

1 **THE EFFECT OF THE LEVEL OF COMPETITION ON**
2 **CONSTRUCTION BID QUALITY**

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6 **ABSTRACT**

7 The Federal Highway Administration (FHWA) mandates the use of a competitive procurement
8 process for most State Department of Transportation projects that are funded through the Federal-
9 Aid Highway Program. For those projects utilizing the traditional Design-Bid-Build (D-B-B)
10 delivery method, FHWA policy stipulates that bids must be received from competing contractors
11 who are solicited by openly advertising the terms and conditions of the contract. Recently the
12 FHWA has accepted the use of Design-Build (D-B) as an alternative project delivery method.
13 Under D-B a select group of contractors is solicited and then a small subgroup is "short listed" to
14 provide sealed bids. In a 2006 study, the FHWA found that the average number of bidders under
15 D-B was almost 40 percent less than for the traditional method. This study examines the effect that
16 a similar reduction in the number of bidders had on the quality of bid results. The study found that
17 as the number of bidders decreased from six to four, the number of unfavorable bids increased from
18 17.5 percent to 40.8 percent.

19 **INTRODUCTION**

20 The Federal Highway Administration (FHWA), and an increasing number of State Department
21 of Transportation (State DOTs), today view Design-Build (D-B) as an acceptable alternative to
22 the traditional Design-Bid-Build (D-B-B) method for public transportation projects. The FHWA
23 recently reported that "State DOTs have found that they can accelerate project delivery, lower project

24 costs and improve project quality” with D-B, and through its increased use “greater flexibility and
25 benefits will be recognized” (FHWA, 2016). This represents a notable shift in policy by the
26 FHWA in support of the accelerated use of D-B. That major shift in procurement strategy grew
27 over a relatively short period of 20 years. In 1995, for instance, in a letter from the Director of
28 the Office of Engineering, the FHWA stated that “although there was some support from state
29 highway agencies to use and evaluate the D-B contracting method, a large portion of the industry
30 had expressed strong disapproval”. Due to the lack of support from the highway community, the
31 FHWA, at that time, decided that no special emphasis would be given to promote the D-B delivery
32 method. (Parvin, 2011).

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

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

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

- 50 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

78 act of Congress in 1972 (Brooks Act), which required public agencies to “negotiate contracts for
79 architectural and engineering services based on demonstrated competence and qualification for the
80 type of professional services required and at fair and reasonable prices”. The QBS method for
81 selecting design professionals is a generally accepted way to ensure that the public’s health, welfare
82 and safety is of primary importance on public projects (Stone, 2012). However, many consider the
83 awarding of the construction contracts to the lowest bidder fraught with peril. The main concern
84 is the subjective nature of the word “responsible”. One often cited definition, in the context of the
85 award of public construction contracts, comes from the California Court of Appeals, which ruled in
86 a civil case that it included an “attribute of trustworthiness but also had reference to quality, fitness
87 and capacity of the low bidder to satisfactorily perform the proposed work” (Therriault, 2004). In
88 addition, the court ruled, “public construction contracts must be awarded to lowest bidder unless
89 it is found that he is not responsible”. Based on the potential legal consequences of this “innocent
90 until proven guilty” interpretation of the law, many State DOTs find it exceedingly difficult to justify
91 rejecting a bid even if they feel the contractor is not responsible to perform the work.

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

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

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

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

Table 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 Upgrade	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	Tappansee 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

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

124 low-bid contractors.

125 Under the D-B best-value selection process, the State DOTs solicit a small number of firms
126 through Request for Qualifications (RFQs), and then a “short list” of selected firms are invited to
127 submit competitive sealed bids. The FHWA has performed just one comprehensive study on the
128 effectiveness of D-B. The study was a requirement of TEA-21 (Transportation Equity Act for the
129 21st Century) which authorized the use of D-B on a small number of State DOT projects. The study,
130 completed in 2006, evaluated 73 D-B and 2,961 D-B-B State DOT projects. One charge of the study
131 was to measure the effect that D-B had on the level of competition. As shown in Table 2, D-B resulted
132 in bidders showing an average of 40 percent less interest in bidding and a 33 percent reduction in the
133 average number of bids received. This was the case even though the D-B contractors were paid an
134 average stipend of 48,500 dollars to submit proposals whereas no stipends were paid to the D-B-B

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

135 contractors.

