

Using Risk Assessment to Improve Highway Construction Project Performance

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The construction industry and its clients are associated with a high degree of risk due to the complex nature of the construction process. The research reported in this paper is part of a comprehensive research study to analyze and evaluate the different risk drivers in highway construction projects in the US. Thirty one significant risk drivers, identified from previous studies, were chosen, analyzed, and evaluated for this study. This paper presents the study findings regarding the process of using of risk assessment techniques and tools for determining its impact on construction cost and schedule performance ratings of highway projects. The analyses included project information and characteristics as well as project risks' cost and schedule impact ratings. The analyses were carried out based on the responses from highway construction related professionals from both the public and the private sectors to a survey. The responses provided both quantitative and qualitative data from several highway construction projects completed in the past. The statistical dependency correlation analyses showed that the use of risk assessment in the reported projects has improved project and construction management practices.

Key Words: Risk drivers, risk assessment, risk management, highway construction.

Introduction

The construction process has numerous uncertainties and risks, which increase with the size and the complexity of a project. Risk has been defined in different ways. Project Management Institute (PMI) defines project risk as an uncertain event or condition and that its occurrence has positive or negative effect on at least one project objective, such as time, cost, scope, or quality (PMI 2004). Project risks may have one or more causes and impacts, and project risk management might be formal or informal process. According to PMI (2004) "*Project risk management includes the process concerned with conducting risk management planning, identification, analysis, responses, and monitoring and control on a project; most of these processes are updated throughout the project.*" Ashley et al. (2006) have emphasized the importance of risk assessment, risk allocation, and risk management in effective management of highway construction projects. Risk management must be forward looking and identify potential problems.

Objective and Scope

The objective of this research study was to understand and evaluate the transportation professional's perception about construction risk assessment and the significant risk drivers within highway construction project context. The scope of this paper was to test and understand the impact of using the risk assessment on highway construction project performance. The testing considered project specific data and characteristics and their correlations with the ratings of impact of encountered significant risk drivers on total project cost and time performance.

Literature Review

Molenaar (2005) emphasized the importance and the effectiveness of using risk management and other cost control processes in lowering the expected costs of projects. Akintoye and MacLeod (1997) studied the perceived risks and found that contractors and project managers in the UK use perceived risk as the likelihood of unforeseen factors occurring, which could adversely affect the successful completion of a project in terms of cost, time, and quality, and concluded that analyzing and controlling risks are the key to improving profit.

Cost overruns and late completion times in large infrastructure projects have been widely recognized as risks impacting project performance (Flyvbjerg et al. 2002). Controlling project budgets over project construction life cycle for mega infrastructure projects is a major challenge for both the public and the private sectors. Accurately estimating cost is an important factor for a successful project cost management from the start of planning phase to the completion of construction (Akintoye and MacLeod 1997; Nassar et al. 2005). Contingency has been used to manage uncertainty and risk in construction projects. To adequately calculate the project contingency, planners should focus on analyzing the potential risk drivers. Contingency amount is greatest in the beginning of a project and is gradually reduced as the project is designed, risks are resolved, or the contingency amount is spent (Ashley et al. 2006).

Design-Build (DB) is an alternative for Design-Bid-Build (DBB) project delivery method in many countries around the world, including the US. In DB project delivery method, the design and construction phases of a project are combined into one contract. In a Federal Highway Administration (FHWA) sponsored design-build effectiveness study (SAIC et al. 2006), the data analysis has shown the following:

1) In both building and highway projects, duration of the projects were found to be 4 to 60 percent lower for projects using DB project delivery method compared to those using DBB project delivery method;
2) In both building and highway projects, DB method has typically resulted in lower project cost compared to that for DBB method. However, there has been anywhere from an 18-percent reduction to a 23-percent increase in cost when using DB method instead of DBB method; and
3) The increased use of DB method in public sector and the need to improve the performance and quality of public highway projects require more familiarity with all performance and risks indicators in this method.

