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COST GROWTH OF HEAVY INDUSTRIAL PROJECTS IN ALBERTA

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Abstract: Capital investment on heavy industrial construction projects in Alberta is expected to exceed $380 billion in the period of 2017 – 2027. However, companies make these investments in an environment that is subject to some of the worlds largest cost growth. This cost growth significantly reduces incentives for further investment in the industry. Thus, it is important to identify the factors contributing to cost growth in Alberta so that mitigating actions can be taken. The objective of this study is to determine which factors influence cost growth on heavy industrial construction projects in Alberta. Companies can focus their attention on these specific areas and factors to best reduce their risk of cost growth. The study is conducted in partnership with the Construction Industry Institute (CII) and the Construction Owners Association of Alberta (COAA) and uses information on 954 projects from Alberta and the United States. Statistically significant differences in project behaviours between Alberta and the United States are determined using inferential statistics such as ANOVA and Pearson correlation coefficients. The results of this analysis demonstrate clearly that projects in Alberta are much more susceptible to variations in cost growth due to both project characteristics and project management choices than projects in the United States. This provides guidance for ways in which heavy industrial construction projects in Alberta can be more effectively managed to help reduce cost growth. Implementing these recommendations could lead to greater cost competitiveness of heavy industrial projects in Alberta, and in turn, increased investment in the Alberta economy.

1 INTRODUCTION

Heavy industrial construction projects make up a large portion of Alberta's economy. Projects such as these are forecasted to make up to $380 billion in capital investments over the next 10 years (Doluweera, Kralovic, and Millington 2017). Unfortunately, these projects are built in an environment which experiences some of the highest cost growth in the world (Chanmeka et al. 2012; Robinson Fayek et al. 2006). Cost growth is the proportion increase in actual project costs compared to the initial budget. This outsized cost growth means that companies are more hesitant to invest in this economy as construction costs are unpredictable. Industry groups such as the Construction Owners Association of Alberta (COAA), and the government of Alberta have begun to seek remedy to this disproportionately large cost growth to increase investment in the industry (Jergeas and Ruwanpura 2010; Sondrol, Mulva, and Jergeas 2014). The objective of this study is to determine which factors influence cost growth on heavy industrial construction projects in Alberta.

This study makes use of data from 954 projects in Alberta and the US to determine which causes of cost growth are particularly important to projects found in Alberta. By benchmarking the performance of projects in Alberta to those in the United States, companies in Alberta can work to improve project performance. The data for this work comes from a database that has been built from 1999 to 2015 through a partnership with the Construction Industry Institute (CII), COAA and the University of Calgary. Inferential statistics are used to determine which factors have an outsized impact on cost growth in Alberta. With this information, projects in Alberta can more easily anticipate which projects should expect cost growth and make better decisions to reduce cost growth to increase the competitiveness of their firms and the industry in general.

2 LITERATURE REVIEW

Owner companies, constructor companies and governments are all interested in reducing cost growth on construction projects (Jergeas and Ruwanpura 2010). Therefore, a large amount of research has been conducted in this area. A literature review was completed to determine which factors that were available in the database might have an impact on cost growth. In this way, these factors could be analyzed using the information contained in the database to lend credibility and quantification of ideas found in literature, with a specific eye to impacts in Alberta.

2.1 Project Characteristics

It is useful to compare the performance of projects on oil and gas projects to those of non-oil and gas projects. Literature often focusses on cost growth in the construction industry as a whole (Flyvbjerg 2014; Lam, Chan, and Chan 2008), or compares heavy industrial construction against other industry groups (Hwang et al. 2009). However, some research suggests that oil and gas projects may experience higher cost growth than other heavy industrial projects (Jergeas 2008; Olaniran et al. 2015). This increased cost growth is blamed on the disproportionate size, complexity and remote locations of oil and gas projects, rather than some other innate characteristic of the project type.

Greenfield projects (new construction) and brownfield projects (sites with existing construction) are another way that literature categorizes projects. Research is divided in determining which projects would see higher cost growth. One study predicted that brownfield projects should have higher cost growth than greenfield projects (Shehu et al. 2014). Another study predicted the opposite, that greenfield projects would have higher cost growth due to land acquisition, clearance costs and other issues (Iyer and Banerjee 2016).