136 Additional antidotal evidence of D-B’s negative effect on competition can be found in a more
137 recent study by the Florida Department of Transportation (FDOT). The FDOT study, completed in
138 2012, showed that for projects ranging in size from 75 - 100 million dollars, the average number
139 of firms showing interest in D-B project delivery, by responding to a RFQ, was just five. (FDOT,
140 2015)

RESEARCH OUTLINE

142 The purpose of this study was to test the hypothesis that D-B produces higher priced bid results
143 because it reduces competition. Auction theory predicts that a decrease in competition will result
144 in higher bid pricing which is an obvious disadvantage to the buyer. The general economic concept
145 that the level of competition plays an important role in construction contract bidding behavior was

146 first formulated in the Friedman Probability Model (Friedman, 1957). Friedman established this
147 connection using historical data to calculate the probability of a bidder's success against a known
148 number of competitors. Later, the Gate's Formula (Gate, 1967), described by Gates as being based
149 on a "balls in the urn" or conditional probability model, was an empirical fit formula developed
150 to better predict competitive bidding behavior. In Gate's model of competitive bidding the most
151 critical issue in determining the probability of placing a winning bid is the mark-up (profit) level
152 (Skitmore, 2007). Recent research on competitive bidding has been based on applying complex
153 mathematical models, including game theory (Ahmed, Eladaway, Coatney, and Eid, 2016), system
154 dynamics (Mahdavi and Hastak, 2014), the maximum likelihood theory (Pérez, Hitschfeldb,
155 Melià, and Domínguez, 2015), and neural networks (Christodoulov, 2010).

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

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

173 reduce the above listed potential variability.

174 Market conditions may also play a role. Using the engineer's estimate as a tool to measure bid
175 quality provides an added benefit because it also sets the baseline for the project's budgeted cost.
176 The FHWA sets a high standard for the accuracy of engineer's estimate on State DOT projects.
177 FHWA guidelines state, in part, that the engineer's estimate must "reflect a fair and reasonable
178 cost of the project in sufficient detail to provide an accurate estimate of the financial obligations
179 to be incurred by the State and FHWA, and permit an effective review and comparison of the bids
180 received". As such, the engineer's estimate, as one measure of a project's anticipated cost, can be
181 compared to the low-bid contractor's price to gauge the profit margin. A low profit margin can
182 reflect the market situation, such as the level of competition and economic conditions, or indicate
183 what is often referred to as the "winners curse". The winner's curse is when the low bidder submits
184 an underestimated bid and is thus cursed by being selected to undertake the project (Ahmed et al.,
185 2015). The FHWA criteria for the accuracy of engineer's estimates is +/-10 percent for at least 50
186 percent of all projects awarded by a State DOT in any given year (FHWA, 2004). This guideline is
187 very close to the Association for the Advancement of Cost Engineering (AACE) range for Class 1
188 Estimates of -5 percent to +10 percent (Molenaar, 2011).

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

199 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

UNFAVORABLE
 ACCEPTABLE
 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

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

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

240 **DATA COLLECTION AND ANALYSIS**

241 The objective of the data gathering process was to obtain certified bid results that were rep-
242 resentative of all State DOT projects (sample population). The State DOTs recurrent bidding for
243 D-B-B projects generally ensures aggressive competition for the work and "levels the field" in
244 regards to openness and fairness (Fu and Drew, 1995). As part of that openness, all State DOTs are

245 required to follow the same federal procurement guidelines (23U.S.C.112) and to openly publish
 246 bid results. Most State DOTs provide this information on-line, however, each has its own format for
 247 recording bid results, and each archive historical data differently. On our preliminary search, we
 248 found four State DOTs that provide similar bid letting information: New York, Michigan, Indiana,
 249 and Washington. Several State DOTs, including New York, do not include the engineer’s estimate
 250 in the public posting of their bid results. Confidentiality of the engineer’s estimate is encouraged
 251 by the FHWA to limit the potential “rigged bids” or, in other words, collusion between bidders. A
 252 summary of the bid tab information for all D-B-B projects awarded by these four State DOTs in
 253 2015 is included in Appendix A. A total of 1,417 bid results for the year 2015 were analyzed which
 254 represented 2.929 billion dollars in contract value. The sample size is significant as these four State
 255 DOTs represented 11.2 percent of FHWA aid obligations for 2015 (FHWA, 2016).

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

$$259 \quad s = 1/n \sum_{i=1}^n i = \frac{b_2 - b_l}{b_l} \quad (1)$$

$$260 \quad e = 1/n \sum_{i=1}^n i = \frac{b_l - EE}{EE} \quad (2)$$

262 $s =$ Average Bid Spread , $e =$ Average Deviation from the Engineers Estimate,
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264 $n =$ No. of Bids by Category , $b_l =$ Lowest Bid , $b_2 =$ Second Lowest Bid , $EE =$ Engineer’s Estimate

265 For each of the variables ($c, \bar{s},$ and \bar{e}) outliers were defined as those data points that were two standard
 266 deviations away from the mean and were removed from consideration. This eliminated 116 data
 267 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	
	e	s	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%	

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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 ($R^2 = .98$) by the logarithmic function:

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

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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, there 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".

