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BEST PRACTICES IMPACTING THE COST PERFORMANCE OF HEAVY INDUSTRIAL PROJECTS

Robu, Mihai[1,2], Sadeghpour, Farnaz[1], and Jergeas, George[1]

[1] Department of Civil Engineering, University of Calgary, Canada

[2] mrobu@ucalgary.ca

Abstract: The heavy industrial sector is a significant contributor to Canada's economy. However, cost overruns are often experienced during the project delivery of heavy industrial facilities which impacts the organization and industry. Project management literature suggests that the implementation of management practices is one of the factors that can positively influence project success. As different management practice may have an impact on different phases of a project, this study will consider individual phase cost performance (front-end planning, detailed engineering, procurement, construction, commissioning) as opposed to overall project cost performance. The objective of this study is to identify which practices are associated with each phase's cost performance. Project data on 1,015 heavy industrial projects from Canada and the United States will be analyzed. Descriptive statistics will be used to show the cost characteristics of each phase. Inferential statistics such as *t*-tests, Pearson's correlation, and their non-parametric equivalents will be used to determine relationships between practices and phase cost performance. Knowledge of which phase a practice can impact aids practitioners in selecting the appropriate practices. The results of the study also highlight that management practices are not associated with better cost performance in every phase. Therefore, management practices may be combined in such a way that all phases can benefit from increase performance.

1 Introduction

The heavy industrial sector is comprised primarily of chemical manufacturing, electrical generation, metal refining, mining, oil and gas exploration/production/processing, pulp and paper manufacturing and other activities (CII 2012). Based on this definition, Canada's heavy industrial sector accounts for almost half of the GDP of its goods-producing industries (Statistics Canada n.d.a) and employs over 600,000 persons (Statistics Canada n.d.b). This sector depends on its facilities for processing materials, however these facilities often experience cost overruns during project delivery as evidenced by Alberta's oil and gas projects (Fayek et al 2006, Jergeas and Ruwanpura 2010). Poor project delivery of capital projects can have a negative impact on the organization undertaking the project and prevents the industry from reaching its full potential. Some studies suggest that poor management is one of the factors contributing to these cost overruns (Chanmeka et al 2012, Jergeas 2008, McTague and Jergeas 2002) and that the implementation of practices is a major contributor to better performance (Palmer and Mukherjee 2006). A number of studies have attempted to quantify the relationship between management practices and project cost performance, but most are not specific to heavy industrial projects and in some cases their results do not concur. Unlike previous studies, this paper will investigate the relationship between practices and phase cost performance exclusively for heavy industrial projects. To achieve this, project data from a pool of 1,015 Canadian and US projects will be analyzed using inferential statistics to determine the impact of a number of project management best practices on the cost performance of each phase. Understanding which practices can impact particular phases can help practitioners in implementing the practice that best addresses their organization's needs. For example, if the company has been repeatedly overbudget in its procurement phase, they may consider implementing a practice that specifically targets the procurement phase's cost performance. The practices considered in this study are introduced in the next section.

2 Best Practices in Project Management

Best practices are procedures and processes that can take many different forms, but all share the common goal of reducing risk and making project success predictable. Some practices are one-time events during the project whereas others are on-going throughout project delivery. Each of the practices analyzed in this study will be defined below and the findings of previous research on will be discussed as it relates to cost performance. The definitions of each practice are based on the CII Large Project Questionnaire (CII 2012).

Front-end planning is the first phase of a project, but it is also the phase where the majority of best practices are performed. The purpose of this process is to develop a plan for executing the project successfully. It includes selection of the project team, project attributes (technology, site, scope), and alternatives. Literature agrees that greater effort and attention to front end planning is associated with lower cost growth (Chanmeka et al. 2012, Kang et al. 2013a, Kang et al 2013b, Pocock et al. 1996, Suk et al. 2016). A number of practices can be performed during this phase. One of these practices involves inviting the contractors (design or construction) to participate in the front-end planning practice. This may benefit the owner by including the design and construction perspectives in planning and developing project alternatives. Participation of contractors in the front-end planning process has not been explicitly studied in literature. Alignment during front-end planning is another practice in which project participants gain a mutual understanding of the project objectives. Literature generally finds that this practice is associated with reduced cost growth (Kang et al 2013a, Suk et al. 2016) though not all studies find this to be the case (Chanmeka et al. 2012). The last practice considered in the front-end planning phase is how clearly the operations and maintenance philosophy is communicated during this phase. This practice has not received much attention in literature to date.

