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Abstract:

Reducing project duration is a significant concern for many industries in the speed-to-market era. Numerous studies have examined the effects of project delivery methods on speeding up the process of construction. However, no study has quantitatively compared the effect of using different *compensation strategies* on schedule duration and schedule reduction. Using the data obtained from 175 international construction projects, this paper focuses on examining the influence of compensation strategy (lump sum versus reimbursable) on project duration while specifically taking into account the industry sector (heavy industrial versus light industrial). The results of the study provide empirical evidence that using a reimbursable compensation strategy can potentially shorten the procurement duration, construction duration, and overall project duration of heavy industrial projects. However, reimbursable contracting did not appear to reduce the project duration on light industrial projects.

Keywords: Compensation strategy, Project duration, Project control, Reimbursable contracting, Lump sum contracting

1. Introduction

In many industries, such as petrochemical and pharmaceutical, speed-to-market is a significant concern because companies can gain a distinct competitive advantage by producing products faster. Companies operating in these markets often rely on construction delivery methods that can reduce the cycle time and thus speed up the process of construction. These delivery methods often include design-build and fast track variations that may reduce the overall project duration by compressing the design and/or construction schedule by overlapping activities (Konchar and Sanvido 1998; Fazio et al. 1998; Williams 1995; Songer et al. 2000). These delivery methods are in stark contrast to more traditional design-bid-build methods, which consist of separate design, procurement, and construction processes that make overlapping of activities infeasible (Gordon, 1994). Traditional design-bid-build delivery methods are appropriate for projects that can be fully designed before procurement and construction begin, where uncertainty is low, and where most costs can be reasonably estimated by vendors and contractors during the bidding process. As a result, traditional design-bid-build methods may also employ a lump sum compensation strategy because costs may be more certain.

Design-build methods, also known as engineer-procure-construct (EPC), on the other hand, may be appropriate when the client wishes to enter into an agreement with one party to complete both the design and the construction. It is also appropriate for complex projects that may require the early involvement of construction contractors who provide pre-construction services or expertise during the design process. Furthermore, design-build methods provide more flexibility during the early stages of a project by allowing construction to begin before the design has been completed, thus providing an opportunity to accelerate the schedule. As a result, EPC methods often employ a reimbursable compensation strategy because costs evolve as the design proceeds and, therefore, costs cannot be estimated with complete accuracy during the bidding process.

A number of studies have compared the performance of design-bid-build delivery methods to design-build (or EPC) and other delivery methods (Konchar and Sanvido, 1998; Fazio et al., 1998; Williams, 1995; Songer et al., 2000). Surprisingly, few studies have focused on the differences in performance achieved when using various *compensation strategies*. Specifically, no study has quantitatively compared the schedule performance of lump sum and reimbursable compensation strategies to determine whether one strategy outperforms the other. For example, there is a pervasive belief in the heavy industrial sector that reimbursable compensation strategies are more appropriate for use on schedule-driven projects for a number of reasons, including (Menches and Chen 2011): (1) a willingness by the contractor to supply more labor because labor costs are reimbursed by the client; (2) the contractor can start the construction work while design is still in progress because the client will reimburse any re-work costs that might arise from design changes; (3) the contractor will be more flexible about where and when they perform certain tasks, thus allowing the client to re-direct efforts when opportunities arise; and, (4) the client is involved in controlling the work alongside the contractor because reimbursable compensation entails using open-book accounting methods and transparent reporting. Consequently, the belief that a reimbursable compensation strategy may facilitate a shorter project duration is common in the industrial sector but has never been empirically tested.

This paper presents the results of a quantitative analysis of the differences in project duration for the design, procurement, and construction phases – as well as the overall project duration – when a lump sum versus a reimbursable compensation strategy is used. Drawing on theory developed during an extensive qualitative study on reimbursable contracting practices, the researchers analyzed empirical data from international construction projects to test the theory that reimbursable contracting was a more suitable strategy for use on schedule-driven projects than a lump sum strategy. The dataset consisted of 175 international capital projects that were completed between 1998 and 2009. The study focused on examining the influence of compensation strategy on project duration while specifically taking into account the industry sector (i.e., heavy industrial and light industrial/pharmaceutical) to answer the question, “Does the use of a reimbursable compensation strategy tend to result in a shorter project duration than the use of a lump sum compensation strategy?”

2. Background

2.1. Lump Sum and Cost-Reimbursable Contracting Strategies Defined

A contract is an agreement between two or more parties that has specific terms in which there is a promise to perform the defined work in return for a specified payment. Although there are a number of different types of pricing strategies associated with contracts, the two most common are fixed price and reimbursable contracts. Fixed price contracts generally include lump sum and unit price contracts, while cost reimbursable contracts consist of a number of variations based on their fee structure, including Cost Plus Percentage Fee, Cost Plus Fixed Fee, Cost Plus Fee with a Guaranteed Maximum Price, and Convertible Reimbursable Contracts (Cibinic And Nash, 2005; Clough et al., 2005; Menches and Chen, 2011).

A contract is also a risk management instrument (Gould, 2003). The terms of the contract will outline each party's rights and responsibilities, leading to an agreement about how risks are allocated between parties. Many owners prefer to allocate most of the risk to the contractor using a firm fixed price contract. However, when it is financially infeasible to allocate most of the risk to the contractor (i.e., the proposed cost will be too expensive), or when much more flexibility is needed during the construction process (for example, when the owner expects scope and design changes to occur during the construction phase), the owner may elect to use a reimbursable contracting strategy.

In a lump sum contract, the contractor agrees to perform all the work stipulated in the contract by charging the owner a fixed sum of money (Clough et al., 2005). Typically, the contractor's fixed price includes all labor, materials, project overhead, company overhead, profit, and a contingency for unknown conditions (Gordon, 1994). Furthermore, in a lump sum contracting environment, the contractor bears the risk of cost and schedule overruns and may have to assign more labor and expend more money to achieve the agreed-upon duration, resulting in a potential loss of, or reduction in, profit. As a result, this type of contract is suitable for projects in which the scope of work can be described with a high level of certainty at the time of contracting, thus allowing the contractor to estimate the cost of the work with reasonable accuracy (Menches and Chen, 2011).

