

Effect of Risk Prolongation on Cost and Schedule of a Project

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Construction projects are fraught with risks. These if occur can impact both cost and schedule of the project. Studies on risk management plan and its phases, risk-based-procurement, risk-based-delivery method selection, and risk-based-bidding, can be found in abundance in literature. However, very little to no research has been conducted to analyze the effect of risk when they are prolonged on a construction project. This study fills in the gap by determining the proportions of risks prolonged on construction projects and the impact of those risks on the cost and schedule of the project. 806 risks from 190 Design-Bid-Build (D-B-B) projects from across the United States and Canada were analyzed. It was found that almost half the time, the risk on construction projects are prolonged. Furthermore, Kruskal-Wallis H test was used to determine if there was an impact on the cost and schedule due to risk prolongation. The result showed no statistical significance exists for schedule impact but does show a statistical significance for cost. For the primary stakeholder on a construction project such as; owner, designer, and contractor, the results of the study provide a reflection on the management of risk on construction projects. Although risk prolongation has no big impact on the schedule and the cost, it does however uses up resources of the company in form of time, labor, and energy, which if resolved early or on time can be used elsewhere in the project.

Key Words: Cost impact, Schedule impact, Risk resolution, Kruskal-Wallis H test, Project control

Introduction

Construction project is in a constant change (Hanna and Swanson, 2007) and risk arises due to the constant change in the circumstances of the project (Simth, 2016). Hence, a construction project is fraught with risks throughout the construction of the project (El-Sayegh, 2008). Risk management is managing of risks in a way that increases the likelihood of positive event, while reducing the likelihood of negative events (Project Management Institute (PMI), 2004). Risk management is an important process in construction projects in order to meet project objectives (Chapman and Ward, 2004), yet it is still not used properly due to the amount of upfront work required and lack of qualified professionals in the company to conduct risk analysis and risk management (Liu et al., 2007), which then cost the owners more due the contingencies and reserve cost built in by the contractors in their proposals (Lee et al., 2017). Although risks can impact the cost and schedule of the of the construction project (Choudhry and Iqbal, 2013), early risk identification can help plan risk efficiently minimizing cost and schedule overruns (Perrenoud et al., 2015).

Literature Review

Risk management is becoming important in the construction industry and if risk are not dealt effectively can have both cost and schedule impact (Wiguna and Scott, 2006). Hence, risk management has been a trending topic amongst the industry professionals and researchers. Many studies have been conducted on different areas of risk management; risk identification (Bypaneni and Tran, 2018), risk assessment (Mulholland and Christian, 1999); risk allocation (Rahman and Kumaraswamy, 2002), and risk response (Baker et al., 1999). While numerous other studies can also be found for risk-based delivery method selection (Tran and Molenaar, 2015), risk-based costing (Saleem et al., 2003), and risk-based safety impact assessment (Seo and Choi, 2008). However, majority of the research on risk analysis are limited to subjective analysis of professionals due to insufficient data on risks on construction projects (Adams, 2006). This study fill in the gap by analyzing actual project data on 190 Design-Bid-Build (D-B-B) projects across United States and Canada.

Moreover, project control is also an important part of project execution and is used to monitor the actual project progress with the baseline schedule and cost (Martens and Vanhoucke, 2018). Effective project control can help the project to finish on time and within budget (Olawale and Sun 2013). Numerous research has been conducted on project control such as, forecasting the final project duration (Elshaer, 2013), optimal buffer sizing (Iranmanesh et al., 2016; Zhang et al., 2016), corrective action plan (Madadai and Iranmanesh, 2012), and constructing tolerance limit for the schedule progress of projects (Martens and Vanhoucke, 2018). But very little research has been conducted on risk control.

