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Delivery Method for Rapid Bridge Construction

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A growing body of previous studies suggested that Alternative Contracting Methods (ACM) could foster constructability, increase innovation, reduce schedules, decrease risks, have a higher project intensity, and eventually save on project costs. The objective of this study was to compare Design-Build procurement and delivery of Bridges in Georgia with Design-Bid-Build in terms of cost, schedule, and intensity. The study used factual data from all Bridges completed using Design-Build and Design-Bid-Build delivery methods between 2008 and 2018. Data points were collected through personal interviews and survey questionnaires with Georgia Department of Transportation (GDOT) personnel. The intended audiences for the study were State DOT officials engaged in the bridge procurement process. The findings from this study would benefit State DOTs by improving their understanding of the advantages of the Design-Build delivery method, most importantly expediting bridge construction projects in metropolitan areas where each day delay could impact millions of users adversely. The study also provided quantitative evidence in support of advantages achieved from the Design-Build delivery method in terms of cost growth, schedule reduction, and project intensity as compared to the Design-Bid-Build delivery method.

Keywords: -Alternative Contracting Method (ACM), Design-Build (DB), Schedule Growth, Cost Growth, Project Intensity, Design-Bid-Build (DBB).

Introduction

‘‘In the DB project delivery method, the state executes a single contract for both the design and construction, awarded on either a Low-Bid or Best-Value basis. This project delivery method is sometimes pursued to reduce project duration and cost over more traditional approaches. Under the traditional transportation project delivery method, known as DBB, a project owner contracts with separate entities to design and construct a transportation project’’ (Borowiec, et al.,2016). ‘‘The shift to DB from DBB allots responsibility and risk to the parties who can best manage the processes and outcomes. It allows for innovation in design, construction techniques, construction phasing, sequencing, risk management, traffic management, Public Information, and cooperative communication’’ (CDOT 2016).

The primary objective of this paper was to offer empirical evidence for the project performance criteria by comparing DB, and the traditional DBB project delivery techniques for Bridge Projects. The focus was to verify that DB was the fastest and effective project delivery method for Bridge Construction in the Georgia Department of Transportation (GDOT). The main question of this

research analyzes ‘‘how do schedule growth, cost growth, and project intensity’’ impact the delivery system of DB and DBB on bridge projects completed between 2008 to 2018.

This paper aimed to improve business and management practices with bridge construction. It also contributed to the construction body of knowledge by presenting one of the first research efforts in the State of Georgia that compared bridge project performances between DBB, and DB projects based on empirical data analysis. The intended audience of this study would be State DOT offices involved in the bridge procurement business. It is also the right moment to evaluate the performance of DB bridge projects in the State of Georgia, which has an aggressive plan to replace more than 377 bridges with the DB delivery method across the State over the next five years.

The State of Georgia’s Bridge Construction

‘‘Georgia’s transportation infrastructure ranks second-best in the nation among the U.S. states’’, according to a report published by MSN Money. According to GDOT’S website and internal publications, the State of Georgia has a total of around 14,750 Bridges. The Department record shows 6,600+ structures (4,500 bridges and 2,100 culverts) with an estimated average age of 43 years. Since the 2014 ASCE Report Card, ‘‘GDOT has reduced the number of posted bridges from 2% to 1.5% of all bridges on the state system’’. Currently, GDOT is scheduled to restore or replace bridges, which are load restricted or closed for traffic on the State bridge system.

Out of 4,300, all National Highway System Bridges found in Georgia, 1997 bridges are in good condition,2,285 in fair condition and 18 are in poor condition’’ (DuVall, B. 2018). ‘‘The Transportation Funding Act of 2015 (TFA) provided nearly $1 billion in additional revenue for Georgia’s transportation system each year, including for the 14,863 bridges and culverts across the state. As a result, Georgia has decreased the percentage of structurally deficient bridges, from 8.6% in 2014 to 4.6% in 2017’’ (ASCE 2019). The American Society of Civil Engineers (ASCE) Infrastructure report card in 2019 rated the Georgia roads and bridges a C+.

