# Examination of Project Duration, Project Intensity, and Timing of Cost Certainty in Highway Project Delivery Methods

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**Abstract:** Although agencies design and construct the vast majority of federally funded highways through the traditional design-bid-build (DBB) method, the use of construction manager/general contractor (CM/GC) and design-build (DB) is increasing. Previous research articles on the performance of these delivery methods include projects of different characteristics and projects from different sectors. This study examined solely US highway projects through a unique analysis of comparable projects. This study compared the project delivery methods that are frequently used in two separate cost pools, $2 million to $10 million and $10 million to $50 million. In the cost pool of $2 million to $10 million, the delivery methods of DBB and low-bid-procured DB (DB/LB) were compared. The delivery methods of DBB, CM/GC, and best-value-procured DB (DB/BV) were compared in the cost pool of $10 million to $50 million. The results show that the alternative contracting methods of CM/GC and DB are superior to the traditional DBB method for the performance metrics of project duration, project intensity, and timing of cost certainty in both cost pools. In comparing the alternative contracting methods in the $10 million to $50 million cost range, the CM/GC method was found to outperform DB/BV, which has not yet been shown in the research literature. With pressure on state transportation agencies to be efficient with funds, the alternative contracting methods are viable options for shortening project durations, establishing early cost certainty during project delivery, and delivering projects at a more intense pace. The findings presented are useful for practitioners to better understand how project delivery methods can meet their needs for US highway construction. **DOI: 10.1061/(ASCE)ME.1943-5479.0000661.** 

## Background and Motivation

Due to an aging infrastructure combined with continuously limited funds, US state agencies are turning to alternative contracting methods in an attempt to more efficiently spend public funds. Alternative contracting methods are all contractual methods that are an alternative to the traditional design-bid-build (DBB) method. In US highway construction projects, design-build (DB) and construction manager/general contractor (CM/GC) are the two primary alternative contracting methods and are the focus of this article.

The documented benefits of the two alternative project delivery methods include cost savings, improved constructability, enhanced innovation, reduced risk, shortened construction schedules, and the potential to lower operational cost and/or project life-cycle costs (Songer and Molenaar 1996; Touran et al. 2011). Notwithstanding the potential benefits, the two alternative project delivery methods are not a panacea for project delivery challenges, and thus the more traditional method of DBB remains indispensable. State highway agencies or departments of transportation (DOTs) need to be efficient in every aspect of highway project delivery. Therein lies pressure on agency professionals to select a suitable project delivery method to achieve successful outcomes in project performance. Hence, the presentation of findings based on empirical project information will be invaluable to agency professionals.

Many empirical studies have compared the performance of DBB and DB for US highways, although almost all have focused on cost and schedule growth (e.g., Ibbs et al. 2003; Hale et al. 2009; Minchin et al. 2013; Chen et al. 2016). Alternatively, studies concerning CM/GC performance in the US highway sector have been qualitative and/or theoretical (Gransberg et al. 2002; Alleman et al. 2017) and lack empirical-based findings. This is the understandable result of the relatively new and growing use of CM/GC versus the more mature DB and traditional DBB method. Although alternative contracting methods have been used since the early 1990s, several agencies are just beginning to use, and others have yet to use, these methods. In addition, the results in the existing literature are not all specific to highway projects, and the findings are frequently based on the perceptions and opinions of construction industry personnel.

To better inform practitioners on the comparisons of alternative contracting methods and to bridge the current gap in the literature, this article explores the timing of cost certainty, project intensity (missing in the literature), and project duration across DBB, CM/GC, and DB (poorly represented in literature).

## Definition and History of Alternative Contracting Methods

It is pertinent to understand both the characteristics and the history of the alternative contracting methods to interpret the findings and apply the results of this study. The majority of the US highway network was built using the DBB delivery method, solidified by the Miller Act of 1935 (Beard et al. 2001). Nationwide use of the alternative contracting methods within the transportation sector began with the enactment of Federal Highway Administration's Special

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Experimental Project Number 14 (SEP-14), "Innovative Contracting," in 1990 (FHWA 2002, 2016). Although SEP-14 opened the door for the use of CM/GC, its growth within the highway network was relatively slow compared with DB (Gransberg and Shane 2010). To facilitate greater CM/GC use, the Moving Ahead for Progress in the 21st Century Act (MAP-21) was enacted in July 2012, which removed the requirement for agencies to request FHWA approval to use CM/GC under the SEP-14 (FHWA 2012).

Concerning the differences between the delivery methods, with DBB, the agency has full ownership of design development, and construction begins only after full design completion. CM/GC also allows the agency to maintain full ownership of the design. Unlike DBB, the agency contracts with a construction manager (CM) for preconstruction services. When the design is mature enough, all parties agree on a price for construction, and the CM becomes the general contractor (GC) (CDOT 2015). At this point, the owner/agency contractually transfers the risk for and the final cost and duration of construction to the GC. In CM/GC projects, construction can be released in phases/packages rather than a single fully completed design for construction of the entire project. The DB projects can be separately distinguished as low-bid-procured DB (DB/LB) and best-value-procured DB projects (DB/BV), with the latter being projects procured through selection factors in addition to cost. With DB, a single entity is contracted to perform both design and construction services, transferring the design risk to the contractor more fully than with CM/GC or DBB (Ellis et al. 1991; AECOM 2006).