Risk control is one of the project control used to track risk plan to the initial risk response. Risk control is used to prevent risk and its severity (Harrington and Niehaus, 2004). Handful of research has been conducted for risk control, which analyses the relationship of risk identification with cost and schedule impact (Smithwick et al., 2015, Perrenoud et al., 2015). However, very little to no research has been conducted on the risk control documents which analyzes the impact on cost and schedule of the project due to risk not resolved on time. This study analyzes the risk and its cost and schedule impact tracked on a risk control document from the start of the construction till the project close out.

Methodology

Data Collection

The data set consisted of 806 risks from 190 D-B-B projects from across the United States and Canada. The projects within the sample size had similar construction scopes, facility types, and procurement procedures, while, all these projects being vertical construction in public institutional facilities. The risk and it associated cost and schedule impact was extracted from final risk report submitted by the contractor to the owner at project completion. The risk report was used as a risk control on the project, which contained all the risks which were being actively managed by the project team. Every week in the project meeting, which included the owner and the contractor, discussion were held on open risks that were actively being managed. While, risks that were resolved were deemed closed. The corresponding cost and schedule impact of these risk were also documented in the risk report. All the risks from 190 projects were compiled together for analysis. Two sets of information was included in the dataset. Information pertaining to the risk resolution and project performance in terms of cost and schedule. Data for risk resolution included; risk identification date, planned risk resolution date, and actual risk resolution date.

Variables: Risk Categories

Risk resolution was divided into three categories; Early Resolved Risk, On-time Resolution, and Prolonged Risk, on the basis of the resolution period with respect to the planned risk resolution date.

Early Resolved Risk: These risks were risks which were resolved before the planned risk resolution date. These risks could be resolved as early as the day it was identified, hence having a -100% resolution period. While the latest these risks can be resolved is a day before planned risk resolution date, with resolution period being less than 0%. The minimum for this dataset was -1%.

On-time Resolution: These risks were risks which were resolved on the same day as planned risk resolution date. Because these risks were resolved the same day as the planned risk resolution date, they had a resolution period of 0%.

Prolonged Risks: These risks were risks which were resolved after the planned risk resolution date. The earliest these risks could be prolonged was a day after the planned risk resolution date. The data set had a minimum resolution period of 2%, for this category, while, there was no upper limit. The data set had a risk prolonged as high as 10300% more than the planned risk resolution date.

Variables: Project Performance

Cost impact: The impact on cost by a risk. The cost impact can be positive or negative, depending on the nature of the risk. *Cost impact* was taken as a percentage of the awarded cost of the project. The maximum cost impact was 128.39%, while the minimum was -5.18%.

Schedule impact: The impact on schedule by a risk. The schedule impact can be positive or negative, depending on the nature of the risk. *Schedule impact* was taken as a percentage of the awarded schedule of the project. The maximum schedule impact for the data set was 618.92%, while the minimum was -9.09%.

Point of Departure and Research Questions

Risk occurs on every project. However, the way risks are managed can ascertain the impact it will have on the cost or schedule of the project. Numerous studies have been conducted in areas of risk management, while other studies have focused on risk-based analysis. With majority of the researches being subjective in nature, and with barely any research on risk control, this study fills in the gap by analyzing 190 D-B-B project for the risk that occurred on the project and managed by the project team. The analysis was done to determine the cost and schedule impact due to risk prolongation; where risk is resolved after the planned risk resolution date. This motivation led us to the development of the following two research questions and hypothesis statements.

The first objective of this study was to determine the distribution of risk resolution across the data sample. An initial analysis of the data sample can help visualize how the risks are being managed by the project team on different projects. This led to the development of the first research question,

Research Question 1) What proportion of the risk are prolonged on a construction project?

The second and the most important objective of the study was to determine the impact to cost and schedule of the project due to risk prolongation. Which led to the development of the second research question and its corresponding two hypothesis statements.

Research Question 2) Is there any impact on the cost and the schedule of the project if the risk was prolonged?

Hypothesis Statement H1: No differences exists between the schedule impacts for the three risk categories.

Hypothesis Statement H2: No differences exists between the cost impacts for the three risk categories.