The literature reviews and interaction with construction industry related professionals allowed appropriate identification of programmatic- and project-specific construction risk drivers for highway projects. Qualitative risk assessment has been conducted in previous studies, and was used in this study for identifying the significant risk drivers and developing rating scale for the encountered risk drivers in the reported projects. However, the previous studies have not correlated project characteristics to the different construction risk drivers in highway projects in quantitative assessments, which identified the need for further research and motivated the conduct of research for this study (Diab, 2011). To address this need, the dependency correlations among the use of risk assessment, some characteristics of the reported projects, and cost and schedule impact ratings of encountered risk drivers have been analyzed and presented in this paper.

Methodology

A survey questionnaire was developed to collect quantitative and qualitative data from completed transportation construction projects in the US. A sample of 660 professionals from 29 states was drawn from our listserv for the distribution of questionnaire. The listserv included contact information of a large pool of transportation professionals from different professional associations. The reported participants in this study were transportation construction related professionals from Federal Highway Administration, State Department of Transportation (DOTs) and other public agencies, A/E Consulting companies, Design Firms, Contractors, and Subcontractors. Total number of responses received was 246, some of which contained responses for more than one project. Out of these responses, 98 responses had partially completed the survey. The number of responses that fully completed all parts of the survey was 48 (about 20 % of all responses received). For testing any parameter, only the responses that reported an observation for that parameter were considered.

A total of 31 significant risk drivers were identified from previous studies (Lam 1999, SAIC 2006, Molenaar 2005, AASHTO 2008). They were grouped in five broad categories: project scope, right of way, utility conflicts, architectural/engineering (A/E) services, and project construction management. The risk drivers are listed in Table1.

The responders were asked to provide project-specific information as well as rate the pre-identified common critical risks encountered for the completed highway construction projects they were involved with. The responders carried out ratings for impact on project construction cost and schedule growth at three levels as high, medium, or low impact. The responders were also given the opportunity to provide information on other risks which the project had encountered, but were not listed in the questionnaire.

Table 1

Construction Risk Drivers

I	**Project Scope**
R1	Project purpose is poorly defined
R2	Changes by owner's request
R3	Changes to unforeseen site environment requirements
II	**Right of Way**
R4	Right of way analysis in error
R5	Land acquisition delay
III	**Utility Conflicts**
R6	Inadequate plan reviews by designers and contractors/ design errors
R7	Poor involvement of utility companies in planning stage
R8	High number of utilities in the site
R9	Inaccuracy of existing utility locations and survey data
R10	Poor coordination among utility agencies, designers, and contractors
R11	Increased utility relocation costs
R12	Poor engineering practice within the state
R13	Utility damages by contractors/subcontractors faults in construction
IV	**A/E Services**
R14	Surveys late and/or surveys in error
R15	Inexperienced professionals for this type of project
R16	Design errors and omissions
R17	Inadequate constructability reviews
R18	Delay in Quality Assurance/Quality Control (QA/QC) services
R19	Poor preliminary soil information and investigations
R20	Unforeseen and/or different geotechnical conditions
R21	Unforeseen hazard conditions
R22	Inaccurate structures design
V	**Project Construction Management**
R23	Poor communication with owner and contractor
R24	Delay of permits
R25	Constraints in construction work window
R26	Material availability and price inflation
R27	Subcontractors errors and delays
R28	Maintenance of traffic/staging/auxiliary lanes
R29	Inexperienced project manager
R30	Safety issues
R31	Warranty issues

It was evident from literature that risk assessment plays a big role in understanding the different project risks and their impact. It was important to investigate whether organizations are actually using any form of formal risk assessment in their highway construction projects, and if they understand the importance of using risk assessment in their highway construction projects. A related research need was to understand if there is any correlation between using risk assessment in a specific project and the different characteristics of the project. Hypotheses (see Table 2) were formulated to study research needs and answer research questions, and also to compare the different perceptions and practices among the public and private organizations in the US. Chi-square tests were used in assessing goodness-of-fit independence in contingency tables since all variables were categorical. In the case when the count in a cell of a contingency table was less than 5, the LR Chi-square test was used. Fisher test was used to test the frequencies of extreme values in contingency tables. The dependency correlations between different variables were analyzed and found by using the statistical software SAS®.

Hypotheses

Eight hypotheses were developed. Each hypothesis tests the null hypothesis (H_o) that there is no dependency correlation and the alternative hypothesis (H_a) tests that there is dependency correlation (see Table 2 on next page).

