ALTERNATIVE CONTRACTING STRATEGIES FOR REBUILDING AGING INFRASTRUCTURE: ARE THEY REALLY EFFECTIVE?

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ABSTRACT

In the United States, incentive/disincentive (I/D) and cost-plus-time (A+B) are the most widely used alternative contracting strategies for responding to the dual challenge of repairing aging infrastructure systems while minimizing traffic inconvenience to the traveling public. However, little is known about their impact on the aspect of project schedule performance. The lack of systematic studies on the strategies now prevents state highway agencies from budgeting accurately and realistically when they are considered for implementation. A quantitative analysis drawing on 1,372 projects was conducted in an attempt to

address this shortcoming by determining the schedule effectiveness. The analysis results demonstrate the power of I/D in shortening construction times, but this schedule saving performance was not seen in A+B projects. A+B projects led to severe schedule delays worse than conventionally contracted projects. The findings of this study can better inform decision-makers when they select among alternative contracting strategies.

INTRODUCTION

Alternative Contracting Strategies

Transportation infrastructure improvement projects in heavily-trafficked urban areas inconvenience the traveling public. Among the undesirable impacts for both state highway agencies (SHAs) and the traveling public created by lane closures during construction are severe congestion, safety problems, and limited property access (Lee and Choi, 2006).

To satisfactorily deliver these costly, badly-needed infrastructure improvements, SHAs must close portions of highways while minimizing the impact of traffic changes during closures on the traveling public and area businesses. These apparently conflicting requirements demonstrate the challenge that SHAs face; they raise the need for alternative contracting strategies that can both reduce construction duration and lessen unfavorable traffic impact.

One groundbreaking way to reduce the duration of project is to offer contractors an early completion incentive bonus that is greater than the cost of utilizing extra resources to meet an accelerated schedule (Christiansen, 1987; Jaraiedi et al., 1993). Incentive/disincentive (I/D) contracting has become one of agencies' favored alternative strategies for motivating contractors to fulfill the public's expectation that projects will be completed early. Time-based I/D provisions are now the most widely used strategy for reducing construction time and they are preferred by SHAs and contractors alike because they can establish win-win situations for both parties (Ibarra et al., 2002). For example, use of these provisions can help agencies save on road-user delay costs by cutting construction time, while contractors can increase their profits by receiving an incentive bonus (Plummer et al., 1992).

Existing Studies on I/D Schedule Effect

The research study of Herbsman and Ellis indicates that 99% of the contractors in thirty-five states who contracted with I/D provisions on infrastructure improvement projects received an incentive bonus (Herbsman and Ellis, 1995). The work of Arditi (Arditi et al., 1997) and Jaraiedi (Jaraiedi et al., 1995) reported that I/D contracting reduced construction time by up to 50%. More specifically, 93% of I/D contracting projects were completed on time or earlier while 41% of non-I/D contracting projects were completed on time or ahead of schedule.

However, these results are out-of-date and might be obsolete as I/D has become increasingly popular in the intervening decade. At the time of these studies, I/D was deemed experimental, and was thus applied in a limited way.

A+B Bidding Mechanism and Effectiveness

In A+B contracting, the winning bidder is the one who turns in the lowest combined bid for cost (A) and time (B) required to complete the project.

The value of daily road user cost (DRUC) is established by the contracting agency for the contractor to incorporate it into the "B" portion in A+B bidding. The California Department of Transportation (Caltrans) guidelines for use of A+B bidding provisions specify that the "daily road user cost should not be more than the liquidated damages; otherwise it might prove to be more economical to pay liquidated damages rather than plan to finish within the bid project duration" (Caltrans, 2000). In Caltrans practice, the real DRUC will typically range from 50 to 100 percent of the calculated daily road user cost. This percentage is determined by the project engineer after seeking input from the Office of Traffic Operations regarding traffic delay significance.

Recently, A+B bidding has become one of the most widely used alternative contracting techniques for shortening construction time. This form of bidding takes advantage of contractors' ingenuity by utilizing their realistic estimates of construction schedule and cost; it is also generally acknowledged that this bidding process eliminates unqualified contractors. However, A+B implementation experiences to date indicate that the effectiveness of A+B contracting is debatable largely due to inherent inaccuracy in letting contractors specify project duration during the bidding. To bridge the gap between these conflicting notions, this study aims to resolve this conflict by exploring which alternative contracting strategy more effectively reduces construction time, compared with conventional contracting projects.

PROBLEMS AND SIGNIFICANCE

Since much of the transportation infrastructure in the U.S. has substantially deteriorated due to age, many SHAs now face the dual challenge of repairing aging infrastructure systems while trying to minimize traffic inconvenience to the traveling public. To complete projects sooner, SHAs have increasingly adopted alternative contracting strategies, including I/D and A+B. Although these two contracting strategies are the most widely used alternatives, little is known about their impact on aspect of project schedule. The lack of systematic studies on these strategies to assess them now prevents SHAs from budgeting accurately and realistically when they are considered for implementation (see Table 1).

Incentive/disincentive (I/D) implementation experiences to date indicate that the effectiveness of allowing contractors to receive monetary incentives in exchange for reduced construction times is debatable, largely because of the inaccuracy of agency engineers' estimates of contract times (Herbsman et al., 1995; Shen et al., 1999; Shr and Chen, 2004). Determination of contract times has relied to a great extent on the experience and judgment of the contracting agency engineers tasked with estimating the duration of project and realistic I/D rates (NYSDOT, 1999). Therefore, the accuracy of schedule estimates varies depending on a number of factors. Overestimation of contract times can result in contractors receiving incentive fees with little effort, which, according to some studies, has happened in 99 percent of the highway construction projects using contracts with I/D provisions (Herbsman and Ellis, 1995). Competitive contractors can also easily earn an incentive bonus without extra commitments for fast-track construction (Rister and Wang, 2004).

