The Impact of Project Type on Risk Timing and Frequency

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ABSTRACT

A great amount of research has focused on improving project risk management processes. However due to the uncertainty and variableness within building projects, past research has not been able to clearly identify the frequency and timing of risk impacts during projects. Further project risk mapping is necessary to understand the characteristics of when risks occur during projects. Understanding risk encounters on different project types can improve predictability of when risks occur during project schedules. This research captures risk management data from 229 Design-Bid-Build building projects over a seven year period. The projects encountered 1,229 risks during the construction phase that had the potential to delay the schedule or increase the cost of the project. An analysis of the risks encountered was able to identify the quantity of risks identified accordingly to the originally planned schedule. The analysis provides a histogram that improves the ability to identify the timing and frequency of project risks during building projects. A discussion on the observations found in the research is presented. The objective of this paper is to determine if the project type has influence on the frequency and timing of the risks.

INTRODUCTION

The perception of the construction industry continues to weaken because of the risks involved with the nature of the industry. The National Institute of Governmental Purchasing and the Institute of Supply Management gathered 557 responses from its members and discovered that, among all goods and services purchased, construction contracts are perceived as having the greatest overall occurrence of problems (Davison & Sebastian, 2009a), and, as being the most likely to experience problematic consequences (Davison & Sebastian, 2009b).

Managing project risk is considered to be a critical skill set for today’s project managers, in as much as associations such as Project Management Institute (PMI) and the Association for Project Management (APM) consider project risk management as one of their core competencies. PMI’s objective with project risk management states:
“the objective is to increase the probability and impact of positive events, and decrease the probability and impacts of negative events in the project” (PMBOK, 2010). Similarly with this article, risk is defined as an uncertain event that, if occurs, will affect the achievement of the projects objectives either positively or negatively (Hillson, 2009; Williams, 1995). Hillson (2009) explains that risks during projects create both opportunities (positive risks) and threats (negative risks) to success. With the increased complexity, size, and scope of today’s projects in the built environment (Dikmen et al., 2008) managing these threats and opportunities proactively becomes a critical skill set.

A key task within risk management is identifying risks. Tools such as risk assessments, planning checklists, management models, and guides are available to improve the identification of uncertainty by the project stakeholders (Taroun, 2013). Often these resources provide direction to identify the various types of risks that can be encountered during building projects but provide little guidance of when they will occur during the construction schedule. This paper aims to provide better understanding to when risks are encountered during the originally planned schedule. Data collected on 229 building projects at a large university in the United States during a seven year period identified 1,229 risks that had the potential to increase the project cost or delay the project schedule. The 1,229 risks are presented in this paper on a histogram of when they were identified accordingly to the originally planned schedule. This data provides better understanding of risk timing and frequency on the Universities capital building projects. The objective of this paper is to analyze and discuss the influence that the project type has on the risk occurrences during the project schedule.

LITERATURE REVIEW

It is said that construction is likely exposed to more risk than any other industry sector (Flanagan & Norman, 1993) and poor performance has been contributed to the failure with risk management (Loosemore et al., 2006; CII, 1995). The risky nature of construction has caused many researchers to focus on defining and improving risk management. The methods and objectives of risk management has been defined as the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact (Hubbard, 2009). With risk identification being the first objective of risk management a great amount of research is available on this subject.

The field of risk management in the construction industry is replete with literature regarding risk identification, planning checklists, management models, and guides to facilitate the process (Taroun, 2013; Batson, 2009). More specific tools related to risk identification are: brainstorming activities, retrospective analysis, risk breakdown structures, scenario analysis, SWOT analysis, expert interviews, (Hillson, 2003; Kendrick, 2003). Although many resources are available to the industry, checklists alone don’t provide the expertise needed for effective identification of project risks (Hillson, 2003). Improvements in research related to risk identification can improve the predictability of risks during building projects.
RISK PREDICTABILITY DURING THE CONSTRUCTION PHASE

Predictive tools such as the Probability-Impact (P-I) model, Fuzzy Sets Theory, and Analytical Hierarchy process have been available to the industry. Based on a literature review of the past 30 years of research on risk management modeling, Taroun found that the Probability-Impact (P-I) model is the most widely used despite its identified areas needing improvement (2013). With the P-I model, the probabilities are largely built upon professional opinions (surveys, interviews, etc.) and case studies or limited data sets. In some cases, the value of the probability could even be assumed rather than calculated. A concern with use of the current models could be regarding how to limit the subjectivity of their inputs in order to generate a more objective, practical risk prediction model.