In a cost reimbursable contract, the owner will reimburse the contractor for all actual labor and materials costs and will pay the contractor a fee to cover overhead and profit (Clough et al., 2005). Consequently, the owner bears most of the cost and schedule risk in a reimbursable contracting environment and may direct the contractor to assign more labor to achieve the agreed-upon duration, which occurs at the owner's expense. As a result, this type of contract is suitable for projects in which the scope of work cannot be described with a high level of certainty at the time of contracting (Menches and Chen, 2011). Furthermore, cost reimbursable contracts may be suitable for projects (1) where the scope and specifications evolve over the duration of the project, (2) when significant changes in the design are expected (O'Toole and Jergeas, 2010), or (3) where fast track or phased construction is needed (Department of the Army 1993).

Research by Menches and Chen (2011) identified other characteristics of projects that make the project particularly well suited for cost reimbursable contracting. For example, cost reimbursable contracts are appropriate for use on projects with numerous risks that are unknown or unquantifiable – risks that are subject to greater than usual uncertainty, and thus make it difficult for a contractor to price the work with any degree of accuracy. Reimbursable contracts are also suitable for use on projects in which the time, performance, and quality objectives outweigh the relative cost. And, reimbursable contracts are suitable for use on projects in which the owner wants to have daily, weekly, or constant input into the decision making process, and when the owner desires regular feedback from the contractor. Finally, the owner who chooses to employ reimbursable contracting may be especially interested in promoting positive long-term relationships among exchange parties while eliminating or minimizing adverse relationships. Consequently, there are circumstances that might make lump sum or reimbursable contracting the more suitable option, and exchange parties should be aware of which option might produce better outcomes.

2.2. Review of Project Duration Studies

Project duration has been the focus of a significant number of studies, particularly quantitative studies that have attempted to *predict* construction duration or *compare* typical durations among different delivery methods. While these studies are too numerous to exhaustively discuss in this article, a few are highlighted to demonstrate the range of issues addressed in prior research. No study has attempted to test existing beliefs about the relationship between (1) how a contractor is compensated for their work and (2) how long it takes them to complete the project. This articles attempts to clarify this relationship.

Numerous studies have attempted to *predict* actual construction duration based on a number of variables such as project type (heavy construction, light construction, building construction, or infrastructure), project size (square feet or floor area), and project budget. These studies have used statistical regression (Abu Hammad et al., 2010), neural network models (Chen and Huang, 2006), optimization methods (Choi et al., 2011; Koo et al., 2010), and other techniques to predict a project's duration. The alternative to *predicting* duration is to *measure and compare* actual duration following completion of the project. Numerous studies have measured and compared project duration between different delivery methods, with some studies arguing that project execution time can be reduced by using a design-build project delivery method rather than a different delivery method (Songer and Molenaar, 1996; Konchar and Sanvido, 1998; Hale et al., 2009). Songer and Molenaar (1996) specifically noted that the primary reason owners select design-build as the delivery method was *the potential to reduce the project's duration*. Konchar and Sanvido (1998) also concluded that using a design-build project delivery method can achieve shorter schedules. Hale et al. (2009) analyzed empirical data from two samples of very similar NAVFAC projects, where one sample contained 39 design-bid-build projects and the other sample contained 38 design-build projects. Statistical analysis indicated that the total project duration for a design-build project was shorter than for a design-bid-build project for the sample.

Finally, a more general approach taken by the Construction Industry Institute involves the measurement of *actual* schedule performance, followed by the development of a metric called *Project Schedule Growth* that conceptualizes schedule performance (i.e., completion ahead of or behind schedule) as the ratio of (1) the difference between *actual* project duration and *predicted* project duration to (2) predicted project duration, where a negative ratio indicates better-than-expected schedule performance (CII, 2005).

In summary, previous studies have largely investigated (1) the use of statistical analysis to *predict* project duration, and (2) the *measurement and comparison* of actual schedule duration between different delivery methods, but, as mentioned, no study has investigated the relationship between compensation structure (i.e., lump sum or reimbursable payment) and project duration to determine whether a cost reimbursable environment consistently produces a shorter project duration. Consequently, this paper presents the results of an empirical comparison of lump sum and reimbursable compensation strategies to determine if one strategy is more conducive than the other to shortening the project's duration.

3. Research Methodology

The study used actual project duration data combined with quantitative analysis to address the research question, "Does the use of a reimbursable compensation strategy tend to result in a shorter project duration than the use of a lump sum compensation strategy?"

3.1. Data Collection, Preparation and Presentation

Data for the analysis was extracted from an existing database of completed international design and construction projects provided by the Construction Industry Institute. The projects that were extracted were completed between 1998 and 2009, and the dataset for this study initially included a total of 1,324 completed projects from the heavy industrial, light industrial, building, and infrastructure sectors. These data were further filtered in accordance with the specific criteria identified in this section to select 175 projects for this analysis.

The projects in the database were reported by (1) owners, (2) contractors who performed design only, (3) contractors who performed construction only, and (4) contractors who performed both the design and the construction for the project. To avoid having a significant amount of missing data, only projects that included information on the duration of the design phase, procurement phase, and the construction phase of the work were selected for analysis. Two groups of data were compared: (1) lump sum projects, in which lump sum compensation was used for detailed design, procurement, and construction; and, (2) cost reimbursable projects, in which cost reimbursable compensation was used for detailed design, procurement, and construction. For convenience, we label these as "pure lump sum" and "pure reimbursable" projects because all three phases (design, procurement, and construction) were implemented using a single compensation strategy (either lump sum or reimbursable).

A project with a total project cost of $5 million or greater was categorized as a large project (Liao, 2008) and projects with a total cost that is less than $5 million was categorized as a small project. Due to the limited number of small projects in the database, the analysis used only data from large projects, whose total project costs ranged from $5 million to $500 million.