Experience has also raised questions about the effectiveness of bidding on cost and time (A+B). For instance, Christiansen reported that A+B bidding was ineffective largely because of the inherent inaccuracy of allowing contractors to specify contract time in the bidding (Christiansen, 1987). On the other hand, according to Herbsman et al., A+B is more effective and less expensive than the I/D strategy because: (1) schedule compression can be achieved prior to construction through competition rather than incentive payments; and (2) bidding on cost and time enables the contractor to devise better schedules and plans (Herbsman et al., 1995).

In effect, the absence of comprehensive data and of systematic studies hinders agencies' ability to determine whether to use an I/D and/or an A+B contracting strategy as compared to the conventional contracting method.

Table 1. Problems, Solutions, and Contributions

Problems	Solutions and Contributions
Problem I: Disagreement about alternative projects' effectiveness	▪ Evaluate the effectiveness on schedule performance by comparing alternative contracting projects with conventionally contracted projects. ▪ Contribution: - Promote the effective application of these alternative strategies by knowing the percentages and overall performance.
Problem II: Lack of data and systematic studies	▪ Conduct a methodical quantitative analysis. ▪ Contributions: - Provide comprehensive evaluation data. - Provide a synthesized analysis approach and make recommendations for taking the next step to effectively use alternative contracting strategies.

RESEARCH METHODS

The main objective of this study is to determine the schedule effectiveness of adopting alternative contracting strategies (I/D and A+B) on infrastructure improvement projects. To evaluate their effectiveness, alternative contracting projects were compared with projects contracted conventionally. The contractors' schedule performance of three major types of projects (roadway, bridge, and capacity-added) built under three different contracting methods (I/D, A+B, and conventional) was evaluated.

A one-way ANOVA analysis was used as a main methodology. As part of the analysis, appropriate planned comparison and post-hoc tests were conducted to test the validity of the research hypothesis that alternative contracting projects shorten project duration significantly more than the conventional projects.

RESEARCH ASSUMPTIONS AND LIMITATIONS

- All projects were independently implemented and completed. Each analysis was also independently performed. All project data to be examined are therefore assumed to be statistically independent.
- Some projects were constructed at night and some during the day. Contractors' labor productivity during daytime and nighttime were assumed to be equivalent.
- Contractors' individual production performance and work experiences were assumed to be identical.
- It is assumed that agency engineers were not biased in setting the original contract duration.
- It is assumed that the contracting agency's choice of A+B and I/D projects was unbiased.

There are three basic types of incentives: cost-based incentives, quality-based incentives, and time-based incentives. This research is limited to the time-based incentives.

DEFINITION OF TERMS

The schedule performance ratio used in this study is the ratio of the difference between the actual final completion time and the original contract time to the original contract time.

- Schedule performance ratio =

[(final completion time – original (and amended) contract time) / original (and amended) contract time]

A negative value implies that the project was completed sooner than originally scheduled. A positive value implies that the project took longer than originally scheduled. If the ratio equals zero, that implies the project was completed on time.

The schedule performance ratio was computed on two different thresholds; that is, original contract time versus amended contract time. The final completion time is defined as the time that the contractor completes all (or any designated portion) of the work called for under the contract, which allows unrestricted traffic on the CWZ. The original contract time is the originally scheduled project duration. The amended contract time reflects time adjustments, required by the imposition of contract change orders including contractor initiated changes, agency directed changes, and contingency changes.

Using the schedule performance ratio, whether the actual project duration was affected by the presence of I/D contracts was mainly examined. In other words, it was used to investigate if alternatively contracting projects offer a decisive time-saving advantage over conventional projects.

Conventional contracting projects are defined as projects contracted in a traditional lump sum contract under the design-bid-build project delivery system (lowest bidder is the winning bidder). Regardless of contracting strategy, the contractor would have a reason to complete the project on time to avoid a penalty imposed by liquidated damages, which are routinely assessed against them when they do not meet the completion date specified. Generally, liquidated damages are assessed separately from disincentives.

DATA COLLECTION AND CLASSIFICATION

Data Collection

A quantitative study drawing on 1,372 infrastructure rehabilitation projects completed in California between 2000 and 2008 was conducted to quantify likely impacts of alternatively contracting projects on project schedule compared with conventional contracting projects. The original project data were received from the Caltrans Division of Construction and Caltrans Office of Project Engineers. The data covers three main areas: project summary, schedule, and cost (see Table 2).

Initial project schedule and contract amount estimates are often adjusted due to contract changes in project scope resulting from frequently occurring contract change orders. Consequently, project data used for quantitative analyses must contain this contract change order information. The data used here include the adjusted days and contract amounts so that the impact of contract and schedule changes can be quantified. The data also contain daily I/D and incentive cap rates.

Data Classification Procedure

Results of this quantitative data analysis could be biased if samples of varied project types and sizes are compared, so to perform an unbiased analysis, project data were sorted by similar project type and by similar project size. Three major project types were identified through the classification procedure:

- So-called "3R" types of roadway renewal projects: resurfacing (maintenance), reconstruction, and rehabilitation of existing roadways;
- Bridge projects: replacement, repair, and rehabilitation of existing bridges; and
- Capacity-added projects: the addition of lanes or the widening existing lanes, often accompanied by 3R types of renewal work.