According to GDOT’s internal report, ‘‘GDOT has created the Local Bridge Replacement Program (LOCBR) to reduce this number. The Low Impact Bridge Program (LIBP) was introduced in 2014 and replaced and reopened 14 bridges with 3 under construction and 33 more programmed for replacement within the next two to three years. The Local Bridge Replacement Program (LOCBR) was initiated in 2017 with 52 bridges solicited for replacement throughout the state and 25 bridges entering Preliminary Engineering activities to date. In the past three years, there has been a growing inventory of 86 Bridges since 2015, excluding the 38 newly built bridges on the Northwest Corridor (NWC)’’. Following the GDOT Design-Build Bridge replacement program, ‘‘Georgia’s Transportation Funding Act of 2015 resulted in an additional $757 million in 2016 and an estimated $824 million in 2017 for GDOT’’. With that, the GDOT bridge program increased from $155 million in 2015 to nearly $168 million in 2016, $279 million in 2017, $301 million in 2018, and $369 in 2019.

GDOT’s program goal was to conduct projects most efficiently to rapidly reduce the number of locally owned bridges in poor condition. For this reason, GDOT decided to use the DB project delivery method combined with low-bid procurement for selecting DB contractors. ‘‘GDOT utilizes resolute ACM staff, a Program Management Consultant (PMC), and General Engineering Consultants (GECs) throughout the ACM pre-award and post-award stages’’ (Gransberg 2018).

Table 1-Summary of Georgia Bridges Condition

State-owned Bridges	Locally owned Bridges	Load restricted Bridges-State owned	Load restricted Bridges-Locally owned	Good condition Bridges	Fair condition Bridges	Poor condition Bridges
6,736	8,014	656	1,451	6,250	8,103	374
14,750		2,107		14,727		

Source: -GDOT Department Record.

Point of Departure

A lot of previous studies have mainly focused on highway road projects at the national level however this research was one of the first research efforts in the State of Georgia and compared the performance of Design-Build delivery method to Design-Bid-Build projects on bridge projects about schedule growth, cost growth, and project intensity. Specific questions that drove the research were:

I. How does the DB delivery method affect cost growth?
II. How does the DB delivery method affect project speed and schedule growth?
III. How does the DB delivery method affect the production rate or project intensity?

Research Methodology

This study collected cost, schedule, and intensity data for DB projects completed by GDOT from 2008 to 2018, analyzed and compared the same with DBB (Antoine et al., 2019), (Douglas et al.,2016), and a technical summary of the Federal Highway Administration Report Alternative Contracting Method Performance in U.S. Highway Construction (DTFH61-13-C-00024). The authors carried out three basic steps: Collecting data, categorizing, and performing statistical analysis.

Data Collection

The questionnaire, which was prepared using MS Excel format, was divided into two sections: General & Procurement Data, and Performance Data. The first section asked for general information about a project, such as a project name and contract description. The additional section asked for data that were available during the procurement phase of the projects, which were the contracting methods, procurement methods, project size, award basis, and Design-Bid Team. The second section asked for data that were available for duration and cost performance metrics such as the contract awarded amount, the final paid amount, awarded days, days used, and job letting date.

Data Analysis

After the data was collected and statistically analyzed, this study calculated the performance metrics, which include cost growth, schedule growth, and Project Intensity, quantitatively defined as follows:

- Cost growth is calculated as the difference between the final project cost and the initial contract award and expressed as:

$$\textit{Cost Growth (\%)} = \left[\frac{\textit{Final actual Cost-Initial planned Cost}}{\textit{Initial Planned Cost}}\right] \times 100$$

- Schedule Growth is calculated as the difference between the actual time taken to complete the project and the planned project duration signed at the contract expressed as:

$$\textit{Schedule Growth (\%)} = \left[\frac{\textit{Actual Completion Time-Planned Schedule Time}}{\textit{Actual Completion Time}}\right] \times 100$$

- ‘‘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’’ (Konchar and Sanvido 1998). It is a measure of how much money is spent per day during 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’’ (Alleman and Antoine 2019).

$$\textit{Project Intensity} = \frac{\textit{Final Contract Cost}}{\textit{Actual Construction Duration}}$$

Result and Discussions

Project Duration

Table 2 reveals that the mean procurement duration from the ‘‘date project advertised’’ to the ‘‘date project awarded’’ was higher for Georgia DB and Bridge projects compared to DBB for other states. This was because procurement efforts in the Design-Build category have required additional time needed to prepare explicitly defined contract documents. On the other hand, Projects executed by the Design-Build delivery method attained substantial schedule acceleration when compared to the traditional Design-Bid-Build system on both cost categories, which eventually construction duration.