Based on these two criteria (pure lump sum/pure reimbursable and size), a total of 204 projects that were completed between 1998 and 2009 were initially selected for analysis. Because the majority of projects in the dataset were from the heavy and light industrial sectors, other types of projects were eliminated from the analysis. Consequently, the study analyzed projects from two major industry groups: heavy industrial and light industrial. Hence, data analysis was performed using heavy and light industrial projects and lump sum and cost reimbursable compensation strategies, resulting in the analysis of 175 projects. Table 1 summarizes the projects by respondent type versus compensation type and Table 2 summarizes the projects by industry group versus compensation type.

Table 1. Sample Summarized by Compensation Type and Respondent Type

Respondent	Compensation Type		Total
	Lump Sum	Reimbursable	
Owner	40	78	118
Contractor	27	30	57
Total	67	108	175

Table 2. Sample Summarized by Compensation Type and Industry Group

Industry Group	Compensation Type		Total
	Lump Sum	Reimbursable	
Heavy Industrial	39	78	117
Light Industrial	28	30	58
Total	67	108	175

From Table 1, it is worth noting that owners reported on twice as many projects as contractors (118 versus 57, respectively). From Table 2, heavy industrial projects account for twice as many projects as light industrial (117 versus 58, respectively), and reimbursable contracts are employed more frequently than lump sum contracts for heavy industrial projects (78 versus 39, respectively) but both reimbursable and lump sum contracts are used almost equally for light industrial projects.

3.2. Description of the Analytical Methods

The analytical methods used in this study consisted of (1) descriptive statistics and (2) hypothesis testing using two-way analysis of variance (two-way ANOVA). As shown in Table 2, the descriptive statistics were summarized for industry group (heavy and light industrial) by compensation type (lump sum and reimbursable). Hypothesis testing essentially tested whether there was a difference in the average project duration for heavy industrial projects that used a lump sum compensation strategy versus a reimbursable compensation strategy. Likewise, a similar comparison was made for light industrial projects. Fundamentally, what the analysis was testing was whether lump sum or reimbursable compensation strategies resulted in: (1) a shorter Overall Project Duration (including detailed design, procurement, and construction), (2) a shorter Detailed Design Duration, (3) a shorter Procurement Duration, and (4) a shorter Construction Duration. The significance level (the criterion used for rejecting the null hypothesis that there is no difference in duration) selected for this analysis was set at 0.05. Two-way ANOVA was used for the analyses because it enables the analyzers to look at two factors simultaneously (industry group and compensation strategy) and how project duration differs for these factors. The use of two-way ANOVA resulted in the development of the following hypotheses:

1. *Hypothesis 1 (H1): "Overall Project Duration" is shorter when a reimbursable compensation strategy is used than when a lump sum compensation strategy is used.* The belief is that the contractor is willing to supply as many resources as necessary to meet more aggressive schedule goals because the client is paying for all direct labor and material costs.
2. *Hypothesis 2 (H2): "Detailed Design Duration" is longer when a reimbursable compensation strategy is used rather than when a lump sum compensation strategy is used.* The belief is that the contractor will take more time to develop accurate design drawings in order to decrease re-work and change

orders during the construction phase, and, furthermore, the extra labor hours will be reimbursed by the client.

3. *Hypothesis 3 (H3): "Procurement Duration" is shorter when a reimbursable compensation strategy is used rather than when a lump sum compensation strategy is used.* The belief is that the contractor will focus less attention on getting the best cost (which may require a longer procurement period and a longer price evaluation process) because the owner will reimburse all procurement costs. Instead, the contractor will focus on procuring materials and services that can be obtained sooner while still achieving high quality.
4. *Hypothesis 4 (H4): "Construction Duration" is shorter when a reimbursable compensation strategy is used rather than when a lump sum compensation strategy is used.* Again, like Hypothesis 1, the belief is that the contractor will provide as many resources as necessary to meet aggressive schedule goals because the client is paying for labor and material costs.

Two-way ANOVA relies on four underlying assumptions: (1) the outcome variable (duration) is at least interval scaled (i.e., a continuous number, or nearly continuous where the distance between adjacent points on the scale are equal); (2) the samples (projects) are randomly selected from the population; (3) the outcome variable (duration) is normally distributed for each of the populations (heavy industrial-lump sum, heavy industrial-reimbursable, light industrial-lump sum, and light industrial-reimbursable); and, (4) the population variances of the outcome variable (duration) are the same for each of the populations. Consequently, the analyzers determined that the first and second assumptions were satisfied in the sample analyzed. The histograms and Q-Q plots (i.e., comparison of probability distributions) for three of the outcome variables (i.e., "Overall Project Duration", "Procurement Duration" and "Construction Duration") show that the data were normally distributed for each of these populations. However, a positive skew was detected in the distribution of the outcome variable *Detailed Design Duration.* As a result, a logarithmic transformation was performed to normalize the distribution, where the logarithmic transformation is a common approach to meet the normality assumption for statistical analysis. Howell (2010) addressed the issue of reporting transformed data. Although it is appropriate to run a statistical test, such as the analysis of variance, on the transformed values, it is customary to report the results in the units of the untransformed scale. This is especially true when the original units are intrinsically meaningful. Therefore, a better approach is to convert all data to logs (if a logarithmic transformation is used), find the mean of those log values, and then take the antilog to convert the mean back to the original units.

Finally, Levene's test was conducted to test whether the samples had equal variances for each of the populations. The null hypothesis for Levene's test is that the samples have equal variances. If the *p*-value of Levene's test is greater than 0.05, the assumption of homogeneity of variance is met. The test results show that each of the outcome variables has equal variances for each of the populations because all the *p*-values are greater than 0.05 (Table 3).

