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VIEWPOINT

Reliance on and Reliability of the Engineer's Estimate in Heavy Civil Projects

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Abstract

To the contractor, the engineer's estimate is the target number to aim for, and the basis for a contractor to evaluate the accuracy of their estimate. To the owner, the engineer's estimate is the basis for funding, evaluation of bids, and for predicting project costs. As such the engineer's estimate is the benchmark. This research sought to investigate the reliance on, and the reliability of the engineer's estimate in heavy civil cost estimate. The research objective was to characterize the engineer's estimate and allow owners and contractors re-evaluate or affirm their reliance on the engineer's estimate. A literature review was conducted to understand the reliance on the engineer's estimate, and secondary data from Washington State Department of Transportation was used to investigate the reliability of the engineer's estimate. The findings show the need for practitioners to re-evaluate their reliance on the engineer's estimate. The empirical data showed that, within various contexts, the engineer's estimate fell outside the expected accuracy range of the low bids or the cost to complete projects. The study recommends direct tracking of costs by project owners while projects are under construction, the use of a second estimate to improve the accuracy of their estimates, and use of the cost estimating practices found in highly reputable construction companies.

Keywords

Engineer's estimate, contract overruns, cost estimation, heavy civil projects, accuracy of cost estimates, reliability

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Introduction

With increasing project overrun on state Department Of Transportation (DOT) projects, the reliability of cost estimates is called into question. Shane et al. (2010) acknowledged the problem where most highway agencies are increasingly finding wide variations between the estimated costs and the actual costs of their projects. On new projects and for various purposes, owners prepare cost estimates detailing the expected costs of those projects. This is then used for obtaining funds for the projects. One of the main reasons for owners to develop cost estimates is for use as the basis to evaluate bids and proposals. On public projects, the cost estimates prepared for evaluating bids and proposals are referred to as the engineer's estimate (Anderson, Molenaar and Schexnayder, 2007).

In the heavy civil sector, the engineer's estimate is considered the benchmark, and has become the yardstick for measuring the accuracy of a contractor's cost estimate, industry experience, and bidding strategy. In most cases, a contractor's bidding strategy is centred on mark-up. AGC (2005) defines mark-up as the amount that is added to the total estimated cost of construction to arrive at the bid price, and this includes a portion of the general and administrative expenses, as well as the profit. According to the FHWA 2004 Guidelines on Preparing the Engineer's Estimate, Bid Review, and Evaluation, "the critical review of any bid depends on the reliability of the estimate it is being compared to." From the owner's viewpoint, the engineer's estimate must not fall too far away from the lowest bid and must be accurate enough to predict the final cost of the project when all project changes are added. The reliance on the engineer's estimate is such that on state DOTs such as Caltrans (California Department of Transportation), the engineer's estimate must be certified by a district director validating that the estimate has complete scope and that it accurately models the cost to construct the project.

The engineer's estimate serves different purposes for different users, and with increasing reliability concerns comes the need to evaluate whether the engineer's estimate can meet those expectations. So much reliance is placed on the engineer's estimate, but often "the engineer who made the estimate can defend its degree of precision but is uncertain about its accuracy" (Park and Chapin, 1992, p.103). As such, the problem is that the reliance that practitioners have on the engineer's estimate is very high, and requires empirical evidence to help practitioners justify their reliance or re-evaluate their reliance on the engineer's estimate. Considering the overwhelming number of cost overruns on public projects, Flyvbjerg, Holm and Buhl (2002) concluded that on most highway projects, the engineer's estimates developed for obtaining funds, evaluating bids, and projecting actual costs are inaccurate and outright misleading. This results from the fact that those cost estimates have significantly failed to come in within range, which questions the reliability of those cost estimates.

This research aims to evaluate the reliance on, and the reliability of, the engineer's estimate and provides the basis for practitioners to re-evaluate their reliance on the engineer's estimate. The first objective evaluates the level of reliance on the engineer's estimate and the second objective evaluates the reliability of the engineer's estimate in relation to the lowest bid and the cost at completion. Following these research objectives, the questions that guide this research are as follows:

1. Using 4062 active and completed projects measured based on the lowest bid as a percentage of the engineer's estimate, what is the likelihood that the engineer's estimate will come within range of the lowest bid?

2. Using 3865 completed projects measured based on amount paid at completion as a percentage of the engineer's estimate, what is the likelihood that the engineer's estimate will come within range of the cost at completion?
3. Is there a statistically significant difference between the means of the two results (the lowest bid as a percentage of the engineer's estimate, compared to the amount paid at completion as a percentage of the engineer's estimate)?