Data Analyses

Examining and analyzing the data from frequency tables and the chi-square dependency correlations provided some interesting insights. Regarding the use of risk assessment in projects by both the public and the private sectors, it was found that about 51% of the responders used it in some projects and 36% of the responders used it in all their projects. Also, 70% of the responders had more than 10 years of experience, which was quiet promising and gave credence to the data obtained from responses to the survey regarding risks in highway construction projects. Majority of the responders considered that risk management played an important role in cost and time performance of highway construction projects. In fact, about 80% of the responders considered risk management as important, very important, or extremely important for good performance of highway construction projects, which is certainly an important recognition of the fact that risk management can lead to project success.

In testing Hypothesis 1, dependency correlation of interest was the perception of the two types of organization regarding the importance of risk management for performance of highway construction project. The test statistics at p-values less than (<) 0.05 indicate that there is not enough evidence to reject the alternative hypothesis and that there is a dependency correlation between organization type and the perception regarding the importance of risk management. About 86% of responders from private sector organizations and 67% of responders from public sector organizations believed that risk management was important, very important, or extremely important. It is clear that both sectors consider risk management as important and in all likelihood there will be increased use of risk assessment and analysis in decades to come.

For Hypothesis 2 the chi-square statistics had p-values less than (<) 0.05, which led to rejection of the null hypothesis. Hence, there is dependency correlation between type of organization and the use of risk assessment (RA) in highway projects. It appears that the private sector organizations have been using RA more than the public sector. About 46% of private organizations have used RA in all their projects reported in the survey, whereas only 15% of public organizations have done the same. This leads to conclusion the use of RA as a program strategy is more prevalent and has more commitment among private sector organizations than public sector organizations. This might be due to the reality that private sector is more closely involved with construction activities. However, it is important to emphasize that use of RA as program strategy is also quite important for public sector agencies as there is a need for more accountability regarding how efficiently tax payers money are being used in highway construction projects.

For Hypothesis 3 there was interest in finding dependency correlation between organization type and the use of RA in the chosen project. There was not enough evidence to reject the alternative hypothesis with p-values less than (<) 0.05. About 73% of private sector organizations have used RA in the chosen projects, whereas only about 41% of public sector organizations have done the same. This leads to the interpretation that at both program and project

levels risk assessment is used more within private sector organizations than within the public sector organizations. This could also be explained by highlighting that private sector organizations are more closely and integrally involved with various construction activities of highway projects than public sector organizations are.

Table 2

Hypotheses Explanation & Data Analyses

NO	*Hypotheses Explanations*	*Results*	*Chi-Square Probability*
(1)	***Type of organization and the importance of risk management in highway construction project.***	***Dependent***	*0.0015*
This hypothesis was intended to answer the research question regarding how both the public and the private sector perceive the importance of risk management process and practice.			
(2)	***Type of organization and the use of risk assessment in highway construction projects.***	***Dependent***	*0.0011*
There is a debate among the transportation professionals whether the public and/or the private organizations are investing their resources adequately for risk assessment process. There is also a perception that public sector is more concerned and willing to use risk assessment in their construction program, perhaps more than the private sector, in order to become more accountable regarding using the tax payer's money and realizing the best value. Hence, it was important to test this hypothesis about dependency correlation between use of risk assessment and types of organizations in their construction program to understand if there are differences in perceptions and practices.			
(3)	***Type of organization and the use of risk assessment in the chosen highway construction project.***	***Dependent***	*0.0041*
This hypothesis was intended to answer the research question as to how prevalent the use of risk assessment is by different type of organizations for individual chosen projects. A related interest is to know if there are significant differences in perception and practices between the public and the private organizations at project level. These differences could pose certain challenges as we transition from projects with DBB project delivery method to those with DB project delivery method, particularly related to risk allocation and management.			
(4)	***Project delivery method and the use of risk assessment in the chosen highway construction project.***	***Dependent***	*0.0236*
The interest in this hypothesis was tied to Hypothesis 3 as there is interest in industry to know if the use of risk assessment and management is more prevalent in DBB or DB project delivery method.			
(5)	***Total planned project cost (TPC) and the use of risk assessment in the chosen highway construction project.***	***Dependent***	*0.0214*
The relevance and importance of this hypothesis comes from the argument that only large project uses risk assessment because only when the project size and scale reaches a certain level there are adverse impacts on project performance and that there are resources available to conduct risk assessment. In addition, large scale projects are more prone to risks.			
(6)	***Total planned project duration (TPD) and the use of risk assessment in the chosen highway project.***	***independent***	*0.4902*
The importance of this hypothesis comes from the argument that if the project is subjected to a tight schedule, it is very important to conduct risk assessment to prevent any risks and resulting consequence which might delay project completion. So the research interest was to find if the smaller the total planned duration led to the greater the use of risk assessment for the project.			
(7)	***Rating for Cost Impact (CI) and the use of risk assessment in the chosen highway project.***	***Dependency for some***	
(8)	***Rating for Schedule Impact (SI) and the use of risk assessment in the chosen highway project.***	***Dependency for some***	
As project is in planning phase, a team of professionals explore the type and number of risks a project may encounter. In addition, the team may assess the level of cost and schedule impact for those risks, based on past experience or some quantitative analyses, including simulation. The Hypotheses 7 and 8 are related to that need of having a risk assessment and management process in place given the cost and schedule impact ratings related to different risks. Hence, there is interest in knowing if there is a dependency correlation between cost impact or schedule impact and the use of risk assessment in chosen projects.			

