2018

Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods

Philip J. Barutha
Iowa State University

Douglas D. Gransberg
Iowa State University, dgran@iastate.edu

Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods

Abstract
Public agencies must justify the decisions they make to their constituents by demonstrating each project delivery decision's value for money (VfM). In the traditional low bid procurement VfM is assured to the public via free and open competition to obtain the best price. Public private partnership (P3) project delivery challenges the idea that value is totally defined by minimizing project capital cost and permits public agencies to extend the value calculus beyond construction completion to the development, design, operations and maintenance phases of a project. P3 also furnishes access to private financing, which decreases the burden to the taxpayer and serves to cover current public funding shortfalls. This study compares the VfM of a P3 mega-project in Pennsylvania to that of a comparable design-build (DB) mega-project in Missouri. The paper seeks to determine the change in VfM when private financing and post-construction maintenance are added to the equation. The paper finds that additional VfM is realized through P3 delivery due to being able to build the infrastructure earlier because of the availability of private financing. The paper also finds putting the concessionaire at risk for maintenance costs influenced the concessionaire to implement higher standard design criteria as measured by an increased bridge design life to minimize life cycle cost risk. The paper's primary contribution is the development of an approach to quantify VfM using comparative value analysis.

Keywords
Alternatives analysis, Case studies, Design build, Economic benefits, Equity (Justice), Megaprojects, Public private partnerships

Disciplines
Construction Engineering and Management

Comments
This is a manuscript of a proceeding published as Barutha, Phil, and Douglas Gransberg. "Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods." Paper no. 18-04234. Transportation Research Board 97th Annual Meeting. Washington, DC. January 7-11, 2018. Posted with permission.

Final accepted manuscript. Published as:
Barutha, P. and Gransberg, D.D., "Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods," *Compendium*, 2018 Transportation Research Board Annual Meeting, Paper # 18-04234, January 2018.

QUANTIFYING MEGA-PROJECT VALUE FOR MONEY: DESIGN-BUILD VERSUS PUBLIC PRIVATE PARTNERSHIP DELIVERY METHODS

Philip J. Barutha[1], and Douglas D. Gransberg[2]

Abstract

Public agencies must justify the decision they make to their constituents by demonstrating each project delivery decision's value for money (VfM). In the traditional low bid procurement VfM is assured to the public via free and open competition to obtain the best price. Public private partnership (P3) project delivery challenges the idea that value is totally defined by minimizing project capital cost and permits public agencies to extend the value calculus beyond construction completion to the development, design, operations and maintenance phases of a project. P3 also furnishes access to private financing, which decreases the burden to the taxpayer and serves to cover current public funding shortfalls. This study compares the VfM of a P3 mega-project in Pennsylvania to that of a comparable design-build (DB) mega-project in Missouri. The paper seeks to post-construction maintenance determine the change in VfM when private financing and post-construction maintenance are added to the equation. The paper finds that additional VfM is realized through P3 delivery due to being able to build the infrastructure earlier because of the private financing. The paper also finds putting the concessionaire at risk for maintenance cost changed fundamental design decisions resulting in an increased bridge design life as the concessionaire sought to minimize life cycle cost risk. .The paper's primary contribution is the development of an approach to quantify VfM using comparative value analysis.

Keywords: Public private partnerships, mega-projects, value for money, highway infrastructure, design build

Introduction

According to Burger and Hawkesworth (2011), "value for money … should be the driving force behind traditional infrastructure procurement… [and] undertaken only if it creates value for money." They go on to postulate that the choice of project delivery method "should be simple: governments should prefer the method that creates the most value for money." With the increased use of alternative project delivery methods, many US public agencies now are authorized to use a full suite of project delivery methods, giving them the flexibility to utilize the method that appears to provide the best value for money (VfM) for their specific project. Public

[1] Graduate Research Assistant, Dept. of Civil, Construction & Environmental Engineering, Iowa State University, Ames, IA 50011-3232, (corresponding author). Email: pbarutha@iastate.edu
[2] Professor, Dept. of Civil, Construction & Environmental Engineering, Iowa State University, Ames, IA 50011-3232, Email: dgran@iastate.edu (515) 294-4148

Private Partnerships (P3) and Design-Build (DB) are two alternatives to traditional low bid procurement.

Two major differences between P3 and DB project delivery are the use of private finance and the private sector involvement in life-cycle decisions. Often, P3 procurement is perceived to include the cost premium for private finance, thus reducing VfM. This study seeks to determine if the P3 cost premium perception is correct and to quantify the impact on P3 project VfM. The research compares a DB mega-project in Missouri to a similar P3 mega-project in Pennsylvania as the basis to measure and compare the VfM of each project. Both projects were configured to deliver over 500 structurally deficient rural bridges in a single contract. The Missouri Department of Transportation (MoDOT) chose to use DB project delivery for the design and construction of 554 farm to market road bridges (Heckman 2012). The Pennsylvania Department of Transportation (PennDOT) used P3 project delivery for a package of 558 similar farm to market road bridges using the design-build-finance-maintain (DBFM) variation of P3. In alternative project delivery projects, VfM is often demonstrated through reduced project delivery periods and increased cost and time certainty (Lopez del Puerto et al. 2016). This leads one to posit whether or not more VfM can be accrued by further involving the private sector in a mega-project's financing scheme and post-construction maintenance via P3 delivery. Therefore, the research proposes to answer the following question:

Does VfM increase if a mega-project is delivered using the DBFM variant of P3 versus DB?

Previous studies have compared the performance of design-bid-build (DBB) and DB projects using metrics like time and cost growth (Tran et al. 2016). Hale et al. (2009) found that DB projects "were proven superior in performance in almost every measure." Other studies have found, "timesaving was a definitive advantage of design/build project delivery, but, the positive effects of cost and productivity changes were not convincing" (Ibbs et al. 2003). A 2008 study found that "design-build projects performed better than design-bid-build projects in terms of cost and schedule and were comparable in quality outcomes." (Gransberg 2008) These previous studies have shown there are opportunities for agencies to accrue value from involving the construction contractor into the design process of design and construction of a public project in terms of both cost and time performance (Gransberg 2013). However, design and construction are just two phases of a project's life cycle. Before the design phase, a project development and finance plan are needed, and following construction, agencies must operate and maintain the facility throughout its service life (Scheepbouwer and Humphries 2011; Miller et al. 2015).