The remaining portion of the paper starts with a literature review, which explores the various viewpoints that practitioners have about the engineer's estimate and their reliance on it. The research design details the research method used, why the method was chosen, what data was collected and how the data was prepared and analysed. The study is then followed by the findings and discussion which looks at the results within the contexts of the research objectives. Finally, a conclusion is presented with recommendations.

Literature Review

The literature review examines what the engineer's estimate means to owners and contractors, what it is used for and how it is relied upon. The literature considers how and why the engineer's estimated price could differ from the lowest bid estimate or the amount paid at completion of a project. Measuring accuracy requires a reference point or range, and the literature evaluated accuracy range for use in measuring the reliability of an engineer's estimate.

THE RELIANCE ON THE ENGINEER'S ESTIMATE AND WHAT IT MEANS TO THE PRACTITIONERS

According to AGC (2005), the life blood of a contractor is a detailed estimate because it offers a competitive edge, provides the basis for project controls, and positions a contractor to win bids and remain in business. To remain in business, a contractor must win bids while working in a very competitive environment. Contractors would want their bids to come in as the lowest bid and with a price that is above the engineer's estimate, and a price that is not too far from the second lowest bidder. Contractors rely on the engineer's estimate and consider it as the target number to shoot for. Targeting the engineer's estimate and coming within range is the goal of every contractor, as they navigate the competitive environment to win bids, remain in business, and avoid bids that may result in out-of-pocket costs or bankruptcy. Equally important is the fact that owners place heavy reliance on the engineer's estimate. Owners want to make sure that their estimates are accurate, not too low, or too high from the lowest bidder. However, for the owners, there are some inherent risks and uncertainties that could not be directly estimated. , all state DOTs add contingencies to their estimates to accommodate risks and unforeseen circumstances such as differing site conditions. Different state DOT's use different parameters to arrive at their contingency.

Irrespective of the percentage added to the engineers estimate for contingency, the actual contingency amount does not mean much if the engineer's estimate being relied upon is inaccurate. Caltrans uses a graduated contingency method that reflects the level of detail and stage of project development. However, at 100% design stage, the contingency is 5% (Caltrans 2014). Contingencies should be commensurate with project risks and unforeseen circumstances that could not be directly estimated.

HOW THE ENGINEER'S ESTIMATE MAY DIFFER FROM THE LOW BID AND AMOUNT PAID AT COMPLETION

Why expect too much from the engineer's estimate and have such reliance on the engineer's estimate when there are so many factors that affect what price a contractor would bid on a project Factors such as competition, the state of the economy, experience, available resources, percentage of scope that is self-performed, use of comparable and accurate historical records, and other factors would affect the estimate prepared by the contractor. These factors are in fact outside the control of the engineer, which makes it difficult for the engineer to accurately prepare estimates that consistently come close to the contractors' estimates. Also, the wide range of bid prices that are submitted by contractors on a given project is a good indication on how difficult it is for the engineer's estimate to consistently fall within range of contractor's bids. On the other hand, the accuracy of the estimate prepared by the engineer could be affected by the cost estimating method, the project complexity, experience of the estimators, and project types. In addition, the accuracy of the engineer's estimate may be dependent on the project delivery method, and the assumptions made regarding construction method that would be used by the contractor. The AACE (2016) practice guide adds to the list of items that would affect accuracy of the estimate, which is why they recommend using an accuracy range of plus-minus.

Project conditions are dynamic, and change happens. Contract changes are pervasive, and according to Flyvbjerg, Bruzelius and Rothengatter (2003), contract overruns on mega projects are common and could range from 50% to 100%. Such situations may point to concerns about the ability of the engineer's estimate at predicting contract overruns. Contract overrun represents the percentage difference between the contract amount at award and the contract amount at project completion. While the percentage of overrun is alarming, practitioners should make efforts to aggregate and breakdown such overruns properly to know if the contract changes are extra work (different from changes to original scope), which should be analysed differently. Caltrans aggregates their contract changes by differentiating from work that is extra work (EW), and work that is tracked as adjustment of compensation (AC), which includes contract changes resulting from and associated with the original scope of work.

Considering all the factors that are inherent sources of difference or misalignment of the estimate produced by the contractors and that produced by the engineer, the reliance on the engineer's estimate remains.