2.2 Owner's Procurement Choices

Project owners can choose from different combinations of delivery types and contract types to best execute their projects. Indeed, projects can be delivered in many different ways, but research rarely considers all options available to project management groups. However, the construction management at risk method is associated with the highest cost growth, while traditional design-bid-build projects are associated with the lowest cost growth, and design-build projects are found in the middle (Shehu et al. 2014). Other research mentions that design-build projects are generally more successful (Lam, Chan, and Chan 2008).

Research has also been done to determine relative success of cost reimbursable and lump sum type contracts. Indeed, the lump sum contract type is considered an important method of minimizing cost growth (Gosling, Naim, and Towill 2013; Johnson 1987). Work has been done on past projects in Alberta which determined that cost reimbursable contract types have lead to higher cost growth on heavy industrial construction projects (Elliott 2005).

2.3 Project Size

Larger projects have bigger budgets, longer durations and are also more complex. These larger projects are generally associated with higher cost growth (Flyvbjerg 2014; Jergeas and Ruwanpura 2010). The most obvious measure of project size, budget size, is commonly related to increased cost growth (Flyvbjerg 2014; Robinson Fayek et al. 2006; Skitmore and Ng 2003; Chanmeka et al. 2012). As project size increases, the management team's ability to predict the final price diminishes (Robinson Fayek et al. 2006). However, research on generally smaller projects in Malaysia found that the ideal size of a project, with lowest cost growth, was between 1 and 16 million USD (Shehu et al. 2014) where smaller projects have larger cost growth. The duration of construction is another factor related to the size of a project and is also generally associated with higher cost growth (Chanmeka et al. 2012; Skitmore and Ng 2003).

Larger projects also become more complex, which is another concept related to the predicted size of cost growth. More complex projects are expected to exceed their budgets more often than less complex projects (Chanmeka et al. 2012). Increased complexity resulting from a project's location or from a project's eventual function can impact design work which will also result in increased cost growth (Shane et al. 2009).

2.4 Engineering Quality

Engineering can also have an impact on a project's cost growth. When engineering deliverables, planning work and decision making is delayed, projects may suffer cost growth (Luu, Kim, and Huynh 2008). Errors in those deliverables may also cause cost growth (Shane et al. 2009). However, it is of utmost importance that engineering work is completed early in the project's lifespan (Jergeas 2008; Jergeas and Ruwanpura 2010; Faniran and Love 1999). Completing more of this work prior to authorization and prior to construction starts is associated with lower cost growth (Robinson Fayek et al. 2006).

Rework of construction can be caused either by poor engineering or construction mistakes, but either way it is associated with increased cost growth on projects (Jarkas and Bitar 2012). In fact, on heavy industrial projects, rework is a particularly important factor affecting cost growth (Hwang et al. 2009). One study found that rework is responsible for 52.1% of cost growth on construction projects (Love 2002).

3 METHODOLOGY

3.1 Data Collection

Data used in this study was collected directly from project documentation at hundreds of subject companies from 1999 to 2015. All data entered was validated by a team of researchers at the Construction Industry Institute (CII) and the Construction Owners Association of Alberta (COAA). This database contains information on 1265 projects in total. Of those, 853 projects are located in the United States while 101 of those projects are located in Alberta. The remaining 311 projects are located elsewhere around the world and are excluded from this analysis to facilitate meaningful comparisons between similar markets. All data was collected using the same rigorous set of definitions and requirements.

To ensure the highest quality data, the database was further inspected for unreasonable and outlier data on all variables. Unreasonable data includes cases where final project prices were identical to project budgets. Though unlikely to be removed by a traditional outlier analysis, these data points are unreasonable as some cost growth or reduction should be expected on all construction projects. Outliers were removed based on 3.0 standard deviations from means after unreasonable data had been removed.

All variables used in this study were either extracted directly from the database or generated using formulas to combine information from several different variables to create new ones. For this study, data is divided into categorical and continuous data types to ease explanation. In all cases cost growth acts as the dependent variable and was generated by combining several measures within the database.

3.2 Variables

3.2.1 Dependent variable

Cost growth was calculated according to equation 1. Positive values indicate an increase in cost over the initial budget while a negative value indicates a cost reduction. The budgeted amount was adjusted to account for intentional changes in scope so that an accurate comparison can be made between the final cost and the budgeted amount for that scope. The budget amount includes project contingency amounts and is set at the time of project sanction.