## Previous Studies of Project Delivery Methods

As stated, there have been multiple research studies to explore the cited potential benefits of early contractor involvement in alternative contracting methods in highway construction. Of these studies, several have confirmed these potential benefits, as follows: DB experiences less cost growth than DBB (Warne 2005; Shrestha et al. 2007; Hale et al. 2009), DB experiences less schedule growth than DBB (AECOM 2006; Ibbs et al. 2003; Shrestha et al. 2007; Ellis et al. 2007; Minchin et al. 2013; Chen et al. 2016), DB's delivery time is faster than DBB's (AECOM 2006; Warne 2005; Ellis et al. 2007), and CM/GC's cost growth is less than DBB's (FHWA 2013).

As can be seen, there is a scarcity of literature on the comparison of CM/GC versus DB schedule performance based on quantitative empirical data. No previous research shows empirical findings between DB and CM/GC in highway projects; notably, empirical information has become particularly relevant with recent legislation (FHWA 2012). However, the overall time savings of alternative contracting methods over DBB are well known in the literature as a benefit (Bennett et al. 1996; Konchar and Sanvido 1998; NYDOT 2003; SAIC 2002; AECOM 2006; Warne 2005; Ellis et al. 2007). The limited literature available on CM/GC versus DB performance suggests DB has superior schedule performance, but these results are based on the perceptions of industry users of the delivery methods rather than empirical/quantitative data (McGraw-Hill Construction 2014; Shrestha et al. 2014; Farnsworth et al. 2016; Bingham et al. 2016). Notably, in the work of Farnsworth et al. (2016), CM/GC was found to promote higher quality, shorten project schedules, and reduce construction cost in comparison to DBB (Farnsworth et al. 2016), and CM/GC has a greater ability to control risk and affect cost in comparison to DB (Farnsworth et al. 2016; Bingham et al. 2016). However, these results are not all specific to highway projects because the researchers used a mix of projects, and the findings are based on the perceptions and opinions of construction industry personnel rather than empirical project information, so there remains room for improvement.

Regarding the performance metrics used in this study, for alternative contracting methods, cost certainty is known to be earlier than DBB, as noted in previous literature (Songer and Molenaar 1996; Shrestha et al. 2007; Gransberg and Shane 2010; Touran et al. 2011). Notably, however, no previous literature has asserted or shown that CM/GC provides earlier cost certainty than DB (Goftar et al. 2014), and none has specifically addressed the highway sector. Alternative contracting methods facilitate increased project intensity, outperforming DBB (Konchar and Sanvido 1998). Increased project intensity is a known benefit of CM/GC and DB (Konchar and Sanvido 1998; Septelka and Goldblatt 2005; Carpenter and Bausman 2016). However, no previous research has quantitatively compared CM/GC and DB.

Although studies comparing the performance of delivery methods is vast, there are limitations and gaps, identified as follows: (1) they compare dissimilar projects, weakening their findings (Shrestha et al. 2012); (2) they lack quantitative empirical examination of the schedule performance of CM/GC versus DB project delivery (Bingham et al. 2016); and (3) they focus on cost and schedule growth, ignoring other performance factors important to practitioners, such as the timing of cost certainty (FHWA 2013). To fill these gaps, this research compared similar projects, investigated the timing of cost certainty, and empirically examined schedule performance through project intensity and project duration. A brief description of these three points follows.

### *Exploring Similar Projects*

The need to have similar projects for the comparison of project delivery methods is recognized in the majority of previous research on the topic of project performance (Roth 1995; AECOM 2006). For instance, the comparison of a highway project is only useful if the project is compared with similar projects (Shrestha et al. 2012). Acknowledging the need to compare similar projects, the authors of this article developed a defensible method to match similar projects among different project delivery methods.

### *Empirical Examination of CM/GC Schedule Performance*

Aggressive schedule compression is the most influential factor when selecting alternative contracting methods (Touran et al. 2011). The main incentive for developing alternative contracting methods is to shorten project schedules (Warne 2005; ODOT 2009; Touran et al. 2011; Shrestha et al. 2012; Goftar et al. 2014). In light of these revelations, this research sought to determine how project delivery methods impact project duration and project intensity.

Project duration is a straightforward schedule metric to study how long agencies are taking to deliver projects through different project delivery methods. This is particularly relevant because agencies most frequently choose alternative contracting methods to shorten project duration (Warne 2005; Touran et al. 2011; Shrestha et al. 2012; Goftar et al. 2014). For project duration, the available literature highlights that the alternative delivery methods outperform DBB, but there is a gap in empirical findings for the performance of DB versus CM/GC. Project intensity is another useful schedule metric to study the rate of delivery of US highway construction projects. This metric provides an indication of the rate at which resources are invested in a project (Konchar and Sanvido 1998; Molenaar and Songer 1998; Shrestha et al. 2012). Of the limited literature on project intensity among delivery methods, none contains a comparison of DB versus CM/GC for highway projects,



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likely a result of the novelty of the CM/GC method at the times of publication.

### *Timing of Cost Certainty*

Through interviews with DOT representatives and discussion with Colorado's Innovative Contracting Advisory Committee, the authors of this article found the timing of early cost completion to be an important metric and a perceived benefit of alternative contracting methods (FHWA 2013). Early cost certainty has also been cited within the literature as another reason why agencies select alternative contracting methods (Songer and Molenaar 1996; Shrestha et al. 2007; Gransberg and Shane 2010; Touran et al. 2011). The point of cost certainty during project delivery is the time at which an agency obtains a fixed and reliable cost. It is important for resource allocation. Although the prevailing literature on the timing of cost certainty highlights the value and advantages of early cost certainty, there is a lack of quantitative comparisons of the performance of the delivery methods.