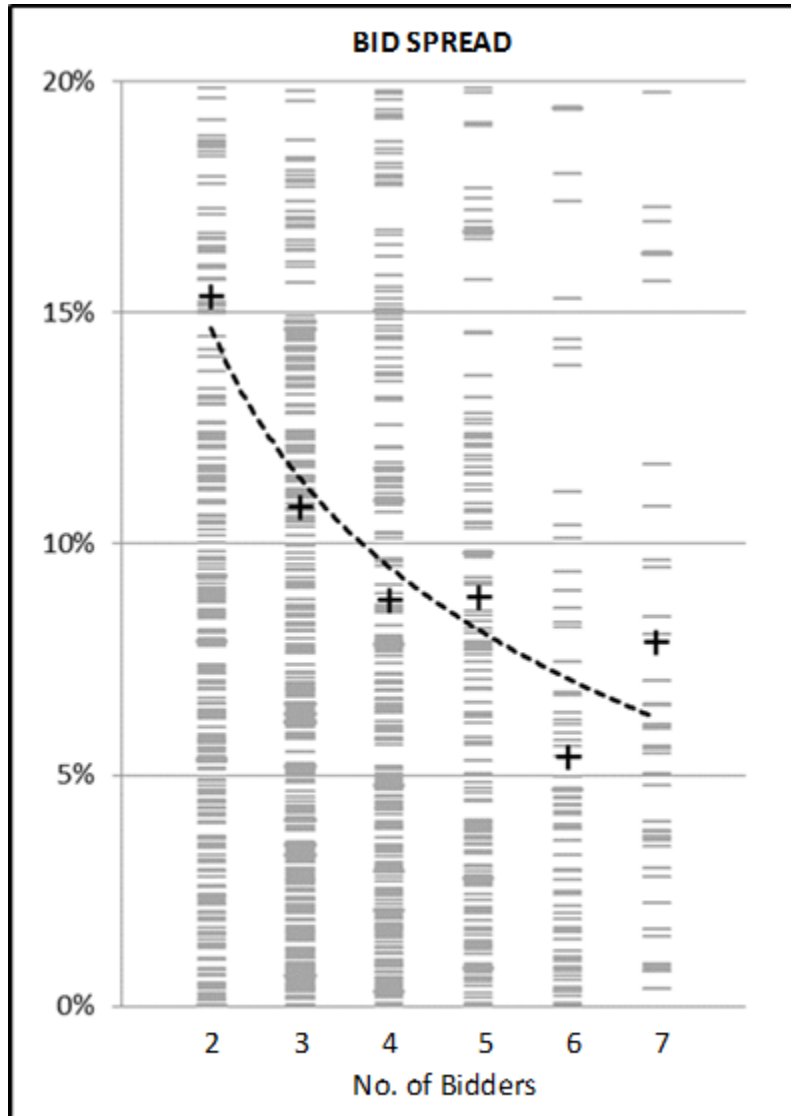


Figure 2. Regression of Bid Spread

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For variable \bar{e} , 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 ($R^2 = .86$) by the third order polynomial function:

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

The relationship is plotted in Figure 3.