[1] Cost Growth = (Cost – Budget) / Budget

3.2.2 Project Characteristics and Contracting Styles

The project type variable separates projects into “oil and gas” and “non-oil and gas” project types. Oil and gas projects include projects such as oil sands mining projects, oil refining projects and tailings projects. Non-oil and gas projects are other types of heavy industrial projects such as chemical manufacturing plants, electrical generating projects and mineral mining projects,

Project nature describes the type of project that was undertaken from a different angle than the project type variable. In this case, projects can be identified as either new construction or construction on a site where previous work has been done. These two categories are called “greenfield” and “brownfield”. The brownfield project nature includes situations such as co-location, modernization, renovation or addition.

Project delivery method refers to the system of project execution that was primarily used on the project. This includes traditional design-bid-build, design-build (EPC), construction manager at risk, and parallel primes.

Project contract type is another decision that owners can make about how a project will run. This variable has only two options, lump sum or cost reimbursable. The cost reimbursable option includes contracts such as unit price. More granular data about contract type was not collected.

3.2.3 Project Size

The budget variable is used in the calculation of the cost growth dependent variable. However, prior to any analysis, the budget was adjusted for inflation and location of construction so that the data is normalized to Chicago 2013 (Choi, Yun, and Oliveira 2016).This reduces the potential for more recent projects to have artificially higher budgets compared with project completed earlier due to inflation. The location adjustment ensures that project budgets are reflective of their size regardless of local construction costs. Further, all budgets were normalized to United States Dollars (Choi, Yun, and Oliveira 2016) so that changes in currency did not affect the sizes of budgets.

The variable for planned construction duration was generated as a difference between the reported start date of construction and finish date of construction. Though the variable is generally normally distributed, there are higher frequencies of durations reported around even numbers of months of construction. When reporting durations of multi-year construction projects, it is understandable to report these durations to a month level of accuracy which explains this pattern. The planned duration of construction (as opposed to actual duration of construction) was used to reduce multicollinearity between this variable and the dependent variable. The presence of unplanned long duration construction periods would undoubtedly be correlated to cost growth, but this would not provide useful information and thus the actual duration of construction was excluded from the analysis.

The complexity of a project is a variable that exists as a native variable in this database. The variable is a self-reported estimate of the complexity of the project compared to other projects completed in the same industry sector. The measure can range from 1 to 7 (low to high complexity). Low complexity projects might include no unproven technology, a small sized project and previously used facility types and construction techniques. A highly complex project might use new construction methods, encompass a very large facility or production capacity or might make use of unproven technology.

3.2.4 Engineering Quality

Engineering deliverables include items such as responses to requests for information, project drawings and site investigation reports (Sondrol, Mulva, and Jergeas 2014). Both the timeliness and accuracy of these deliverables are variables in the database that can range from 1 to 7. The timeliness of engineering deliverables is measured on a scale from seldom to always being released in a timely manner to support construction operations. The accuracy of engineering deliverables is measured on a scale from seldom to always complete and accurate. Both variables are self reported estimates collected at the end of projects.

Percentage of engineering done before authorization and construction is a quantified measure of the number of hours of engineering completed prior to either authorization or construction, divided by the total number of engineering hours completed on the project. Authorization, also known as authorization for expenditure or project sanction, is the date on which management approves the project's scope, budget, and schedule. The start of construction is defined as the date on which construction of foundations or piling begins.

The rework factor variable is generated based on the value of rework on the project, divided by the total actual cost of the project. The value of rework is restricted to direct costs required to execute the rework itself. It is necessary to scale this variable to the project size as it is reasonable to expect that larger projects would experience more rework than smaller projects.

3.3 Data Analysis

Prior to running statistical tests on the data, it was cleaned in several steps to ensure that it best represented the conditions being tested by this study. Firstly, data was inspected for reasonableness to detect mis-entered data and times when data was entered despite quantities being truly unknown. This process removed data points which exactly matched other data points on the same projects (e.g. when budgeted costs exactly matched final costs to 7 or more significant figures). Data was then inspected on each variable for univariate outliers. Values exceeding 3.0 standard deviations were removed.