As the deterioration of the nation's highway network reached critical stages, public agencies have increasingly turned to the private sector to accelerate the design and construction process through DB contracts and now some public agencies are also asking the private sector to design, build, finance, operate, and maintain highway assets as a means to bring additional value to their projects. (Yescombe 2007) P3s incorporate these additional phases of the project life cycle. One variation is referred to as Design Build Finance Operate and Maintain (DBFOM). While public agencies see the value of involving the private sector into the post-construction phases of a project life cycle, many agencies are challenged with how to quantify the value gained from private sector involvement in the post-construction phases. As a result, the objective of this study is to compare a DB project of similar scope, complexity and magnitude as a P3 project to provide better understanding of perceived and actual VfM. In essence, since the comparison is DB versus DBFM, the hypothesis being tested is as follows:

Adding private financing and maintenance to a DB project yields greater VfM than merely delivering the project using DB.

Background

"The increasing use of the design-build delivery method has resulted in it now being one of the most popular nontraditional methods for delivering road, bridge, mass transit, and rail projects in the United States" (Gatti 2014). As previously indicated, many studies have shown multiple benefits of delivering a project using the DB method. Tangible performance metrics such as budget and schedule performance have been used to quantify the costs and benefits of DB along with other intangible metrics like conforming to expectations and owner satisfaction (Molenaar 1999). Figure 1 depicts some of the typical metrics used to measure VfM when considering DB project delivery. (FHWA 2006)

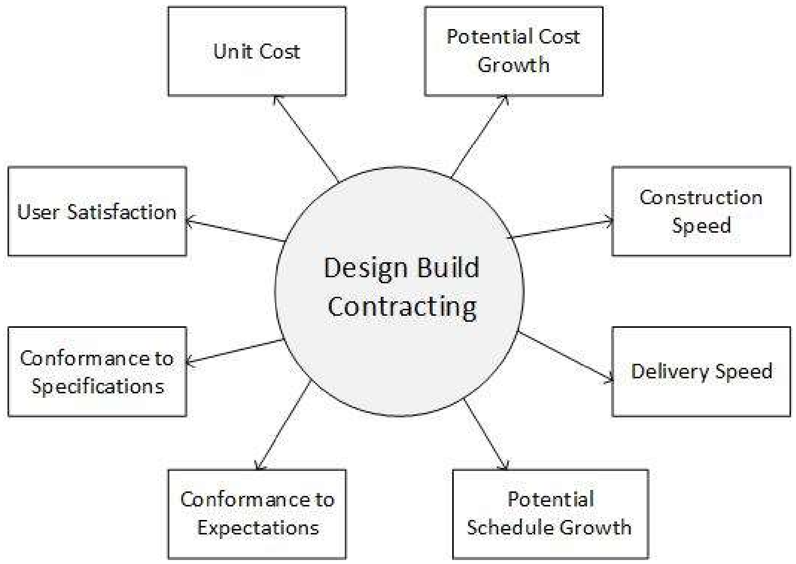

Fig. 1: DB Project Delivery Evaluation Criteria (adapted from FHWA 2006)

Reduced cost and schedule growth are often cited as typical benefits of DB project delivery. Three studies comparing DBB with DB highway projects in the mid 2000's found that DB projects generally offer better cost and schedule certainty (Hale et. al 2009). For example, The Federal Highway Administration (2006) conducted a study showing DB Projects had schedule growth 9% lower than that for DBB. Shrestha's (2007) study of 11 DBB and 4 DBB highway projects found that DB projects had 9.6% less cost growth than DBB projects. This increased cost and time certainty has shown to be a major benefit of the DB project delivery. The FHWA (2006) study also revealed that agency contract administration and inspection costs were reduced in DB projects. The same study found that DB projects had fewer change orders due to design inadequacies than DBB projects. This further supports the idea there are benefits of engaging the contractor earlier in the design phase.

P3 mega-projects have also experienced the benefit of enhanced cost and time certainty. Flyvberg, et al. (2002) studied 258 large transportation infrastructure projects in 20 countries, and the majority were delivered using "conventional approaches to public procurement." The study found in 90 percent of the projects the costs were "substantially". MacDonald (2002) conducted a study for UK Treasury of 50 large public procurement projects in the UK over the last 20 years; 11 projects were P3s. It found that the P3 projects all were completed ahead of schedule as compared to a 17 percent schedule growth for the others. P3 capital expenditures were observed to be 1 percent over budget on average. Whereas the traditionally procured projects experienced an average cost overrun of 47 percent, Grimsey (2005) stated that:

> "Further evidence for the UK comes from HM Treasury (2003) in its own review of 61 P3 projects, where it was found that 89 percent of the P3 projects were delivered on time or early and that all P3 projects were within budget. About 75 percent of major infrastructure projects in the UK were late and over budget before P3's came into play. Under P3 arrangements, 75 percent of projects are on time and on budget" (Grimsey 2005).

As a result of the above discussion it is apparent that both DB and P3 provide the potential for a public agency to enhance a project's VfM over traditional project delivery methods. Therefore, the question becomes which one adds the greater value.

Economies of Scale

Conventional wisdom holds that as the quantities produced of a given product increase that the unit cost of that product drops (McCarthy and Anagnostou 2004). The same phenomenon has also been observed in highway construction (Yeo and Tiong 2000; Williams 2003). By packaging 554 bridges into a single contract for, Missouri DOT sought to capture the efficiencies due to economies of scale and therefore experience the cost and time savings found in these efficiencies. Silbertson (1972) identifies six possible sources of achieving economies of scale: 1) initial fixed costs, 2) working capital, 3) specialization of labor, 4) vertical linking economies, 5) increased size, and 6) specialization of plant and/or equipment. Most of Silbertson's sources for achieving economies are found in the DB and P3 case study projects collected for this paper. According to Akintoye (2005), "the achievement of economies of scale by developing an integrated solution is seen as an important and attractive opportunity to broaden the context of P3 to include projects that might otherwise not be considered as suitable for this type of procurement."

Most traditional bridge construction projects are limited to a single bridge and as such any economies of scale are limited to components of the bridge like precast concrete structural members. Hallmark et al. (2012) held that "the total cost of a bridge is not limited to the amount spent on concrete, steel, and labor… Construction activities disrupt the typical flow of traffic around the project and result in additional cost to the public in the form of longer wait times, additional mileage traveled to get around the work zone, or business lost attributes to customers avoiding the construction." This phenomenon is typically referred to as the user cost of construction (Herbsman 2005). This notion advocates that "Finding a way to shorten the time spent on the jobsite is beneficial to the contractor, the owner, and the traveling public." The bridge construction industry has long used pre-fabrication of bridge components to reduce the time a construction project will impact both the traveling public and the surrounding community. Logically, as the amount of pre-fabrication increases, the unit costs decrease due to economy of scale. Additionally, since most of the work is performed off-site, the time that traffic is disrupted also decreases, reducing user costs and the overall project cost (Owens et al. 2011). This idea presented in Hallmark et al.'s study compliments the idea of achieving economies of scale. Pre-fabrication of bridge elements techniques were utilized on both case study projects and was examined during the case study analysis to determine the level of value this process brought to the two projects.