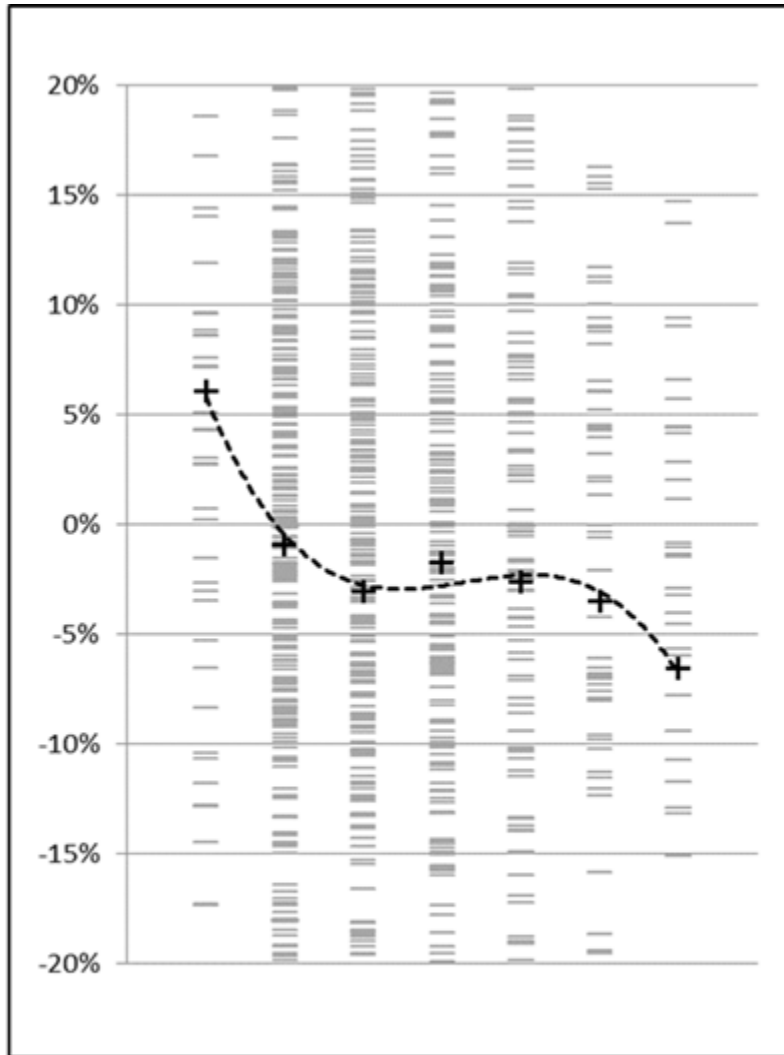


Figure 3. Regression of Deviation from Estimate

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

TABLE 2 - CROSS REFERENCE CHART - BID QUALITY

BID QUALITY MATRIX			Deviation from the Engineer's Estimate					TOTAL
			≥10%	5% → 10%	5% ↔ -5%	-5% → -10%	≤-10%	
			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

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

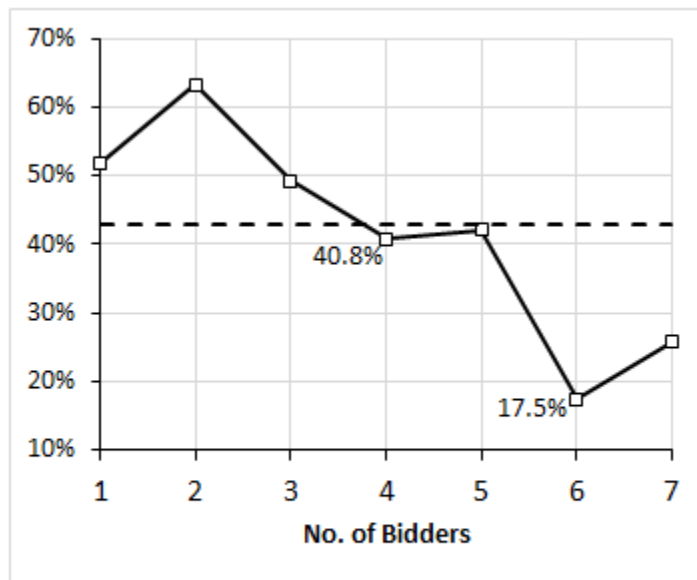


Figure 5. Probability of a Unfavorable Bid

300

301 **CONCLUSIONS**

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

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

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

318
$$e_2 = -.0029 * (2)^3 + .0376(2)^2 - .1554(2) + .1793e_6 = -.010$$

319
320
$$e_6 = -.0029 * (6)^3 + .0376(6)^2 - .1554(6) + .1793e = -.032$$

321
322
$$e_2 - e_6 = .022$$

323
324
$$\Delta b_l = .022 * 58,000,000,000 = 116,000,000$$

325 There is no reason to believe that the same principles of economic theory do not apply to D-B
326 contracts. This is why federal law stipulates unrestrained competition for both public and private
327 work. Congress passed the Sherman Act, in 1890 as a "comprehensive charter of economic liberty

328 aimed at preserving free and unfettered competition as the rule of trade." The presumption of
329 capitalism is free and open competition. By limiting competition, D-B increases the potential for
330 unfavorable bid outcomes. It is only the degree of the effect that is in question.

331 **REFERENCES, CITATIONS AND BIBLIOGRAPHIC ENTRIES**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

380 Pereza, P., Hitschfedold, M., Meliaa, and Domiguez, D. (2015). Modeling bidding competi-
381 tiveness and position performance in multi-attribute construction auctions. Journal of Operations

382 Research Perspectives, 2, 24-35

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

386 Serbu, J. (2013). “Critics say federal D-B construction contracts stifling competition”, Federal
387 News. Retrieved from <http://federalnewsradio.com>

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

391 Skitmore, M., Pettitt, A., and McVinish, R. (2007). The Gates Bidding Model. The Journal
392 of Construction Engineering and Management Washington State Department of Transportation.
393 (2015). Tabulated Bid Results [Data File]. Retrieved from www.wsState DOTs.wa.gov

394 Theriault, K. (2004) Determination of Lowest Responsible Bidder. The Procurement Connec-
395 tion Retrieved from www.theprocurementconnection.com/articles/defbid.html

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

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