THE EFFECT OF THE LEVEL OF COMPETITION ON CONSTRUCTION BID QUALITY

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ABSTRACT

The Federal Highway Administration (FHWA) mandates the use of a competitive procurement process for most State Department of Transportation projects that are funded through the Federal-Aid Highway Program. For those projects utilizing the traditional Design-Bid-Build (D-B-B) delivery method, FHWA policy stipulates that bids must be received from competing contractors who are solicited by openly advertising the terms and conditions of the contract. Recently the FHWA has accepted the use of Design-Build (D-B) as an alternative project delivery method. Under D-B a select group of contractors is solicited and then a small subgroup is "short listed" to provide sealed bids. In a 2006 study, the FHWA found that the average number of bidders under D-B was almost 40 percent less than for the traditional method. This study examines the effect that a similar reduction in the number of bidders had on the quality of bid results. The study found that as the number of bidders decreased from six to four, the number of unfavorable bids increased from 17.5 percent to 40.8 percent.

INTRODUCTION

The Federal Highway Administration (FHWA), and an increasing number of State Department of Transportation (State DOTs), today view Design-Build (D-B) as an acceptable alternative to the traditional Design-Bid-Build (D-B-B) method for public transportation projects. The FHWA recently reported that “State DOTs have found that they can accelerate project delivery, lower project costs and improve project quality" with D-B, and through its increased use "greater flexibility and benefits will be recognized" (FHWA, 2016). This represents a notable shift in policy by the FHWA in support of the accelerated use of D-B. That major shift in procurement strategy grew over a relatively short period of 20 years. In 1995, for instance, in a letter from the Director of the Office of Engineering, the FHWA stated that "although there was some support from state highway agencies to use and evaluate the D-B contracting method, a large portion of the industry had expressed strong disapproval". Due to the lack of support from the highway community, the FHWA, at that time, decided that no special emphasis would be given to promote the D-B delivery method. (Parvin, 2011).

Although the FHWA policy has since transformed and it is now promoting D-B, the contractor community's "strong disapproval" of D-B remains. This is primarily due to the belief that D-B reduces competition and adds subjectivity into the procurement process. Per a White Paper on the Use of Alternative Contract Award Methods in Highway Construction sponsored by the Association of General Contractors (AGC), the introduction of subjectivity into the bid process is believed to have a negative impact on integrity because "subjectivity tends to politicize the selection procedure, and opens the door for impropriety" (AGC – 2002). Many contractors also believe that D-B restricts competition by eliminating small and medium sized firms because they do not have the wherewithal to assume the elevated risk of D-B project delivery.

It is also a well-known economic principle that open and fair competition leads to lower prices, an obvious advantage to the owner. In a study for the FHWA, Texas AM University confirmed this using a calibrated simulation model of construction contract bidding. The simulation predicted that the lowest bid, when eight bidders are present would be approximately 25 percent lower than the lowest bid with only two bidders present (Damnjanovic, 2008).

The aim of this study was to provide additional evidence that reducing competition increases construction bid prices. Specifically, using both actual bid results from State DOTs and economic theory, the objective was to:

1. Compare the relative degree of competitiveness of D-B-B vs. D-B;

2. Define bid quality, and determine the evaluation factors that should be considered;
3. Define an optimal bid outcome;
4. Determine the ideal level of competition that most likely would result in an optimal bid price;

HISTORY OF STATE DOT PROCUREMENT

For well over a century, the federal government mandated the use of the Design-Bid-Build (D-B-B) delivery method for all public construction projects. Because of its long history, the D-B-B method is often called the traditional approach to public contracting. The D-B-B approach mandates a linear, and prerequisite relationship between the discrete project phases. Separate entities perform design services and construction work, and design is required to be completed prior bidding, and the start of construction. By clearly separating roles and responsibilities, the D-B-B approach is thought to set the adequate level of checks and balances, which in turn is thought to enhance accountability of the project team toward the owner.

The requirement to use the D-B-B delivery method on public projects can be traced back in time to the construction of the Transcontinental Railroad and the Credit Mobilier scandal of 1872. The Credit Mobilier scandal was the result of a rigged bidding system which allowed the railroad contractor to charge the government far higher rates than the market, and in return, 9 million dollars in stock was secretly given as bribes to 15 powerful Washington politicians, including the Vice-President, the Secretary of the Treasury, four senators, and the Speaker and some members of the House (US House of Representatives Archives, 2015). The Credit Mobilier scandal is an example of what we would refer today as a “pay to play” scheme. One consequence of the scandal was the formal separation of design services from construction work on federal projects through an act of Congress in 1893, and ultimately, today’s legislation at both the federal and state levels requiring the use of the D-B-B approach on State DOT projects.