Hallmark et al.'s study also refers to the impact to the traveling public. Herbsman (1995) conducted a study, which evaluated the impact to the road user from the delays and inconvenience caused by road construction and rehabilitation projects in the US. The study also evaluated the use of alternative contracting methods, including DB and P3, to reduce the overall impact to the road users. The study concluded that all alternative methods were successful in reducing construction times. Time reductions of 20-50% were observed versus similar projects delivered using conventional methods. Based on the result of this study, the researchers decided to measure road user impact as part of the case study project comparison.

"Maximizing value and minimizing waste at the project level is difficult when *the contractual structure inhibits coordination, stifles cooperation and innovation*, and rewards individual contractors for both reserving good ideas and optimizing their performance at the expense of others" (Matthews 2005 italics added). Findings from the Matthews study illustrate the benefits of integrated project delivery to include the following:

- Shared manpower,
- Problem resolution,

- Handling major changes to the work,
- Work across traditional boundaries,
- Avoid redundant effort and expense,
- Enhancements to job site safety, and
- Spending more to save more. (Matthews 2005)

This study also identifies four major systemic problems with the traditional contractual approach:

1. Good ideas are held back,
2. Contracting limits cooperation and innovation,
3. Inability to coordinate,
4. The pressure for local optimization. (Matthews 2005)

Molenaar (1999) found that "project cost and schedule performance was excellent under the design build method. 59% of the projects were with 2% or better of the budget established when the design builder was hired. 77% of the projects were within 2% or better of the schedule established when the design builder was hired." Molenaar et. al (2014) also state, DB's "main benefit is that it allows overlapping of the design and construction phases often reducing project completion time." Therefore, based on the studies by Matthews and Molenaar et al, the decision was made to measure the benefits of integrated delivery for the two case studies regarding difference between the level of integration achieved in DB versus P3 using DBFM project delivery.

Case Study Research Methodology

A case study is an empirical study and is the preferred strategy when "how" and "why" questions are being posed, when the investigator has little control over the events, and when the focus is within some real-life context (Yin 1994). Briefly, the case study allows the investigation to retain the holistic and meaningful characteristics of real-life events. Another benefit of using a case study is the ability to cover contextual conditions when the researcher believes that they might be highly pertinent to the analysis. In this sense, the case study is not either a data collection protocol or merely an experimental design feature, but a comprehensive research strategy. "Case studies can be based on any mix of quantitative and qualitative evidence" (Yin 1994). Case studies involving participant interviews allow the researcher to probe the rationale behind events that produced the project performance outcomes (Harris and Brown 2010), which in turn permits a context to be defined in a manner unlike more common analytical/statistical research instruments.

The primary input to the case study project analysis was gathered through face-to-face structured interviews with agency personnel, contractors, and consultants that participated in the delivery of the two projects. The structured interview questionnaire was developed on lines similar to the methodology prescribed by the US Department of Education (DOE) (ERIC/AE 1997). The DOE methodology is prescribed for use when the researcher needs to "spend considerable time probing participant responses, encouraging them to provide detail and clarification" (Harris and Brown 2010). The structured the interview is best used when "information must be obtained from program participants or members of a comparison group… or when essentially the same information must be obtained from numerous people for a multiple case-study evaluation" (GAO

Final accepted manuscript. Published as:
Barutha, P. and Gransberg, D.D., "Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods," *Compendium*, 2018 Transportation Research Board Annual Meeting, Paper # 18-04234, January 2018.

1991). Since both of these conditions apply to the problem at hand, the instrument is the appropriate tool for this research.

The process requires a questionnaire to be created and made available to case study project personnel being interviewed in advance of the interview. This permits them to prepare for the interview as well as to assemble any necessary information or documentation and have it available at the time of the interview. The questionnaire was designed using Oppenheim's (1992) protocol. Both open and closed ended questions were included. The closed ended questions were used to ensure that specific perceptional information was collected on both projects; whereas the open-ended questions were intended to stimulate discussion of the interviewee's rationale for each answer as well as to collect factual information that was not included specifically in the questionnaire itself.

Once the face-to-face interview commences, responses are collected in the same order using the same questions for each interviewee. After each question and answer, the interviewer ensures that the interviewee understands the question and that the answer is fully understood by the data collector. Interviewees are allowed to digress as desired, allowing the researchers to collect potentially valuable information that was not originally contemplated.

The case studies analyzed using a protocol for cross-case comparison proposed by Yin (2004). The use of the structured interviews in conjunction with the information found in the literature allows the researcher to not only maintain a high level of technical rigor in the research but to also adhere to Yin's three principles of case study analysis:

1. Use of multiple sources,
2. Creation of a database, and
3. Maintaining a chain of evidence (Yin, 2004).

The interview analysis output is then used to derive both the agency's and the contractor's perspectives on VfM in each case study project.

The case study data collection and analysis process is shown in Figure 2. To answer the research question posed in a previous section, a set of three sub-questions were defined:

1. Is additional value added by private sector involvement in DBFM delivery as compared to DB delivery?
2. Is additional value added with including the private sector with the finance of the project?
3. Is additional value added by involving the private sector with the long-term maintenance of the project?