Results

Descriptive Testing

Descriptive analysis of the sample size was done to answer the first research question. The descriptive for three risk categories; Early Resolved Risk, On-time Resolution, and Prolonged Risk, are provided in table 1 below. Table 1 shows that almost half the times the risks were prolonged on construction projects; that is these risks were not resolved on the planned risk resolution date. While the rest half of the time, the risk were resolved either early or on time. Furthermore, the risks that were prolonged had a median of 150%. This shows that almost 50% of risk prolonged took at least 2.5 times more time to be resolved than initially planned.

Table 1

Descriptive for risk categories

	N	% of total	Max.	Min.	Mean	Median	Std. Dev.
Early Resolved Risk	147	18%	-1.00%	-100.00%	-45.56%	-40.00%	30.554%
On-time Resolution	281	35%	0.00%	0.00%	0.00%	0.00%	0.000%
Prolonged Risk	378	47%	10300.00%	2.00%	448.66%	151.00%	924.735%

Inferential Testing

To answer the second research question, inferential testing was used. Kruskal-Wallis H test was used as an inferential test to determine the impact on schedule of the project due to risk prolongation. Kruskal-Wallis H test compares the median value amongst the group and the spread of values (shape of the box plot) in each category. Because the median value for every risk categories were same (median = 0%), therefore, the spread in values were compared. Table 2 below shows no statistical significant difference exist between the medians and the spread of the values amongst the three groups.

Table 2

Kruskal-Wallis H test for schedule impact with risk categories

	N	Max	Min	Mean	Median	Stn. Dev.	p-value
Early Resolved Risk	147	346.15%	-4.55%	12.21%	0.00%	39.36%	
On-time Resolution	281	233.33%	-9.09%	10.35%	0.00%	54.91%	0.504
Prolonged Risk	378	618.92%	0.00%	12.92%	0.00%	57.76%	

*Significant at 0.05

Similarly, Kruskal-Wallis H test was used to determine the impact on cost of the project due to risk prolongation. The test was used to compare if the median value for each of the three categories were different for each other. Table 3 below shows the result from the test conducted. The test was statistically significant at p-value of 0.048, at 0.05 level of significance. Although, the median for all the three categories were same (0%), the result for the inferential test conducted showed that the three categories were different from each other. This difference could be because of the spread in values (shape of the box plot) for the three categories. Further analysis was conducted to determine where the difference lies.

Table 3

Kruskal-Wallis H test for cost impact with risk categories

	N	Max	Min	Mean	Median	Stn. Dev.	p-value
Early Resolved Risk	147	88.19%	-0.22%	1.79%	0.00%	8.06%	
On-time Resolution	281	128.39%	-5.18%	2.13%	0.00%	9.69%	0.048*
Prolonged Risk	378	25.39%	-0.58%	0.95%	0.00%	3.32%	

*Significant at 0.05

Mann-Whitney U test was conducted as a post hoc test to determine the in-group difference between the three risk categories for cost. Table 4 below shows the results from the test conducted. A statistically significant difference exists between Prolonged Risk and On-time Resolution with p-value of 0.020, at 0.05 level of significance. Although the median of both the group was 0%, therefore, the test conducted compares the spread of values for both the categories were compared. The mean values were used to compare the significance between the two categories.

The mean cost increase for On-time Resolution (2.13%) was found to be significantly more than the mean cost increase for Prolonged Risk (0.95%).

Table 4

Mann-Whitney U test for cost impact with risk resolution period

Factor 1	Median	Factor 2	Median	p-value
Early Resolved Risk	0.00%	On-time Resolution	0.00%	0.086
Early Resolved Risk	0.00%	Prolonged Risk	0.00%	0.800
Prolonged Risk	0.00%	On-time Resolution	0.00%	0.020*

*Significant at 0.05

Discussions

The descriptive analysis of the risk categories shows that almost half the time the risks in the project were prolonged. Even so, 50% of the risks were prolonged for more than 2.5 times then the original resolution period. Such high numbers can be explained due to a couple of reasons. Firstly, the risk reporting for these projects were setup in a way that the contractor was obligated to update the risk report every week for any risk that was being actively managed. When these risks were entered, the contractor usually provided the shortest resolution period, which maybe un-realistic in order to please the client. Another reason could be the judging the intensity of risk wrongly by a contractor team. The contractor team although manages the risk actively but tries to respond to the risk with minimum involvement from company's official. At times, these risk are prolonged to such a point, where the team couldn't resolve the risk on its own and had to call in the company's official in order to resolve the risk.