Data was split into Alberta projects, and those taking place in the United States so that projects in Alberta could be benchmarked against those in the United States. While projects in the United States experience an average of 0.074% cost growth, projects in Alberta experience an average of 6.2% cost growth. A summary of this data is shown in Figure 1.

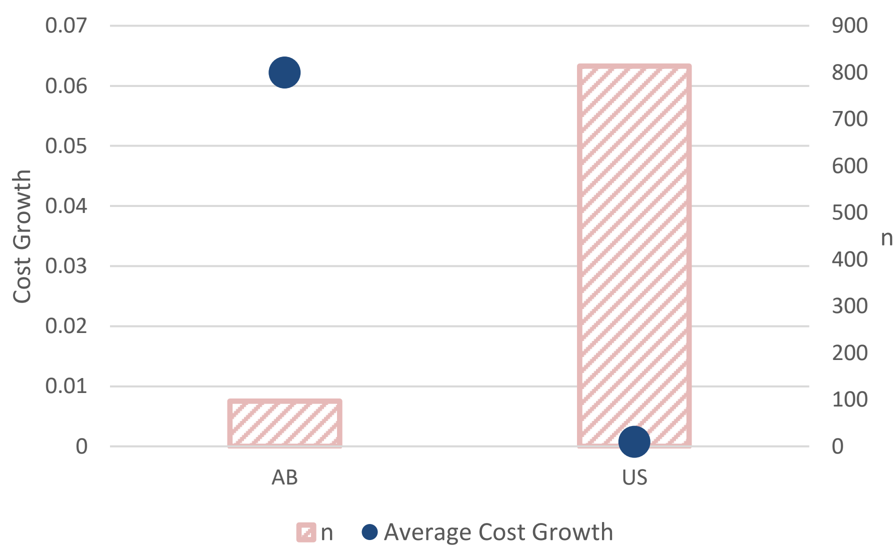

Figure 1: Sample size and average cost growth, US vs. Alberta

Continuous variables were analyzed against the cost growth dependent variable using a Pearson correlation coefficient. This test determines the degree of association between two continuous random variables such as those in this study (Decoursey 2003). The value obtained from this analysis was checked for statistical significance to determine if it was significantly different from zero. Statistical significance is met when the p-value is < 0.05 (two tailed test). If a statistically significant relationship was found for cost growth in both Alberta and the United States, a Fisher r-to-z transformation was performed to determine if these two correlation values were significantly different from each other.

Categorical variables were analyzed using a two-way ANOVA procedure to determine if the means of cost growth were different within and between the groups being analyzed. In this way, the root cause of differences could be identified as being based on location, based on the independent variable being measured, or based on a combined effect. In cases of 3 or more groups on the independent variable being tested, statistically significant interaction effects were further analyzed using Tukey's post hoc test to identify the sources of these different behaviours in cost growth.

4 RESULTS

4.1 Project Characteristics and Contracting Styles

Analyzing variables related to project characteristics and contracting styles produced results that are shown in Figure 2.