A total of four project participants were interviewed. The following is a list of their roles on each project:

- Safe and Sound (S&S) DB Project: MoDot Project Director, KTU Constructors Project Director
- Rapid Bridge Replacement (RBR) Project: PennDot Director of the P3 Office, Plenary Walsh Keystone Partners Chief Operating Officer

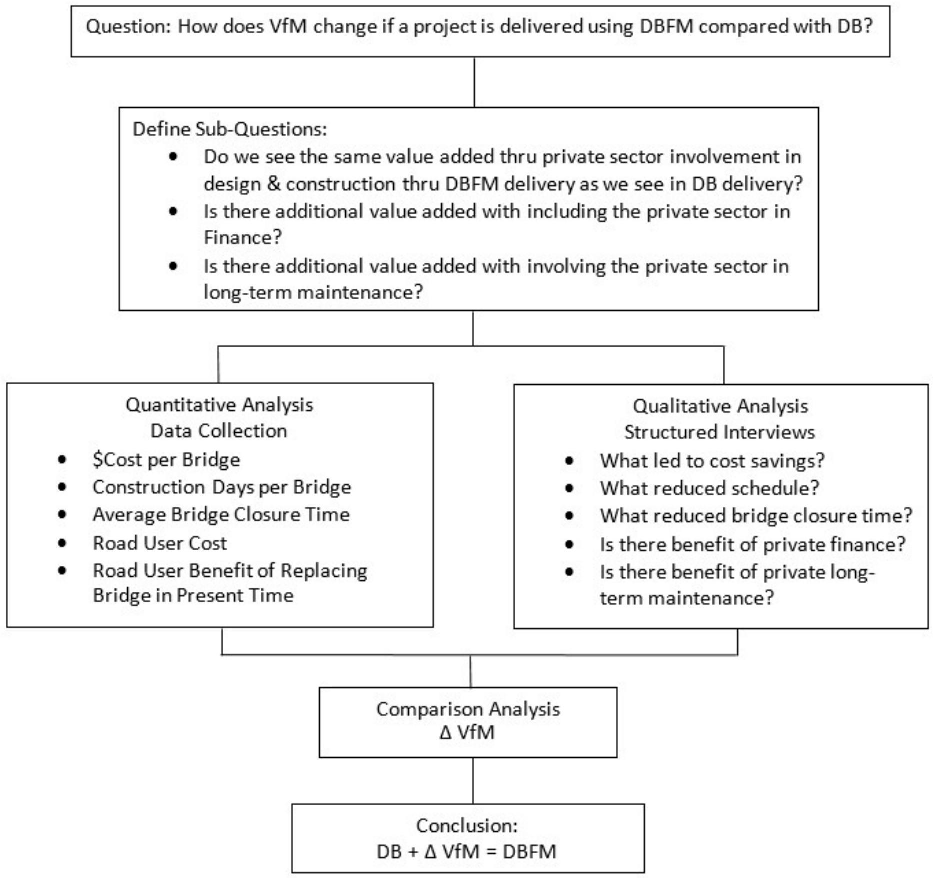

Fig. 2: Case Study Methodology.

The collection of each case study commenced by contacting the agency telephonically to identify the both the agency and contractor's project participants. The initial contact also included a request for project documentation that was used to develop the questionnaires. A date and time for the interviews was established and the research team traveled to the designated site to conduct the interviews. Because of the scope of the two projects including over 500 bridges, no attempt was made to visit the project sites. However, a map of the locations of the projects was made available during the interviews to give both the researchers and the interviewees a common document upon which to make reference. Once the interviews were complete, the researchers reduced the data and sent it to each agency to verify that it was correct. The final step was to analyze the results and use the output to test the hypothesis.

Case Study Analysis

The two case study projects were selected based on being similar in size, scope, and delivery time. The details are shown in Table 1. The DB project selected for case study is the Missouri DOT S&S Project comprising 554 rural bridges located statewide. The DBFM project case study is the Pennsylvania DOT RBR Project consisting of 558 rural bridges located statewide. The S&S Project was awarded in 2009 and completed in 2011. The RBR Project began design and construction in 2015 and has an anticipated completion in 2017.

Table 1: Case Study Project Description.

	Case Study Description	
Description	**Design Build**	**Design Build Finance and Maintain**
Agency	Missouri DOT	Pennsylvania DOT
Project Title	Safe and Sound	Rapid Bridge Replacement
Project Type	Structurally Deficient Bridge Replacement	Structurally Deficient Bridge Replacement
Project Location	Statewide - Rural	Statewide - Rural
Number of Bridges	554	558
Number of Counties	111	66
Private Sector Contract Scope	Design and Construction	Finance, Design, Construction, and 25 year Maintenance
Notice to Proceed Date	November, 2009	June, 2015
Design and Construction Duration	36 Months	31 Months
Project Cost	$487,000,000	$899,000,000
Private Finance Contribution	N/A	$793,000,000
O & M and Finance Costs	N/A	$220,000,000
% of Structurally Deficient Bridges at Start of Construction	Approximately 50% had some type of restriction	Approximately 20% had some type of restriction

Quantitative Results

Table 2 contains the results of the quantitative analysis. As can be seen a number of metrics were developed to permit a cross-case comparison on a quantitative level. Since the major operational difference of the two projects was the addition of contractor financing and a post-construction maintenance period to the P3 project, the metrics used for comparison were designed to separate the pre-construction and post-construction aspects to clearly identify the impact of financing and maintenance by the agency versus by the private sector.

Table 2: Case Study Project Quantitative Outcomes.

	Case Study Quantitative Results	
Description	**Design Build**	**Design Build Finance and Maintain**
$ per Bridge (DB/P3)	$879,062	$1,611,111
$ per Bridge (Traditional)	$1,024,433	$1,722,781
Average Schedule Days per Bridge (DB/P3)	43 Days	55 Days
Average Schedule Days per Bridge (Traditional)	90-120 Days	175 Days
Average Road User Cost per Bridge per Day	$36,859	$22,907
Bridge Design Life	50 years	100 years

Cost per Bridge

A comparison was made to determine the cost of building a bridge using the traditional method compared to bundling the design and construction of the bridges using DB or P3 methods. Using average cost per bridge was determined to be the best unit of comparison to compare the costs of the different projects. Both case study projects were comprised of over 500 rural bridges crossing streams located throughout their respective states. Samples of conventional single bridge projects were gathered in each state to permit the quantification of the impact of bundling multiple projects for each state. The Missouri sample consisted of 29 DBB projects of

Final accepted manuscript. Published as:
Barutha, P. and Gransberg, D.D., "Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods," *Compendium*, 2018 Transportation Research Board Annual Meeting, Paper # 18-04234, January 2018.

comparable scope and size to those delivered in the S&S project taken from bid results from January 2014 to December 2015. The Pennsylvania sample consisted of 28 projects of comparable scope and size to the RBR project taken from bid results from July of 2013 to June 2014.