For projects in a cost category of $2M to $10M in Table 2 showed that the mean project duration for DB Projects in Georgia was found to be 49% shorter than DBB for all states. In the same cost category, DB Georgia Bridge projects were 57% shorter than DBB for all states. For projects in a cost category of $10M to $50M in Table 3, the mean project duration for DB Projects in Georgia was found to be 54% shorter than DBB for all states while DB Georgia Bridge projects were 56% shorter than DBB for all states.

In GDOT bridge construction history, the following bridge projects could be taken as a success story for expedited bridge construction. In March of 2017, the Interstate 85 bridge collapsed because of a fire incident under the bridge. Despite the incident, GDOT reopened the bridge several weeks ahead of schedule by formulating a more advanced plan to rebuild the bridge using contractor incentives in addition to DB to expedite the project. Moreover, the bridge carrying State Route 299 over I-24 in Northwest Georgia was fully replaced using an Accelerated Bridge Construction (ABC) method in 56 hours. GDOT also demolished and reconstructed the 110-year-old Courtland Street Bridge by using the Design-Build procurement method as well as (ABC) technology. This bridge connects Martin Luther King Jr. Drive to Gilmer Street in Downtown Atlanta close to the Georgia State Capitol and serves as a major link to the Georgia State University campus. The road closed for approximately six months and interrupted traffic for many commuters as well as for 32,000 GSU students. MARTA (Metropolitan Atlanta Rapid Transit Authority) rerouted bus service and other transits were also impacted by the bridge construction. If the bridge was constructed by the traditional DBB delivery system, it could have been worse and taken up to two years. Thanks to the ABC and DB Alternative Contracting Method that reduced the scheduled growth up to 41% as shown in Table 4 and made it possible in less than six months. Generally, GDOT bridge construction reduced the scheduled growth by 12% as shown in Table 4 and this number will be higher as the department gain more experience on bridge construction projects through the DB delivery system in the future.

Table 2. The Average duration for DBB and DB projects between $2 million and 10 million

Delivery Method	Sample Size	Mean Project duration(days)	Mean Design duration (days)	Mean Procurement duration(days)	Mean Construction duration(days)
DBB for All states	19	1,506*	795*	51*	508*
DB for All States	10	773*	181*	116*	380*
DB Georgia	7	771	217	216	507
DB Bridge Georgia	2	651	179	197	342

Note. * from " Technical summary of the Federal Highway Administration Report Alternative Contracting Method Performance in U.S. Highway Construction (DTFH61-13-C-00024)'', 2018.

Table 3. The Average duration for DBB and DB projects between $10 million and 50 million

Delivery Method	Sample Size	Mean Project duration(days)	Mean Agency Design duration (days)	Mean Procurement duration(days)	Mean Construction duration(days)
DBB for All states	34	2,130*	1,139*	67*	818*
DB for All States	10	1,420*	638*	127*	639*
DB Georgia	7	973	300	351	752
DB Bridge Georgia	3	948	309	251	710

Note. *from " Technical summary of the Federal Highway Administration Report Alternative Contracting Method Performance in U.S. Highway Construction (DTFH61-13-C-00024)'', 2018.

Project Cost

One of the advantages of the Design-Build delivery system is minimizing the potential for design errors and omissions. It is also permitting simultaneous activities of design and construction for distinct sections of the same project. DB provided flexibility during construction that allowed for changes to be made on the fly without requiring a supplemental agreement, which ultimately save money and benefit the owner by transferring the risk to the DB contractor. On the contrary, the Design-Bid-Build contracting method, design modifications, and unforeseeable issues would result in a supplemental agreement or a change order which increases the cost to the owner.