Table 2. Nature of Project Data

	No.	Value type	Description
Project Summary	1	EA number	6 digit unique project ID
	2	District	
	3	County	
	4	Route	
	5	Postmiles	lane-miles rebuilt
	6	Location description	
	7	Project description	work description (project type)
	8	Name of contractor	
	9	Contracting type	
Time	11	Origianl contract time	originally scheduled duration of project
	12	CCO days	times adjusted due to contract change orders
	13	Amended contract time	equals 11+12
	14	Actual project time	days spent to complete the project
	15	Project time change	equals 12/11
Cost	16	Original contract amount	initial bid amount
	17	Engineer's estimate amount	project cost estimates done by agency engineers
	18	CCO amount	all costs adjusted due to contract change orders
	19	Amended contract amount	equals 16+18
	20	Final project cost	final project cost actually spent for the project
	21	Project cost change	equals 18/16
	22	Daily I/D rate	
	23	Incentive cap amount	Maximum incentive amount allowed for the project

Figure 1 shows the data classification procedure undertaken in this study. All 1,372 projects were classified by their contracting strategy: I/D, A+B, or conventional. The projects were then sorted by project type and in doing this they were further identified as either major or minor projects. In this part of the procedure, some minor projects were excluded, such as work on shoulders, lighting, and bike paths/trails, bridge painting, access/drainage improvement, tree planting, etc.

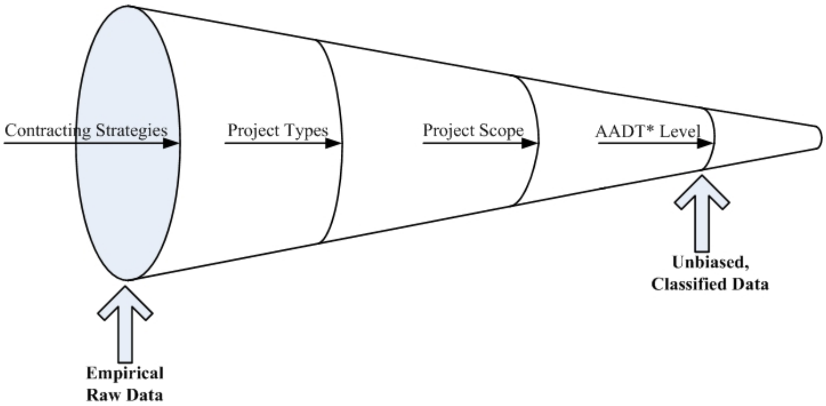

Figure 1. Data classification procedure (*AADT: Annual Average Daily Traffic).

In the second classification round, projects already sorted by type and contracting strategy were classified by similar project size, in terms of the original contract amount. In the third classification round, hundreds of conventional contracting projects were excluded due to the low construction work zone traffic volumes (based on AADT). This was done because low traffic level at a construction work zone can directly affect both project planning and construction practice, so it is relatively easy for contractors to define project scope on rurally situated projects. These projects are likely to result in fewer contract change orders during construction, subsequent lower cost growth, and a higher likelihood of on-time project delivery.

STATISTICAL ROBUSTNESS CHECK OF DATA

When conducting a one-way ANOVA analysis, the data should satisfy the following three assumptions for a test variable (i.e., schedule performance ratios):

1. Normality: The test variable should be normally distributed.
2. Homogeneity of variances: The population distributions have the same variances.
3. Independence: Three contracting project groups are independent of one another.

It is known that ANOVA is quite robust over moderate violations of the first assumption. The normality was checked by performing the Shapiro-Wilk test due to the data size (Rice, 1995). The test indicated that project data to be examined for this study are normally distributed.

Because the Shapiro-Wilk test can produce a misleading result, normality of the project data was confirmed by a graphical plot, quantile-quantile (Q-Q) plot, and there was no evidence to show that the data was not normally distributed.

The second assumption that the variances of samples are statistically equal was examined by the Levene's *F* test (test of homogeneity of variances). The results of Levene's *F* test statistics for the equality of variances suggest that the variances of schedule performance ratios are equal.

A project could be affected by some externalities (e.g., inclement weather conditions and schedule delays due to unexpected equipment breakdowns during construction), but there should not be correlation between projects because all projects were independently implemented and completed at different locations in different times. Therefore, it is reasonable to assume that all projects are statistically independent.

SCHEDULE IMPACT OF ALTERNATIVE CONTRACTIG STRATEGIES

Substantial Completion versus Final Completion

Substantial completion and final completion are the two benchmarks used to determine project completion time for paying incentives or charging disincentives. Substantial completion is defined as the time when parts of lanes are opened to traffic under minor construction work being performed, such as site cleanup, planting, and lane marking (Arditi et al., 1997). On the other hand, final completion is defined as the time that the contractor completes all (or any designated portion) of the work called for under the contract and allows unrestricted traffic on the construction work zone. In practice, the selection of the benchmarks varies from one state highway agency to another; some states (e.g., Illinois) adopt the former as a baseline for setting an I/D amount and other states, such as California, accept the latter. Therefore, the actual project time used for the analyses presented in this study is the final completion time.

Impacts on Overall Project Schedule

The impact of I/D on project schedule compared with A+B and conventional projects was measured by the schedule performance ratio defied earlier. It was noted that 58.6% of I/D projects were completed earlier than originally scheduled, while just 12% of A+B projects and 32.4% of conventional projects were completed ahead of schedule. I/D contracting reduced construction time by up to 57%.