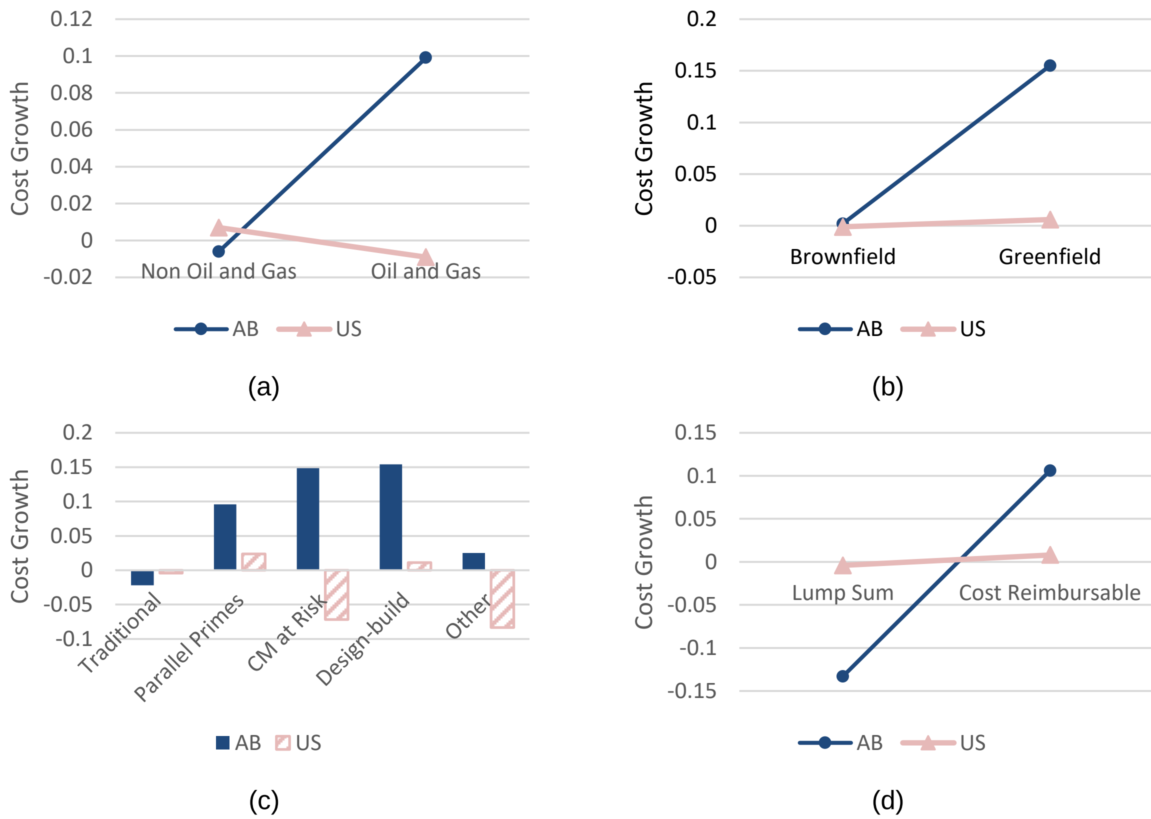

Figure 2: Cost growth by categorical variables:
(a) Project Type, (b) Project Nature, (c) Project Delivery Method, (d) Contract Type

The means of cost growth for different project types in Alberta and the United States with are shown in Figure 2(a). Analysis showed that even when accounting for differences in predominate project types, there is still a statistically significant difference between projects in the United States and Alberta ($p = 0.033$). The analysis also showed a statistically significant difference between project types ($p = 0.044$) with an average cost growth for oil and gas projects of 4.5%, and only 0.1% for non-oil and gas projects. There is also a statistically significant interaction effect between location and project type ($p = 0.007$). Oil and gas projects in Alberta have an average cost growth of 9.9% while the same projects in the United states have a cost growth of -0.1%.

The effect of project nature on cost growth for both Alberta and the United States is shown in Figure 2(b). Projects in Alberta and the United states still behave differently, even when accounting for the project nature ($p < 0.001$). Overall, at 8.0%, greenfield projects have a higher average cost growth than brownfield projects at 0.0% ($p < 0.001$). There is also a statistically significant interaction effect between these variables which makes the effect of higher cost growth for greenfield projects more pronounced in Alberta ($p < 0.001$).

Cost growth for different project delivery methods are shown in Figure 2(c). The differences between Alberta and the United states remain significant even with the effect of delivery method accounted for ($p < 0.001$). The delivery methods themselves also allow for significantly different cost growth values ($p = 0.014$). There is also a statistically significant interaction effect where the impact of project delivery methods is different in Alberta and the United States ($p = 0.012$).

The impact of contract type on cost growth in Alberta and the United States is shown in Figure 2(d). After accounting for the effect of contract type, there is still a significant difference in cost growth between Alberta and the United States ($p < 0.001$). The contract type itself does offer a significant difference in cost growth ($p = 0.026$). A statistically significant difference also exists for the interaction of location and contract type ($p = 0.021$).

4.2 Project Size

Project size variables were measured for correlation with project cost growth on Alberta and US based projects. These correlations were checked for statistical significance and are presented in Table 1.