Under the D-B-B approach today, State DOTs award design services based on a qualifications-based selection process (QBS), while construction work is awarded based on the lowest responsive bid by a responsible contractor. QBS procurement was mandated for design services through an act of Congress in 1972 (Brooks Act), which required public agencies to "negotiate contracts for architectural and engineering services based on demonstrated competence and qualification for the type of professional services required and at fair and reasonable prices". The QBS method for selecting design professionals is a generally accepted way to ensure that the public's health, welfare and safety is of primary importance on public projects (Stone, 2012). However, many consider the awarding of the construction contracts to the lowest bidder fraught with peril. The main concern is the subjective nature of the word "responsible". One often cited definition, in the context of the award of public construction contracts, comes from the California Court of Appeals, which ruled in a civil case that it included an "attribute of trustworthiness but also had reference to quality, fitness and capacity of the low bidder to satisfactorily perform the proposed work" (Theriault, 2004). In addition, the court ruled, "public construction contracts must be awarded to lowest bidder unless it is found that he is not responsible". Based on the potential legal consequences of this "innocent until proven guilty" interpretation of the law, many State DOTs find it exceedingly difficult to justify rejecting a bid even if they feel the contractor is not responsible to perform the work.

Design-Build is a method of project delivery in which one entity – the D-B team – works under a single contract with the project owner to provide design and construction services. The primary advantage of the D-B method is the contractor's enhanced ability to fast-track a project. Because the rules that separate design from construction are relaxed, and the pace of work is determined by the contractor, construction can begin prior to the completion of design. This is a more efficient progression of project tasks and can significantly reduce the project duration, and through the "time-is-money" principle, also significantly reduce project costs.

In 1996 Congress passed the Clinger-Cohen Act, which empowered the FHWA to decide whether D-B is an appropriate procurement method for State DOT projects (Kovars, 2011). The Clinger-Cohen Act required the FHWA to consider the following factors:

1. If three or more contractors will submit proposals,
2. The extent to which the project requirements are defined,and
3. The capability of the State DOT to manage the D-B procurement process.

One of the criticisms of the D-B project delivery method is that it does not allow for the competitive bidding of completed plans and specifications. Unlike the D-B-B method, contracts are awarded and executed when design is still in the conceptual stage. Critics contend that this limits the number of firms able, or willing, to participate due to the increased risk assumed by the bidder (Serbu, 2013). One advantage of D-B contracts is that they can be awarded by the State DOTs as either "low-bid" or "best-value". An opportunity to use the best-value selection criterion in D-B is often highlighted as an important owner advantage over the low-bid only criteria of D-B-B, because best-value selection allows for the consideration of additional factors, such as experience, qualifications, technical innovation, management approach, schedule, level of quality, and other related criteria in addition to price. Advocates contend that this results in the selection of the best contractor for the work. However, use of best-value to choose a contractor when design is still in the conceptual stage, can result in a wide range of bid prices as shown in Table 1.

Tabel 1. Best Value Bid Results ($Billions)

Year	Agency	Project	Delivery Method	Bids	Engineer's Estimate	Lowest Bid	Next Bid
2009	FDOT	Port of Miami Tunnel	DB-FOM	3	$1.30	$1.07	$1.61
2009	FDOT	I-595 Upgrade	DB-FOM	2	$2.51	$1.83	$2.38
2010	NJDOT	Geothals Bridge	DB-F	3	$1.00	$1.50	$1.61
2010	TDOT	I-635 Managed Lanes	DB-F	2	$2.87	$2.62	$3.93
2014	INDOT	I-69 Upgarde	DB-FOM	4	$0.39	$0.37	$0.48
2014	FDOT	I-4 Ultimate Lanes	DB-FOM	4	$2.20	$2.32	$2.47
2015	NYDOT	Tappanzee Bridge	DB	3	$5.40	$3.10	$4.00
DB-Design Build; DB-F Design-Build-Finance; DB-FOM Design-Build-Finance-Operate-Maintain					**$15.67**	**$12.81**	**$16.48**

This is the case because the scope, and even the scale, of a project, is not well defined. Critics contend that this adds subjectivity to the procurement process which is inappropriate for public works. It may not lead to selection of the “best” contractor as believed either. Consider that in the seven D-B projects shown in Table 1, the lowest bid amount was 12.81 billion dollars against an engineer’s estimate of 15.67 billion dollars. More telling perhaps, was the amount of money "left on the table", which was 3.67 billion dollars, which represents the foregone profit of the seven low-bid contractors.

Under the D-B best-value selection process, the State DOTs solicit a small number of firms through Request for Qualifications (RFQs), and then a “short list” of selected firms are invited to submit competitive sealed bids. The FHWA has performed just one comprehensive study on the effectiveness of D-B. The study was a requirement of TEA-21 (Transportation Equity Act for the 21st Century) which authorized the use of D-B on a small number of State DOT projects. The study, completed in 2006, evaluated 73 D-B and 2,961 D-B-B State DOT projects. One charge of the study was to measure the effect that D-B had on the level of competition. As shown in Table 2, D-B resulted in bidders showing an average of 40 percent less interest in bidding and a 33 percent reduction in the average number of bids received. This was the case even though the D-B contractors were paid an average stipend of 48,500 dollars to submit proposals whereas no stipends were paid to the D-B-B contractors.