Figure 2 shows that I/D projects reduced construction time by compressing the "original" contract schedule by an average of 4.16%, while A+B and conventional projects increased the construction time by 31.55% and 18.58%, respectively. A similar trend was observed when the schedule impact is viewed in terms of "amended" contract time, which includes time extensions forced by contract change orders; I/D projects still led to a positive schedule change (15.85% compression), and conventional and A+B projects showing negative schedule changes.

According to the analysis, I/D contracting projects showed much better schedule performance on both schedule baselines (original and amended) than other contracting projects; 22.74% and 35.71% better than those of conventional and A+B projects, respectively.

An unusual, unforeseen pattern was observed in A+B projects. It was initially expected that A+B projects provided schedule-saving performance similar to I/D projects. However, in reality, A+B projects underwent a fairly negative schedule change (31.55% overruns), which reveals a severe schedule reliability problem in letting the contractor specify contract time in the bidding process.

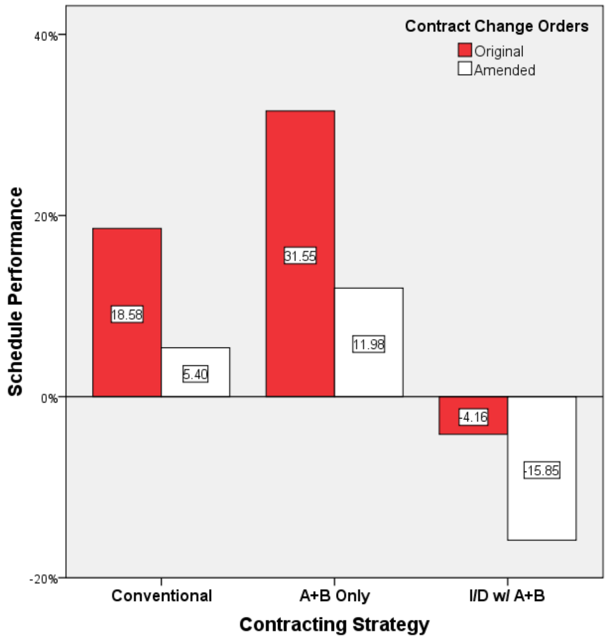

Figure 2. Overall schedule performance versus contracting strategy.

Figure 3 displays a box-and-whisker plot of project schedule performance on the three contracting strategies, indicating five-number summaries such as minimum, lower quartile, median, upper quartile, and maximum. The middle line in the box depicts the median, which is more representative of the central tendency since it limits the impact of extreme cases known as outliers. When the level of schedule performance was analyzed by looking at the median value, the same trend was observed; I/D projects produced the best schedule performance, followed by conventional and A+B projects. When the degree of project dispersion for schedule performance (the length of boxes labeled "original") was considered, it is seen that the schedule performance of A+B projects varied highly from one project to another. This may convey the fact that A+B projects did not start with a well-defined project scope.

Figure 3 also indicates that the conventional contracting strategy had many outlier projects. This means that the schedule performance result for conventional projects could be dramatically affected by those outlier projects. To scientifically verify the aforementioned results, a one-way ANOVA analysis was conducted to compare the means of three contracting project groups. To further examine where the schedule changes (positive or negative) occurred, a detailed analysis was undertaken on three major project types in the subsequent sections.

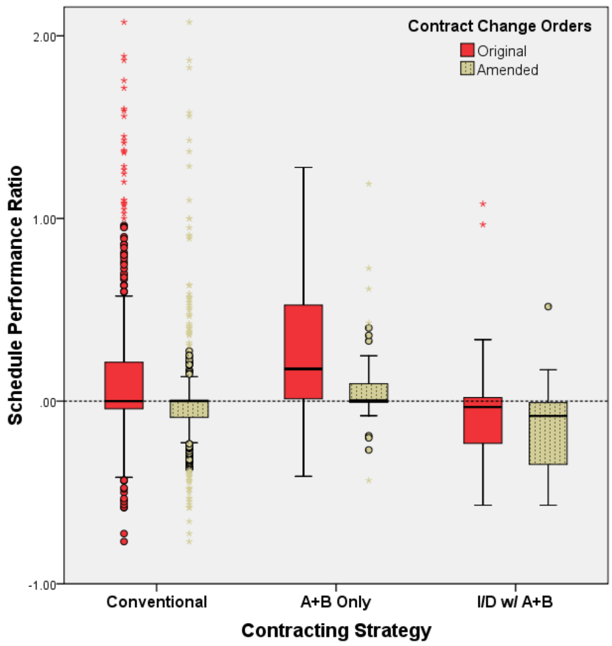

Figure 3. Schedule performance box plot of all projects.

Schedule Performance versus Project Types

Roadway 3R Projects

During the eight-year study period, 2000 to 2008, roadway projects including maintenance (resurfacing), reconstruction, and rehabilitation of existing facilities represented approximately 50% of all project establishments and 45% of all project cost allotments. These percentages indicate that improvement and renewal of existing roadways has been the central focus of recent infrastructure projects. By this reasoning, knowing how the scheduling effectiveness of alternative contracting strategies varies with roadway type and comparison with the conventional strategy is important for contracting agencies; this knowledge can help agencies uncover the problems with the alternative contracting strategies in current practice so they can plan better in the future.

On the selected roadway projects, 40.0% of the I/D projects were completed sooner than initially scheduled. By comparison, 33.6% of conventional projects were completed ahead of schedule, and 14.8% of A+B projects were completed earlier. As shown in Figure 4, I/D projects produced schedule overruns on average by 7.72% on the original contract time, while A+B projects underwent schedule delays of 31.85%, and conventional projects led to schedule overruns of 20.47%. When schedule extensions resulting from contract change orders are considered, it appears that while A+B and conventional projects led to schedule delays, I/D projects shortened construction time by 7.18% (see Figure 4).