For Hypothesis 4 test statistical results indicated dependency correlation between project delivery method and the use of risk assessment in the chosen project. There was not enough evidence to reject the alternative hypothesis with p-values less than (<) 0.05. About 85% of the projects using DB project delivery method used RA, whereas only 53% of the projects using DBB project delivery method used RA. This indicates that the use of RA is more prevalent, significant and important in projects using DB project delivery method, and could impact the cost and schedule of these projects more significantly than the projects using DBB project delivery method.

For Hypothesis 5 there was interest in finding dependency correlation between total planned cost (TPC) and the use of risk assessment at alpha (α) value of 0.05. There was not enough evidence to reject the alternative hypothesis. About 77% of responders used RA in projects over 50 million in TPC. RA was used in about 61% of medium size projects, which are between 20 and less than 50 million in TPC. Hence, it appears large highway construction projects are more likely to use risk assessment. Large highway construction projects not only have more risks, but the impact of risks is potentially high also. Thus, risk assessment helps control and manages projects better as the project size and scope increases. However, the statistics is indicating RA is quite important for projects with both large and medium TPC, which are 20 million dollars or more.

For Hypothesis 6, the results indicated that there was no statistical evidence to accept the alternative hypothesis and that there is dependency correlation between total planned project duration (TPD) and the use of RA in the chosen project. Of the reported projects in survey responses that had total planned duration of 36 months or more, about 36% had conducted RA and 22% had not conducted RA. Also, the projects with long planned duration (more than 18 months) are most likely use RA as construction management tool to enhance cost and schedule performance of highway construction projects. However, based on statistical correlation, the TPD does not seem to impact project team's decision to use risk assessment or not.

For Hypotheses 7 and 8 the dependency correlations between ratings of CI and SI for 31 different risk drivers and the use of risk assessment in project provided some interesting insights at alpha (α) values of 0.10. The probability values for different analyses that were performed are summarized below (see Tables 3and 4).

Table 3

The dependency correlation statistics for the use of risk assessment and cost impact ratings

The risk driver	Chi-Square	Likelihood Ratio Chi-Square	Fisher's Exact Test
R3	0.0513	0.0523	0.0582
R10	0.0561	0.0467	0.0654
R12	0.0240	0.0092	0.0173
R17	0.0373	0.0331	0.0362
R21	0.0486	0.0396	0.0604
R29	0.0074	0.0035	0.0049
R30	0.0082	0.0065	0.0049

Table 4

The dependency correlation statistics for the use of risk assessment and schedule impact ratings

The risk driver	Chi-Square	Likelihood Ratio Chi-Square	Fisher's Exact Test
R3	0.0226	0.0072	0.0194
R10	0.0449	0.0393	0.0562
R12	0.0327	0.0153	0.0237
R15	0.0413	0.0231	0.0316