One of the major benefits of two-way ANOVA is that it allows researchers to examine the *interaction* of two factors in addition to the main effects (the effects of factors taken individually) (Howell, 2010). In this study, two-way ANOVA enabled the analyzers to examine the main effects of industry group and compensation type, *respectively*, on project duration *as well as* the interaction effect of compensation type by industry group on project duration. The presence of an interaction means that there are different compensation strategy effects for the two industry groups, where the compensation strategy may result in shorter or longer durations for heavy or light industrial projects. As a result, it is important to examine whether the general compensation strategy effect applies equally to heavy industrial as well as light industrial projects.

Table 3. Test Results of Homogeneity of Variance

Outcome Variables	Levene Statistic	Significance	Met Assumption
Overall Project Duration	2.591	0.057	Yes
Log (Design Duration)	2.508	0.063	Yes
Procurement Duration	0.817	0.488	Yes
Construction Duration	0.649	0.585	Yes

3.3. Descriptive Statistical Analysis Results

The description of the schedule duration by project phase, by industry type, and by compensation strategy is presented in Table 4. The outcome variables included four types of schedule duration: (1) Overall Project Duration, (2) Detailed Design Duration, (3) Procurement Duration, and (4) Construction Duration. For the heavy industrial projects that used a ***lump sum*** compensation strategy, (1) the minimum "Overall Project Duration" was 39 weeks and the maximum was 204 weeks, with a mean of 123 weeks; (2) the minimum "Detailed Design Duration" was 13 weeks and the maximum was 182 weeks, with a mean of 58 weeks; (3) the minimum "Procurement Duration" was 22 weeks and the maximum was 129 weeks, with a mean of 77 weeks; and, (4) the minimum "Construction Duration" was 33 weeks and the maximum was 139 weeks, with a mean of 91 weeks. For the heavy industrial projects that used a ***reimbursable*** compensation strategy, (1) the minimum "Overall Project Duration" was 49 weeks and the maximum was 162 weeks, with a mean of 90 weeks; (2) the minimum "Detailed Design Duration" was 22 weeks and the maximum was 95 weeks, with a mean of 55 weeks; (3) the minimum "Procurement Duration" was 15 weeks and the maximum was 112 weeks, with a mean of 55 weeks; and, (4) the minimum "Construction Duration" was 9 weeks and the maximum was 122 weeks, with a mean of 58 weeks.

Table 4. Summary of Project Duration (in weeks)

Outcome Variable	Minimum (weeks)	Maximum (weeks)	Mean (weeks)	Median (weeks)
Overall Project Duration				
Heavy Industrial-Lump sum	39	204	123	130
Heavy Industrial-Reimbursable	49	162	90	88
Light Industrial-Lump sum	28	163	82	85
Light Industrial-Reimbursable	53	172	106	98
Detailed Design Duration				
Heavy Industrial-Lump sum	13	182	58	66
Heavy Industrial-Reimbursable	22	95	55	56
Light Industrial-Lump sum	12	126	29	27
Light Industrial-Reimbursable	17	112	51	52
Procurement Duration				
Heavy Industrial-Lump sum	22	129	77	75
Heavy Industrial-Reimbursable	15	112	55	50
Light Industrial-Lump sum	9	84	39	31
Light Industrial-Reimbursable	30	139	74	71
Construction Duration				
Heavy Industrial-Lump sum	33	139	91	94
Heavy Industrial-Reimbursable	9	122	58	54
Light Industrial-Lump sum	17	157	61	52
Light Industrial-Reimbursable	19	130	76	74

Consequently, for heavy industrial projects, (1) the mean "Overall Project Duration" for projects that used a reimbursable compensation strategy was 27% shorter than for projects that used a lump sum compensation strategy; (2) the mean "Detailed Design Duration" for projects that used a reimbursable compensation strategy was almost the same as projects that used a lump sum compensation strategy; (3) the mean "Procurement Duration" for projects that used a reimbursable compensation strategy was 29% shorter than for projects that used a lump sum compensation strategy; and, (4) the mean "Construction Duration" for projects that used a reimbursable compensation strategy was 36% shorter than for projects that used a lump sum compensation strategy.

For the light industrial projects that used a ***lump sum*** compensation strategy, (1) the minimum "Overall Project Duration" was 28 weeks and the maximum was 163 weeks, with a mean of 82 weeks; (2) the minimum "Detailed Design Duration" was 12 weeks and the maximum was 126 weeks, with a mean of 29 weeks; (3) the minimum "Procurement Duration" was 9 weeks and the maximum was 84 weeks, with a

mean of 39 weeks; and, (4) the minimum "Construction Duration" was 17 weeks and the maximum was 157 weeks, with a mean of 61 weeks. For the light industrial projects that used a ***reimbursable*** compensation strategy, (1) the minimum "Overall Project Duration" was 53 weeks and the maximum was 172 weeks, with a mean of 106 weeks; (2) the minimum "Detailed Design Duration" was 17 weeks and the maximum was 112 weeks, with a mean of 51 weeks; (3) the minimum "Procurement Duration" was 30 weeks and the maximum was 139 weeks, with a mean of 74 weeks; and, (4) the minimum "Construction Duration" was 19 weeks and the maximum was 130 weeks, with a mean of 76 weeks.

Consequently, for light industrial projects, (1) the mean "Overall Project Duration" for projects that used a reimbursable compensation strategy was 29% longer than for projects that used a lump sum compensation strategy; (2) the mean "Detailed Design Duration" for projects that used a reimbursable compensation strategy was 76% longer than for projects that used a lump sum compensation strategy; (3) the mean "Procurement Duration" for projects that used a reimbursable compensation strategy was 90% longer than for projects that used a lump sum compensation strategy; and, (4) the mean "Construction Duration" for projects that used a reimbursable compensation strategy was 25% longer than for projects that used a lump sum compensation strategy.