Findings emerged from this analysis on the roadway 3R projects are summarized as follows:

- Even if I/D projects had a negative change (schedule delay) on original contract time, they showed far better time saving performance than any other contracting strategy.
- A+B projects experienced significant schedule delays and their schedule performance ratios are highly dispersed (see Figure 5 to compare the degree of dispersion of A+B projects with that of I/D projects).
- The composition of schedule performance on I/D and A+B projects conveys the facts that the contracting agency benefited by significant time savings using the I/D contracting strategy, and that A+B projects have a crucial problem with the inaccuracy of contractors' original schedule estimates, which were underestimated.

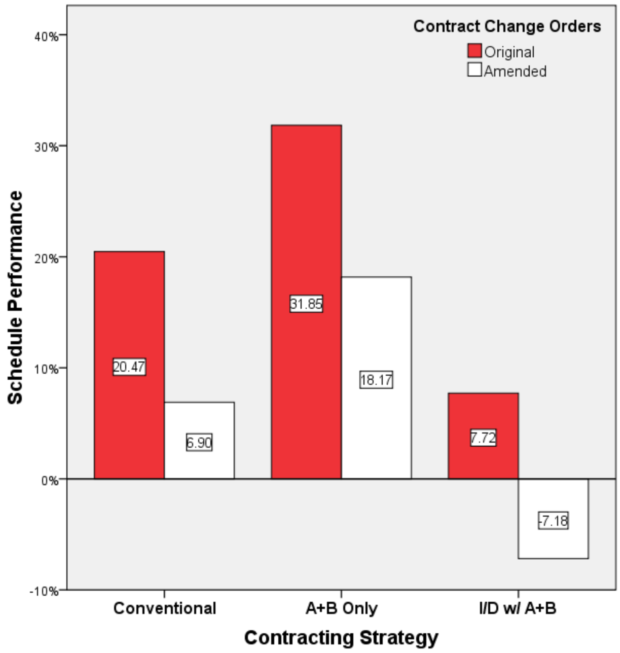

Figure 4. Schedule performance on roadway projects versus contracting strategy

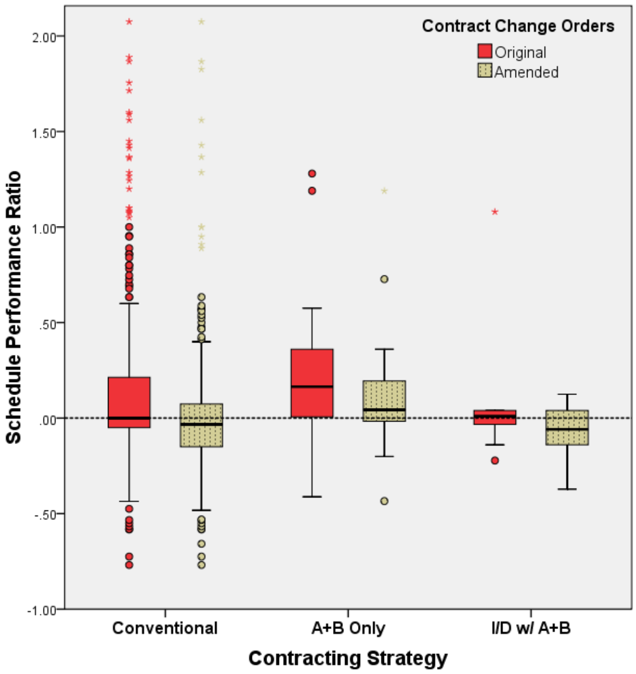

Figure 5. Schedule performance box plot of roadway projects.

Bridge Projects

Bridge projects presented in this study include replacement, repair, and rehabilitation of existing bridges, which represents 5.8% of all project establishments and 7.0% of all project cost allotments over the study year period, 2000–2008. It is striking that 100% of all I/D bridge projects were completed sooner than projected, while 38.7% of conventional projects were completed ahead of schedule. As noticed in the roadway type, A+B projects on the bridge type also reveal a severe schedule delay problem; namely, 50% of the project produced a schedule overrun (only one project among four was completed sooner than the schedule called for).

Figure 6 indicates that I/D projects on bridges type resulted in a decisive schedule saving advantage over conventional and A+B projects; I/D projects reduced construction time significantly (45.77%) on the installed original contract time, while A+B and conventional projects had schedule delays (17.54% and 13.43%, respectively). It is also seen that all six I/D projects were located in heavily populated and trafficked urban areas; 33 percent within the Los Angeles basin, and 67 percent in the San Francisco Bay Area.

When schedule extensions resulting from contract change orders are considered, all of three contracting groups provided schedule savings, unlike other project types (Figure 6 and Figure 7). A likely reason that all the bridge projects shortened construction times from their contract times amended due to contract change orders was increased public pressure on the agencies to open the bridges early or on time, regardless of contracting strategy, to re-establish critical services (such as emergency services) to the adjacent communities. In addition, construction work on the existing bridges resulted in direct and indirect environmental impacts on the adjoining communities, another spur to project completion.

Findings that emerged on bridge type are summarized as follows:

- I/D projects that were situated in highly urbanized areas showed a definitive schedule-saving advantage.
- A+B projects showed the worst schedule compression effect.
- Based on amended contract time reflecting contract change orders, all three contracting projects produced some degree of schedule compression.