## Point of Departure

As stated previously, there exist limitations and gaps within the literature, including comparisons of dissimilar projects; a lack quantitative empirical examination of the schedule performance of CM/GC versus DB project delivery; and a lack of consideration of performance factors important to practitioners, such as the timing of cost certainty. The goal of this study was to fill these gaps through a comparison of like projects, investigating project duration, project intensity, and the timing of cost certainty. Along with bridging an existent gap in the literature, increasing the understanding of the difference between delivery methods is necessary for practitioners' selection of a project delivery method.

Much of the existing body of knowledge with regard to empirical project performance contains a mix of projects from multiple sectors. In most cases, the projects studied were for vertical facilities (Konchar and Sanvido 1998; Molenaar and Songer 1998; Septelka and Goldblatt 2005; Hale et al. 2009; Carpenter and Bausman 2016). In the current article, the authors address recommendations for a more detailed study, designed to collect a project-based data set that represents a specific and more homogeneous construction project category. The results presented in this article are therefore specific and highly relevant to US highway construction. The unique analysis of comparable highway projects between delivery methods further enhances the pertinence of the results.

In addition to the more commonly studied metric of project duration, this study explored the less cited schedule performance metrics of the timing of cost certainty and project intensity. Early knowledge of project costs and the rate of project execution are important to highway construction agencies. Project intensity is a hybrid measure of the rate that resources are put into a project and a solid indicator of a highway construction project's delivery speed. Project intensity was seminally used by Konchar and Sanvido (1998). In this article, the unit of measure for project intensity is dollars per day ($/day), unlike in the work of some previous researchers, who have based the metric on the rate of completion of specific physical aspects of a project. Although project intensity can be a useful schedule metric, a limitation of the intensity measure could be the impact of high-priced materials or other cost factors on a project (e.g., the cost of high-tech construction). The authors address this by comparing similar projects with the use of defined complexity classifications.

Given the existing academic body of knowledge and the practical need for understanding the performance of alternative delivery methods on similar projects, this research explored the following question:

- How does the performance of the project delivery methods of DBB, CM/GC, and DB compare on highway projects in terms of project duration, the timing of cost certainty during project delivery, and project intensity?

## Research Methodology

To investigate the research question, the authors performed three basic research steps: collecting data, grouping projects, and executing statistical analysis. These steps are described in greater detail in the following sections.

### *Data Collection*

The project information was acquired for this study by contacting personnel from 54 agencies across the United States over the course of 18 months. Although time-consuming, the authors found that a two-phase approach enhanced the data-collection process. In the first phase, contract managers and estimators were contacted to request information on the general project characteristics, cost, and schedule data from the historic contract administration or estimating records. The information obtained was prefilled into project-specific questionnaires, which were then sent to project managers, who completed any remaining sections. Ultimately, empirical project information was obtained for 136 projects completed between 2004 and 2015. The projects were solely from DOTs and the FHWA Office of Federal Lands Highway.

To lend objectivity to the study, the projects using alternative contracting methods were randomly selected from agencies actively engaged in those delivery methods. Then, the agencies supplied DBB projects with similar characteristics for each DB and CM/GC project according to set criteria. The contract award date of the similar DBB projects was within $\pm 2$ years and within $\pm 25\%$ of the award cost of the corresponding DB or CM/GC projects. Additionally, attempts were made to have projects similar in scope. It should be noted that the authors did not attempt to provide matching of specimens through statistical techniques in which two measurements are matched or paired and may come from the same observation (Dallal 2015). Rather, the researchers applied the stated criteria in requesting projects from state transportation agency personnel.

The data from each project were obtained via a tested and well-structured questionnaire that was administered to agency professionals. The quality of the data was ensured both at the schema and instance levels through rigorous quality control techniques (Rahm and Do 2000). Quality control was facilitated by double-checking responses with superior staff at the DOTs and by manual and low-level programming checks for verification of correct data entry. Multiple-source problems were minimal because there was no need to integrate data from multiple sources for a single project. Where necessary, the DOT professionals were able to pass on partially completed questionnaires to other individuals within their agency for the provision of missing information. This served as an additional self-correcting or vetting process.

### *Statistical Analysis*

In this study, statistical differences were checked by population tests. The *t*-test is used for parametric cases, and the Mann-Whitney

U test is used for nonparametric cases (Sheskin 2011). The *t*-test is an independent sample statistical test that compares the means for two groups. The Mann-Whitney U test performs the same function for nonparametric cases/samples based on checking the assumption of normality of these cases/samples. In addition to identifying and validating the underlying assumptions of each statistical test (e.g., random sample, normality, homogeneity of variance), the authors performed basic descriptive and graphical analyses of the data using tools such as box and whisker plots and histograms facilitated by computational software to thoroughly examine the data. The statistical tests were done at the 95% confidence level, which indicates the probability of the values of means being different. These results are reported throughout the article.