The degree of scope definition is also one of the practices that will be studied. In this paper, the Project Definition Rating Index (PDRI) developed by CII will be used to measure the degree of scope definition. Studies using PDRI as a measurement of scope definition found better scope definition to be related to better cost performance (Chanmeka et al. 2012, Cho et al. 2009, Suk et al. 2016) and was also a significant factor used in neural network models for predicting cost performance (Kang et al 2013a, Wang and Gibson 2010).

Partnering agreements are commitments between two or more organizations involved in the project that prioritizes collaboration and trust over organizational boundaries. The intent is that the organizations involved can utilize their resources more efficiently and focus on achieving shared goals. Literature suggests that partnering has a positive impact on project cost performance (Pocock et al. 1996, Suk et al. 2016).

Team building is a formal process that trains project participants in collaborative problem solving. The process is meant to minimize barriers and build trust between project stakeholders so that the main focus is on delivering the project. Previous studies suggest that team building is not significantly associated with improved cost performance (Chanmeka et al. 2012, Suk et al. 2016).

Risk assessment and risk mitigation are practices that go hand-in-hand. Risk assessment focuses on identifying situations and scenarios that may impact the achievement of project objectives, whereas risk mitigation involves developing strategies for managing the risks identified through assessment. Most studies focus on risk assessment and results are conflicting on its association with cost performance, with one study finding an association (Chanmeka et al 2012) and two studies finding no association (Kang et al. 2013a, Suk et al. 2016).

Constructability involves the integration of construction knowledge into the planning, design, and construction of a project in order to make the construction process more cost-effective and fast. In this study the development of the plan, its integration, and its success are studied with respect to its impact on cost performance. One study suggests that the potential benefits of constructability are not realized in practice (Jergeas and Van der Put 2001). Most studies on constructability did not find it to be associated with improved cost performance (Chanmeka et al. 2012, Jaselskis and Ashley 1991, Kang et al 2013a, Suk et al. 2016) though it was considered a significant predictive in a neural network model for predicting cost performance (Chua et al. 1997).

Change management consists of identifying, planning, and evaluating project changes in a structured way in order to manage change. This study considers if a documented change management process was used, how clearly it was detailed in the project contract, and how well project personnel understood the process. Literature on change management's impact on cost performance is inconclusive, with some studies showing a relationship (Kang et al. 2013a, Suk et al. 2016) and other studies not (Cho et al. 2009, Kang et al. 2013b).

The studies referenced above generally had low sample sizes which can make it difficult to determine if a significant relationship exists. Many of these studies do not focus explicitly on heavy industrial projects and in some cases the samples have a mixture of building, infrastructure, and industrial projects. Analyzing a combination of different project types has the potential to show different results than if only one type of project were considered. Furthermore, these studies considered the impact of practices on the project cost growth, as opposed to individual phases. As this study will show, the characteristics and behaviour of each phase is different so it may be necessary to study the impact of practices on each phase separately. This study will apply both parametric and nonparametric techniques to address any sample size issues, will consider only heavy industrial projects from Canada and the United States, and will analyze the impact of best practices on each phase separately. The definition of each of the five project phases is described in greater detail in the following section.

3 Project Phase Definitions

The five project phases are front-end planning, detailed engineering, procurement, construction, and commissioning. Table 1 shows the start and end points of each phase with the typical costs elements that are inluded. Owner personnel, and project manager/construction manager fees are common to every phase. The front-end planning, detailed engineering, and commissioning phase generally have human-related costs whereas the procurement and construction phase costs are related to the physical end product.