While the idea of prediction in risk management is not new, there is limited literature relating to the application of mapping and forecasting of project risks in the construction industry. Few models have been applied, real-time, on a large data set of projects. The lack of a structure that models building project risk impacts has had adverse effects on projects, as projects are commonly late and over budget (Perrenoud & Sullivan, 2013; Flyvbjerg, B et al., 2002). Furthermore, this gap poses potential negative impacts to construction management decisions and pre-planning. If there was a way to predict risk impacts within building projects with a model and baseline of comparison, it would have positive implications and high value-added to the industry. The need for an approach to forecast project performance in regards to risk has been identified (Palomo et al., 2007). This risk prediction would be used to benefit the forecasting and pre-planning process, for multiple building project stakeholders.

Risk checklists identify what risks correlate to what activities during the construction phase and models seek to provide a more absolute determination as to how likely a risk is to occur (given a set of circumstances); however, both provide little validation as to the probability of when the risks will occur. There are realized benefits to using real project data over retroactive models and simulations (Meredith, 1998). Using real project data of when risks occurred in past projects can provide a baseline for construction managers and increases their ability to estimate when risks will be encountered during the project. This paper presents data that can serve as a benchmark for the construction industry in understanding when risks are encountered in the project schedule. The objective of the paper is to examine if and how the type of a project will influence when risks occurred throughout the project as a future basis for prediction. This would involve obtaining a large data set of project risks, plotting the risks over the projects’ timeline, and analyzing the relationship between risks encountered by project type.

DATA COLLECTION

During the years of 2005 and 2012, data was captured on new and renovation capital projects on the main campus at a large university in the Midwest United States. The data presented in this research is part of a wider study that involved introducing risk management tools within a construction organization. A data tool referred to as Weekly Risk Reports (WRR) captured extensive information related to the risks that were experienced during the construction phase. While this paper will
briefly describe the WRR, complete descriptions of the process and objectives of the WRR can be found in Sullivan et al. (2006) and Perrenoud and Sullivan (2013).

The WRR captured data on 229 Design-Bid-Build building projects during the seven years. A WRR was provided to the awarded contractor before the start of the projects. The contractor was responsible to maintain and update the risk report and it was validated and confirmed by the university’s project representative. Education related to consistent WRR management was provided by the research team. The WRR captured and measured the initial project conditions assigned in the awarded contract, including: project type, beginning construction date, planned completion date, and the original contract cost. All risks that were encountered during the project were recorded by the contractor in the WRR. Information required for each risk encountered, included:

- Date entered – The date in which the risk was encountered.
- Risk category – Type of risk are identified and categorized.
- Risk details – Detailed information of the risk, what the plan was to mitigate the risk, individual(s) responsible to mitigate the risk, risk impact assessment, and weekly updates to the status of the risk and the plan to mitigate the risk.
- Planned resolution date – The planned date that the risk would be resolved.
- Actual date resolved – The actual date that the risk was resolved.
- Impact to overall project duration – The resulting impact of the risk to the project schedule (in number of days).
- Impact to overall project cost – The resulting impact of the risk to the project cost.
- The client PM satisfaction rating – The client’s project managers level of satisfaction with the contractor’s performance related to the risk.

The risks that were collected in the WRR were combined and analyzed by the author. The risk encounters or the time in which the risks were identified on the WRR were captured by equation 1. With this equation, it is clear to see the relationship between the schedule progress of a particular project and correlate it with the time in which a risk was identified on that project.

\[
\text{RISK ENCOUNTER}_{RE} = \frac{OCD - BCD}{RID} \tag{1}
\]

*OCD = original completion date; BCD = beginning contract date; RID = risk identification date.

**PROJECT TYPE**

The data collected in the 229 WRR were transferred into one file for statistical analysis. In total 1,229 individual risks were recorded on the 229 projects, an average of 5.4 risks per project. Table 1 presents the types of the projects that were recorded at the university. In this paper project type is defined by the type of project and the specialty of the contractor awarded the project. This paper focuses on building projects at the university, the capital department distinguished the project by type due
to the nature of the project. Electrical, mechanical, and roofing projects included one awarded contractor as general construction included various subcontractors (Ndekguri & Turner, 1994). The majority of the building projects (65%) were general projects which were awarded to general contractors, which may or may not include specialty subcontractors. The remaining 35 percent of the projects were awarded directly to specialty contractors: (17%) electrical; (14%) mechanical; and (4%) roofing.