RELIABILITY OF THE ENGINEER'S ESTIMATE AND THE RANGE OF ACCURACY

According to Park and Chapin (1992), there is no such thing as 100% accurate cost estimate, and estimating accuracy is only a measure of the degree to which costs vary from a given point. This means understanding what level of precision is acceptable under different conditions. An acceptable degree of variance between the engineers estimate and the lowest bid must be determined first.

Similarly, an acceptable degree of variance should be defined between the estimated costs and the actual costs to construct a project. Following this understanding, an estimate would then be deemed reliable or not reliable depending on where it falls within the acceptable ranges defined.

Tehrani (2016) sought to understand how reliable the engineer's estimate is at predicting project cost and the author looked at 22 projects with similar scope, size, and duration to evaluate the reliability of the engineer's estimates in capturing the true cost of the projects.

The study found that, instead of using the engineer's estimate or the low bid as predictors of the final cost, the trimmed average of the bids (excluding all the outliers) is a better predictor. AbouRizk, Babey and Karumanasseri (2002) evaluated 200 projects and found that the cost estimate at bid were not reliable at predicting the final cost of a project within an expected accuracy range of ±10%.

Typically, the engineer's estimate is generated using the historical bid item price method or detailed estimate method. The study by Schexnayder, Weber and Fiori (2003) found that, regardless of the estimating method used by the state DOT to generate the engineer's estimate, 20% to 40% of the time, the lowest bidders came in with bid prices greater than 5% over the engineer's estimate. AACE (2016) practice guide states that the expected range of accuracy for a project with 100% definition is between -10% to +10% and figure 1 highlights the range of accuracy based on different phases or classes of a project following the level of definition and the completeness of contract plan and specifications.

Schexnayder and Mayo (2004) showed that accuracy of a cost estimate will differ at different project phases as well as under different cost estimating methods. The authors posit that the expected level of accuracy of an estimate for construction is plus or minus 5%. Flyvbjerg, Holm and Buhl (2002) found that on highway projects, actual construction costs were underestimated in almost 9 out of 10 projects, and the likelihood of actual costs being larger than estimated costs was 86%, while the likelihood of actual costs being lower than or equal to estimated costs was 14%. However, Flyvbjerg, Holm and Buhl (2002) did not elaborate on the recommended range of accuracy used.

Research Design

This research uses a quantitative design method, and secondary data was collected from WSDOT. The data included all completed and active projects. This study included data for each project on the year completed, the engineer's estimate amount, and the prime bid amount. Other relevant data included are data on the amount paid at completion, project delivery method, and the name of the prime contractors. The data included all projects from

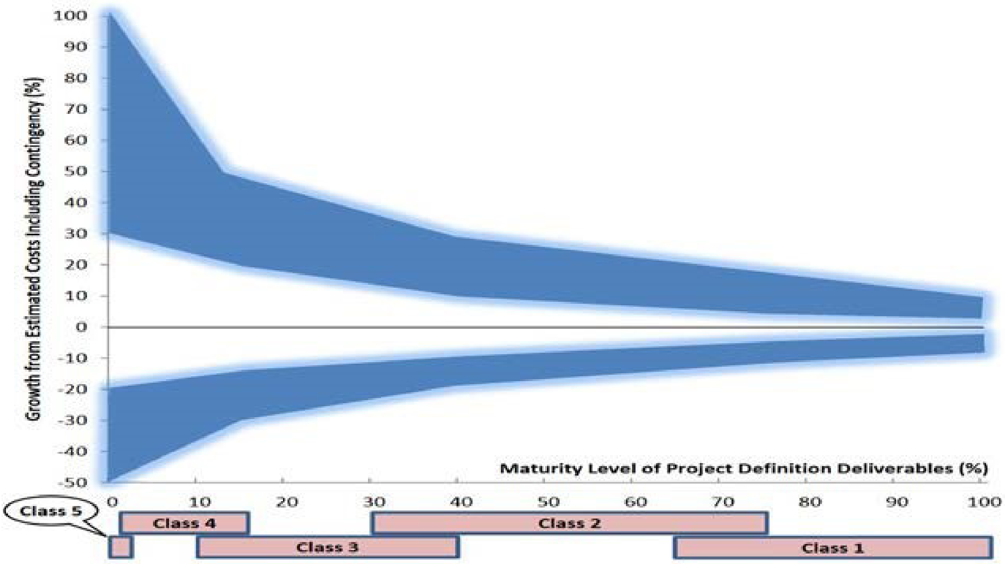

Figure 1 AACE – Example of the Variability in Accuracy Ranges for a Process Industry Estimate