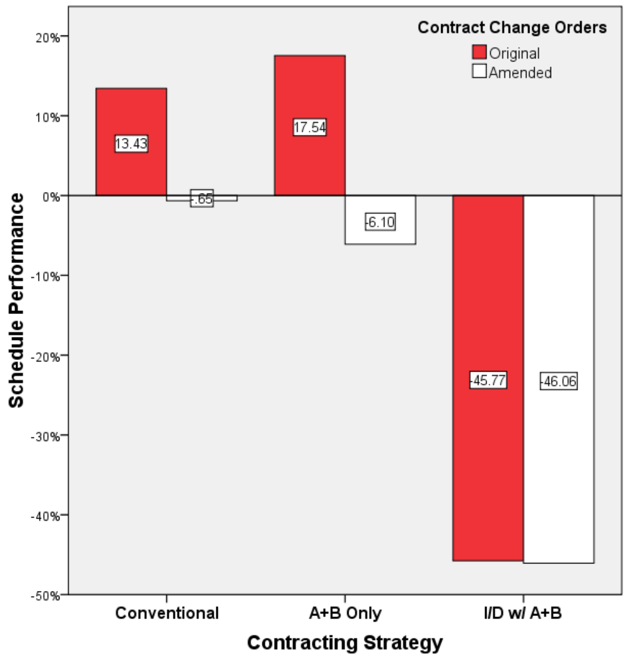

Figure 6. Schedule performance on bridge projects versus contracting strategy.

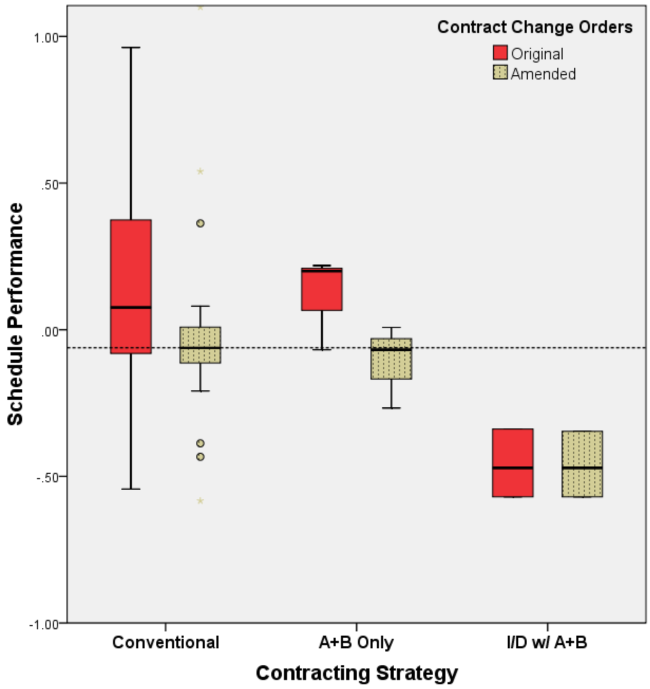

Figure 7. Schedule performance box plot of bridge projects.

Capacity-added Projects

The capacity-added projects presented in this study include adding or widening lanes performed concurrently with some renewal work on existing lanes, such as resurfacing, reconstruction, or rehabilitation. This project type represents 10.5% of all project establishments over the study year period, 2000 to 2008, and 31.0% of all project cost allotments. It appears that this type of project received the largest investment among all the project categories. Owing to their large size, projects of the capacity-added type create major negative impacts on the traveling public. Therefore, it is especially worthwhile for agencies to know the percentages of schedule performance for this project type.

Fifty percent of the capacity-added I/D projects were completed earlier than originally planned, while 24.4% of the conventional projects were completed ahead of schedule. Significantly, 100% of capacity-added A+B projects did not meet their scheduled completion dates. In addition, Figure 8 shows that A+B projects also underwent significant schedule delays by 37.0%, whereas I/D projects reduced construction time on average by 2.5%. The same trend was seen when compared with median values; I/D projects showed the greatest schedule-saving performance, followed by conventional, and A+B projects (see Figure 9).

The followings summarize findings emerged from this analysis on the capacity-added projects:

- I/D projects held a definitive schedule-saving advantage over other contracting strategies.
- A+B projects showed a severe problem with schedule delays.
- Figure 9 shows a higher degree of dispersion of ratios on A+B projects, suggesting that they did not start with well-defined project scope.

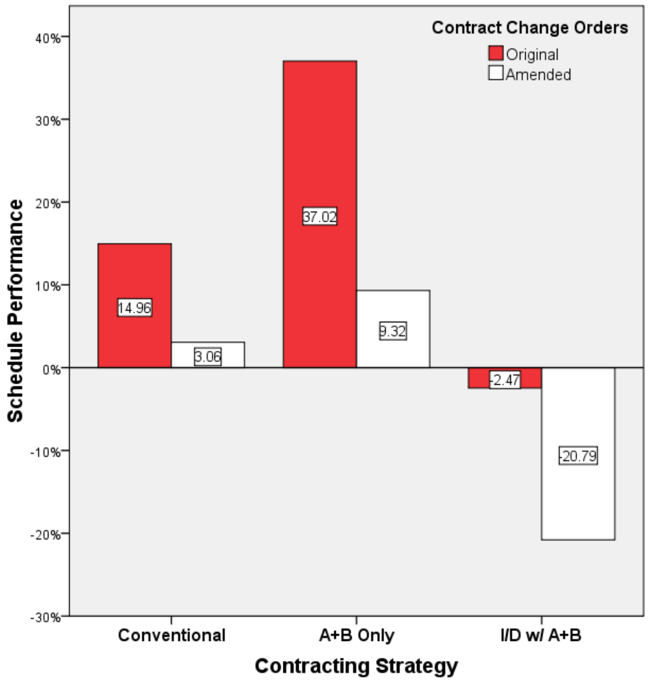

Figure 8. Schedule performance on capacity-added projects versus contracting strategy.