### Table 1. Background Data

<table>
<thead>
<tr>
<th>Description</th>
<th>Overall</th>
<th>General</th>
<th>Electrical</th>
<th>Mechanical</th>
<th>Roofing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Projects</td>
<td>229</td>
<td>149</td>
<td>38</td>
<td>32</td>
<td>10</td>
</tr>
<tr>
<td>Awarded Cost (In Millions)</td>
<td>$79.0</td>
<td>$59.9</td>
<td>$5.7</td>
<td>$8.6</td>
<td>$4.8</td>
</tr>
<tr>
<td>Original Schedule (Days)</td>
<td>18,135</td>
<td>11,317</td>
<td>2,511</td>
<td>3,550</td>
<td>757</td>
</tr>
</tbody>
</table>

During the projects, the contractors’ encountered 1,229 different issues that were recorded on the WRR. The project stakeholders were able to resolve 218 of the risks so that they impacted neither the project schedule nor the cost. However, as can be seen in Table 2, 51 percent of the projects experienced risks that increased the project cost and 54 percent of the projects’ schedules were delayed. Overall, the cost of the projects was increased by eight percent and the overall delay rate was 39 percent during the construction phase.

### Table 2. Project Deviation Data

<table>
<thead>
<tr>
<th>Description</th>
<th>Overall</th>
<th>General</th>
<th>Electrical</th>
<th>Mechanical</th>
<th>Roofing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projects with cost increase</td>
<td>51%</td>
<td>59%</td>
<td>24%</td>
<td>28%</td>
<td>50%</td>
</tr>
<tr>
<td>Overall change order rate</td>
<td>8%</td>
<td>8%</td>
<td>11%</td>
<td>6%</td>
<td>8%</td>
</tr>
<tr>
<td>Projects that were delayed</td>
<td>54%</td>
<td>58%</td>
<td>29%</td>
<td>47%</td>
<td>60%</td>
</tr>
<tr>
<td>Overall delay rate</td>
<td>39%</td>
<td>50%</td>
<td>30%</td>
<td>25%</td>
<td>72%</td>
</tr>
</tbody>
</table>

### DATA ANALYSIS AND DISCUSSION

Figure 1 presents the histogram of the risk identified in the projects, included is a trend line which shows the frequency of the risks during the schedule. From the collected information there were four observational consequences: 1) the largest peak of RE occurred during 20 and 30 percent of the original project schedule; 2) out of all of the large increases in RE, there appeared to be multiple dramatic spikes in RE during the project schedules; 3) a large spike in RE occurred towards the OCD; and 4) thirty percent of the RE occurred after the original completion dates (OCD). The data and discussion will be presented in this section of the paper.
This histogram presents an interesting and unique type of analysis and use of project data. With this information, the timing of risks on this project data set can be easily seen and examined. The dashed vertical line represents the projects’ original completion dates (OCD) (drawn at 100 percent). The first observational consequence can be seen that the maximum number of risk encounters occurred during 20 – 30 percent of schedule. Due to the nature of building projects the data reflects a large amount of issues occurring in the beginning of the project. This large amount of RE can be attributed to: low scope definition; scope changes; unknown site conditions; and other issues experienced earlier in projects. The overall trend line presented in Figure 2 shows one large peak during 20 to 70 percent of the project, but looking at the moving average of the risks impacts there appears to be common peaks in which risk impacts are seen. Future research can explore the multiple peaks observed in the histogram. The second observation was the multiple peaks in the risk encounters during the building project, these peaks occurred at 20-30 percent, 60-75 percent, 90-100 percent, and 115-125 percent. These common occurrences of risk show that there are common periods during the project schedule that contractors identify and communicate project risks to project stakeholders. The third observation was seen with the peak in the last ten percent of the project schedule before OCD. This peak can be attributed to two factors: 1) contractors experiencing issues with the close out portion of the project; and 2) contractors delaying information from project stakeholders up until the end of the project, hoping that they would be able to resolve the issue before impacting the project. Future research can identify the characteristics of the risks that occurred during these first three observations to help identify the common issues that were seen during these peak periods of risk encounters.
The descriptive statistics of the Risk Encounters (RE), categorized by project type, are presented in Table 3. The mean RE value was 0.79, representing the average time that the risks were identified on the project schedules. The four different project types experienced similar risk encounter during the projects, ranging from 64 to 84 percent of the original schedule. The fourth (4) observations in this paper was that seventy percent of the risk encounters occurred up to the OCD with thirty percent of the risks being identified after the OCD, which can be seen in row seven and eight of Table 3. Although 46 percent of the projects were not delayed and completed on the OCD, thirty percent of the combined risks identified occurred after the OCD of the projects that had delays. The tail of the trend line in Figure 2 carries well past the OCD, as some of the projects experienced risks 160 percent further than the original completion date.