Table 4. Georgia Design-Build Projects Schedule Growth by Award Value

Project Award Value	**Sample Size**	**Schedule Growth (%)**
All Project	18	-3.49%
Over $ 20M	7	-3.87%
Under $20M	11	-3.24%
Under $ 10M	9	-3.40%
Under $ 5M	5	4.22%
All Bridge	5	-11.93%
Courtland Street ABC Project	1	-41.09%
SR 299 at I-24 Bridge Replacement ABC Project	1	-35.57%

The cost growth for DB Georgia bridge project at each cost category showed no increase except over $ 20 million with a 1.43% upsurge. This fact demonstrated that the DB delivery method saved cost over the traditional approach. In the same token, the cost growth for DB Georgia projects at each cost category showed an insignificant increase except over $20 million cost category with a 5.41% rise but it is still better compared to the DBB delivery system. According to the Federal Highway Administration study, ‘‘the mean cost growth for DBB projects in the US was 4.1 percent’’. The data analysis for Design-Build projects completed as of 2018 in GDOT showed that there was a 1.94% cost growth with an average of nearly three change orders per project as well as a budget increase of $971,284.03 per project. Many of the change orders could have added value to the project but further study will require whether these change orders were agency directed, plan errors and omissions, plan quantity changes, unforeseen conditions, or others.

Table 5 showed DB Georgia and DB Georgia bridge projects almost did not show any cost growth except the DB project over $20M cost category. These two projects were the I-85 Express Lane extension and SR-400 widening that showed 7.65% and 22.48% cost growth, respectively. Many of the supplemental agreement on the I-85 express lane project was for additional scope due to coordination with other corridor projects. In the same manner, the cost growth on the SR-400 widening project was due to the full depth slab and outside shoulder replacement.

Project Intensity

The project intensity for DB for Georgia and DB Georgia Bridge projects was found to be higher when compared with DBB or DB for all states. Table 6 showed that DB for Georgia projects spent an average of $16,216 per day while DB Bridge projects for Georgia spent $26,652 per day on average for a cost category between 2 and 10 million. For the cost category between 10 and 50 million on Table 7 exhibited that the mean amount spent daily were $35,158 and $40,167, respectively. Table 8 also disclosed higher construction intensity for DB bridge projects under the 10 and 20 million award categories. From the result, we concluded that the higher the money spent each day indicated projects completed at a faster pace and reduced construction impact on the end-users.

Table 5. Average Cost growth by Delivery Type and Award Value

Delivery Method	Over $20M		Under $20M		Under $10M		Under $ 5M	
	Sample Size	Cost Growth	Sample Size	Cost Growth	Sample Size	Cost Growth	Sample Size	Cost Growth
DBB for All States	47*	6.2%*	83*	3.4%*	52*	2.3%*	36*	1.00%*
DB for All States-LB	6*	3.40%*	31*	3.2%*	26*	3.8%*	20*	3.80%*
DB for All states -BV	42*	4.40%*	35*	3.30%*	19*	2.2%*	9*	3.80%*
DB Georgia	7	5.41%	11	0.24%	9	0.04%	5	-0.47%
DB Bridge Georgia	3	1.43%	2	0.00%	2	0.00%	1	0.00%

Note. * from ‘‘The Use and Performance of Alternative Contracting Methods on Small Highway Construction Projects,’’ by Douglas et al, 2016.

Table 6. Project Intensity for DBB and DB projects between $2 million and $10 million

Delivery Method	Sample Size	Mean ($/day)	Standard Deviation($/day)	Minimum ($/day)	Median ($/day)	Maximum ($/day)
DBB for all states	10	$4,431*	3,129*	$838*	$3,710*	$11,101*
DB for All States	10	$8,040*	6,004*	$2,728*	$5,864*	$23,509*
DB Georgia	7	$16,216	13,291	$6,705	$12,639	$44,905
DB Bridges Georgia	2	$26,652	25,814	$8,398	$26,652	$44,905

Note. * from "Examination of project duration, Project Intensity, and Timing of Cost certainty in Highway Project Delivery Methods,” Antoine et al,2019

Table 7. Project Intensity for DBB and DB projects between $10 million and $50 million

Delivery Method	Sample Size	Mean ($/day)	Standard Deviation($/day)	Minimum ($/day)	Median ($/day)	Maximum ($/day)
DBB for all states	10	$17,201*	16,985*	$4,723*	$13,021*	$63,397*
DB for All projects	10	$18,679*	11,412*	$3,846*	$31,718*	$159,031*
DB for Georgia	7	$35,158	18,668	$18,023	$26,565	$67,374
DB Bridge Georgia	3	$40,167	24,304	$20,705	$32,272	$67,374

Note. * from "Examination of project duration, Project Intensity, and Timing of Cost certainty in Highway Project Delivery Methods," Antoine et al,2019.