This descriptive statistical analysis highlights two trends. For the heavy industrial projects, the use of ***reimbursable*** compensation strategies may result in a shorter "Overall Project Duration", a shorter "Procurement Duration", and a shorter "Construction Duration." In contrast, for light industrial projects, the use of ***lump sum*** compensation strategies may result in a shorter "Overall Project Duration", a shorter "Detailed Design Duration," a shorter "Procurement Duration", and a shorter "Construction Duration." The next section presents the results of the inferential statistical analysis in which the researchers tested the four hypotheses to determine whether reimbursable compensation strategies are more appropriate for projects that are schedule-driven.

3.4. Hypothesis Testing and Findings

Two-way ANOVA was used to test the previous four research hypotheses to determine if a reimbursable compensation strategy is more suitable for schedule-driven projects than a lump sum compensation strategy.

Hypothesis 1 (H1): "Overall Project Duration" is shorter when a reimbursable compensation strategy is used than when a lump sum compensation strategy is used.

A 2×2 ANOVA was conducted to evaluate the effects of two industry project types (heavy industrial and light industrial) and two compensation strategies (lump sum and reimbursable) on "Overall Project Duration." The means and standard deviations for each of the combination groups are presented in Table 5. The results for the ANOVA indicated a non-significant main effect for industry project types ($p = 0.14 > p = 0.05$), which means that the industry project type alone (heavy industrial or light industrial) does not have a significant effect on "Overall Project Duration." It also indicated a non-significant main effect for compensation strategy ($p = 0.58 > p = 0.05$), which means that the type of compensation strategy alone (lump sum or reimbursable) does not have a significant effect on "Overall Project Duration." However, the results indicated a significant interaction between industry project type and compensation strategy ($p < 0.001$), which means that the average "Overall Project Duration" for heavy industrial projects and for light industrial projects is significantly different for lump sum and reimbursable compensation strategies. In fact, an examination of the means in Table 5 indicates that for heavy industrial projects, the mean "Overall Project Duration" for projects that use a reimbursable compensation strategy is shorter than for projects that use a lump sum compensation strategy. But for light industrial projects, the trend is the reverse: the mean "Overall Project Duration" for projects that use a reimbursable compensation strategy is longer than for projects that use a lump sum compensation strategy. Therefore, the type of compensation strategy implemented may influence the "Overall Project Duration" *differently* for heavy and light industrial projects, and, consequently, a statistical test was performed to determine whether the duration is *significantly shorter* for heavy industrial projects that used reimbursable compensation strategies and whether the duration is *significantly longer* for light industrial projects that used reimbursable compensation strategies.

Table 5. Mean and Standard Deviation for Overall Project Duration (in weeks)

Industry Group	Compensation Strategy	Mean	SD
Heavy Industrial	Lump Sum	123	44
	Reimbursable	90	28
Light Industrial	Lump Sum	82	38
	Reimbursable	106	30

To probe whether the difference in the average "Overall Project Duration" was *statistically shorter* for heavy industrial projects that implemented reimbursable versus lump sum compensation strategies, the simple main effect of compensation strategy on average "Overall Project Duration" was examined using a within-group analysis approach. The significance level was reduced to 0.025 to control for Type I error, where a Type I error occurs when one rejects the null hypothesis when it is true, and the analysis indicated that the difference in the "Overall Project Duration" for heavy industrial projects that implemented reimbursable versus lump sum compensation strategies was, in fact, statistically shorter ($p = 0.002 < p = 0.025$). This finding thus supports Hypothesis 1.

A similar analysis was conducted to determine whether the difference in the average "Overall Project Duration" was *statistically longer* for light industrial projects that implemented reimbursable versus lump sum compensation strategies, and no *statistically* significant difference was noted ($p = 0.027 > p = 0.025$). However, because the *p*-value ($p = 0.027$) is close to the significance threshold ($p = 0.025$), the results are essentially inconclusive. In other words, it cannot be concluded with complete certainty that the average "Overall Project Duration" was not *statistically longer.*

Generally, the analysis indicated that the type of compensation strategy implemented on heavy industrial projects had a significant impact on "Overall Project Duration," where reimbursable compensation resulted in a shorter duration.

Hypothesis 2 (H2): "Detailed Design Duration" is longer when a reimbursable compensation strategy is used rather than when a lump sum compensation strategy is used.

A 2×2 ANOVA was conducted to evaluate the effects of two industry project types (heavy industrial and light industrial) and two compensation strategies (lump sum and reimbursable) on "Detailed Design Duration." The means and standard deviations for each of the combination groups are presented in Table 6. The results for the ANOVA indicated a statistically significant main effect for industry project type ($p = 0.001 < p = 0.05$), which means that the type of industry project (heavy or light industrial) has a significant effect on "Detailed Design Duration." It also indicated a statistically significant main effect for compensation strategy ($p = 0.015 < p = 0.05$), which means that the type of compensation strategy (lump sum or reimbursable) has a significant effect on "Detailed Design Duration." Furthermore, the results indicated a statistically significant interaction between industry project type and compensation strategy ($p = 0.004 < p = 0.05$), which means the average "Detailed Design Duration" for heavy industrial projects and for light industrial projects is significantly different for lump sum and reimbursable compensation strategies. An examination of the means in Table 6 indicates that for heavy industrial projects, the average "Detailed Design Duration" for projects that implemented a reimbursable compensation strategy is shorter than for projects that implemented a lump sum strategy, but for light industrial projects, the trend is the reverse: the average "Detailed Design Duration" for projects that implemented a reimbursable compensation strategy is longer than for projects that implemented a lump sum strategy. Therefore, the type of compensation strategy implemented may influence the "Detailed Design Duration" *differently* for heavy and light industrial projects, and, consequently, a statistical test was performed to determine whether the duration is significantly shorter for heavy industrial projects that used reimbursable compensation strategies and whether the duration is significantly longer for light industrial projects that used reimbursable compensation strategies.