Table 1: Construction Project Phase Definitions

Phase	Start	End	Cost Elements
Front End Planning (FEP)	Single project adopted and formal project team established	Project sanction	Consultant Fees & Expenses, Environmental Permitting Costs
Detailed Engineering (ENGG)	Contract award to engineering firm	Release of all approved drawings and specs for construction	Owner Project Management Personnel, Designer Fees
Procurement (PROC)	Procurement plan for engineered equipment	All major equipment has been delivered to site	Procurement & Expediting Personnel, Engineered Equipment, Transportation, Shop QA/QC
Construction (CONST)	Commencement of foundations or driving piles	Mechanical completion	Building Permits, Inspection QA/QC, Construction Labour, Equipment & Supplies, Bulk Materials, Construction Equipment, Warranties
Commissioning (COMM)	Mechanical completion	Custody transfer to user/operator	Consultant Fees & Expenses, Operator Training Expenses, Wasted Feedstocks, Vendor Fees

*Adapted from CII/COAA Benchmarking and Metrics Definitions Document (COAA and CII 2007)

4 Cost Characteristics of Project Phases

To conduct the analysis, cost data for each phase is extracted from a pool of 1,015 projects. Average cost performance for each phase (CP) can be calculated by dividing the actual phase cost by the budgeted phase cost for each project and taking the average of this ratio across all projects, as shown in Equation 1:

$$[1]\quad CP_i = \frac{\sum_{j=1}^{n} \frac{A_{ij}}{B_{ij}}}{n}$$

where *i* is the phase, *j* is the project, *A* is actual cost for project *j*, *B* is budgeted cost for project *j*, and *n* is the total number of projects for phase *i*.

Prior to investigating the relationship between practices and cost performance, it is useful to understand what percentage of the project budget each phase forms, and their respective cost performance. A summary of each phase is shown below in Figure 1; each bar represents the phase cost performance as calculated using Equation 1. Beneath each bar is the phase's proportion of the total project budget. The commissioning phase has the worst cost performance, at 15% overbudget on average. This may not have a large impact on the overall project, as it only forms about 4% of a project's budget on average. Front end planning, which is similar in size to commissioning has a much better cost performance than commissioning. Engineering forms the next largest part of the project budget and has a cost performance of approximately 11% overbudget – less than commissioning, but since it forms a larger part of the project budget it can have a greater impact on the overall project cost performance. Procurement accounts for one third of a project's budget and is on average 0.1% overbudget. This is because the 36% of projects that are overbudget in this phase are countered by the 60% of projects that are underbudget.

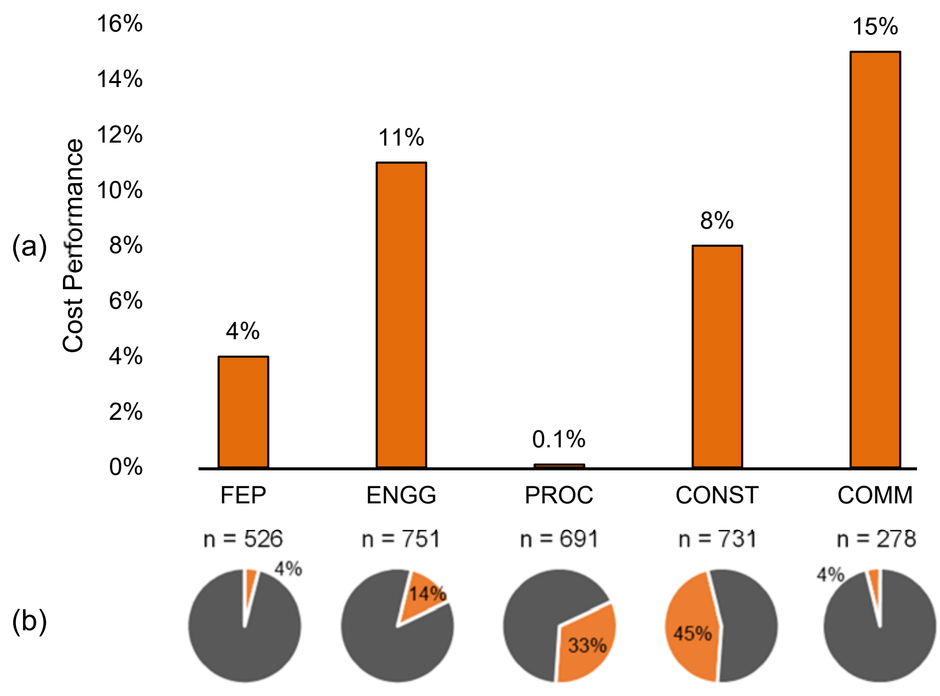

Figure 1: Project Phase Cost Characteristics (a) Cost Performance (b) Proportion of Budget