1992 to 2016, with 3865 completed and 197 active projects. The data was then prepared for analysis by computing for each project: 1) the lowest bid as a percentage of the engineer's estimate, and 2) the amount paid at completion as a percentage of the engineer's estimate. To allow for more detailed analysis and characterization, the data was classified by project type (bridges and roadways), project size (small size and medium size), time-period (1992 to 2004 and 2005 to 2016), contractor type (bridge contractor and paving contractor), and finally, delivery method (design-bid-build and design-build). The data was then analysed for likelihood of the engineer's estimate falling within a specific range of, and to answer the question on:

1. What is the likelihood that the engineer's estimate will come within range of the lowest bid?
2. What is the likelihood that the engineer's estimate will come within range of the amount paid at completion?

In addition, a t-test was conducted to evaluate if there is a statistically significant difference between the lowest bid amount obtained for each project and the actual amount paid at completion. Both the lowest bid amount and the amount paid at completion were computed as a percentage of the engineer's estimate. The t-test was conducted by using the overall data of 4062 projects (lowest bid as a percentage of the engineer's estimate) and 3865 projects (amount paid at completion as a percentage of the engineer's estimate).

To characterize the engineer's estimate, the data was filtered and analysed within the context of:

1. The overall bids,
2. The bids representing two types of projects (bridge, roadway),
3. The bids representing small size projects <$10M), and medium size projects ($10$100M)
4. The bids grouped from 1992 to 2004 and from 2005 to 2016
5. The bids representing two select contractors (known for bridges and paving respectively),
6. The bids representing the two project delivery methods (design-bid-build and design-build)

Findings and Discussions

The first set of charts (Figures 2 to 12) descriptively show the likelihood that the engineer's estimate will come within range of the lowest bid as represented by the following probability curves showing the ranges and the probability of engineer's estimate falling within range

1. All the bids were analysed and included active and completed projects for a total of 4062 bids. For all the bids received, 11.91% of the engineer's estimate came within a range of 95-105% (±5%) of the lowest bids, only 32.14% of the engineer's estimate came within the ±10% range of the lowest bids, and 50.96% of the engineer's estimate came within the ±15% range of the lowest bids.
2. Bridge and roadway project types were analysed and included 43 bridge projects and 40 roadway projects. For the bridge projects, 14.19% of the engineer's estimate came within the ±5% range of the lowest bids, 35.66% within ±10% range, and 57.02% within the ±15% range. For the roadway project, 13.59% of the engineer's estimate came within the ±5% range of the lowest bids, 38.04% within the ±10% range, and 55.66% within the ±15% range

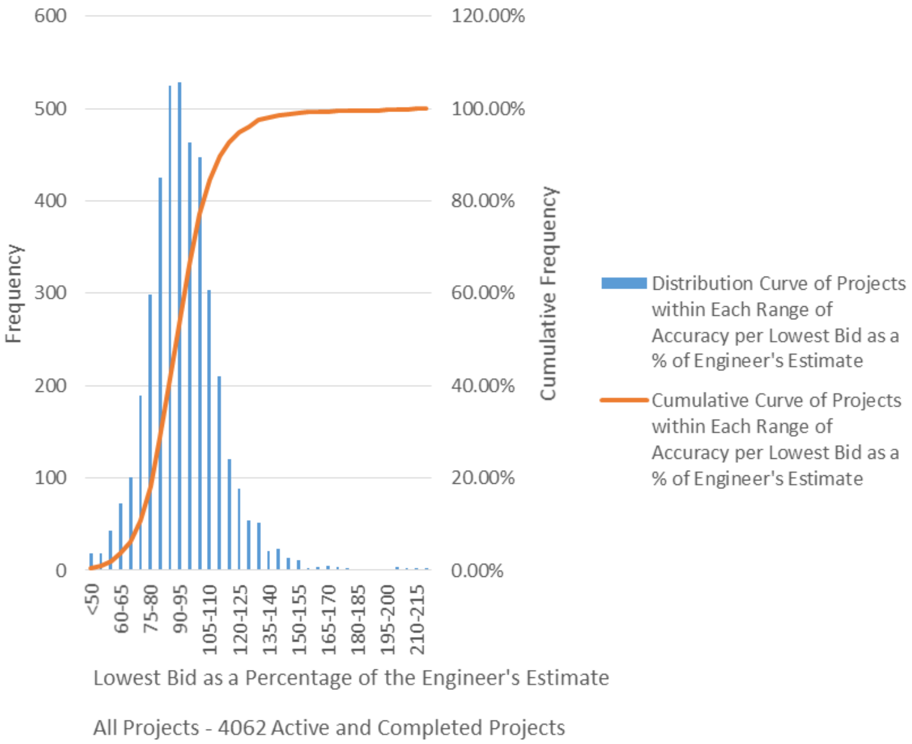

Figure 2 Overall distribution and probability curve per the lowest bid as percentage of the engineer’s estimate