Table 3: Traditional versus Bundled Contract Details

	Missouri		**Pennsylvania**	
	S & S	**Traditional**	**RBR**	**Traditional**
Number of Bridges	554	29	558	28
Construction Period	November 2009 - November 2011	January 2014 - December 2015	June 2015 - December 2017	July 2013-June 2014
Includes Design Cost	Yes	No	Yes	No
Cost per Bridge	$879,062	$1,024,433	$1,611,111	$1,722,781
Approximate Design Costs	Included Above	10-15% of Bid Amount	Included Above	10-15% of Bid Amount
Difference in Cost per Bridge between DB/P3 to Traditional Method	($145,371)		($111,670)	
Design Life (years)	50	-	100	-
Cost per Bridge per Year of Design Life	*$17,581.24*		*$16,111.11*	

The cost savings Missouri's S&S Project was estimated to be $145,371 per bridge. This does not include any design savings the state may have experienced due to economies of scale achieved in the S&S project process. The cost savings Pennsylvania's RBR Project was estimated as $111,670 per bridge, which also includes design costs so there is potential for additional savings if the design costs of traditional procurement are factored in as well. A state to state cost comparison between Missouri's S&S Project and Pennsylvania's RBR Project was performed using a simple calculation of dividing the total cost per bridge by the Design Life in years. The S&S Project had a total Design Life of 50 years while the RBR project had a total Design Life of 100 years.

- Safe and Sound DB Project: $17,581 per bridge per year of design life
- Rapid Bridge Replacement P3 Project: $16,111 per bridge per year of design life

Time per Bridge

Missouri and Pennsylvania both experienced time savings in their projects. Missouri was originally scheduled to complete the 554 bridges in 36 total months, and Pennsylvania is scheduled to complete the 558 bridges in 31 total months. The average number of days to complete a bridge under S&S was 43 days, as compared to a typical bridge construction completion schedule of 90-120 days per bridge in Missouri. The RBR Project is scheduled to have an average of 55 days to complete each bridge, as compared to typical bridge construction completion schedule of 175 days per bridge in Pennsylvania. The S&S Project has demonstrated some clear time savings experienced from typical bridge construction in Missouri with a total time savings of greater than 45 days per bridge.

Road User Costs

"Road User Costs are defined as the estimated incremental daily costs to the traveling public resulting from construction work being performed. Those costs are primarily time lost because of conditions such as detours/rerouting that add to travel time, reduced roadway capacity that slows travel speed and increases travel time, or a delay in the opening of a new or improved facility that prevents users from gaining travel time benefits" (Daniels et. al 2005). Average road user cost was used to determine the monetary benefits to the public road user affected by each project. The average road user cost consists of both vehicle operating expense and the cost of time to the driver impacted by the detour of the bridge closure.

Final accepted manuscript. Published as:
Barutha, P. and Gransberg, D.D., "Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods," *Compendium*, 2018 Transportation Research Board Annual Meeting, Paper # 18-04234, January 2018.

<u>Vehicle Operating Expense:</u>

Cost per mile (Automobile): $0.54 (MDOT 2016)

Cost per mile (Truck): $1.87 (MDOT 2003)

<u>Cost of Time to Driver:</u>

Cost per hour (Automobile): $18.00 (MDOT, date)

Cost per hour (Truck): $31.76 (MDOT, date)

Table 4 shows the traffic data collected for both projects, and Table 5 illustrates the results of the user cost analysis.

Table 4: Project Traffic Data

	Safe and Sound	**Rapid Bridge Replacement**
Average ADT per Bridge	1800	2700
Percent of Trucks per Bridge	10%	9%
Average Detour per Bridge	20 miles	8 miles

Table 5: Average Road User Detour Cost Per Bridge Per Project.

	Safe and Sound Project		**Rapid Bridge Replacement**	
Vehicle Operating Expense	Automobiles	Trucks	Automobiles	Trucks
AADT	1680	180	2457	243
Cost per Mile	$0.54	$1.87	$0.54	$1.87
Average Detour	20 miles	20 miles	8 miles	8 miles
Subtotal per Bridge	$18,144	$6,732	$10,614	$3,635
Cost of Time of the Driver				
AADT	1680	180	2457	243
Cost per Hour	$18.00	$31.76	$18.00	$31.76
Avg. Detour Time	0.333 Hours	0.333 Hours	0.167 Hours	0.167 Hours
Subtotal per Bridge	$10,079	$1,904	$7,371	$1,286
Average Detour Cost	$36,859		$22,907	

One can see the benefit to the public of Missouri with completion of the S&S bridges in half the time it took to complete a typical bridge replacement. Quantifying the road user benefits of completing the construction of the replacement bridges in half the time can be conservatively be approximated as shown in Equation 1:

$$\text{Total Benefit} = (D_T - D_S)CB \qquad \text{Eq. 1}$$

Where: D_T = Average completion days per bridge

D_S = Average completion days per bridge

C = Daily detour cost per bridge

B = Total number of bridges.

Total Benefit = (90 days – 43 days) x $36,859 x 554 bridges = $959,734,642

The time savings experienced during construction of the S&S Project gave a monetary benefit to the public road users travelling through the state of Missouri of nearly $1.0 billion.

Qualitative Results

Structured interviews were conducted with all parties, public and private, on both the S&S and RBR Projects. As previously stated, this study was seeking to answer the "how" and "why" and was seeking to compare the similarities and differences between the two projects and the quantitative results. Interviews were conducted in March of 2016 with a representative of Missouri DOT supervising the S&S Project and the project manager of the private DB firm designing and constructing the project. A representative of PennDoT supervising the RBR Project was interviewed in March of 2016 and, in a separate interview, the supervisor for the private concession group designing, building, financing, and maintaining the RBR project. The following questions were posed to all parties:

1. What do you think Value for Money is?
2. What factors do you believe resulted in project cost savings?
3. What factors do you believe contributed to a shortened project schedule?
4. What factors do you believe contributed to reduce the amount of bridge closure time?
5. What are the benefits of replacing the bridges in present time?

Questions reserved for the RBR Project Dot and private concession group (DBFM):

6. What are the benefits of involving the private sector with the finance of the project?
7. What are some of the benefits of having a long-term maintenance agreement with the Concession group that designed and built the project?

Each interviewee was asked to identify what factors led to achieving the desired question and to rank the number one factor to achieving each question. Table 6 is a list of the top responses combined for both projects, including both public and private perspectives.