Tabel 2. Competition Level (SEP-14)

	Design-Build			**Design-Bid-Build**		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
Expressed Interest	6	15	3	10	40	0
Submitted a Bid	4	6	2	6	12	0
Stipend Received	$48,500	$250,000	$0	$0	$0	$0

Additional antidotal evidence of D-B’s negative effect on competition can be found in a more recent study by the Florida Department of Transportation (FDOT). The FDOT study, completed in 2012, showed that for projects ranging in size from 75 - 100 million dollars, the average number of firms showing interest in D-B project delivery, by responding to a RFQ, was just five. (FDOT, 2015)

RESEARCH OUTLINE

The purpose of this study was to test the hypothesis that D-B produces higher priced bid results because it reduces competition. Auction theory predicts that a decrease in competition will result in higher bid pricing which is an obvious disadvantage to the buyer. The general economic concept that the level of competition plays an important role in construction contract bidding behavior was first formulated in the Friedman Probability Model (Friedman, 1957). Friedman established this connection using historical data to calculate the probability of a bidder's success against a known number of competitors. Later, the Gate's Formula (Gate, 1967), described by Gates as being based on a "balls in the urn" or conditional probability model, was an empirical fit formula developed to better predict competitive bidding behavior. In Gate's model of competitive bidding the most critical issue in determining the probability of placing a winning bid is the mark-up (profit) level (Skitmore, 2007). Recent research on competitive bidding has been based on applying complex mathematical models, including game theory (Ahmed, Eladaway, Coatney, and Eid, 2016), system dynamics (Mahdavi and Hastak, 2014), the maximum likelihood theory (Péreza, Hitschfeldb, Meliàa, and Domíngueza, 2015), and neural networks (Christodoulov, 2010).

The approach for this study was to use the statistical analyses of a large sample of State DOT bid results to test the null hypothesis that D-B project delivery has no effect on the level of competition and on the quality of bids. The level of competition was quantified as the number of bidders per bid. Bid quality was qualified using two important metrics: (i) the bid spread, and, (ii) the deviation of the lowest bid from the engineer's estimate. These two metrics are often used by practitioners to evaluate bids and to make recommendations regarding the award of contract. The bid spread, or the "amount left on the table", as it is sometimes referred to, is used by contract underwriters for example, to gauge the risk level of a bid. The general rule of thumb for the bonding agencies is that if the value of the bid spread is over 10 percent that is a call for additional scrutiny to ensure the low bidder has not left something out of the bid (Golia, 2014).

The deviation of the lowest bid from the engineer's estimate is a more complex metric to use in the evaluation of bids. Because there are several reasons why an engineer's estimate may be well off the mark. The accuracy of the engineer's estimate, the accuracy of the low bid, the capability of the low bidder to perform the work, and the standard of care taken by the owner to produce the bid documents, are just a few. Recurring bid situations reduce these variations in process quality due to the standardization of methods and procedures. For State DOT projects, the use of unit pricing, the use of the D-B-B project delivery method, and the consistency of project participants all further reduce the above listed potential variability.

Market conditions may also play a role. Using the engineer's estimate as a tool to measure bid quality provides an added benefit because it also sets the baseline for the project's budgeted cost. The FHWA sets a high standard for the accuracy of engineer's estimate on State DOT projects. FHWA guidelines state, in part, that the engineer's estimate must "reflect a fair and reasonable cost of the project in sufficient detail to provide an accurate estimate of the financial obligations to be incurred by the State and FHWA, and permit an effective review and comparison of the bids received". As such, the engineer's estimate, as one measure of a project's anticipated cost, can be compared to the low-bid contractor's price to gauge the profit margin. A low profit margin can reflect the market situation, such as the level of competition and economic conditions, or indicate what is often referred to as the "winners curse". The winner's curse is when the low bidder submits an underestimated bid and is thus cursed by being selected to undertake the project (Ahmed et al., 2015). The FHWA criteria for the accuracy of engineer's estimates is +/-10 percent for at least 50 percent of all projects awarded by a State DOT in any given year (FHWA, 2004). This guideline is very close to the Association for the Advancement of Cost Engineering (AACE) range for Class 1 Estimates of -5 percent to +10 percent (Molenaar, 2011).

The major challenge of this study was to find a reliable way to determine the quality of D-B bids under the current situation of limited available data from State DOTs on awarding of D-B contracts. The FHWA's Special Experimental Projects No. 14 - Alternative Contracting (SEP-14) program is a good example of why. For the SEP-14 program, which was specifically mandated by TEA-21 to determine the effectiveness of D-B contracting method, less than 3 percent of the projects reviewed were D-B. Until more D-B projects are completed, a one-on-one statistical comparison with D-B-B, will not be very reliable. So, the approach taken for this study was the indirect path of using bid data from D-B-B projects, which is readily available, and to extrapolate what might be expected under D-B. Although not ideal, the approach provides useful and timely information which can be augmented in the future when more D-B bid results are available.