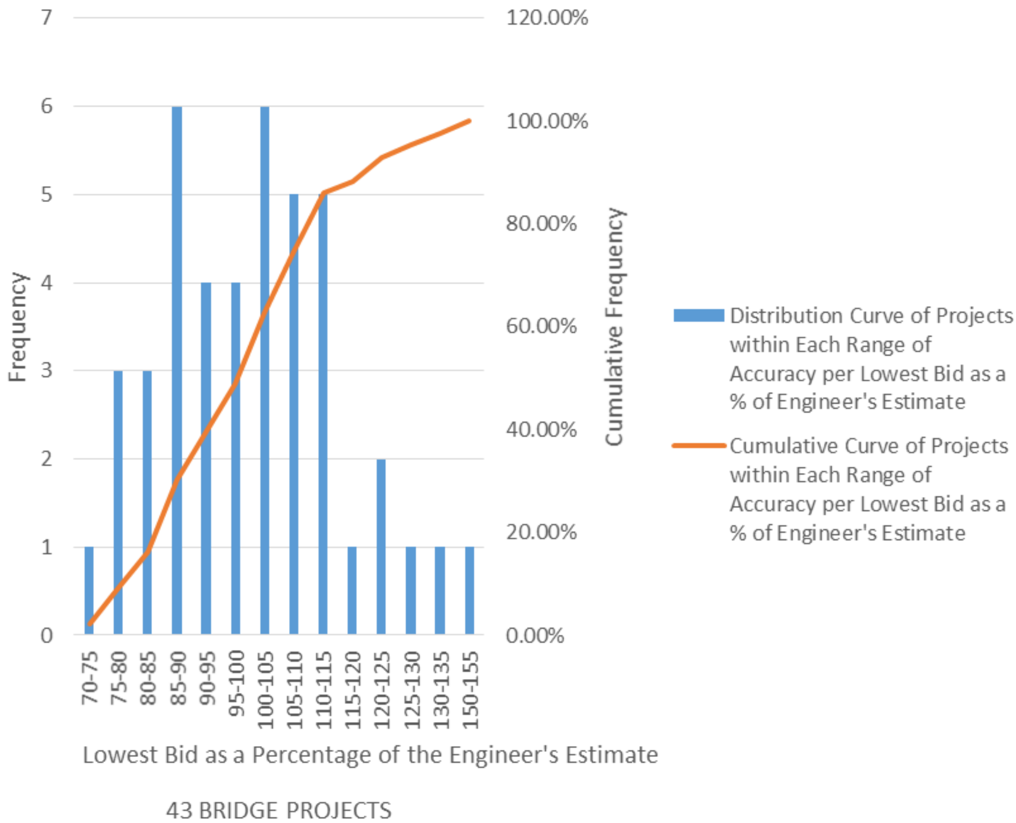

Figure 3 Bridge distribution and probability curve per lowest bid as a percentage of the engineer’s estimate