The results show that every project phase is overbudget on average, indicating that there are opportunities for improvement in cost performance. Improving performance is especially important for phases which form a large proportion of the project budget, such as construction, procurement, and engineering. The next section will investigate which practices are associated with each phase's cost performance.

5 Methodology

Data on best practices use is collected through the same questionnaire used for collecting project cost. Responses regarding practices are either yes/no or on a Likert scale measuring level of implementation or success. Inferential statistics is used to determine which practices are associated with the cost performance of each phase. It is very difficult to determine whether a practice is the direct cause of increased cost performance. The results of these types of analyses are not able to establish causation, but they indicate whether there is a relationship between a practice and the cost performance in each phase. Furthermore, the analyses used are bivariate, meaning that it compares only two variables at a time. As a result, it does not take into account overlap between practices. In other words, it would not be entirely appropriate to compare the practices against each other to determine which has the greatest impact. This would require a multivariate analysis such as multiple regression, however, listwise deletion greatly reduces the sample size and does not allow for these types of analyses.

Two different inferential tests are required for the way the data is structured. A comparison of means is used when comparing cost performance against a practice that was either implemented, or not implemented (dichotomous yes/no variable). Correlations are used to determine the relationship between cost performance and the implementation level or degree of success of a practice (measured on a Likert scale). For each type of test a parametric and nonparametric version will be conducted. This is done in order address low sample sizes and violations of certain assumptions such as the normality assumption, which preliminary analysis using the Shapiro-Wilks tests indicate is not met in almost all cases. Parametric tests such as the *t*-test and Pearson's correlation require that the data meet a number of assumptions in order to be reliable. These tests can be robust to a certain degree of deviation from the normality assumption but there is no exact threshold. In cases such as these it is sometimes recommended that nonparametric tests are used. These tests do not require assumptions regarding the distribution of the data and are generally not affected by outliers to the same degree as parametric tests. The disadvantage of nonparametric tests is that they lack statistical power, which means that an association that exists may not be detected. Lastly, these tests differ slightly in their hypotheses from parametric tests, which may also contribute discrepancies between the test results.

Table 2: Comparison of Parametric and Non-Parametric Techniques Used

Test Name	Test Type	Assumptions
Pearson's correlation (Parametric)	Measure of strength and direction of association of two continuous variables	1. Variables are ratio or interval level of measurement 2. Variables approximately normally distributed 3. Linear relationship between the two variables 4. Limited presence of outliers 5. Homoscedasticity
Spearman's Correlation (Nonparametric)	Measure of strength and direction of a monotonic association of two ranked variables	1. Variables are ratio or interval level of measurement
Independent Samples *t*-test (Parametric)	Comparison of means	1. One continuous dependent variable and one categorical independent variable with two groups 2. Dependent variable is normally distributed within each group 3. Homogeneity of Variance 4. Independent observations
Mann-Whitney U-test (Nonparametric)	Comparison of medians/mean ranks	1. One continuous or ordinal dependent variable and one categorical independent variable with two groups 2. Distribution of independent variable has the same shape for the two groups 3. Independent observations

Because every analysis is unique in terms of its sample size, and to ensure that a true association is detected, both parametric and nonparametric tests will be conducted. Results with significance levels of $p<0.05$ will be considered statistically significant in this study. If both the parametric and non-parametric analyses are significant, then the practice will be considered to have a significant association with cost performance. If, for example, the parametric test is significant at $p<0.05$ and the nonparametric test is significant at $p<0.10$, the practice will also be considered to have an association and vice versa. The differences in p-values between the tests can be due to a number of reasons – the presence of outliers, gross violations of the test's assumptions, low statistical power, and the difference in the hypothesis being tested. Cases such as these may require larger sample sizes and further investigation into the causes the difference. If a practice is identified as significant, its parametric values will be reported because nonparametric results are based on ranks and not as interpretable.