Table 6: Qualitative Analysis Outcomes

	Question Description	**Top Response(s) (4 Total Responses)**
1.	What do you think Value for Money is?	Quantitative analysis
2.	What factors do you believe resulted in project cost savings?	Standardized design
		Economies of scale
		Use of pre-fabricated materials
3.	What factors do you believe contributed to a shortened project duration?	Use of pre-fabricated materials
4.	What factors do you believe contributed to reduce the amount of bridge closure time?	Designing in reduced closure time
		Standardized design
		Use of pre-fabricated materials
5.	What are the benefits of replacing the bridges in present time?	Do not need to place load restrictions on bridges impacting local economy
	Rapid Bridge Replacement Project Only (DBFM)	**Top Response(s) (2 Responses)**
6.	What are the benefits of involving the private sector with the finance of the project?	Ability to replace the bridges in the present time
		Life Cycle Decisions, i.e. higher quality over the lifetime of the project
7.	What are the benefits of having a long-term maintenance agreement with the Concession Group that designed and built the project?	Transfer of Risk to One Entity Life Cycle Innovation

The results from the structured interview illustrate how the bundling of the bridges into one single Design and Construction Agreement (DB – S&S, DBFM – RBR) was able to not only reduce the overall cost of the bridges, but also reduce the overall construction time and the amount of bridge closure time. The benefits of the bundling into one single agreement include: 1) Standardized Design, 2) The use of Pre-Fabricated Materials, 3) Designing in reduced closure times, and 4) Economies of Scale.

Value for Money by Private Finance

"77% of all bridges nationwide and 63.5% of all structurally deficient bridges are located in rural areas illustrating the potential that inadequate and maintenance funding to keep those rural bridges operating at their current structural load capacities could have an enormous economic impact on a state's economy" (Davis, et. al 2013). Miller et al. (2015) posited that the deteriorated condition of the nation's transportation system costs the U.S. economy $129 billion each year. The problem is more pronounced in states where agriculture is a significant portion of its economy. "The effects of ignoring low-volume bridges has been publicized in studies, which found that agricultural states, with vast rural areas, have a large number of deficient bridges." The state of Pennsylvania has some of the most structurally deficient bridges in the country (Miller and Gransberg 2015).

The structured interview results provided a valuable insight to identifying the value of including private finance with public infrastructure project delivery. One of the top benefits identified by the RBR project team was using private finance to allow the ability to replace bridges in the present time. Both project teams in Missouri and Pennsylvania identified the top benefit of replacing the bridges in present time was not needing to place load restrictions on bridges impacting the local economy. This study examined the benefit to the public of using private finance to develop infrastructure, in this case, using private finance to fund the replacement of bridges in the state of Pennsylvania. At the time when the RBR Project was starting, PennDot had identified 20% of the total number of bridges to be replaced under the RBR project were found to be structurally deficient and some sort of load restrictions were placed on the bridges.

Load restrictions on bridges impact the total weight of the load crossing the bridge, meaning there is a reduction in the total load allowed to cross the bridge or in some situations the bridge is closed to vehicles of any weight. This reduction in allowable load negatively impacts the road users by having to use an alternate route, or detour, around the structurally deficient bridge often times incurring more travel miles and time around the detour. Miller et al. 2015 have utilized a method of determining an economic impact of structurally deficient bridges. "To conduct this analysis, it was first necessary to identify stakeholders for each bridge. …. Users were classified in two categories based on different economic impact: light to medium vehicles and heavy vehicles." A similar method of calculating economic impact due to the structurally deficient bridges was utilized for this study.

Using a hypothetical scenario, where structurally deficient bridges were not able to be replaced for a year due to lack of funding and without the ability to use private finance, the economic impact to the users of the rural road network in Pennsylvania can be determined in a similar manner to Table 5. Using the previously calculated road user cost (Table 5) and assuming that 20% of the RBR bridges are structurally deficient bridges, the impact is calculated and shown in

Table 7. The study shows the economic impact of a conservative scenario where there are only reduced load restrictions imposed on the bridges impacting only heavy vehicles, and worst case scenario where all structurally deficient bridges are closed to the travelling public, both light to medium vehicles and heavy vehicles.

Table 7: Cost of a Hypothetical One Year Delay in RBR Project

	Scenario 1	**Scenario 2**	
Vehicle Operating Expense	Heavy Vehicles	Heavy Vehicles	Light to Medium Vehicles
AADT	243	243	2457
Cost per Mile	$1.87	$1.87	$0.54
Average Detour	8 miles	8 miles	8 miles
Subtotal per Bridge	$3,635	$3,635	$10,614
Cost of Time of the Driver			
AADT	243	243	2457
Cost per Hour	$31.76	$31.76	$18.00
Avg. Detour Time	0.167 Hours	0.167 Hours	0.167 Hours
Subtotal per Bridge	$1,286	$1,286	$7,371
Average Detour Cost per Bridge	$4,922	$4,922	$17,985
20% Structurally Deficient	111 Bridges	111 Bridges	111 Bridges
Delay Time to Replace Bridge	365 Days	365 Days	365 Days
User Cost to Delay Bridges	$199,397,003	$199,397,003	$728,671,999
Total Cost to User per year	$199,397,003	$928,069,002	

Using the conservative scenario (Scenario 1), the benefit of having the bridges replaced in present time (one year earlier) to the users of the rural road network in Pennsylvania is approximately equal to $200 million per year. Based on this analysis, the approximate VfM of private finance on the RBR project will range from $200 million to as much as $1.0 billion annually.

Value for Money of Private Long-term Maintenance Partnership

"Whole-life costing is perhaps the most important element of the VfM case for PPPs." (Yescombe 2007) The project team for the RBR project identified life cycle innovation as the greatest benefit of contracting the designer and builder to maintain the project for 25 years. An example of how this benefit was incorporated in the RBR project was the use of a polymer overlay as the road surface for the bridges being replaced. This technology increased the initial construction costs, but reduced the amount of resurfacing treatments required at each bridge thus reducing the overall costs needed to maintain the bridges for their life cycle. This improved the overall life cycle quality of the project while reducing the overall life cycle costs. While the FHWA requires life cycle cost analysis to be performed on all federally funded bridge projects (Hawke 2003), life cycle considerations are often overcome by the stark financial reality of insufficient availability of the necessary funding (Gransberg et al. 2013). Additionally, the requirement for the contractor to maintain the facility for a concession period after construction creates a tangible incentive to making design decisions in a manner that minimizes life cycle cost (Garvin 2011).

Since the RBR project is not complete at this writing, there is no data available to perform a quantitative analysis on the total maintenance costs or benefits of using private industry for long-term maintenance of the project, but by extrapolating the qualitative information from the parallels found with the structured interviews, there is sufficient information to reasonably infer there is verifiable VfM associated with involving the private sector in the long-term maintenance of the project.