To investigate whether the difference in the average "Detailed Design Duration" is *statistically shorter* for heavy industrial projects that implemented reimbursable versus lump sum compensation strategies, the simple main effect of compensation strategy on average "Detailed Design Duration" was examined using a within-group analysis approach. The significance level was again reduced to 0.025 to control for Type I error, and the analysis indicated that the difference in the "Detailed Design Duration" for heavy industrial projects that implemented reimbursable versus lump sum compensation strategies *was not*

statistically shorter (p = 0.735 > p = 0.025). Thus, the mean "Detailed Design Duration" for heavy industrial projects that used a reimbursable compensation strategy was similar to, rather than significantly shorter than, projects that used a lump sum compensation strategy.

Table 6. Mean and Standard Deviation for Detailed Design Duration (in weeks)

Industry Group	Compensation Strategy	Mean*	SD**
Heavy Industrial	Lump Sum	58	NA
	Reimbursable	55	NA
Light Industrial	Lump Sum	29	NA
	Reimbursable	51	NA

* The mean of Detailed Design Duration is obtained by taking the antilog of transformed value to convert the mean back to the original units.
**SD is not available as converting standard deviations will create unjust results.

A similar analysis was conducted to determine whether the difference in the average "Detailed Design Duration" was *statistically longer* for light industrial projects that implemented reimbursable versus lump sum compensation strategies. The analysis indicated that the difference in the average "Detailed Design Duration" for light industrial projects that implemented reimbursable versus lump sum compensation strategies was, in fact, *statistically longer* (p = 0.001 < p = 0.025), thus supporting Hypothesis 2.

Overall, the analysis indicated that the type of compensation strategy implemented on light industrial projects had a significant impact on "Detailed Design Duration," where reimbursable compensation resulted in a longer duration.

Hypothesis 3 (H3): "Procurement Duration" is shorter when a reimbursable compensation strategy is used than when a lump sum compensation strategy is used.

A 2×2 ANOVA was conducted to evaluate the effects of two industry project types (heavy industrial and light industrial) and two compensation strategies (lump sum and reimbursable) on "Procurement Duration." The means and standard deviations for each of the combination groups are presented in Table 7. The results for the ANOVA indicated a non-significant main effect for industry project type (p = 0.13 > p = 0.05), which means that the industry project type alone (heavy industrial or light industrial) does not have a significant effect on "Procurement Duration." It also indicated a non-significant main effect for compensation strategy (p = 0.30 > p = 0.05), which means that the type of compensation strategy alone (lump sum or reimbursable) does not have a significant effect on "Procurement Duration." However, the results indicated a significant interaction between industry project type and compensation strategy (p < 0.001), which means the average "Procurement Duration" for heavy and light industrial projects is significantly different for lump sum and reimbursable compensation strategies. In fact, an examination of the means in Table 7 indicates that for heavy industrial projects, the mean "Procurement Duration" for projects that use a reimbursable compensation strategy is shorter than for projects that use a lump sum compensation strategy. But for light industrial projects, the trend is the reverse: the mean "Procurement Duration" for projects that use a reimbursable compensation strategy is longer than for projects that use a lump sum compensation strategy. Therefore, the type of compensation strategy implemented may influence the "Procurement Duration" *differently* for heavy and light industrial projects, and, consequently, a statistical test was performed to determine whether the duration is *significantly shorter* for heavy industrial projects that used reimbursable compensation strategies and whether the duration is *significantly longer* for light industrial projects that used reimbursable compensation strategies.

Table 7. Mean and Standard Deviation for Procurement Duration (in weeks)

Industry Group	Compensation Strategy	Mean	SD
Heavy Industrial	Lump Sum	77	32
	Reimbursable	55	27
Light Industrial	Lump Sum	39	22
	Reimbursable	74	29

To examine whether the difference in the average "Procurement Duration" was *statistically shorter* for heavy industrial projects that implemented reimbursable versus lump sum compensation strategies, the simple main effect of compensation strategy on average "Procurement Duration" was examined using a within-group analysis approach. The significance level was reduced to 0.025 to control for Type I error, and the analysis indicated that the difference in the "Procurement Duration" for heavy industrial projects that implemented reimbursable versus lump sum compensation strategies was, in fact, statistically shorter ($p = 0.006 < p = 0.025$). This finding thus supports Hypothesis 3.

A similar analysis was conducted to determine whether the difference in the average "Procurement Duration" was *statistically longer* for light industrial projects that implemented reimbursable versus lump sum compensation strategies, and the analysis indicated that the difference in the average "Procurement Duration" for light industrial projects that implemented reimbursable versus lump sum compensation strategies was, in fact, *statistically longer* ($p < 0.001 < p = 0.025$).

Overall, the analysis indicated that the type of compensation strategy implemented on both heavy and light industrial projects had a significant impact on "Procurement Duration," where reimbursable compensation resulted in a shorter duration on heavy industrial projects and a longer duration on light industrial projects.

Hypothesis 4 (H4): "Construction Duration" is shorter when a reimbursable compensation strategy is used rather than when a lump sum compensation strategy is used.

A 2×2 ANOVA was conducted to evaluate the effects of two industry project types (heavy industrial and light industrial) and two compensation strategies (lump sum and reimbursable) on "Construction Duration." The means and standard deviations for each of the combination groups are presented in Table 8. The results for the ANOVA indicated a non-significant main effect for industry project type ($p = 0.48 > p = 0.05$), which means that the type of project alone (heavy or light industrial) does not have a significant effect on "Construction Duration." The results also indicated a non-significant main effect for compensation strategy ($p = 0.13 > p = 0.05$), which means that the type of compensation strategy alone (lump sum or reimbursable) does not have a significant effect on "Construction Duration." However, the results indicated a significant interaction between industry project type and compensation strategy ($p < 0.001$), which means the average "Construction Duration" for heavy and light industrial projects is significantly different for projects that implemented a lump sum versus a reimbursable compensation strategy. An examination of the means in Table 7 indicates that for heavy industrial projects, the average "Construction Duration" for projects that implemented a reimbursable compensation strategy is shorter than for projects that implemented a lump sum strategy, but for light industrial projects, the trend is the reverse: the average "Construction Duration" for projects that implemented a reimbursable compensation strategy is longer than for projects that implemented a lump sum strategy. Therefore, the type of compensation strategy implemented may influence the "Construction Duration" *differently* for heavy and light industrial projects, and, consequently, a statistical test was performed to determine whether the duration is *significantly shorter* for heavy industrial projects that used reimbursable compensation strategies and whether the duration is *significantly longer* for light industrial projects that used reimbursable compensation strategies.