### Project Groupings

Down-sampling from the data set of 136 projects, the authors sought the most consistent means to compare the project delivery methods based on projects with similar characteristics. This proved challenging because of the novelty of the alternative contracting methods. For instance, although the use of the CM/GC method continues to grow, fewer than 50 federally funded CM/GC projects were complete across the United States at the time of this study. Similarly, some of the highway agencies had completed fewer than 10 DB projects at the time of this study. Through numerous iterations, the authors ascertained that certain delivery methods were more frequently used within two distinct cost ranges. Hence, two smaller cost pools of projects were analyzed. The first cost pool included projects with award costs from $2 million to $10 million. This grouping compared 10 DBB and 10 DB/LB projects because these were found to be the delivery methods more frequently chosen for projects in this cost range. The second cost pool included projects with award costs from $10 million to $50 million and compared 10 DBB, 10 CM/GC, and 10 DB/BV projects. Within each cost pool, the authors selectively chose projects with similar project characteristics (size/cost, complexity, facility type, and project type) across each project delivery method. Projects were considered similar based on the following criteria:

1. The award cost of each project is ±25% of each other.
2. The complexity rating is similar, based on the definitions provided in NCHRP Report 574 (Anderson et al. 2007).
3. The facility type (i.e., road or bridge project) is similar.
4. The project type (i.e., new construction or rehabilitation/renewal project) is similar.

## Data Characteristics

As presented in Table 1, DBB and DB/LB projects in the cost pool of $2 million to $10 million had similar average award costs of $4,776,575 and $4,745,533, respectively. Likewise, DBB, CM/GC, and DB/BV projects in the cost pool of $10 million to $50 million had similar average award costs of $23,081,092, $23,912,981, and $18,604,503, respectively, as shown in Table 2. To further emphasize the similarity of projects in each cost pool, the differences among the average award costs of the project delivery methods were not statistically significant at the 95% confidence level in either cost pool. It should be noted that the authors used the National Highway Construction Cost Index (NHCCI) of the FHWA to convert all costs in the database to equivalent costs in June 2015. This conversion permitted a fair comparison of project costs from different delivery methods. The empirical project information collected for this study included information on change orders for each project. Thus, the calculation of the performance metrics was derived from final cost and schedule values that included change orders.

## Findings

As shown in Table 3, the DBB and DB/LB projects compared in the cost pool of $2 million to $10 million had similar complexity ratings, with the majority of projects in each delivery method having a rating of moderately complex. The two most complex DBB and DB/LB projects in this cost pool drew the attention of the authors to investigate why these projects were rated as the most complex. One of the DBB projects used technology that was completely new to the agency at that time. It involved the construction of the first-ever posttensioned precast deck panel bridge in the state. The other DBB project had significant and ongoing right-of-way issues that resulted in extreme scope changes that necessitated utility cell tower relocations to be included in the project's scope. Of the DB/LB projects, in one project, because of the frequency of vehicle collisions with wildlife, the agency had commitments to provide wildlife mitigation features in the project's design and accommodate wildlife mitigation during construction. At the inception of the other DB/LB, the scope was just for rehabilitation of a bridge over a section of a railroad. However, further investigation of the rehabilitation needs of the structure revealed that the cost was similar in magnitude to the cost of full reconstruction/replacement, which was significantly impacted by issues with the railroad.

**Table 3.** Distribution of the complexity rating for DBB and DB/LB projects between $2 million and $10 million

| | Complexity rating | | |
|---|---|---|---|
| Delivery method | Most complex | Moderate | Noncomplex |
| DBB ($n = 10$) | 2 | 6 | 2 |
| DB/LB ($n = 10$) | 2 | 6 | 2 |

**Table 1.** Award cost descriptive statistics for DBB and DB/LB projects between $2 million and $10 million

| Delivery method | $n$ | Mean ($) | Standard deviation ($) | Minimum ($) | Median ($) | Maximum ($) |
|---|---|---|---|---|---|---|
| DBB | 10 | 4,776,575 | 2,592,518 | 2,067,493 | 4,935,703 | 9,474,478 |
| DB/LB | 10 | 4,745,533 | 2,013,985 | 2,393,999 | 4,140,000 | 7,504,820 |

**Table 2.** Award cost descriptive statistics for DBB, CM/GC, and DB/BV projects between $10 million and $50 million

| Delivery method | $n$ | Mean ($) | Standard deviation ($) | Minimum ($) | Median ($) | Maximum ($) |
|---|---|---|---|---|---|---|
| DBB | 10 | 23,081,092 | 8,671,426 | 11,429,469 | 22,332,388 | 37,574,315 |
| CM/GC | 10 | 23,912,981 | 8,849,869 | 10,634,644 | 21,571,119 | 39,600,000 |
| DB/BV | 10 | 18,604,503 | 10,169,378 | 10,875,000 | 15,149,741 | 43,960,798 |

The DBB, CM/GC, and DB/BV methods compared in the cost pool of $10 million to $50 million also had similar complexity ratings, with the majority of projects rated as the most complex, as shown in Table 4. Upon investigation, the single DBB project in this cost pool was likely rated as noncomplex because it was a straightforward pavement patch and rehabilitation job, but the extent of the work along with necessary road-user accommodations heightened the project's cost.

Regarding specific facility types, respondents gave the percentages of the work components for each project in the categories of the road, bridge, and other work. For facility type, the qualitative explanations provided by respondents revealed that the category of *other work* included work such as landscaping, guardrail installation, and signalization. At the aggregate level in the cost pool of $2 million to $10 million, the DBB projects were on average 55% road, 40% bridge, and 5% other work. The DB/LB projects in this cost range were on average 43% road, 54% bridge, and 3% other work. In the cost pool of $10 million to $50 million, at the aggregate level, the DBB projects were on average 73% road, 20% bridge, and 7% other work. The CM/GC projects in this cost range were on average 72% road, 19% bridge, and 9% other work. The DB/BV projects were on average 46% road, 46% bridge, and 8% other work. The higher percentage of bridge work is the only notable difference in the cost pool of $10 million to $50 million.