Conclusion and Discussion

The study sought to determine how the VfM changes if a mega-project is delivered using P3. To answer this question, a comparative analysis of two case studies of roughly the same size, type, and complexity were compared both quantitatively and qualitatively. The study investigated three phases of a public infrastructure project: the design and construction phase, the finance and development phase, and the long-term maintenance phase. Similar value was found in the design and construction phase for DB and P3-DBFM both qualitatively and quantitatively. By using private finance the RBR Project was able to replace the bridges well in advance of when they could using 100% public finance. Including private sector long-term maintenance on the project was found to increase VfM via increased design life, which essentially trades higher present capital costs for lower future maintenance costs by design and building a more robust structure.

The following conclusions are drawn from the cross-case comparative analysis and are consolidated in Table 8. This paper's primary contribution to the body of knowledge in alternative project delivery and VfM theory is to demonstrate a method for quantifying the change in VfM using comparative, cross-case analysis. It also validates the perception that favorable economies of scale can be achieved by bundling small projects into a mega-project and delivering that project using an alternative contracting method (Li et al. 2008; Gransberg and Scheepbouwer 2015).

Final accepted manuscript. Published as:
Barutha, P. and Gransberg, D.D., "Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods," *Compendium*, 2018 Transportation Research Board Annual Meeting, Paper # 18-04234, January 2018.

Table 8: Summary results of Qualitative and Quantitative VfM Benefits

Project Phase	Delivery Method	Qualitative VfM Benefits	Quantitative VfM Benefits
Design and Construction	DB & P3	By bundling the replacement of the bridges under a single contract, benefits were identified via: • Standardized design • Pre-fabrication • Designing in reduced closure times • Economies of scale	Cost savings ranged from approximately $100,000 to $150,000 per bridge. Time savings were roughly 50% time savings per bridge for S & S and RBR.
Private Finance	P3 Only	Ability to replace the bridges in present time. An increased life cycle expectancy due to having available funds.	Value to public of having bridges built in present time reduces travel delay time. Benefit estimated to be between $200M and $1.0B.
Private Long-term Maintenance	P3 Only	Transfer of risk to one entity for long-term maintenance and life cycle innovation.	100-year design life, twice that of the DB Project.

To summarize, the study shows that increased VfM can be quantified to support the use of P3 project delivery accruing benefits by replacing needed infrastructure in the present time through the access to private finance as well as transferring infrastructure life cycle maintenance risk. The study also demonstrated the increased VfM associated with bundling multiple small projects into a single mega-project with both case studies demonstrating substantial cost and time savings over traditional single bridge contracts.

This study illustrates how a public infrastructure mega-project delivered as a P3 permits the demonstration of VfM to the public and can be a valuable contracting tool for public agencies to use in developing their projects. One of the posted goals for MAP 21 from the FHWA is "Reduced Project Delivery Delays - To reduce project costs, promote jobs and the economy, and expedite the movement of people and goods by accelerating project completion through eliminating delays in the project development and delivery process, including reducing regulatory burdens and improving agencies' work practices". (FHWA 2015) This research has demonstrated how both MoDOT and PennDOT have utilized alternative project delivery to achieve this national goal to bring value for money to the public which they serve. For other practitioners, the case study provides a potential contribution of evidence suggesting how P3 delivery can bring additional VfM to their project and can serve as justification for agencies to include as a procurement tool for development of infrastructure projects.

Limitations

It must be noted that having two nearly identical, save location and delivery method, mega-projects is a highly fortuitous situation for the research team. Thus, while the conclusions listed above are well-supported by the data, one must be careful in attempting to generalize the findings to the universe of public infrastructure projects. It is impossible to "calibrate" or "extrapolate" the findings beyond the two case study projects with any degree of confidence. Nevertheless, the findings must be judged as promising and may easily be used to demonstrate the potential VfM found in both bundled contracts and seeking private finance and maintenance via P3 project delivery.

Final accepted manuscript. Published as:
Barutha, P. and Gransberg, D.D., "Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods," *Compendium*, 2018 Transportation Research Board Annual Meeting, Paper # 18-04234, January 2018.

Acknowledgements

The authors would like to acknowledge Missouri Department of Transportation and Pennsylvania Department of Transportation for their cooperation and openness with furnishing their time, the information, and interview responses. The authors are grateful for the support given in completing this study.

References:

Akintoye, A., Bing. L., Edwards, P.J., and Hardcastle, C., (2005) "Perceptions of Positive and Negative Factors Influencing the Attractiveness of PPP/PFI Procurement for Construction Projects in the UK." Engineering, Construction, and Architectural Management. Vol. 12, No. 2, pp. 125-148.

Burger, P., and Hawkesworth, I. (2011). How to attain value for money: comparing PPP and traditional infrastructure public procurement. OECD Journal on Budgeting, 11(1), 91.

Daniels, G., Stockton, W.R., and Hundley, R. (2005) "Estimating Road User Costs Associated with Highway Construction Projects, Simplified Method." Transportation Research Record 1732: Paper No. 00-0328. Transportation Research Board of the National Academies, Washington, D.C.,

Davis, S.C., Diegel, S.W. and Boundy. R.G.,(2013) Vehicle Technologies Market Report 2012. Oak Ridge National Laboratory, .

ERIC/AE Staff. (1997). "Designing Structured Interviews for Educational Research." Practical Assessment, Research and Evaluation, 5 (12). <http://pareonline.net/getvn.asp?v=5&n=12>(Apr 2, 2016)

FHWA (2015). "Transportation Performance Management, TPM and MAP-21, National Goals." >https://www.fhwa.dot.gov/tpm/about/goals.cfm.> (July 1, 2016).

Flyvberg, B., Holm, M. S., Buhl, S. (2002) "Underestimating Costs in Public Works Projects: Error or Lie?" Journal of the American Planning Association, 68(3), 279-295. 2002

Gatti, U.C., Migliaccio, G.C., and Laird, L. (2014) "Design Management in Design-Build Megaprojects: SR 99 Bored Tunnel Case Study." ASCE Practice Periodical on Structural Design and Construction. Pp 148-158.

Final accepted manuscript. Published as:
Barutha, P. and Gransberg, D.D., "Quantifying Mega-Project Value for Money: Design-Build Versus Public Private Partnership Delivery Methods," *Compendium*, 2018 Transportation Research Board Annual Meeting, Paper # 18-04234, January 2018.

Ibbs, C. W., Kwak, Y.H.., Ng, T.., and Odabasi, A.M., (2003). "Project Delivery Systems and Project Change: Quantitative Analysis." ASCE Journal of Construction Engineering and Management.

Hale, D.R., Shrestha P. P., Gibson, E., and Migliaccio, G.C., (2009) "Empirical Comparison of Design/Build and Design/Bid/Build Project Delivery Methods." ASCE Journal of Construction Engineering and Management.