To examine whether the difference in the average "Construction Duration" was *statistically shorter* for heavy industrial projects that implemented reimbursable versus lump sum compensation strategies, the simple main effect of compensation strategy on average "Construction Duration" was examined using a within-group analysis approach. The significance level was again reduced to 0.025 to control for Type I error, and the analysis indicated that the difference in the "Construction Duration" for heavy industrial projects that implemented reimbursable versus lump sum compensation strategies was, in fact, *statistically shorter* ($p < 0.001$), thus supporting Hypothesis 4.

A similar analysis was conducted to determine whether the difference in the average "Construction Duration" was *statistically longer* for light industrial projects that implemented reimbursable versus lump sum compensation strategies, and no statistically significant difference was noted ($p = 0.14 > p = 0.025$). Consequently, the average "Construction Duration" is similar, rather than different, on light industrial projects that implemented reimbursable and lump sum compensation strategies.

Overall, the analysis indicated that the type of compensation strategy implemented on heavy industrial projects had a significant impact on "Construction Duration," where reimbursable compensation resulted in a shorter duration.

Table 8. Mean and Standard Deviation for Construction Duration (in weeks)

Industry Group	Compensation Strategy	Mean	SD
Heavy Industrial	Lump Sum	91	32
	Reimbursable	58	28
Light Industrial	Lump Sum	61	36
	Reimbursable	76	28

4. Discussion

There is a pervasive belief in both the heavy and light industrial construction sectors that a reimbursable compensation strategy may facilitate a shorter project duration (Menches and Chen 2011), but, until now, this theory has never been empirically tested. Consequently, the study reported here empirically compared lump sum and reimbursable compensation strategies to determine if a reimbursable compensation strategy is more conducive to shortening a project's duration than a lump sum strategy. This issue is important because many projects rely on speed-to-market to gain a competitive advantage by introducing new products and services before their competitors. Furthermore, a longer project duration exposes a company to unexpected increases in material and labor costs, labor shortages, currency rate fluctuations, and a host of other unforeseen circumstances. Hence, most companies would like to complete projects as soon as feasibly possible. The analysis results are summarized in Table 9 and discussed in the next few paragraphs.

4.1. Heavy Industrial Projects

The data suggest that heavy industrial projects, such as oil refineries or liquefied natural gas plants, that implemented a reimbursable compensation strategy did, in fact, achieve a statistically shorter procurement and construction duration and, thus, a statistically shorter overall project duration than projects that implemented a lump sum strategy. However, the detailed design duration was not statistically different regardless of whether a reimbursable or lump sum compensation strategy was implemented. These findings are consistent with Hypothesis 1 ("Overall Project Duration" is shorter when a reimbursable compensation strategy is used than when a lump sum compensation strategy is used), Hypothesis 3 ("Procurement Duration" is shorter when a reimbursable compensation strategy is used than when a lump sum compensation strategy is used), and Hypothesis 4 ("Construction Duration" is shorter when a reimbursable compensation strategy is used rather than when a lump sum compensation strategy is used) but do not support Hypothesis 2 ("Detailed Design Duration" is longer when a reimbursable compensation strategy is used rather than when a lump sum compensation strategy is used). Experts (both owners and contractors) who manage heavy industrial projects were consulted to identify plausible reasons why the procurement, construction and overall project durations were shorter for heavy industrial projects that implemented a reimbursable compensation strategy and why there was no different in design duration regardless of whether a lump sum or reimbursable contracting strategy was used.

Design Duration. The experts suggested that there might be more than one plausible explanation for "no difference" in design duration for reimbursable and lump sum compensation strategies. For example, one expert suggested that the design duration might actually consume more resources in a reimbursable environment – that is, the duration would be longer under a reimbursable contract, as hypothesized, except that the contractor can add more people to complete the design in a shorter length of time because the owner will reimburse all direct labor costs. Furthermore, under a lump sum strategy, the contractor is at risk for all design costs; therefore, the contractor will carefully control design duration in order to control labor costs. Under these two scenarios, a statistical analysis would likely result in a finding of "no difference" in design duration regardless of compensation strategy.

Procurement Duration. One expert suggested that a reimbursable compensation strategy often allows the contractor to utilize a greater number of procurement specialists who can thus purchase materials and equipment at a relatively faster pace than might be possible if a lump sum strategy had been used. Therefore, when materials and equipment can be delivered to the site earlier, then construction can start and finish earlier, and products can be brought to market sooner. Another expert suggested that 45% of the total project cost is often spent on materials and equipment, and therefore, a compensation strategy that places the contractor at risk for all project costs (such as a lump sum strategy) often leads the contractor to spend much more time receiving and reviewing bids so that the lowest price can be obtained

from subcontractors and vendors. This ultimately causes the procurement duration to be longer in a lump sum compensation environment.

Table 9. Summary of Results

Industry Group	Type of Duration	Compensation Strategy	Duration Outcome
Heavy Industrial Projects	Overall Project Duration	Lump Sum	Longer
		Reimbursable	Shorter
	Detailed Design Duration	Lump Sum	Equal
		Reimbursable	Equal
	Procurement Duration	Lump Sum	Longer
		Reimbursable	Shorter
	Construction Duration	Lump Sum	Longer
		Reimbursable	Shorter
Light Industrial Projects	Overall Project Duration	Lump Sum	Equal
		Reimbursable	Equal
	Detailed Design Duration	Lump Sum	Shorter
		Reimbursable	Longer
	Procurement Duration	Lump Sum	Shorter
		Reimbursable	Longer
	Construction Duration	Lump Sum	Equal
		Reimbursable	Equal

Construction Duration. More than one expert suggested that the primary reason that the construction duration is shorter in a reimbursable environment is because the contractor is willing to supply as many resources as necessary to meet aggressive schedule goals as long as the client is willing to pay for all direct labor and material costs. Furthermore, on lump sum projects, the contractor is at risk for all project costs and is thus driven to control costs by controlling the amount of resources allocated to the project. In this environment, the focus is on completing the project on time rather than completing the project in a shorter length of time.