R21	0.0291	0.0235	0.0321
R29	0.0074	0.0035	0.0049
R30	0.0497	0.0445	0.0459

The dependency correlations between ratings of CI and SI for 31 different risk drivers and the use of risk assessment, based on the projects reported in the survey responses, provided several insights. The use of risk assessment in highway construction projects lowered the rating of CI and SI of some critical risk drivers. Lack of use of risk assessment increased the rating of CI and SI of some critical risk drivers. The CI of risk drivers R3, R10, R12, R17, R21, R29, and R30 was rated as low in highway construction projects that used RA. In other words, the project team was able to mitigate impact of these risk drivers with development of plans to deal with the risks and their impact on cost growth (CG).

The SI of risk drivers R3, R10, R12, R15, R21, R29, and R30 was rated low in highway construction projects that used risk assessment. The development of appropriate plans can ably minimize the impact of these risk drivers on schedule growth. It should also be noted that when RA was not used in project, the cost impact of risk driver R3 was rated high compared with other risks. There also seems to be an agreement that the risk driver R12 does not impact CG. Similarly, there seems to be an agreement that the risk drivers R12, R15, and R30 do not impact schedule growth (SG). This analysis does not consider if there is any actual cost or schedule growth related to specific risk drives in the reported projects, because it is difficult to recognize which risk drivers have contributed to the project's cost or schedule growth. However, with other regression analyses some correlations of different risk drivers on cost and schedule growth were studied which is not part of this paper. When the RA was not used in projects reported in survey responses, there was no significant evidence of recognizing the highest and lowest values of cost and schedule impact of these risks, which indicate that using risk assessment would be useful tool and technique to evaluate the impact of construction risks on project performance, in particular cost and schedule impacts.

Conclusions and Recommendations

Majority of responders (80%) indicated that risk assessment was important for highway construction projects. The use of risk assessment was more prevalent in private sector organizations than public sector organizations. It has been used more often in design build projects than design bid build highway projects. This might be due to the fact that formal risk assessment is more required and it is considered an essential part in planning phase. The reason for this, from construction management point of view, is that the use of risk assessment potentially impacts cost and time performance much more significantly for design build projects than for the design bid build projects. Also, larger projects (with TPC over 20 million dollars) used risk assessment more often. However, the total planned duration (TPD) of project had statistically no significant impact on whether project team used risk assessment or not. In the majority of the projects reported in survey responses, the cost growth (CG) and schedule growth (SG) percentages were both between zero and 6%, It must be noted that cost or schedule growth is the percentage difference between actual and planned values to the planned value. About 66% of the reported projects had positive cost growth and about 49% of the reported projects had positive schedule growth. So using risk assessment did not eliminate cost and schedule growth. It must also be recognized that the use of risk assessment in the reported projects has improved project performance and construction management practices, which in turn led to the low ratings of CI and SI of certain risk drivers. The use of risk assessment lowered the rating of CI and/or SI for the following risk drivers:

1) R3 (changes to unforeseen site environment requirements)
2) R10 (poor coordination among utility agencies, designers, and contractors)
3) R15 (inexperienced professionals for this type of project)
4) R17 (inadequate constructability reviews)
5) R21 (unforeseen hazard conditions)
6) R29 (inexperienced project manager)
7) R30 (Safety issues)

The project cost and time performance measures the variance from project planned duration and total planned cost. This will lead to more savings related to project total cost and duration, use of increased contingency amount, cost overruns, or late project completion. The use of risk assessment improves project and construction management practices by helping transportation professionals to focus on the potential significant risk drivers in the planning phase. This practice would also improve cost and schedule performance through better management of potential risks. Consequently adequate program and project contingency amount can be determined and also allocated effectively. Although some departments of transportation in few states, like California, Minnesota and Washington States, have developed formal risk management programs, there was no clear evidence that the transportation professionals used quantitative risk assessment in there analyses**.** There is a need to focus more on education and training regarding the use of formal risk assessment techniques and tools for transportation professionals in the context of transportation programs and project risk management in the US.

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