Hallmark, R., White, H., and Collin, P. (2012) "Prefabricated Bridge Construction across Europe and America." ASCE Practice Periodical on Structural Design and Construction.

Harris, L.R. and Brown, G.T.L. (2010) Mixing interview and questionnaire methods Practical Assessment, Research & Evaluation, 15 (1) p. 2.

Hawk, H. (2003). Bridge life-cycle cost analysis (No. 483). Transportation Research Board.

Heckman, D. (2012). "Taking Design-Build Statewide. Missouri's Safe and Sound Bridge Improvement Program." AASHTO Subcommittee on Bridges and Structures. <http://bridges.transportation.org/Documents/SCOBS%20presentations%202012/Missouri's%20Safe%20and%20Sound%20Bridge%20Improvement%20Program.pdf>(July 1, 2016).

Herbsman, Z., Chen, W.T., and Epstein, W. (1995) "Time is Money: Innovative Contracting Methods in Highway Construction." ASCE Journal of Construction Engineering and Management. .

Garvin, M. J. (2011). International practices in public-private partnerships: Synthesis and Discussion. TR News, (274).

Gransberg, D.D. and Scheepbouwer, E. "US Partnering Programs and International Partnering Contracts and Alliances," *Transportation Research Record: Journal of the Transportation Research Board, No. 2504*, Transportation Research Board of the National Academies, Washington, D.C., 2015, pp. 73-77.

Gransberg, D.D., "Case Studies of Early Contractor Design Involvement to Expedite the Delivery of Emergency Highway Projects," Transportation Research Record No. 2347, Journal of the Transportation Research Board, National Academies, 2013, pp. 19-26. 2013

Gransberg, D.D., J.S. Shane, K. Strong, and Lopez del Puerto, C.,(2013). "Project Complexity Mapping in Five Dimensions for Complex Transport Projects," Journal of Management in Engineering, ASCE, Vol.29, (4), pp. 316-326.

Gransberg, D.D., and Molenaar, K.R., (2008) "Does Design-Build Project Delivery Affect the Future of the Public Engineer?" Transportation Research Record: Journal of the Transportation Research Board, No. 2081, Transportation Research Board of the National Academies, Washington, D.C.,pp 3-8.

Grimsey, D., and Lewis, M., (2005) "Are Public Private Partnerships value for money? Evaluating alternative approaches and comparing academic practitioner views." Elsevier Accounting Forum. 2005. Volume 29, Issue 4, pp 345-378.

Li, S., Foulger, J. R., & Philips, P. W. (2008). Analysis of the Impacts of the Number of Bidders Upon Bid Values Implications for Contractor Prequalification and Project Timing and Bundling. *Public Works Management & Policy*, *12*(3), 503-514.

Lopez del Puerto, C., Craigie, E. and Gransberg, D.D., (2016). **"**Construction Cost Certainty Versus Construction Savings: Which is the Correct Approach?" *Compendium,* 2016 Transportation Research Board Annual Meeting, Paper 16-2754.

MacDonald, M. (2002) "Review of Large Public Procurement in the UK" London: HM Treasury.

Matthews, O. and Howell, G. (2005) "Integrated Project Delivery an Example of Relational Contracting." Lean Construction Journal. Vol 2 #1.

McCarthy, I., & Anagnostou, A. (2004). The impact of outsourcing on the transaction costs and boundaries of manufacturing. International journal of production economics, 88(1), 61-71.

Michigan Department of Transportation. "Construction Congestion Cost." 2016. <http://www.michigan.gov/mdot/0,4616,7-151-9625_54944-227053--,00.html>(Jul 1 2016).

Miller, M.C. and Gransberg, D.D. (2015). "Integrating Social Impact to Bridge Asset Management Plan," Infrastructure Asset Management. Vol. 1, No. 1, pp.

Miller, C., Rueda-Benavides, J.A., and Gransberg, D.D. "Applying Social Return on Investment to Risk-Based Transportation Asset Management Plans in Low Volume Bridges," Transportation Research Record No. 2473, Journal of the Transportation Research Board, National Academies, 2015, pp. 75-82.

Molenaar, K.R., Harper, C., Yugar-Arias, and I.. (2014) "Guidebook for Selecting Alternative Contracting Methods for Roadway Projects: Project Delivery Methods, Procurement Procedures, and Payment Provisions." Next-Generation Transportation Construction Management Transportation Pooled Fund Program Study TPF-5(260).

Molenaar, K.R., Songer, A.., and Barash, M. (1999) "Public-Sector Design/Build Evolution and Performance." ASCE Journal of Management in Engineering. March/April 1999
Oppenheim, A. N. (1992). Questionnaire Design, Interviewing and Attitude Measurement, Continuum, London.

Owens, J., J. Ahn, J.S. Shane, K.C. Strong, and Gransberg, D.D., (2011). "Defining Complex Project Management of Large US Transportation Projects: A Comparative Case Study Analysis," Public Works Management and Policy, Vol. 16 (4), pp.

Scheepbouwer, Eric, and Adam B. Humphries. (2011). "Transitional issues in adopting the early contractor involvement (ECI) project delivery method." *Transportation Research Board Annual Meeting, 90th, 2011, Washington, DC, USA*. No. 11-2197.

Shrestha, P., Migliaccio, G., O'Connor, J., and Gibson, E. (2007) "Benchmarking of Large Design-Build Highway Projects. One-to-One Comparison and Comparison with Design-Bid-Build Projects." Transportation Research Record, 1994(1), 17-25.

Silberston, A. (1972) "Economies of Scale in Theory and Practice." The Economic Journal, pp. 369-391.

Tran, D., Molenaar, K.R., and Gransberg, D.D. (2016). "Implementing Best-Value Procurement for Design-Bid-Build Highway Projects," *Transportation Research Record, No, 2573. Journal of the Transportation Research Board*, National Academies, pp. 26-33.

U.S. Department of Transportation, Federal Highway Administration. (2006). "Design-build Effectiveness Study." <http://www.fhwa.dot.gov/reports/designbuild/designbuild.pdf> (Apr 2, 2007)

Williams, T. P. (2003). Predicting final cost for competitively bid construction projects using regression models. International Journal of Project Management, 21(8), 593-599.

Yeo, K. T., & Tiong, R. L. (2000). Positive management of differences for risk reduction in BOT projects. International Journal of Project Management,18(4), 257-265.

Yin, R.K. (1994) "Case Study Research, Design and Methods." Sage Publications. 1994. Thousand Oaks, California.