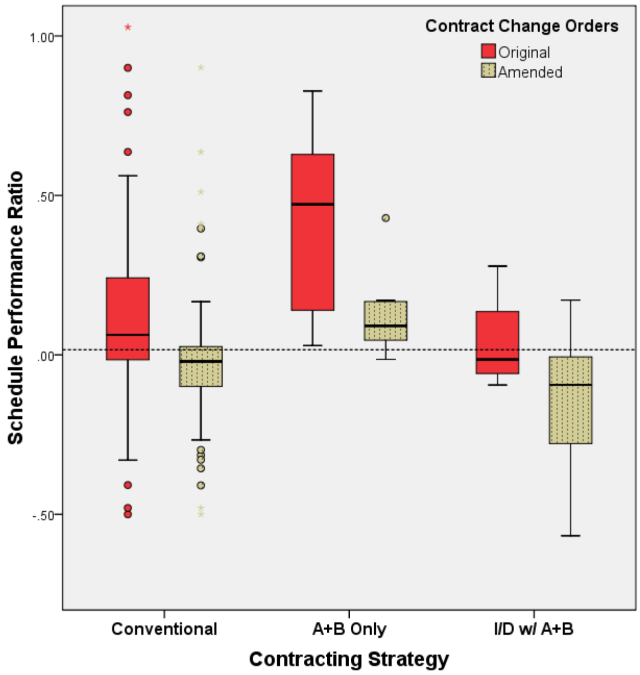

Figure 9. Schedule performance box plot of capacity-added projects.

Hypothesis Testing of Schedule Changes

Based on the analyses performed in earlier sections, it was known that I/D projects were more effective than A+B and conventional strategies in reducing construction time. They held a relative time-saving advantage over other contracting strategies. The analyses also showed that use of A+B was resulted in schedule overruns, worse than conventional projects. To further explore this case, a one-way ANOVA analysis for comparing means of three contracting groups was conducted to test the validity of the following research hypotheses:

- Actual contract duration is affected by the presence of an I/D provision; for shortening completion time, the I/D contracting strategy is preferable to the other two strategies.
- Alternative contracting (A+B and I/D) strategies shorten the duration of projects significantly more than the conventional method does.

Table 3 presents the summary statistics of schedule performance for three contracting groups with regard to all projects. Standard deviations show that the variability of I/D projects is much lower than that of other contracting project groups. The fact that I/D projects usually start with a better definition of project scope could be evidenced by their relatively lower variability in schedule performance.

Table 3. Average Schedule Performance versus Contracting Strategy

Descriptives

Overall

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Conventional	518	.1858	.61838	.02717	.1324	.2392	-.77	5.49
A+B Only	58	.3155	.45770	.06010	.1952	.4359	-.41	2.67
I/D w/ A+B	29	-.0416	.36939	.06859	-.1821	.0990	-.57	1.08
Total	605	.1873	.59791	.02431	.1396	.2351	-.77	5.49

Table 4 shows the summary of the main ANOVA analysis, which is divided into *between-group effects* (i.e., effects due to the implementation of different contracting strategies) and *within-group effects* (i.e., unsystematic variation in the data). The between group effect is further divided into a linear and quadratic term for a trend analysis. The test of whether the mean difference of three contracting project groups is statistically significant is represented by the F-ratio (3.488) for the combined between-group effect. The significance value (df = 2, p = .031) suggests that the likelihood that an F-ratio of this size would have occurred by chance is less than 5%. Hence, it is concluded that there is sufficient evidence to show that the mean difference of three contracting project groups is significant.

Table 4 also displays the results of the trend analysis to examine the schedule effect between a linear relationship and a quadratic relationship. From Table 4, it is seen that the schedule effect is better explained by the quadratic relationship (F = 6.343, P = .012). The quadratic relationship among three contracting project groups implies that there is a negative change in schedule performance as the contracting strategy has changed from a conventional to an A+B, and the negative change is shifted to a positive change as the contracting strategy has changed from an A+B to an I/D. To further investigate this trend, planned comparison and post-hoc tests were followed.

Table 4. Summary of ANOVA Analysis on Schedule Performance

ANOVA

Overall

			Sum of Squares	df	Mean Square	F	Sig.
Between Groups	(Combined)		2.474	2	1.237	3.488	.031
	Linear Term	Unweighted	1.420	1	1.420	4.004	.046
		Weighted	.225	1	.225	.634	.426
		Deviation	2.249	1	2.249	6.343	.012
	Quadratic Term	Unweighted	2.249	1	2.249	6.343	.012
		Weighted	2.249	1	2.249	6.343	.012
	Within Groups		213.458	602	.355		
	Total		215.931	604			

To examine the difference in schedule performance of three contracting project groups, four planned comparisons were conducted with the following one-tailed hypotheses (see Table 5);

1. Alternative contracting projects would shorten construction time significantly more than conventional projects (Contrast 1: alternative versus conventional).
2. Conventional projects would reduce the duration of projects significantly more than A+B projects (Contrast 2: conventional versus A+B).
3. I/D projects would cut the length of project duration significantly more than conventional projects (Contrast 3: I/D versus conventional).
4. Use of incentives/disincentives would make a difference to schedule performance in comparison to A+B projects (Contrast 4: I/D versus A+B).