Table 3. Descriptive Statistics

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Overall</th>
<th>General Construction</th>
<th>Mechanical Project</th>
<th>Electrical Project</th>
<th>Roofing Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mean</td>
<td>.79</td>
<td>.79</td>
<td>.84</td>
<td>.79</td>
<td>.64</td>
</tr>
<tr>
<td>2 Median</td>
<td>.69</td>
<td>.68</td>
<td>.78</td>
<td>.70</td>
<td>.51</td>
</tr>
<tr>
<td>3 Count</td>
<td>1229</td>
<td>997</td>
<td>101</td>
<td>79</td>
<td>52</td>
</tr>
<tr>
<td>4 RE by 25%</td>
<td>18%</td>
<td>19%</td>
<td>15%</td>
<td>14%</td>
<td>17%</td>
</tr>
<tr>
<td>5 RE by 50%</td>
<td>36%</td>
<td>36%</td>
<td>33%</td>
<td>32%</td>
<td>48%</td>
</tr>
<tr>
<td>6 RE by 75%</td>
<td>54%</td>
<td>54%</td>
<td>49%</td>
<td>54%</td>
<td>32%</td>
</tr>
<tr>
<td>7 RE at 100% (OCD)</td>
<td>70%</td>
<td>69%</td>
<td>68%</td>
<td>75%</td>
<td>81%</td>
</tr>
<tr>
<td>8 RE after 100% (OCD)</td>
<td>30%</td>
<td>31%</td>
<td>32%</td>
<td>25%</td>
<td>19%</td>
</tr>
</tbody>
</table>

PROJECT TYPE DATA DISCUSSION

The influences of the project type versus the risk encounters were examined. Figure 2 shows the histogram for each the four project types. A similar trend line with a positive skew is seen among the four project types. The charts show that the largest peak occurs towards the beginning of the project with risks tapering off towards the OCD. The authors found very little to no difference between the four project types with regards to the four observations discussed earlier. As there were more General Building projects the histogram appears to be more complete comparing to the types such as the roofing projects that had less data available. Nevertheless there seems to be a multiple peaks within each project type, one occurring towards the beginning of the project and one occurring right at the OCD. From this analysis the authors are able to determine that project type had little influence on when risks are identified during building projects.
CONCLUSION

The implications of this research on understanding risk frequency and timing during building projects has the potential to positively impact the field of risk management in working towards future goals. A data set of 229 projects was analyzed regarding the influence that the project type has on the risk occurrences during the project schedule. Very little difference was found between the different project types that were studied. But the analysis uncovered four common observations among the projects, they were: 1) the largest number of risks were identified to occur during the period of 20 to 30 percent within the original schedule; 2) there was four common periods during construction that experienced an increase in the number of risks identified; 3) a large increase in risks identified were found to occur right before the original completion date; and 4) thirty percent of the risks identified during the projects occurred after the original completion date.

This research highlights the importance of proactive risk management throughout the project schedule and that there are common periods during the construction schedules that encounter risks. By providing real project data of when risks occurred in past projects, this research provides benefit to construction managers and increases their ability to estimate when risks will be encountered during the project. The research can serve as a benchmark for the construction industry in understanding when risks are encountered in the project schedule. Furthermore, this research will benefit academics and researchers in the field of risk management by providing a dataset of useful risk analysis and a study of the impact of project type on risk timing and frequency. Research and testing on this model in
other environments and project types would also be beneficial. Cross validation of this and future models for risk analysis would provide major advances in overall building project risk prediction.

REFERENCES