As stated earlier, fundamental research on competitive bidding has focused on two metrics for evaluating bid results: the bid spread and the deviation of the lowest bid from the engineer's estimate (Skitmore 1988). These are also the two primary factors used by practitioners to evaluate bid results and to gauge the general effectiveness of a procurement program. To properly determine the quality of bid results both metrics must be taken into consideration because they are both important for different reasons. The bid spread, for example, can be thought of as primarily a measure of performance risk as it is the low-bid contractor's foregone profit. The deviation of the lowest bid from the engineer's estimate, on the other hand, can be thought of as primarily process risk, as it is a measurement of the effectiveness of the owner's procurement program.

An effective process to utilize both metrics to evaluate the quality of a bid is illustrated in Table 1.

TABLE 1 - CROSS REFERENCE CHART - BID QUALITY

BID QUALITY MATRIX			Deviation from the Engineer's Estimate				
			≥10%	5% →10%	5% ↔-5%	-5% →-10%	≤-10%
			1	2	3	4	5
Bid Spread	≥10%	A	U	U	U	U	U
	8% →10%	B	U	A	A	A	A
	6% →8%	C	U	A	A	A	A
	4% →6%	D	U	A	I	A	A
	2% →4%	E	A	A	I	A	A
	0 →2%	F	A	A	I	A	A

BID QUALITY KEY

Light grey	UNFAVORABLE
White	ACCEPTABLE
Dark grey	IDEAL

The cross-reference chart developed for this study (Table 1) uses the acceptance criteria established by the FHWA for the accuracy of engineer's estimates (+/-10 percent), and those established by the bonding agencies for the bid spread (also 10 percent). This sets the upper limits for each and then different combinations of the two are appraised subjectively to determine what they would suggest about the bid acceptance. Like risk assessment, evaluating bid results is both an art and a science, therefore some level of subjectivity cannot be avoided.

The cross-reference chart can be used to define the combination of the two evaluation factors that would most likely indicate an ideal, acceptable, or an unfavorable, bid outcome. Unfavorable results are those that exhibit elevated risk for the bidder as well as the owner and are labeled "U". An unfavorable bidding result is characterized as one with a large bid spread, which would indicate heightened risk to the low bidder, and a large deviation from the engineer's estimate, that would indicate heightened risk to the owner. There are two categories of acceptable results. Acceptable results are labeled "A" which indicate an acceptable combination of the bid spread and deviation of the low bid from the engineer's estimate. Some results labeled "A" are above the engineer's estimate and are acceptable only if the budget allows. Ideal results are labeled "I" and represent low bids that have low bid spreads (less than 6 percent) and are within +/- 5 percent of the engineer's estimate. The optimum level of competition can be determined as the number of bidders/bid that most likely would produce the fewest unfavorable bid results.

The adverse effect of limited competition on the quality of bid results is an important factor for State DOTs to consider during their due diligence for justifying the use of D-B project delivery. This is especially true now as the current trend is toward increased use of the D-B delivery method (Huffman, 2012). Although many of the attributes of D-B, such as cost and time savings from fast-tracking, are often taken as positive factors, the negative impact of inferior bid results, due to the loss of competition, seldom is. At present, all State DOTs have utilized D-B for transportation projects and 30 State DOTs have established a D-B authority. A survey of those 30 State DOTs by the Design-Build Institute of America (DBIA) in 2015 showed an increase from 140 D-B projects, to over 1,000 (600 percent increase), since the last survey was taken in 2001. This trend is likely to continue as the FHWA, through its Every Day Counts initiative, is promoting D-B to "help reduce the time it takes to deliver highway projects to the public and reduce construction-related risks".

DATA COLLECTION AND ANALYSIS

The objective of the data gathering process was to obtain certified bid results that were representative of all State DOT projects (sample population). The State DOTs recurrent bidding for D-B-B projects generally ensures aggressive competition for the work and "levels the field" in regards to openness and fairness (Fu and Drew, 1995). As part of that openness, all State DOTs are required to follow the same federal procurement guidelines (23U.S.C.112) and to openly publish bid results. Most State DOTs provide this information on-line, however, each has its own format for recording bid results, and each archive historical data differently. On our preliminary search, we found four State DOTs that provide similar bid letting information: New York, Michigan, Indiana, and Washington. Several State DOTs, including New York, do not include the engineer's estimate in the public posting of their bid results. Confidentiality of the engineer's estimate is encouraged by the FHWA to limit the potential "rigged bids" or, in other words, collusion between bidders. A summary of the bid tab information for all D-B-B projects awarded by these four State DOTs in 2015 is included in Appendix A. A total of 1,417 bid results for the year 2015 were analyzed which represented 2.929 billion dollars in contract value. The sample size is significant as these four State DOTs represented 11.2 percent of FHWA aid obligations for 2015 (FHWA, 2016).

