedule growth were significantly different between the project groups. If the p-value was found to be less than 0.05, then the null hypothesis would be rejected [13], confirming the research hypothesis that the mean values of these groups are significantly different. If the p-value was found to be less than 0.05, the difference in mean values would be considered as highly significant. The results of these tests are described in the following sections.

4. RESULTS

The normal Q-Q plots for cost and schedule metrics are shown in Figure 1 and 2. The normal distributions tend to fall closely along the straight line. In Figures 1 and 2, the normal Q-Q plots form an approximately straight line, so we can assume that the performance data are normally distributed.

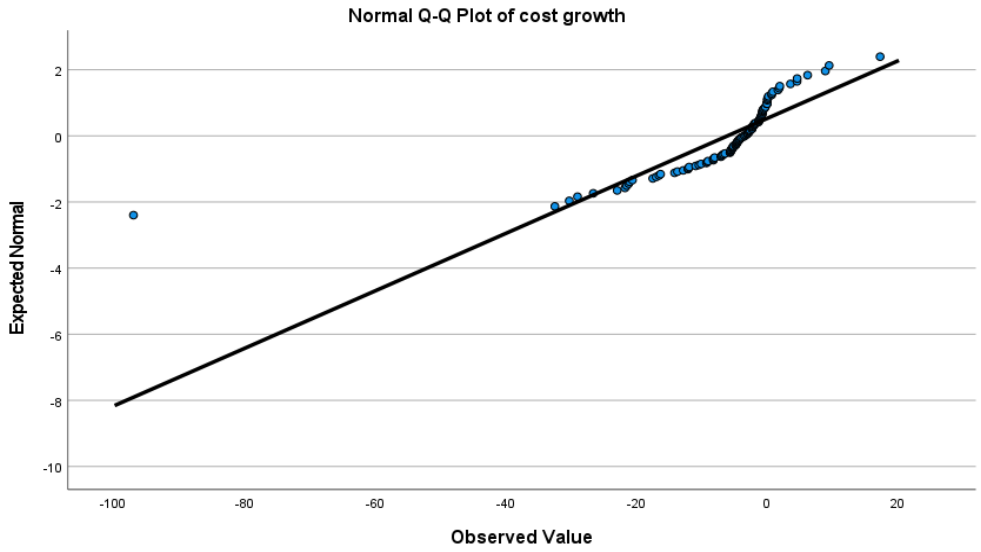

Figure 1. Normal Q-Q plot for cost growth

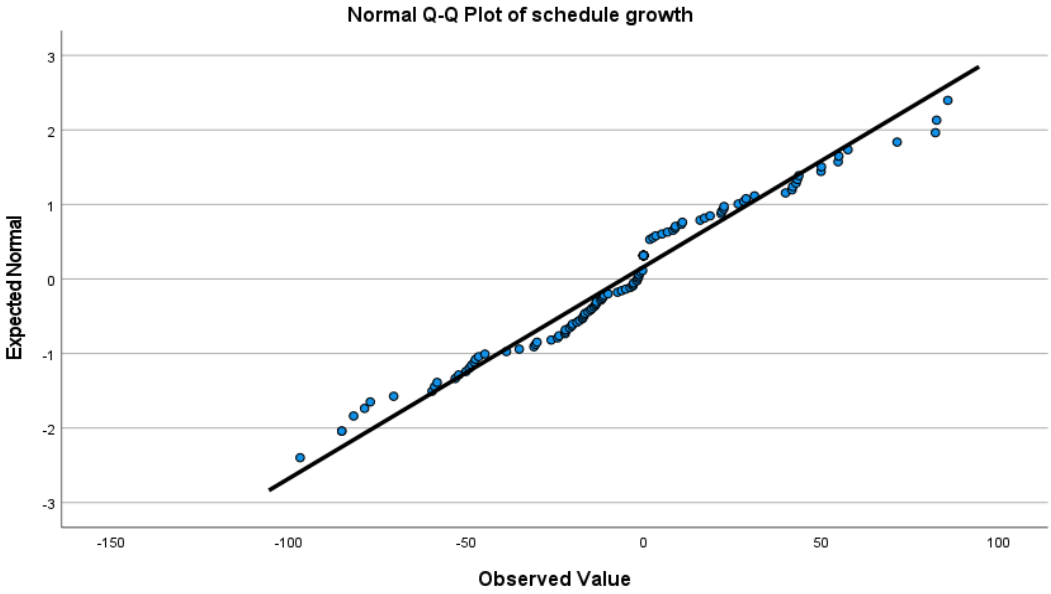

Figure 2. Normal Q-Q plot for schedule growth

The mean cost and schedule growth for overall data is shown in Figure 3. The statistics shows that mean values of cost growth and schedule growth are -6.06% and -5.74% respectively which means that there is negative cost and schedule growth when the projects have no change orders.