Overall Project Duration. Logically, if there is no statistical different in design duration under a lump sum or reimbursable compensation strategy but both the procurement duration and construction duration are shorter in a reimbursable environment, then the overall project duration is also prone to be shorter under a reimbursable strategy.

4.2. Light Industrial Projects

The overwhelming majority (57%) of the light industrial projects examined for this study were from the pharmaceutical industry. Consequently, experts in the pharmaceutical industry were consulted about the research findings. The data suggest that light industrial projects, such as a drug development center or medical equipment manufacturing plant, that implemented a reimbursable compensation strategy *did not* achieve a statistically shorter procurement, construction, or overall project duration than projects that implemented a lump sum strategy. In fact, the construction duration and overall project duration were similar for projects that implemented lump sum and reimbursable compensation strategies. However, the detailed design duration and procurement duration were statistically longer for projects that implemented a reimbursable compensation strategy and statistically shorter for projects that implemented a lump sum compensation strategy. These findings are consistent with Hypothesis 2 but do not support Hypothesis 1, Hypothesis 3, or Hypothesis 4. Experts who manage light industrial (i.e., primarily pharmaceutical) projects were consulted to identify plausible reasons why the design and procurement duration were longer under a reimbursable contracting strategy, while there was no statistical difference in construction or overall project duration regardless of compensation strategy.

Design Duration. More than one expert suggested that one reason the design duration is longer under a reimbursable contracting strategy is because there is no incentive to stop designing when the owner is paying all of the direct labor costs. Furthermore, technology changes at such a fast pace in the pharmaceutical industry that the design often changes frequently to accommodate the latest technology,

thus slowing down the process of completing the design. Finally, the engineers are often given tremendous latitude when designing new pharmaceutical technology; as a result, they tend to "tinker" – essentially experimenting with a number of different designs, allowing the design to slowly evolve through iteration – which slows down the design process. However, under a lump sum compensation strategy, the contractor is responsible for all design costs and, as such, has an incentive to complete the design as quickly and efficiently as possible to keep costs at a minimum.

Procurement Duration. One expert suggested that the reason the procurement duration is longer under a reimbursable compensation strategy is because a reimbursable procurement process is nearly always associated with a reimbursable design process. Given that the design tends to evolve – experiencing numerous changes during the course of the design process – the frequent changes to the design cause a slowing down of the procurement of materials and equipment. Thus, the two processes are linked. Likewise, under a lump sum design process, the contractor is likely to complete the design in a timely manner to control costs, and a timely design completion facilitates a timely procurement process. Thus, the procurement duration may be shorter under a lump sum strategy because no additional changes occur, and hence complete information is available for purchasing the required materials, equipment, and technology.

Construction Duration. One expert suggested that a plausible explanation for why there is no difference in construction duration regardless of whether a lump sum or reimbursable compensation strategy is implemented is because the owner may be waiting on regulatory approval for the pharmaceutical product that will be produced inside the facility. Construction may be implemented while the owner is awaiting regulatory approval, but the owner is essentially proceeding "with caution but as planned" rather than accelerating the construction duration. A lack of regulatory approval will significantly slow down construction efforts.

Overall Project Duration. One expert suggested a plausible explanation for why there is no difference in overall project duration regardless of whether a lump sum or reimbursable compensation strategy is implemented: the detailed design duration and procurement duration are both shorter in a lump sum environment, but they are longer in a reimbursable environment. However, the construction duration is statistically equal for projects that implement either a lump sum or a reimbursable compensation strategy. Hence, because the construction phase often overlaps the detailed design and procurement phases on a reimbursable project, the net effect is that the overall project duration is statistically equal for lump sum and reimbursable projects.

4.3. Discussion Conclusion

Heavy industrial projects that are time-driven should consider implementing a reimbursable compensation strategy because evidence suggests that this strategy tends to shorten a project's duration. However, light industrial projects may not gain a significant time advantage by implementing a reimbursable compensation strategy, and other factors might need to be considered when trying to choose between reimbursable and lump sum strategies, such as the need for pre-construction services or the need/desire to start construction before the design is fully complete, which is feasible if a reimbursable compensation strategy is selected.

5. Limitations, Summary, and Future Research

The results of the study presented in this article provide empirical evidence that using a reimbursable compensation strategy can potentially shorten the procurement duration, construction duration, and overall project duration of heavy industrial projects. However, reimbursable contracting did not appear to reduce the project duration on light industrial projects. Hence, these findings partially support long-held beliefs that reimbursable contracts are suitable for use on schedule-driven projects. While the results of this analysis are interesting, the study has several limitations that should be kept in mind when interpreting the results, and suggestions are presented here for expanding this line of analysis.

Because a specific analysis was not conducted for building and infrastructure industry types, it is not clear whether building and infrastructure projects tend to resemble light industrial or heavy industrial projects. No conclusions can be drawn about the relationship between duration and compensation strategy for these two industry types. Furthermore, analyses of the project definition phase and commissioning phase were not conducted as part of this study. Hence, no conclusions can be drawn about the relationship between duration and compensation strategy for these two phases of the extended project lifecycle.

One additional direction for future research that would be beneficial to industry and academic institutions is to investigate the influence that equal or shorter durations have on project costs in a reimbursable environment. One lingering unanswered question is whether a shorter duration comes at a higher cost because additional labor and materials were needed to achieve the shorter schedule. This, too, is a pervasive belief in the industry that would benefit from a rigorous empirical analysis.

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