Table 1: Impact of project size on cost growth

	Alberta			United States		
Variable	r	Sig.	n	r	Sig.	n
Budget amount	**0.268****	**0.010**	**92**	0.018	0.599	812
Planned Construction Duration	**0.541****	**0.000**	**64**	0.050	0.254	518
Complexity	**0.256****	**0.014**	**92**	**0.085***	**0.032**	**638**

*p < 0.05, **p < 0.01

This analysis shows a positive correlation between budget amount and cost growth in Alberta ($r = 0.268$, $p = 0.010$). This suggests that projects with higher initial budgets, on average, see larger cost growth. Although the relationship is statistically significant, only 7.2% of the variance in cost growth can be explained by the size of the budget. There was no significant relationship found in projects in the United States.

Planned construction duration shows a positive correlation with cost growth in Alberta ($r = 0.541$, $p < 0.001$). Projects that plan for a long construction duration see higher cost growth. 29% of the variance in cost growth can be explained by the duration of the construction phase. This effect was not statistically significant in the United States.

The complexity of projects shows a positive correlation with cost growth in both Alberta ($r = 0.256$, $p = 0.014$), and the United States ($r = 0.085$, $p = 0.032$). As projects become more complex, they experience higher cost growth. In Alberta, the complexity of a project explains 6.6% of the variance in cost growth, while the effect is less pronounced in the United States where complexity only explains just 0.72% of this variance. However, a Fisher r-to-z transformation was performed on these correlation coefficients which found that they are not significantly different from each other ($p = 0.119$).

4.3 Engineering Quality

Engineering quality variables were measured for correlation with project cost growth on Alberta and US based projects. These correlations were checked for statistical significance and are presented in Table 2.

The timeliness of engineering deliverables is negatively correlated to cost growth in Alberta ($r = -0.465$, $p < 0.001$). Projects with more timely submitted engineering deliverables, are more likely to have lower cost growth. The timeliness of engineering deliverables explains 22% of the variance in a project's cost growth. There was no statistically significant effect found in the United States.

Table 2: Impact of engineering quality on cost growth

	Alberta			United States		
Variable	r	Sig.	n	r	Sig.	n
Eng. Deliverables Timely	**-0.465****	**0.000**	**61**	-0.170	0.123	84
Eng. Deliverables Accurate	**-0.321****	**0.015**	**57**	-0.094	0.394	84
% Eng. before authorization	-0.231	0.115	48	-0.080	0.203	257
% Eng. before construction	**-0.536****	**0.000**	**52**	-0.070	0.253	265
Rework Factor	-0.251	0.299	19	**0.206****	**0.001**	**242**

$^*p < 0.05$, $^{**}p < 0.01$

The accuracy of engineering deliverables was also found to be important in Alberta as it is negatively correlated with cost growth $r = -0.321$, $p = 0.015$. More accurate engineering deliverables are seen on projects with lower cost growth. The accuracy of engineering deliverables explains 10% of the variance in cost growth. There was not a statistically significant effect in the United States.

The percent of engineering workhours done before construction is started was negatively correlated with cost growth $r = -0.536$, $p < 0.001$. This effect was only observed in Alberta. When a higher percentage of engineering work hours are completed before construction, cost growth is significantly lower. Interestingly, there was no statistically significant effect observed for percentage of engineering workhours completed before project authorization. Further, this relationship was not observed in the United States.

In the United States, the rework factor is positively correlated to cost growth, $r = 0.206$, $p = 0.001$. Projects on which rework costs make up a larger portion of the budget see higher cost growth. The rework factor explains 4.2% of the variance in cost growth. This effect was not observed in Alberta.

5 DISCUSSION AND CONCLUSION

The results from this analysis allow for many useful conclusions about the causes of cost growth on heavy industrial construction projects in Alberta. Projects in Alberta experience much higher cost growth than projects in the United States (6.2% vs. 0.074%). While some factors of a project that cannot be changed do have an influence on this cost growth, there are also many factors that can be changed by the project team that have a significant impact on cost growth, especially in Alberta.

Project type and nature influence cost growth on these heavy industrial projects. These are two elements innate to a project that are unchangeable by the project team. For instance, a greenfield oil and gas project in Alberta could expect to experience much higher cost growth than a brownfield non-oil and gas project in the United States. While these factors help explain why some projects have higher cost growth than others, their utility is limited for project managers because project teams cannot often choose what type or nature of project they would like to execute.