6 Practices Associated with Cost Performance

Statistical analyses were conducted for each practice and phase to determine which relationships were statistically significant. The results of the analyses are shown in Table 3 and discussed below.

Front-end participation is associated with on average 9% better engineering cost performance ($p<0.05$) and 10% better construction performance ($p<0.1$). Alignment during front end planning, however, did not appear to have a significant correlation. This suggests that the participation of project participants is sufficient, and alignment of participants towards a commonly understood set of project objectives is not associated with improvement in cost performance. However, the sample sizes for the alignment analysis are also quite low, which may partially explain the lack of significance. The findings on front-end planning match with previous studies that showed participation in front-end planning as being beneficial to cost performance. Alignment during front-end planning was not significant in this dataset, which coincides with studies that had a sample composed purely of heavy industrial projects. Studies that had a combination of project types, however, found that alignment was significantly associated with cost performance. Lastly, no association was found between how clearly the operations and maintenance philosophy was communicated. It may be that this practice is related to the success of the project after turnover, and therefore would not show a correlation with cost performance during project delivery. Previous studies did not consider this particular practice and its connection to cost performance.

Scope definition (PDRI) is associated with procurement and construction cost performance. Better scope definition as measured by PDRI score has a significant ($p<0.05$) correlation that is weak, bordering on moderate, in strength. These findings coincide with previous research that points to the importance of good scope definition on improving cost performance. For the engineering phase, the nonparametric test is almost significant with $p=0.051$ but the parametric test is far from significant with $p=0.277$, therefore scope definition was not considered to have a significant relationship with engineering cost performance. This is surprising as it would be expected that greater scope definition would result in fewer design modifications and in turn fewer cost overruns. Further investigation into possible outliers that may affect the parametric test results would be required.

Like scope definition, partnering agreements are also associated with better cost performance in procurement (11%) and in construction (18%). These findings coincide with previous research that points to the importance of a collaborative mindset on improving cost performance.

Team building is also associated with better engineering (5%) and construction (8%) cost performance. These findings are contrary to previous research on team building that did not find a significant association between team building and project cost performance. The two studies referenced had low sample sizes for team building, which may explain the lack of statistical significance.