Table 8. Project Average Construction Intensity by Delivery Type and Award Level

Delivery Method	Over $20M		Under $20M		Under $10M		Under $ 5M	
	Sample Size	Construction Intensity	Sample Size	Construction Intensity	Sample Size	Construction Intensity	Sample Size	Construction Intensity
DBB for All States	-	-	81	$14,151*	50*	$9,881*	34*	$5,869*
DB for All States-LB	-	-	30	$13,018*	25*	$10,975*	19*	$9,464*
DB for All states -BV	-	-	34	$17,862*	19*	$11,119*	9*	$6,495*
DB Georgia	7	$67,431	11	$16,090	9	$13,795	5	$8,722
DB Georgia	3	$40,117	2	$26,652	2	$26,652	1	$8,398

Note. * from "The Use and Performance of Alternative Contracting Methods on Small Highway Construction Projects, " Douglas et al,2016.

Conclusions

According to the post-Design-Build evaluation report of GDOT, ‘‘Design-Build projects’ goal was to expedite delivery and to make use of the available fund’’**.** GDOT benefited from the Design-Build delivery method by integrating the design and construction stages into a single contract, which accelerate project delivery. One of the most significant findings that emerged from this study was that GDOT Design-Build projects were found to have substantial time saving with 50-60 percent over DBB projects. It also accelerated the schedule with the overall project duration from award to completion when they compared to the traditional delivery technique in all cost categories. The FHWA's January 2006 Report to Congress, titled: Design-Build, Effective Study documented that ‘‘the greatest motivation and realized benefit to a project contracting agency of using DB instead of DBB contracting is the ability to reduce the duration of the project development process by eliminating a second procurement process for the construction contract, reducing the potential for design errors and omissions, and allowing for more concurrent processing of design and construction activities for different portions of the same project ’’. However, how DB benefits were not yet fully understood throughout the State and favorable legislation would be formulated to allow local agencies to procure with DB delivery method.

The prominent aspect of the Design-Build delivery system is encouraging innovation and collaboration, which ultimately saved time and money. This integrated and highly collaborative process encourages teamwork, creativity, and problem-solving skills in the DB team. One of its manifestations has been shown on facilitating a faster and inexpensive utility relocation process by avoiding conflict. During the Design-Build contract, many projects achieved efficiencies in delivery time because of the high degree of Contractor/Designer collaborative interaction. The construction work could partially start concurrently while another part of the project was under design by the Design-Build team. The early start of the design and construction phase simultaneously shortens the schedule and accelerated the project delivery time by overlapping activities.

The other major finding was that Georgia DB projects had lower average cost growth of 1.94% when compared to DBB with 4.1%. In addition, the project intensity results for DB Georgia projects were found to be higher when compared with DBB or DB for all states. The Design-Build method was

facilitating project delivery at a rapid pace, where the rate of resources expended in the project per day with relatively insignificant cost growth. Generally, Design-Build is the best-suited delivery method for projects that require acceleration as well as projects that need a proper transfer of risk to the Design-Build Team. What is more, the Design-build contracting method is a viable delivery option for projects with opportunities to innovate and significantly decrease contract time, reduce costs, improve the safety and quality of the project. The findings from this study would benefit State DOTs by improving their understanding of the advantages of the Design-Build delivery method, most importantly expediting bridge construction projects in metropolitan areas where each day delay could impact millions of users adversely.

GDOT needs to keep using the DB delivery method, especially when projects are in Urbanized or Central Business districts and when projects need innovative design solutions that best manage the processes and outcomes. A Similar study will be conducted in the future after all ongoing DB projects have been completed to effectively measure the performance metric findings. GDOT also will need to keep post-Design-Build evaluation report and advance record-keeping for adequate and quality data related to change order, Design cost, Engineering estimate, Project size (Bridge width, length), and the role of Disadvantaged Business Enterprises participation on each project.

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