The first step in the process to analyze the bid results was to provide an uniform definition for the evaluation metrics. For each level of competition (denoted as c) the average bid spread (denoted as $\bar{s}$) and the average deviation from the engineer's estimate (denoted as $\bar{e}$) was defined as follows:

$$s = 1/n \sum_{i=1}^{n} i = \frac{b_2 - b_l}{b_l} \tag{1}$$

$$e = 1/n \sum_{i=1}^{n} i = \frac{b_l - EE}{EE} \tag{2}$$

$s =$ Average Bid Spread , $e =$ Average Deviation from the Engineers Estimate,

$n =$ No. of Bids by Category , $b_l =$ Lowest Bid , $b_2 =$ Second Lowest Bid , $EE =$ Engineer's Estimate

For each of the variables (c,$\bar{s}$,and $\bar{e}$) outliers were defined as those data points that were two standard deviations away from the mean and were removed from consideration. This eliminated 116 data points, and resulted in a data set of 1,301 bids with the following characteristics:

Table 3. Descriptive Statistics of Bid Results

BIDDERS	1	2		3		4		5		6		7	
Metrics	e	e	s	e	s	e	s	e	s	e	s	e	s
Bids	52	297	342	278	344	206	273	126	163	63	79	35	48
Minimum	-54.7%	-42.6%	0.0%	-53.7%	0.0%	-57.8%	0.0%	-39.8%	0.0%	-31.9%	0.0%	-44.7%	0.4%
Maximum	57.7%	48.0%	77.7%	44.8%	49.3%	55.3%	42.5%	52.9%	39.3%	20.5%	26.2%	14.7%	29.0%
1st Quartile	-3.9%	-9.9%	5.3%	-12.0%	3.2%	-11.1%	2.5%	-13.6%	2.7%	-10.7%	1.6%	-12.3%	3.3%
Median	6.1%	0.0%	10.3%	-1.8%	8.1%	-1.8%	6.4%	-2.1%	6.9%	-4.2%	4.2%	-3.2%	5.6%
3rd Quartile	-17.2%	10.2%	21.0%	8.5%	14.4%	8.6%	13.5%	7.6%	12.3%	6.1%	6.8%	3.5%	9.9%
Mean	6.1%	-0.9%	15.3%	-3.1%	10.8%	-1.7%	8.8%	-2.6%	8.8%	-3.5%	5.4%	-6.6%	7.9%
SD	18.4%	16.4%	14.6%	17.4%	10.2%	17.5%	8.1%	15.6%	8.3%	12.7%	5.3%	14.6%	6.9%

The results were analyzed to determine if a correlation between the two dependent variables ($\bar{s}$ and $\bar{e}$) and the independent variable (c), existed. Results from that analysis verified that there was a significant relation between the level of competition (No. of Bidders) and both dependent variables $\bar{s}$ and $\bar{e}$. Each of the two variables showed an inverse relationship with the number of bidders (c), as expected. For the variable bid spread, for which the sample data can be modeled as an exponential distribution pattern (at 90 percent CI, the p-value = 62.5), the relationship was best described (R2 = .98) by the logarithmic function:

$$s = -.047ln(c) + .1476 \quad (3)$$

The relationship is plotted in Figure 2, with the individual bid results displayed in strip chart format (horizontal lines) grouped by the number of bidders per bid (level of competition). The average bid spread for each grouping is displayed by the "+" symbol. As predicted by the Friedman Model(Friedman, 1957), the general trend showed that as the number of bidders increased the average bid spread decreased. However, their was an anomaly in the trend, when the number of bidders increased from 6 to 7. For that portion of the data set, the bid spread actually increased significantly (5.4 percent to 7.9 percent) as competition increased. This may be the case because of the phenomena of "low balling" and the "winners curse".