Table 5 shows the results of the planned comparisons. The *p*-values in the table need to be divided by two to obtain the one-tailed probability. The upper part of the table, titled "Assume equal variances," should be referred to because the second assumption of equal variance was not significant. The *t*-statistic of -.673 (df = 602, p = .502/2 = .251) for Contrast 1 indicates that there is no significant evidence to show that alternative contracting projects would reduce construction time significantly more than conventional projects. The significance of Contrast 2 (df = 602, p = .116/2 = .058) shows that there is no significant evidence to prove that conventional projects (0.1858) performed much better than A+B projects (0.3155). The significance (p<.05) of Contrast 3-4 proves that I/D performed much better than other contracting projects.

Table 5. Results of Planned Comparison Test on Schedule Performance

Contrast Tests

		Contrast	Value of Contrast	Std. Error	t	df	Sig. (2-tailed)
Overall	Assume equal variances	1	-.0976	.14518	-.673	602	.502
		2	-.1297	.08245	-1.573	602	.116
		3	.2274	.11363	2.001	602	.046
		4	.3571	.13543	2.637	602	.009
	Does not assume equal variances	1	-.0976	.10616	-.920	122.551	.360
		2	-.1297	.06596	-1.967	82.302	.053
		3	.2274	.07378	3.082	37.426	.004
		4	.3571	.09120	3.916	67.848	.000

Some post-hoc tests were followed to further identify which contracting strategy is significantly better than other strategies in shortening the duration of projects. The post-hoc tests are for further investigation after a significant effect among testing variables has been found through a one-way ANOVA analysis (Rice, 1995). The post-hoc analysis was needed to determine which contracting groups performed significantly better in shortening construction times. Table 6 shows the results of Hochberg's test, Games-Howell, and Dunnett's test. The Hochberg's test was chosen due to the fact that the sample sizes of the three contracting groups are very different. Along with the Hochberg's test, the Games-Howell procedure was chosen to confirm the research hypothesis that I/D projects had a significantly better schedule compression effect than other contracting projects. The Dunnett's test was selected to compare alternative contracting projects against the conventional project (Garson, 2008). For each pair of contracting strategies in the post-hoc tests described above, the difference between the average schedule performance of two contracting strategies, the standard error of that difference, and the significance level of that difference are presented in Table 6. When conventional projects were compared to A+B and I/D projects, a similar result with the planned comparisons was observed, which confirms that I/D contracting strategy is preferable to the other two strategies for shortening completion time.

Table 6. Results of Post-Hoc Tests on Schedule Performance

Multiple Comparisons

Dependent Variable:Overall

						95% Confidence Interval	
	(I) Strategy_ Overall	(J) Strategy_ Overall	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Hochberg	Conventional	A+B Only	-.12973	.08245	.309	-.3271	.0677
		I/D w/ A+B	.22737	.11363	.131	-.0447	.4994
	A+B Only	Conventional	.12973	.08245	.309	-.0677	.3271
		I/D w/ A+B	.35709*	.13543	.026	.0329	.6813
	I/D w/ A+B	Conventional	-.22737	.11363	.131	-.4994	.0447
		A+B Only	-.35709*	.13543	.026	-.6813	-.0329
Games-Howell	Conventional	A+B Only	-.12973	.06596	.127	-.2871	.0277
		I/D w/ A+B	.22737*	.07378	.011	.0473	.4074
	A+B Only	Conventional	.12973	.06596	.127	-.0277	.2871
		I/D w/ A+B	.35709*	.09120	.001	.1386	.5756
	I/D w/ A+B	Conventional	-.22737*	.07378	.011	-.4074	-.0473
		A+B Only	-.35709*	.09120	.001	-.5756	-.1386
Dunnett t (<control)[a]	A+B Only	Conventional	.12973	.08245	.996		.2910
	I/D w/ A+B	Conventional	-.22737*	.11363	.045		-.0051

*. The mean difference is significant at the 0.05 level.

a. Dunnett t-tests treat one group as a control, and compare all other groups against it.

CONCLUSIONS

This study presents a case in which cost-plus-time (A+B) contracting performed much worse than conventionally contracted projects. This reveals an opposite result of what has been commonly believed on A+B.

The A+B contracting strategy is used with the presumption that competition at a project's outset will encourage contractors to reasonably shorten their bids on the "B" (duration) portion of the contract. However, it was seen that A+B projects actually suffered severely from contractors' underestimations of their bids on the "B" portion in A+B bidding. Based on the analysis results, it appears that contractors often manipulated the duration of project downward to win contracts, and this ultimately resulted in significant schedule overruns. Meanwhile, projects that applied the incentive/disincentive (I/D) contracting strategy demonstrated the power of I/D clauses: many of these types of projects achieved or surpassed the agency's goal of early project completion. In conclusion, it is recommended that A+B contracting be used with an I/D provision in order for contractors to be motivated to meet a scheduled completion date.

The current analyses presented in this study form the basis for a future study. It is recommended that how contract change orders impact project schedule be further investigated. The research results and findings can help state highway agencies and decision-makers make a better- informed decision when choosing an appropriate contracting strategy.

ACKNOWLEDGMENTS

The funding for this research study was provided by the California Department of Transportation and the authors would like to express gratitude for the information and coordination support in obtaining project data, especially to Mr. Anthony Perry and Mr. John Kung at the Division of Construction and the Office of Project Engineers for their contributions to the project data collection.

Opinions expressed are those of the authors and are not necessarily those of Caltrans.

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