On the other hand, there are many variables identified in this study that project teams do have some control over that can have significant impacts on the likelihood of cost growth. The project delivery method and contract type are two decisions that project teams must make during project execution. In Alberta, project teams looking for lower cost growth should make better use of lump sum contracts and traditional design-bid-build delivery systems. The effect is much less pronounced in the United States, but in this case, projects run with a construction manager at risk would be associated with having a lower cost growth.

Larger, longer and more complex projects are all associated with higher cost growth in Alberta. These are all factors that are commonly cited in the definitions of megaprojects (Flyvbjerg 2014; Jergeas and Ruwanpura 2010). As Alberta projects become more like megaprojects, they experience higher cost growth. Although these factors may seem unchangeable, project management teams do have the option of breaking up projects into smaller areas with smaller budgets, shorter durations and less complex execution. These adjustments would likely lead to lower cost growth according to the relationships found in this study.

The quality of engineering on a heavy industrial construction project also has a significant impact on cost growth in Alberta. More timely engineering deliverables and more accurate engineering deliverables are both associated with lower cost growth. Additionally, when more engineering is completed before construction, cost growth is generally lower. These factors highlight the importance of quality engineering being completed well before it is used in the field for construction. Certainly, the common process of fast-tracking leads to higher cost growth in Alberta. Further, poor-quality engineering is one factor leading to rework (construction mistakes being the other) so it can be seen that good quality engineering is also important to reduce cost growth in the United States where rework significantly impacts cost growth. Without making any claims about the quality of engineering in Alberta, this research shows that, in general, varying quality of engineering has a bigger impact on project cost growth than in the United States.

In short, project management decisions that have the greatest ability to increase cost growth are the same decisions most commonly associated with shortening project planning durations. These expensive, but time-saving decisions include:

- Using cost reimbursable contracts which require limited project definition,
- Using design-build delivery methods that only require one interface between the owner and their contractors,
- Completing work as one large, long, complex project instead of several smaller projects, and
- Fast-tracking project execution with minimal engineering completed.

It appears that projects in Alberta are particularly susceptible to the risk of increasing costs when making these time-saving decisions. So, counterintuitively, while projects in Alberta have the greatest ability to control cost growth by using these project management decisions, these projects also have the greatest cost growth. This suggests that either poor decisions have been made on these Alberta projects, or that cost control may not be the primary objective of these projects. If project management teams in Alberta are seeking lower cost growth, there are many options available to them as demonstrated by this research. The impact of these decisions will be much larger than it would be in the United States. However, each of these decisions requires sacrificing some speed of execution from planning to construction.

References

Chanmeka, Arpamart, Stephen R. Thomas, Carlos H. Caldas, and Stephen P. Mulva. 2012. “Assessing Key Factors Impacting the Performance and Productivity of Oil and Gas Projects in Alberta.” *Canadian Journal of Civil Engineering* 39: 259–70. doi:10.1139/l11-128.

Choi, Jiyong, Sungmin Yun, and Daniel P De Oliveira. 2016. “Developing a Cost Normalization Framework for Phase-Based Performance Assessment of Construction Projects.” *Canadian Journal of Civil Engineering* 1086 (October): 1075–86. doi:10.1139/cjce-2016-0223.

Decoursey, William. 2003. *Statistics and Probability for Engineering Applications*. Elsevier Science.

Doluweera, Ganesh, Paul Kralovic, and Dinara Millington. 2017. “Economic Impacts of Canadian Oil and Gas Supply in Canada and the US (2017-2027).” Calgary.

Elliott, Bruce. 2005. “Project Historical Databases for the Canadian Oilsands.” *AACE International Transactions EST.02 Project*, 1–5.

Faniran, Olusegun O, and Peter E D Love. 1999. “Optimal Allocation of Construction Planning Resources.” *Journal of Construction Engineering & Management* 125 (5): 311. doi:10.1061/(ASCE)0733-9364(1999)125:5(311).

Flyvbjerg, Bent. 2014. “What You Should Know about Megaprojects and Why: An Overview.” *Project Management Journal* 45 (2): 6–19. doi:10.1002/pmj.21409.

Gosling, Jonathan, Mohamed Naim, and Denis Towill. 2013. “Identifying and Categorizing the Sources of

Uncertainty in Construction Supply Chains.” *Journal of Construction Engineering and Management* 139 (1): 102–10. doi:10.1061/(ASCE)CO.1943-7862.0000574.