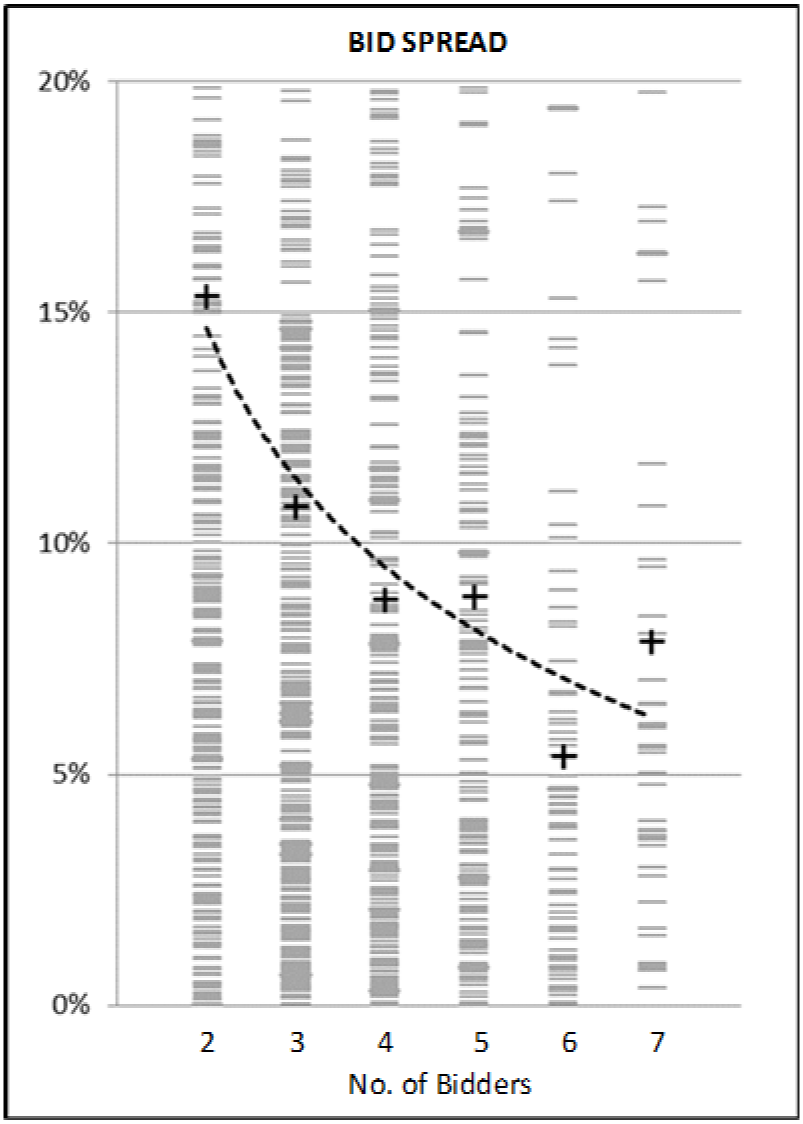

Figure 2. Regression of Bid Spread

For variable ē, the difference between the engineer's estimate and the lowest bid, the sample data can be modeled as a logistic distribution pattern (at 95 percent CI, the p-value = 90.7), and the relationship between variables can best be described (R2 = .86) by the third order polynomial function:

$$e = -.0029(c)^3 + .0376(c)^2 - .1554(c) + .1793 \qquad (4)$$

The relationship is plotted in Figure 3.

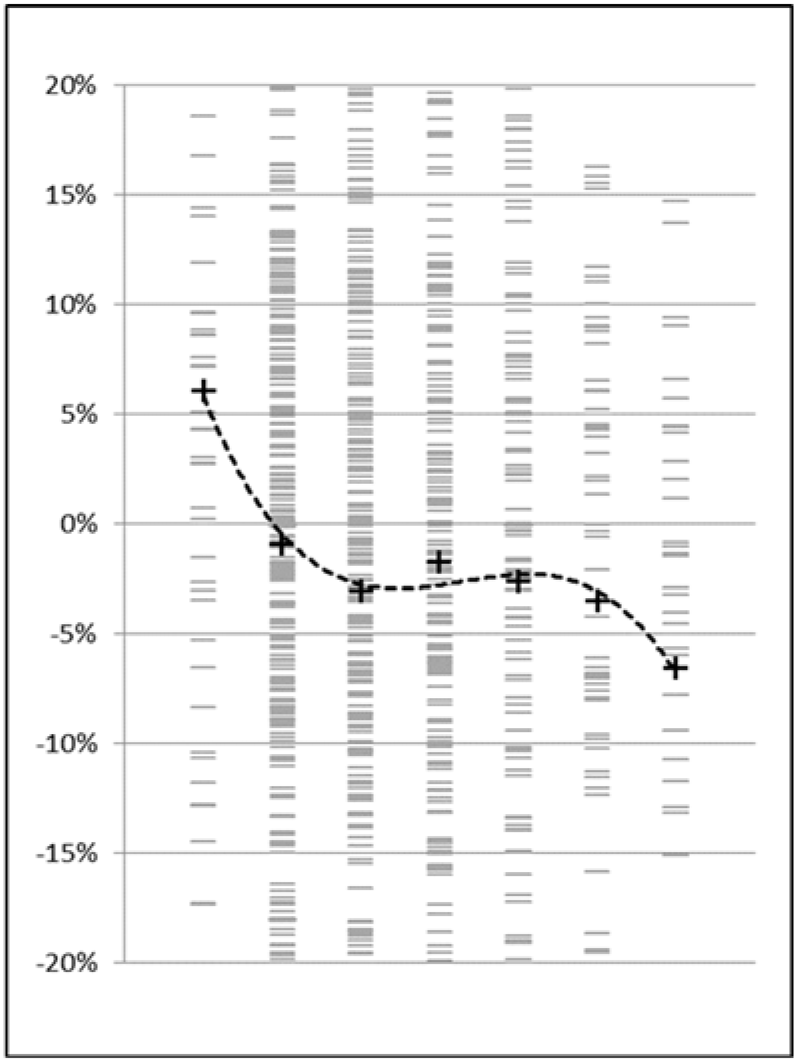

Figure 3. Regression of Deviation from Estimate

Next the the cross-reference chart was utilized to qualify the bid results (see Figure 1). Figure 5 shows the proportions from the sample data for each combination of values. The highlighted cells represent unfavorable bids which totaled 34 percent.