Table 3: Correlation and Tests of Mean Differences Results

Best Practices		Project Phase									
		FEP		ENGG		PROC		CONST		COMM	
		Par	NPar	Par	NPar	Par	NPar	Par	NPar	Par	NPar
Front-end Planning	Δ means	0.073	**21.95***	**-0.087****	**-24.87****	-0.037	-6.25	**-0.096***	**-16.30***	0.046	-1.15
Participation	*p*-value	0.342	**0.058**	**0.018**	**0.007**	0.354	0.482	**0.056**	**0.061**	0.780	0.815
Difference of Means	n (Y/N)	109/9	**109/9**	**148/72**	**148/72**	140/68	140/68	**132/81**	**132/81**	42/20	42/20
Front-end Planning	Δ means	-0.132	-5.62	1.022	3.59	0.057	3.58	0.077	1.20	**0.280***	2.91
Alignment	*p*-value	0.116	0.187	0.160	0.485	0.464	0.477	0.531	0.827	**0.098**	0.475
Difference of Means	n (Y/N)	32/13	32/13	46/20	46/20	44/19	44/19	52/22	52/22	**26/10**	26/10
Front-end Planning	coefficient	-0.158	-0.026	-0.106	-0.078	0.186	0.164	-0.021	0.065	0.028	0.016
Project O&M Philosophy Clear	*p*-value	0.295	0.863	0.377	0.519	0.135	0.188	0.858	0.581	0.866	0.925
Correlation	n	46	46	71	71	66	66	74	74	39	39
	coefficient	-0.003	0.006	0.111	**0.198***	**.246****	**.285****	**.237****	**0.175***	-0.019	0.179
Scope Definition (PDRI)	*p*-value	0.981	0.961	0.277	**0.051**	**0.014**	**0.004**	**0.020**	**0.087**	0.918	0.319
Correlation	n	68	68	98	**98**	**99**	**99**	**96**	**96**	33	33
	Δ means	0.036	-0.84	-0.071	-4.82	**-0.115****	**-9.39***	**-0.185***	**-12.03****	-0.076	-3.64
Partnering Agreement	*p*-value	0.644	0.841	0.363	0.404	**0.031**	**0.087**	**0.079**	**0.038**	0.712	0.373
Difference of Means	n (Y/N)	15/26	15/26	21/57	21/57	**21/52**	**21/52**	**21/57**	**21/57**	15/29	15/29
	Δ means	-0.024	**-19.82***	**-0.047***	**-27.92****	-0.021	-6.02	**-0.076****	**-27.18****	-0.063	-5.63
Team Building	*p*-value	0.464	**0.060**	**0.094**	**0.032**	0.412	0.636	**0.022**	**0.033**	0.504	0.497
Difference of Means	n (Y/N)	203/92	**203/92**	**283/152**	**283/152**	287/144	287/144	**288/162**	**288/162**	120/74	120/74
Risk Management	coefficient	0.059	0.084	0.005	-0.001	-0.005	-0.027	**-0.192***	-0.141	-0.015	-0.024
Assessment Conducted	*p*-value	0.691	0.569	0.959	0.993	0.961	0.8	**0.059**	0.165	0.917	0.864
Correlation	n	48	48	92	92	89	89	**98**	98	53	53
Risk Management	coefficient	0.153	0.202	-0.108	-0.126	-0.083	-0.094	**-.278****	-0.166	-0.02	-0.148
Mitigation Implemented	*p*-value	0.359	0.224	0.359	0.284	0.481	0.421	**0.014**	0.149	0.896	0.331
Correlation	n	38	38	74	74	75	75	**77**	77	45	45
Constructability	Δ means	-0.048	**-20.84***	-0.051	**-17.69***	-0.048	-18.7	-0.064	-18.62	-0.001	-0.99
Plan Developed	*p*-value	0.212	**0.068**	0.124	**0.096**	0.144	0.163	0.104	0.147	0.995	0.913
Difference of Means	n (Y/N)	198/45	**198/45**	286/72	**286/72**	282/75	282/75	278/93	278/93	125/30	125/30
Constructability	coefficient	-0.091	-0.041	0.006	0.04	0.06	-0.09	**-.390****	**-.258****	0.033	-0.047
Integrated	*p*-value	0.599	0.813	0.963	0.765	0.651	0.494	**0.002**	**0.047**	0.849	0.788
Correlation	n	36	36	59	59	60	60	**60**	**60**	35	35
Constructability	coefficient	-0.31	0.019	-0.237	**-0.274***	-0.166	-0.196	**-.566****	**-.346****	-0.103	-0.131
Successful	*p*-value	0.109	0.923	0.132	**0.079**	0.288	0.209	**0.000**	**0.021**	0.623	0.531
Correlation	n	28	28	42	**42**	43	43	**44**	**44**	25	25
	Δ means	0.020	8.52	-0.082	-9.32	-0.040	-21.95	-0.156	-24.47	-0.161	-1.63
Change Management	*p*-value	0.750	0.597	0.233	0.706	0.489	0.308	0.110	0.200	0.539	0.895
Difference of Means	n (Y/N)	219/19	219/19	329/20	329/20	316/22	316/22	316/30	316/30	141/15	141/15

*Cells that are bolded indicate statistical significance; * $p<0.1$, ** $p<0.05$

Based on the criteria of both parametric and nonparametric tests being significant, risk assessment/ mitigation does not have a significant association with cost performance. Pearson's correlation shows that while conducting a risk assessment is associated with better cost performance (p<0.10), implementing the risk mitigation plan is even more strongly associated with better cost performance and is significant at a higher level (p<0.05). This indicates that conducting a risk assessment may be beneficial, implementing the risk mitigation plan appears to be even more beneficial to construction cost performance. A similar pattern can be seen with Spearman's correlation though the p-values do not meet the significance requirements. The findings are contrary to what would be expected of this practice, but the lack of significance may be due to the reduced statistical power of Spearman's correlation. Previous studies focused on risk assessment obtained differing results on its significance, which may be a result of the sample, method of measurement, or significance level chosen. More studies on the assessment and mitigation of risk may be required to reach a conclusion.