Further analysis of the data set included the testing for effect of risk prolongation on the cost and the schedule of the project. The result from Kruskal-Wallis H test to find the effect of risk prolongation on impact to schedule of the project yielded no significant result. The researchers failed to reject the null hypothesis and therefore, $H1_0$ was retained; such that no differences exists between the schedule impacts for the three risk categories.

Lastly, the result for the impact on cost was found to be significant. The researchers rejected the null hypothesis and therefore accepted $H2_1$; such that a differences does exists between the cost impacts for the three risk categories. Analysis using post hoc test revealed a statistically significant result for Prolonged Risk and On-time Resolution. Although the median for both the categories were 0%, but the spread of values for both the categories led to a significant result. Hence, the mean was used to compare the two categories. The mean for On-time Resolution was 2.13% compared to 0.95% for Prolonged Risk. Although this shows that the cost impact was more for risk resolved on time, rather than risk which were prolonged. According to the researchers this anomaly could be due to a few reasons. Firstly, the sample size contains a lot of outliers for cost impact, with the maximum going as high as 128%, which mean that the one risk had a cost impact of more than actual cost of the project. Also, the other reason for such an anomaly could be inclusion of value added and innovative options as a risk categorized as On-time Resolution. As part of the procurement process for these project, the contractor was asked to provide a list of alternates which were not in the scope of the project, which may increase or decrease the cost of the project, while, increasing the quality and adding value to the project. Once accepted these were written down as On-time Resolution in the risk report. Because these risks always had a cost impact, at times even substantially higher cost impact than the actual cost of the project, can skew the mean values.

Conclusions

Every construction project has risks. These risks can be have a negative impact on the project (threat) or have a positive impact (opportunity). It is very important to identify these risk as early in the project as possible, so that the project team can prepare a response to each of the risk. However, when risks do occur on a project, these can impact the cost or schedule, or both, of the project. This study analyzes 806 risk from 190 different D-B-B projects from across the United States and Canada, filling the gap by analyzing the effect of risk prolongation on the cost and schedule impact on per risk basis. The analyses showed that almost half the risk in the project were resolved after the initially planned risk resolution date. The data set was further analyzed to determine if risk prolongation has any impact on the cost and schedule performance of the project. Inferential testing using Kruskal-Wallis H test revealed that there was no significant difference between the schedule impact for the risks which were prolonged or not. However, for cost the result was statically significant. Prolonged Risk was found to have a statistical significant difference from the On-time Resolution. From the mean and the spread of values, On-time Resolution had a higher cost impact than Prolonged Risk category. This may sound counter intuitive as one would expect a risk prolonged to have a higher cost impact, but because On-time Resolution category had many risks which were value added and innovative ideas, amounting in substantially high cost impact, skewing the data towards high mean value.

This study can be helpful to professional industry as well as adds value to the body of knowledge. The results of the study showed that risk if prolonged does not have any considerably different cost or schedule impact from those risk which were resolved on time or early. But, these risks analyzed were all being managed actively by the project team, hence, any unresolved risk was being discussed in the weekly meeting, taking up resources and time which could be utilized in other places of interest on the project. Early or timely resolution of risk can ensure proper utilization of time and resources on a project. The results for this study were limited to D-B-B project. Furthermore, no analyses was conducted for the source of the risk. Similarly, the data set analyzed construction, electrical, mechanical, and plumbing projects all together. These limitation will be the drivers of future study which would consist of 6000 risk from across 1000 D-B-B project.

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