With regard to specific project types, respondents provided percentages for the descriptions of new construction, rehabilitation/renewal (rehab/renew), and others. For project type, the qualitative explanations provided by respondents revealed that the category of *other* described projects that were for minor maintenance, replacement, and/or restoration purposes. At the aggregate level in the cost pool of $2 million to $10 million, the DBB projects were on average 53% new construction, 47% rehab/renew, and 0% other. The DB/LB projects in this cost range were on average 46% new construction, 54% rehab/renew, and 0% others. In the cost pool of $10 million to $50 million, at the aggregate level, the DBB projects were on average 15% new construction, 85% rehab/renew, and 0% other. The CM/GC projects in this cost range were on average 18% new construction, 82% rehab/renew, and 0% other. The DB/BV projects were on average 42% new construction, 47% rehab/renew, and 1% other. The higher percentage of rehab work is the only notable difference in the cost pool of $10 million to $50 million.

**Table 4.** Distribution of the complexity rating for DBB, CM/GC, and DB/BV projects between $10 million and $50 million

| Delivery method | Complexity rating: Most complex | Moderate | Noncomplex |
|---|---|---|---|
| DBB ($n = 10$) | 6 | 3 | 1 |
| CM/GC ($n = 10$) | 6 | 4 | 0 |
| DB/BV ($n = 10$) | 6 | 4 | 0 |

## Results and Discussion

This section presents a discussion of the findings within the metrics studied: project duration, the timing of cost certainty, and project intensity. When comparing the results of this study to the aforementioned research in project delivery performance, readers should note a few key differences. The procurement process for highways is substantially longer than that for building projects. Owners can procure building projects with less design requirements and more performance-based requirements. Highway procurement has stringent requirements needed for highway construction safety and continuity within the road network. Furthermore, highway construction is more likely to be affected by issues such as the National Environmental Policy Act (NEPA) and right-of-way requirements, which need to be resolved or at least thoroughly understood prior to issuing a request for proposal (RFP). Although previous research has included projects with different characteristics, or even from different sectors, this article presents an examination of alternative contracting methods specifically within the US highway construction sector. As previously mentioned, projects within the delivery methods in the respective cost pools were similar based on characteristics of award cost, complexity, facility type, and project type. For this study, the means of the various durations were compared on a pairwise basis among the delivery methods at the 95% confidence level by using appropriate statistical tests for means. With regard to the inferential statistics, the results tables indicate the few cases in which the values compared had a statistically significant difference from each other based on the *t*-test when both samples compared satisfied normality (parametric) and the Mann-Whitney U test for nonparametric cases.

### Project Duration

Agencies chose alternative contracting methods to shorten project durations, which the data from this study show they are achieving. Tables 5 and 6 present the duration of each phase of project delivery for each cost pool studied. Project duration was based on the final duration, including all contract changes and/or builder delays. It should be noted that construction duration for DB projects included design-builder design and construction duration (i.e., the DB contract duration from award to completion).

The time savings of DB/LB versus DBB confirms the well-cited schedule acceleration benefit of DB (Bennett et al. 1996; Konchar and Sanvido 1998; NYDOT 2003; SAIC 2002; AECOM 2006; Warne 2005; Ellis et al. 2007). This acceleration is often attributed to being able to expedite procurement by the minimal design effort required of agencies and by the early start of construction, which may overlap with design duration (Songer et al. 1996; ODOT 2009; MnDOT 2011; VDOT 2011; CDOT 2014; FDOT 2017).

Table 6 summarizes the duration of the DBB, CM/GC, and DB/BV projects in the cost pool of $10 million to $50 million. The mean CM/GC project duration was found to be 69% and 53%

**Table 5.** Duration for DBB and DB/LB projects between $2 million and $10 million

| Delivery method | Mean project duration (days) | Mean agency design duration (days) | Mean procurement duration (days) | Mean construction duration (days) |
|---|---|---|---|---|
| DBB ($n = 10$) | 1,431[a] | 751[a] | 51 | 477 |
| DB/LB ($n = 10$) | 773[a] | 181[a] | 116 | 380 |

[a]Values that have a statistically significant difference from the other values within each column.

**Table 6.** Duration for DBB, CM/GC, and DB/BV projects between $10 million and $50 million

| Delivery method | Mean project duration (days) | Mean agency design duration (days) | Mean procurement duration (days) | Mean construction duration (days) |
|---|---|---|---|---|
| DBB ($n = 10$) | 2,106 | 1,117 | 67 | 865 |
| CM/GC ($n = 10$) | 662[a] | 281[a] | 48[b] | 349[a] |
| DB/BV ($n = 10$) | 1,420 | 638 | 127[b] | 639 |

[a]Values that have a statistically significant difference from the other values within each column.
[b]Values that have a statistically significant difference from each other, whereas there is no difference when compared with the other values within each column.