Simply having a constructability plan does not appear to have a significant association with cost performance. However, when constructability is integrated into the project execution plan, the association becomes significant (p<0.05) with moderate strength. If the project participants believe constructability to also be successful, the association is significant at an even higher level (p<0.01) and the correlation becomes strong. A correlation of constructability integration and success suggests that the two are strongly related and significant (p<0.001), suggesting that greater integration of constructability into the project execution plan may lead to constructability success. Constructability was not found to have a relation with cost performance in previous studies, perhaps because it does not have a strong or clear enough association with the overall project's cost performance or due to the way it was measured. More research into the various aspects and levels of implementation of constructability may be required to reach a conclusion on its association with cost performance.

Change management documentation was not found to be significantly associated with any of the phases. While it may not be associated with cost performance, it could have a relationship with other success measures such as schedule, quality, safety, or owner satisfaction. There were also very few projects that did not have a documented change management process, so the comparison to such a small group may have made it difficult to detect a significant difference. Literature on this practice is split on its association with cost performance. These differences may come down to the sample considered and the significance levels chosen.

7 Conclusion

This paper analyzed the phase cost characteristics of heavy industrial projects and identified the management practices impacting the cost performance of each phase. It is interesting to note that none of the practices were significantly associated with decreased cost performance – they were either positively associated or not associated at all. Table 4 summarizes the results of the analysis.

No relationships were found between the front-end planning and commissioning phases and the practices considered in this study. One explanation for front-end planning could be that many practices are conducted in the front-end planning phase, with the intended effect being on later phases. Other possible reasons for lack of statistical significance may be due to the low sample sizes or because the practices being considered are not intended to impact these two phases. Though these phases are on average overbudget and could benefit from practices to improve cost performance, they also form a small proportion of the budget, so controlling their cost is not as important as the construction phase, for example, which forms almost half of the project budget.

Table 4: Summary of Practices Associated with Cost Performance

Best Practices	Project Phase				
	FEP	ENGG	PROC	CONST	COMM
Front-end Participation		■		■	
Alignment During FEP					
Project O&M Philosophy					
Scope Definition (PDRI)			■	■	
Partnering Agreement			■	■	
Team Building		■		■	
Risk Assessment/Mitigation					
Constructability Plan				■	
Change Management					

*Cell is highlighted when significance is achieved for both parametric and nonparametric tests.

The engineering phase's cost ratio benefits from front-end participation and team building. This makes sense because there's generally a great deal of interaction between the designers and other stakeholders. Early participation and improved relationships brought about through team-building may contribute to streamlined engineering, fewer changes, and a more cooperative environment.

Procurement benefits from good scope definition and partnering agreements. Since the majority of procurement costs stem from the equipment being purchased, having a well-defined scope and partnering agreement that improves communication may help in setting an appropriate budget and meeting it.

Approximately half of the practices considered were associated with improved construction cost performance. Involvement in front-end planning, good scope definition, collaboration between stakeholders and integrating constructability into the project execution plan are all associated with better construction cost performance. This reiterates the importance allocating proper effort in the planning phase and establishing a collaborative working environment from the beginning of the project.

This study shows that in general, participation of contractors in the front-end, good scope definition, and good relationships between stakeholders involved in project delivery has a positive impact on cost performance. The findings can help guide practitioners in selecting the appropriate practices for improving the cost performance of specific phases. Combining the costs of implementing these practices would allow for a cost-benefit analysis to be conducted. The results also show that the project phases behave differently with respect to their cost performance and the practices that impact them, suggesting that these phases may need to be considered separately when determining factors that impact projects.

This study can be expanded in a number of ways. More project data on cost and best practices, especially in the front-end planning and commissioning phases, can improve some of the analyses that currently have lower sample sizes. Additional best practices beyond the ones considered in this study could also be included to the analysis and their impact evaluated. Lastly, a similar process as shown in this study can also be applied for phase schedule performance and other project success criteria in order to determine how each best practice can benefit a project.

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