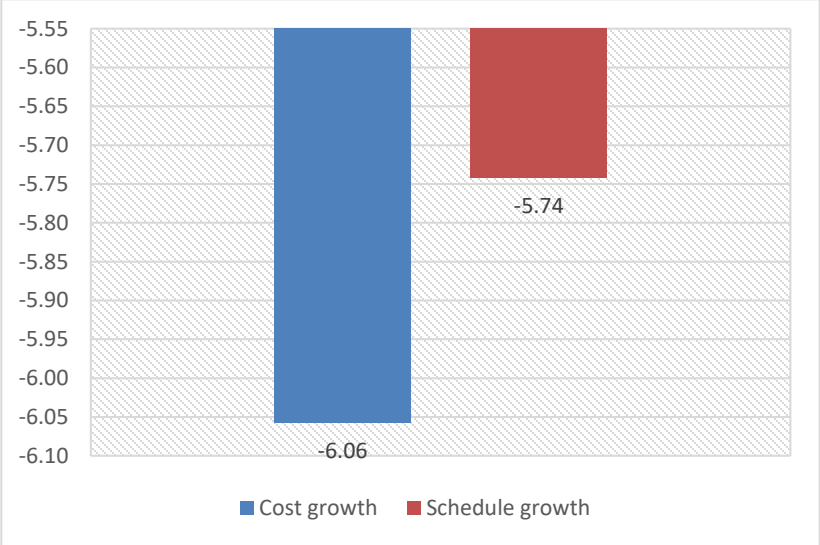

Figure 3. Mean values of cost and schedule growth

In the study, ANOVA test determined whether the cost and schedule performance metrics were significantly different between the considered groups based on different project types. To determine homogeneity between the groups, the Levene's test for homogeneity of variances was conducted. The results from Levene's test are shown in Table 1. The test results show that cost and schedule growth have equal variances, as the significance values for these three metrics are more than 0.05. Thus, we can accept the null hypothesis of equal variances across the groups which state that there is no significant difference in variances between these groups.

Table 1. Results of Levene's Test

Performance metrics	Sample size	Levene's Statistic	Significance
Cost growth	120	0.813	0.489
Schedule growth	120	0.262	0.853

As the assumption of equal variances was not violated, the Tukey post hoc test was performed for cost and schedule growth based on their project types. The results of the post-hoc Tukey test for cost growth for different project types is shown in Table 2.

Table 2. Results of Tukey post-hoc test for Cost Growth

Project Types	No. of sample	Mean	Mean difference	Significance
Maintenance	30	-7.347	-3.34	0.674
Structure	30	-4.001		
Structure	30	-4.001	0.73	0.72
Rehabilitation	30	-4.731		
Rehabilitation	30	-4.731	3.41	0.15
Safety	30	-8.150		

The post hoc results showed that the mean cost growth in all four project types was negative, which means that there was no significant cost growth in projects that had no change orders. The mean cost growth for maintenance, structural, rehabilitation and restoration; and safety works projects were -7.35%, -4.0%, -4.73% and -8.15% respectively.

However, when data was analyzed for schedule growth, the results were different. Table 3 shows the mean schedule growth of projects based on work types.

Table 3. Results of Tukey post-hoc test for Schedule Growth

Project Types	No. of sample	Mean	Mean difference	Significance
Maintenance	30	-25.998	8.47*	0.004
Structure	30	3.325		
Structure	30	3.325	-6.36	0.876
Rehabilitation	30	9.689		
Rehabilitation	30	9.689	19.67	0.099
Safety	30	-9.987		

* The mean difference is significant at the 0.05 level.

The results found that the mean schedule growth in maintenance (-25.99%) and safety (-9.98%) type projects were negative but structural (3.32%), rehabilitation and restoration type (9.98%) work had positive mean schedule growth. This shows that even though the project had no change orders, the structural, rehabilitation and restoration type projects were delayed. In addition, the results

found that maintenance and safety projects have better schedule performance compared to structural, and rehabilitation and restoration projects.

5. DISCUSSION AND CONCLUSION

The objective of this study is to determine the mean values of cost and schedule growth when the projects had zero or negative change orders based on project types. The study found no significant cost growth in all the project groups analyzed for TXDOT highway projects that had no change orders. Similarly, the analysis shows no significant schedule growth for maintenance and safety projects. However, statistical tests show that even though the projects have no change orders, Rehabilitation and Restoration type projects and structural projects experienced schedule growth compared to other project types. The data results show better schedule performance for maintenance and safety projects compared to structural, and rehabilitation and restoration projects.

Although TXDOT highway projects has less cost and schedule growth for projects that had no or negative change orders, some types of projects experience schedule delays even in the absence of change orders. Therefore, it is necessary to investigate and understand possible variables aside from change orders that contribute to a highway project's schedule growth. Findings from the study will help project managers, planners, and engineers to get better insight on how different types of highway projects perform in terms of cost and schedule and eventually derive appropriate solutions to minimize cost and schedule growth in such projects.

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