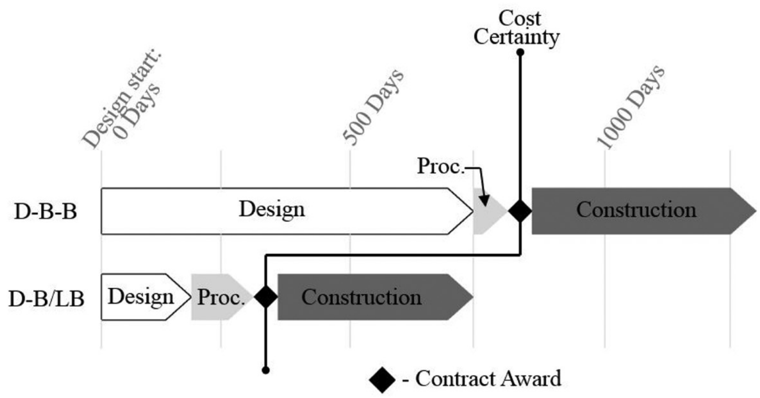


**Fig. 1.** Point of cost certainty for DBB and DB/LB projects between $2 million and $10 million.

shorter than DBB and DB/BV, respectively. Shorter CM/GC mean durations were found in both design and construction. The shorter design duration for CM/GC is surprising because the CM/GC process, similar to DBB, brings the design to 100% completion prior to contract award. The shorter CM/GC design duration is likely due to multiple factors. Having the construction manager on the team during design can lead to a shorter design length, which allows the agency to fast-track the design (Gransberg 2013a; Gransberg and Shane 2010). In addition to gaining contractor input, there is no need to develop full designs for competitive bidding, as in DBB (Gransberg 2013b). The shorter CM/GC construction duration is likely due, at least in part, to involving the contractor in the project design process (Gransberg 2013a). In comparison to DB/BV, the shorter duration of CM/GC may be the result of a shorter, less complicated RFP process. In DB/BV, the developed RFPs are often voluminous and sometimes need extended industry review periods along with lengthier agency evaluations (Migliaccio et al. 2009).

The shorter CM/GC project duration in comparison to DBB is a confirmation of previous literature findings (Konchar and Sanvido 1998). However, CM/GC being shorter than DB/BV is not common in previous research, and this warrants further investigation to establish whether this is indeed a potential advantage of CM/GC versus DB/BV. As expected, DB/BV also showed substantially shorter mean project, design, and construction duration compared with DBB.

Although the empirical findings between DB and CM/GC are new, the overall time savings of alternative contracting methods are well known in literature as a benefit (Bennett et al. 1996; Konchar and Sanvido 1998; NYDOT 2003; SAIC 2002; AECOM 2006; Warne 2005; Ellis et al. 2007). Because the analysis compared projects that were similar in scope and award cost, the findings indicate how an agency can use an appropriate project delivery method to minimize public impact and the expenditure of agency resources.

### *Timing of the Point of Cost Certainty*

Alternative contracting methods are providing agencies with much earlier cost certainty. Cost certainty equates to the point at which the agency obtains a reliable project cost. Agencies value early cost certainty for both project and program management to better manage and allocate resources during project delivery because early cost certainty facilitates the optimal use of often-limited capital (Hastak 2015). It can indicate the probability of completing a project within the budget agreed on by clients and contractors (Xiao and Proverbs 2003). Thus, achieving project cost certainty early during project delivery allows agencies to more efficiently manage the expenditure of project funds.

Fig. 1 presents the point of cost certainty based on the magnitude of the mean, design, procurement, and construction durations for DBB and DB/LB projects between $2 million and $10 million, as shown in Table 7; only the mean cost certainty timing was statistically tested. In DBB, the initial contract cost (i.e., point of cost certainty) is known at the time of contract award. In DB/LB, the initial contract cost is known at the point of design-builder selection. For DBB and DB/LB projects in this pool, DB/LB cost certainty was known more than 60% earlier, concurring with previous literature (Songer and Molenaar 1996; Shrestha et al. 2007; Gransberg and Shane 2010; Touran et al. 2011).

Fig. 2 illustrates the point of cost certainty based on the mean design, procurement, and construction durations for DBB, CM/GC, and DB/BV projects between $10 million and $50 million, as shown in Table 8; only the mean cost certainty timing was statistically tested. The potential reasons for the point of cost certainty in DBB and DB/BV projects were previously explained with the DB/LB results discussion. The point of cost certainty for CM/GC projects is known after the cost for the last construction package is established. CM/GC projects may have one or more construction packages. For ease of illustration, Fig. 2 combines all bid packages

**Table 7.** Timing of cost certainty for DBB and DB/LB projects between \$2 million and \$10 million

| Delivery method | Start of design to start of procurement (days) | Procurement duration (days) | Construction duration (days) | Project duration (days) | Timing of cost certainty (days) |
|---|---|---|---|---|---|
| DBB ($n = 10$) | 751 | 51 | 477 | 1,431 | 801[a] |
| DB/LB ($n = 10$) | 181 | 116 | 380 | 773 | 297[a] |

[a]Values that have a statistically significant difference from the other values within each column.