Hwang, Bon-Gang, Stephen R Thomas, M Asce, Carl T Haas, and Carlos H Caldas. 2009. “Measuring the Impact of Rework on Construction Cost Performance.” *Journal of Construction Engineering and Management* 135 (3): 187–98. doi:10.1061/ASCE0733-93642009135:3187.

Iyer, K. Chandrashekhar, and Partha S. Banerjee. 2016. “Measuring and Benchmarking Managerial Efficiency of Project Execution Schedule Performance.” *International Journal of Project Management* 34 (2). Elsevier Ltd and Association for Project Management and the International Project Management Association: 219–36. doi:10.1016/j.ijproman.2015.10.008.

Jarkas, Abdulaziz M., and Camille G. Bitar. 2012. “Factors Affecting Construction Labour Productivity in Kuwait.” *Journal of Construction Engineering and Management* 138 (July): 811–20. doi:10.1061/(ASCE)CO.1943-7862.0000501.

Jergeas, George F. 2008. “Analysis of the Front-End Loading of Alberta Mega Oil Sands Projects.” *Project Management Journal* 39 (4): 95–104. doi:10.1002/pmj.

Jergeas, George F., and Janaka Ruwanpura. 2010. “Why Cost and Schedule Overruns on Mega Oil Sands Projects?” *Practice Periodical on Structural Design and Construction* 15 (1): 40–43. doi:10.1061/(ASCE)SC.1943-5576.0000024.

Johnson, Dwight R. 1987. “Lump-Sum Contracting: An Owner’s Perspective.” *Cost Engineering* 29 (2).

Lam, Edmond W., Albert P. Chan, and Daniel W. Chan. 2008. “Determinants of Successful Design-Build Projects.” *Journal of Construction Engineering and Management* 134 (5): 333–41. doi:10.1061/(ASCE)0733-9364(2008)134:5(333).

Love, Peter E. D. 2002. “Influence of Project Type and Procurement Method on Rework Costs in Building Construction Projects.” *Journal of Construction Engineering and Management* 128 (1): 18–29. doi:10.1061/(ASCE)0733-9364(2002)128:1(18).

Luu, Van Truong, Soo Yong Kim, and Tuan Anh Huynh. 2008. “Improving Project Management Performance of Large Contractors Using Benchmarking Approach.” *International Journal of Project Management* 26 (7): 758–69. doi:10.1016/j.ijproman.2007.10.002.

Olaniran, Olugbenga Jide, Peter E.D. Love, David Edwards, Oluwole Alfred Olatunji, and Jane Matthews. 2015. “Cost Overruns in Hydrocarbon Megaprojects: A Critical Review and Implications for Research.” *Project Management Journal* 46 (6): 126–38. doi:10.1002/pmj.

Robinson Fayek, Aminah, Stephen O. Revay, Doug Rowan, and Donald Mousseau. 2006. “Assessing Performance Trends on Industrial Construction Mega.” *Cost Engineering* 48 (10): 16–21.

Shane, Jennifer S., Keith R. Molenaar, Stuart Anderson, and Cliff Schexnayder. 2009. “Construction Project Cost Escalation Factors.” *Journal of Management in Engineering* 25 (4): 221–29. doi:10.1061/(ASCE)0742-597X(2009)25:4(221).

Shehu, Zayyana, Intan Rohani Endut, Akintola Akintoye, and Gary D. Holt. 2014. “Cost Overrun in the Malaysian Construction Industry Projects: A Deeper Insight.” *International Journal of Project Management* 32 (8). Elsevier Ltd and IPMA: 1471–80. doi:10.1016/j.ijproman.2014.04.004.

Skitmore, R. Martin, and S. Thomas Ng. 2003. “Forecast Models for Actual Construction Time and Cost.” *Building and Environment* 38 (8): 1075–83. doi:10.1016/S0360-1323(03)00067-2.

Sondrol, Larry, Stephen Mulva, and George Jergeas. 2014. “Alberta Report # 2 COAA Major Projects Performance Assessment System Project Performance Engineering Productivity Construction Productivity.” *Construction Owners Assocation of Alberta*. Edmonton.