TABLE 2 - CROSS REFERENCE CHART - BID QUALITY

BID QUALITY MATRIX			Deviation from the Engineer's Estimate					
			≥10%	5% →10%	5% ↔-5%	-5% →-10%	≤-10%	TOTAL
			1	2	3	4	5	
Bid Spread	≥10%	A	7.7%	3.7%	8.7%	1.4%	15.1%	36.6%
	8% →10%	B	2.1%	0.7%	2.5%	1.5%	1.4%	8.1%
	6% →8%	C	2.2%	1.7%	2.4%	1.4%	2.5%	10.1%
	4% →6%	D	1.8%	0.9%	3.3%	1.5%	1.4%	8.9%
	2% →4%	E	3.4%	1.5%	3.0%	2.4%	2.7%	13.1%
	0 →2%	F	4.0%	1.7%	5.2%	8.7%	3.6%	23.2%
	TOTAL		21.1%	10.1%	25.1%	16.9%	26.8%	100%

BID QUALITY KEY

UNFAVORABLE ACCEPTABLE IDEAL

Then the number of unfavorable bids for each level of competition was determined. For the special case of just one bidder, an unfavorable result was defined based on the FHWA criteria (when the deviation from the estimate was +/− 10 percent). The results are plotted in Figure 5.

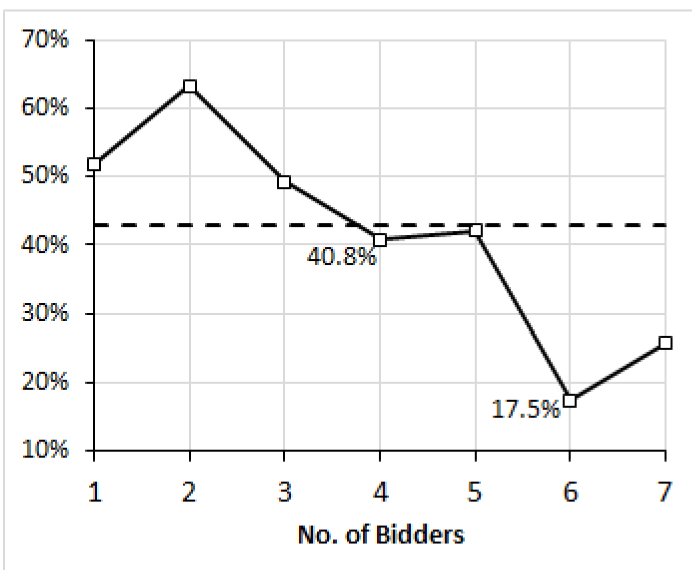

Figure 5. Probability of a Unfavorable Bid

CONCLUSIONS

The analyses show that as the level of competition decreases for a D-B-B project, the risk of an unfavorable bid result significantly increases. For example, reducing competition from six (average for D-B-B in the 2006 FHWA study) to four (average for D-B in the 2006 FHWA study) bidders caused a 57 percent increase in unfavorable bids. That result is in general agreement with previous studies and is in accordance with economic theory.

The challenge of this study was to formulate an inference from the D-B-B results to D-B projects. Although not an ideal approach, it was necessary because there is limited available data on D-B. The reason for this is two fold. First, D-B for State DOTs is fairly new, and second, the bid process for D-B is much less transparent than D-B-B. Yet it is critical that the consequences of limited competition be considered when deciding if D-B is the appropriate project delivery method for public transportation projects.

Many of the State DOT projects that have been chosen for D-B to-date (see Table 1) are major endeavors with large public expenditures. A small reduction in the difference between the engineer's estimate and the low bid can result in significant savings. Take the case of the NJDOT I-595 and TDOT I-635 projects which received just two bids each. A forecast of the saving, based on Equation (4), if six bids were received instead of two, is 116 million dollars:

$$e_2 = -.0029 * (2)^3 + .0376(2)^2 - .1554(2) + .1793e_6 = -.010$$

$$e_6 = -.0029 * (6)^3 + .0376(6)^2 - .1554(6) + .1793e = -.032$$

$$e_2 - e_6 = .022$$

$$\triangle\ b_l = .022 * 58,000,000,000 = 116,000,000$$

There is no reason to believe that the same principles of economic theory do not apply to D-B contracts. This is why federal law stipulates unrestrained competition for both public and private work. Congress passed the Sherman Act, in 1890 as a "comprehensive charter of economic liberty aimed at preserving free and unfettered competition as the rule of trade." The presumption of capitalism is free and open competition. By limiting competition, D-B increases the potential for unfavorable bid outcomes. It is only the degree of the effect that is in question.