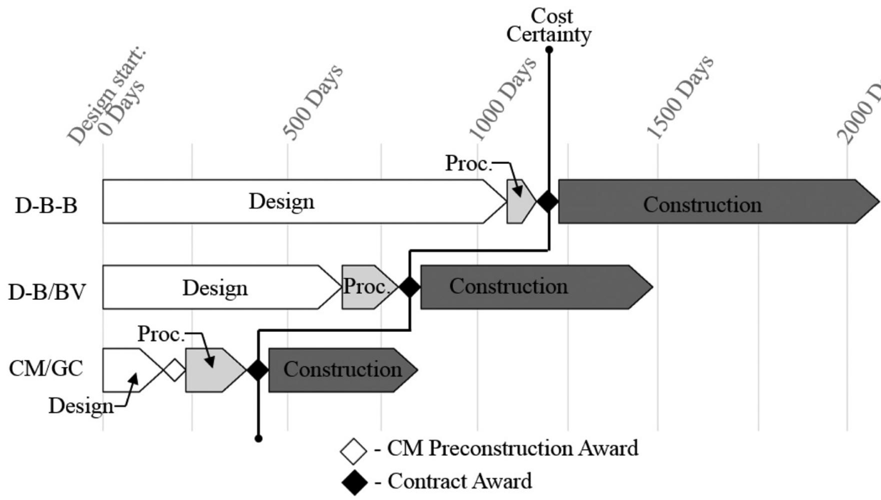


**Fig. 2.** Point of cost certainty for DBB, CM/GC, and DB/BV projects between \$10 million and \$50 million.

**Table 8.** Timing of cost certainty for DBB, CM/GC, and DB/BV projects between \$10 million and \$50 million

| Delivery method | Start of design to start of procurement (days) | Procurement duration (days) | Construction duration (days) | Project duration (days) | Timing of cost certainty (days) |
|---|---|---|---|---|---|
| DBB ($n = 10$) | 1,117 | 67 | 865 | 2,106 | 1,184[a] |
| CM/GC ($n = 10$) | 281 | 48 | 349 | 662 | 329[a] |
| DB/BV ($n = 10$) | 638 | 127 | 639 | 1,420 | 765 |

[a]Values that have a statistically significant difference from each other, whereas there is no difference when compared with the other values within each column.

with the award of the last bid package and does not show the overlap of design and construction (although it does exist). Again, when compared to DBB, the alternative contracting methods were found to outperform, concurring with previous literature (Songer and Molenaar 1996; Shrestha et al. 2007; Gransberg and Shane 2010; Touran et al. 2011). Notable, however, is that no previous literature has asserted or shown that CM/GC provides earlier cost certainty than DB (Goftar et al. 2014).

In summary, agencies are receiving cost certainty substantially quicker with alternative contracting methods. CM/GC early cost certainty is of special note and should be the focus of future research to solidify this feature as an advantage of CM/GC. With increasing funding deficits and the deterioration of existing infrastructure, it is vital that agencies efficiently plan and spend their funds. Cost certainty allows agencies to acquire better spending efficiency and to better plan spending at both a project and programmatic level.

## *Project Intensity*

In this article, project intensity is a measure of how much money is spent per day during project delivery. Higher intensity equates to a faster rate of project delivery. Intensity is therefore an excellent measure of how agencies are minimizing the impact of highway construction on the traveling public by completing projects at a faster pace. Furthermore, the normalizing effect (i.e., the ratio of investment over the duration) makes this metric ideal for comparing the project delivery methods. Project intensity is defined by the following equation:

$$\text{Project intensity} = \frac{\text{final cost (\$)}}{\text{actual project duration (days)}} \tag{1}$$

Table 9 provides the project intensity metrics for similar DBB and DB/LB projects in the cost pool of \$2 million to \$10 million; only the mean project intensity was statistically tested. In comparison to similar DBB projects in the cost pool of \$2 million to \$10 million, the project intensity of DB/LB was found to be higher, which is an unsurprising result because alternative contracting methods facilitate increased project intensity (Konchar and Sanvido 1998).

Table 10 provides the project intensity metrics for similar DBB, CM/GC, and DB/BV projects in the cost pool of \$10 million to \$50 million; only the mean project intensity was statistically tested. The shorter project duration and higher contract cost of the CM/GC

**Table 9.** Project intensity for DBB and DB/LB projects between \$2 million and \$10 million

| Delivery method | Mean (\$/day) | Standard deviation (\$/day) | Minimum (\$/day) | Median (\$/day) | Maximum (\$/day) |
|---|---|---|---|---|---|
| DBB ($n = 10$) | 4,431 | 3,129 | 838 | 3,710 | 11,101 |
| DB/LB ($n = 10$) | 8,040 | 6,004 | 2,728 | 5,864 | 23,509 |

**Table 10.** Project intensity for DBB, CM/GC, and DB/BV projects between \$10 million and \$50 million

| Delivery method | Mean (\$/day) | Standard deviation (\$/day) | Minimum (\$/day) | Median (\$/day) | Maximum (\$/day) |
|---|---|---|---|---|---|
| DBB ($n = 10$) | 17,202 | 16,985 | 4,723 | 13,021 | 63,397 |
| CM/GC ($n = 10$) | 48,269 | 41,605 | 19,910 | 31,718 | 159,031 |
| DB/BV ($n = 10$) | 18,679 | 11,412 | 3,846 | 16,768 | 42,393 |



and DB/BV projects were found to result in much higher project intensity than similar DBB projects in the cost pool of \$10 million to \$50 million. These results concur with literature showing that increased project intensity is a benefit of CM/GC and DB (Konchar and Sanvido 1998; Septelka and Goldblatt 2005; Carpenter and Bausman 2016). However, the similar intensity of DBB and DB/BV is surprising and warrants further examination.

In summary, agencies appear to be placing more work within a shorter amount of time through alternative contracting methods. Because serving the public is the number-one goal of all governmental agencies, minimizing public impact is a welcome benefit. This finding can aid agency personnel in choosing an appropriate project delivery method, particularly when projects are in urban or heavy economic areas.

## Conclusions

The unique analysis of comparable projects in this study provides intriguing new results that highlight key benefits of alternative contracting methods. As expected, DB/BV was found to have substantially shorter mean project, design, and construction duration compared with DBB. However, CM/GC being 53% shorter than DB/BV is not common in previous research, and this warrants further investigation. This accords with the trend for project duration noted by Shrestha et al. (2016), which shows that CM/GC is shorter than DB by a more modest percentage of 18%, but Shrestha's results were based on CM/GC projects restricted to three US states, whereas the CM/GC projects in this study were from a wider geographic area. Results concur with findings from previous researchers showing that alternative contracting methods provide shorter project durations than the traditional DBB method (Konchar and Sanvido 1998; Molenaar and Songer 1998; Septelka and Goldblatt 2005; AECOM 2006; Hale et al. 2009; Carpenter and Bausman 2016). No previous highway construction research studies have included statistical tests for the differences in project duration between DB and CM/GC projects.

The timing of cost certainty during highway project delivery has not been quantified by previous researchers. However, as expected, alternative contracting methods were found to provide agencies with cost certainty at a point in time that is much earlier during project delivery than the traditional DBB method. The results of this research address this gap in knowledge by quantitatively showing how the timing of cost certainty relates to different highway project delivery methods, especially CM/GC versus DB, which is novel. When compared with similar DBB projects, the average point of cost certainty for alternative contracting methods was found to be much earlier, which the previous literature has already revealed as a benefit of the CM/GC method (Gransberg and Shane 2010; Touran et al. 2011) and of the DB method (Songer and Molenaar 1996; Shrestha et al. 2007; Gransberg and Shane 2010; Touran et al. 2011) No previous studies have compared the timing of the point of cost certainty between DB and CM/GC. In this study, the comparison of CM/GC projects to similar DB/BV projects in the cost pool of \$10 million to \$50 million found that the point of cost certainty is known approximately 40% earlier in CM/GC projects.

With regard to project intensity, the shorter project duration and higher contract cost of CM/GC and DB/BV projects were found to result in higher project intensity than for similar DBB projects in the cost pool of \$10 million to \$50 million. In comparing DBB projects to similar DB/LB projects in the cost pool of \$2 million to \$10 million, the project intensity of DB/LB was found to be higher. Again, these results coincide with the previous research finding that alternative contracting methods have faster project delivery than the traditional DBB method (Konchar and Sanvido 1998; Molenaar and Songer 1998; Septelka and Goldblatt 2005; AECOM 2006; Hale et al. 2009; Carpenter and Bausman 2016). However, contrary to the results of the two previous research studies that compared project intensity between DB and CM/GC (Konchar and Sanvido 1998; Touran et al. 2011), this study found that CM/GC greatly outperformed DB/BV. The difference is likely due to the lengthy DB/BV procurement process that is required for highway construction projects.

With state transportation agencies constantly seeking ways to be more efficient with public funds for US highway construction, the alternative contracting methods of CM/GC and the two distinct forms of DB, DB/LB and DB/BV, are viable options for shortening project durations. The alternative contracting methods are delivering projects at a faster pace to reduce impacts to road users, in addition to establishing early cost certainty during project delivery.

## Limitations and Recommendations for Future Research

The collection of accurate project duration/schedule data proved challenging throughout the data collection for this study. Agency personnel found it challenging to provide the required data in sufficient detail for various reasons. Nevertheless, this study accomplished the research objectives by selecting projects in which adequate data were provided on a small number of projects for design, construction, and project duration. With the provision of larger samples in future work, more in-depth analyses can be performed, such as an examination of the design overlap duration in DB projects and the phasing of work packages in CM/GC. Additionally, with new approaches to procurement in the different project delivery methods, it would be worth studying the effect on project performance of innovative techniques such as competitive guaranteed maximum price in CM/GC or DB (Tran et al. 2018).

Although actual schedule data were obtained for the projects studied, as a result of the sparseness of the planned schedule data, the authors were unable to compare schedule growth of the projects among the delivery methods. This is a consequence of the difficulty in obtaining accurate project delivery planned schedule dates from agency design through construction completion from agencies, for various reasons. Future work to obtain accurate planned schedule data will facilitate an examination of the schedule growth metric among the project delivery methods.

As the use of alternative contracting methods continues to grow, particularly for the CM/GC method, research that considers larger sample sizes will be beneficial to industry and academia. Research with larger sample sizes may then facilitate statistical comparisons of other key performance metrics among the project delivery methods. In the future, it would also be prudent to obtain accurate cost information for agencies' design costs for projects in each project delivery method. As an alternative to studying structured project delivery methods, considerations can also be made to study project management strategies for delivering successful projects (Anantatmula 2015).

It is noteworthy that the authors have made significant efforts to avoid implying causality and/or directly stating that any delivery method is better because there are numerous other confounding factors that may influence project performance. To reiterate, the objective of the study was to indicate the performance of highly similar projects obtained from a database of empirical project information. With adequate data permitting, future work could reveal interesting supplemental findings based on the comparison of similar road projects separate from similar bridge projects among the different contracting methods.

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