REFERENCES, CITATIONS AND BIBLIOGRAPHIC ENTRIES

Anderson, S. and Damnjanovic, I. (2008). Selection and Evaluation of Alternate Contracting Methods to Accelerate Project Completion. National Cooperative Highway Research Program (NCHRP), TRB, National Academy Press, Washington, DC.

Association of General Contractors. (2002). Design Build Whitepaper. Public Contracting Coalition

Ahmed, M., Eladaway, I., Coatney, K., and Eid, M. (2015). Construction Bidding and the Winner's Curse: Game Theory Approach. J. Constr. Eng. Manage.

Christodoulou, S. (2010). Bid markup selection using artificial neural networks and an entropy metric. Engineering, Construction and Architectural Management, Vol. 17 Issue: 4

Federal Highway Administration. (2016). Center for Accelerated Innovation. Retrieved from www.fhwa.dot.gov/innovation

Federal Highway Administration. (2015) TEA-21 Moving Americans into the 21st Century. Retrieved from www.fhwa.dot.gov/tea21

Federal Highway Administration. (2015). Special Experimental Projects No. 14 Alternative Contracting. Retrieved from www.fhwa.dot.gov/programadmin/contracts/

Federal Highway Administration. (2004). Guidelines on Preparing Engineer's Estimate, Bid Reviews and Evaluation. Retrieved from www.fhwa.dot.gov/programadmin/contracts/

Federal Highway Administration. (2016). An Innovation Partnership with States. Retrieved from ww.fhwa.dot.gov/innovation/everydaycounts

Florida Department of Transportation. (2015). Design-Build Procurement and Administration.

Friedman, L. (1957). A competitive bidding strategy. Doctoral dissertation, Case Institute of Technology

Fu, W. and Drew, D. (1995). Contractors' bidding behavior in a recurrent bidding situation.

Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

Gadbois, B, Heisse, J, and Kovars, J. (2011). Turning a Battleship: Design-Build on Federal Construction Projects, Construction Lawyer Winter

Gates, M. (1967). Bidding strategies and probabilities. Journal of the Construction Division, Proceedings of the American Society of Civil Engineers 93 (CO1), 75-107.

Gates, M. (1976). Discussion of bidding models: truths and comments. Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, 102(4) 696-9.

Golia, S (2014). Bid Spreads. Secrets of Bonding Blog. Retrieved from www. Secrets of bonding.com/

Huffman, R. (2015) Emerging Trends and Lessons Learned in the First 20 years of Design-Build Design. Build Institute of America.

Indiana Department of Transportation. (2015). Tabulated Bid Results [Data File]. Retrieved from www.bidx.com/in/main

Letsinger, T. (2010). Analysis of Criteria Used to Select Design/Build Teams. College of Technology Directed Projects, Paper 20.

Mahdavi, A, Hastak, M, (2014). Quantitative Analysis of bidding strategies: a hybrid agent based–system dynamics approach. Construction Research Congress

Michigan Department of Transportation. (2015). Tabulated Bid Results [Data File] Retrieved from www.michigan.gov/mState DOTs

Molenaar, K, Anderson, S, Schexnayder, C (2011). AASHTO Practical Guide to Estimating. AASHTO Technical Committee on Cost Estimating

New York State Department of Transportation. (2015). Tabulated Bid Results [Data File] Retrieved from www.State DOTs.ny.gov

Parvin, A, (2011) The Right to Build. University of Sheffield School of Architecture

Pereza, P., Hitschfedold, M., Meliaa, and Domigueza, D. (2015). Modeling bidding competitiveness and position performance in multi-attribute construction auctions. Journal of Operations

Research Perspectives, 2, 24-35

Stone, C. (2012) The Brooks Act at 40: A Law that Works. Council on Federal Procurement of Architecture and Engineering Services (COFPAES). Retrieved from www.news.asce.org/the-brooks-act-at-40-a-law-that-works/

Serbu, J. (2013). "Critics say federal D-B construction contracts stifling competition", Federal News. Retrieved from http://federalnewsradio.com

Skitmore, M. (1988) Fundamental Research in Bidding and Estimating. In Proceedings British/Israeli Seminar on Building Economics; The International Council for Building Research Studies and Documentation

Skitmore, M., Pettitt, A., and McVinish, R. (2007). The Gates Bidding Model. The Journal of Construction Engineering and Management Washington State Department of Transportation. (2015). Tabulated Bid Results [Data File]. Retrieved from www.wsState DOTs.wa.gov

Theriault, K. (2004) Determination of Lowest Responsible Bidder. The Procurement Connection Retrieved from www.theprocurementconnection.com/articles/defbid.html

US House of Representatives. (2015) The Crédit Mobilier Scandal. History, Art and Archives Retrieved from www.history.house.gov.

Washington State Department of Transportation. (2015). Tabulated Bid Results [Data File]. Retrieved from www.wsState DOTs.wa.gov