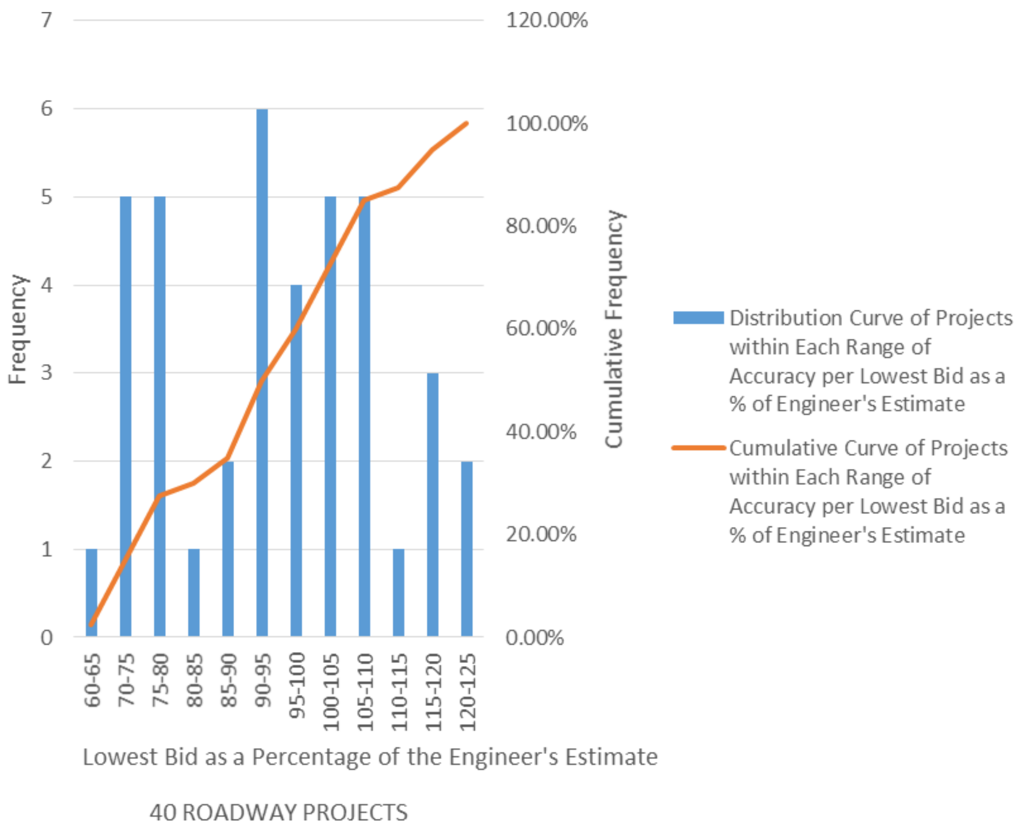

Figure 4 Roadway distribution and probability curve per lowest bid as a percentage of the engineer's estimate

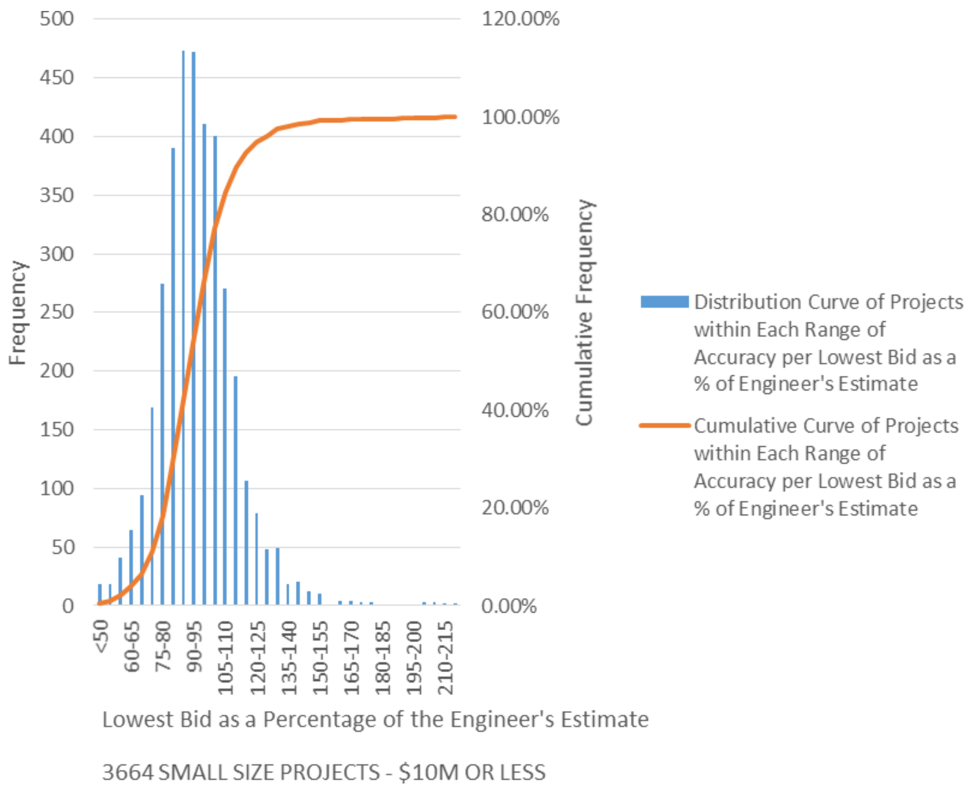

Figure 5 Small size project distribution and probability curve per lowest bid as a percentage of the engineer's estimate

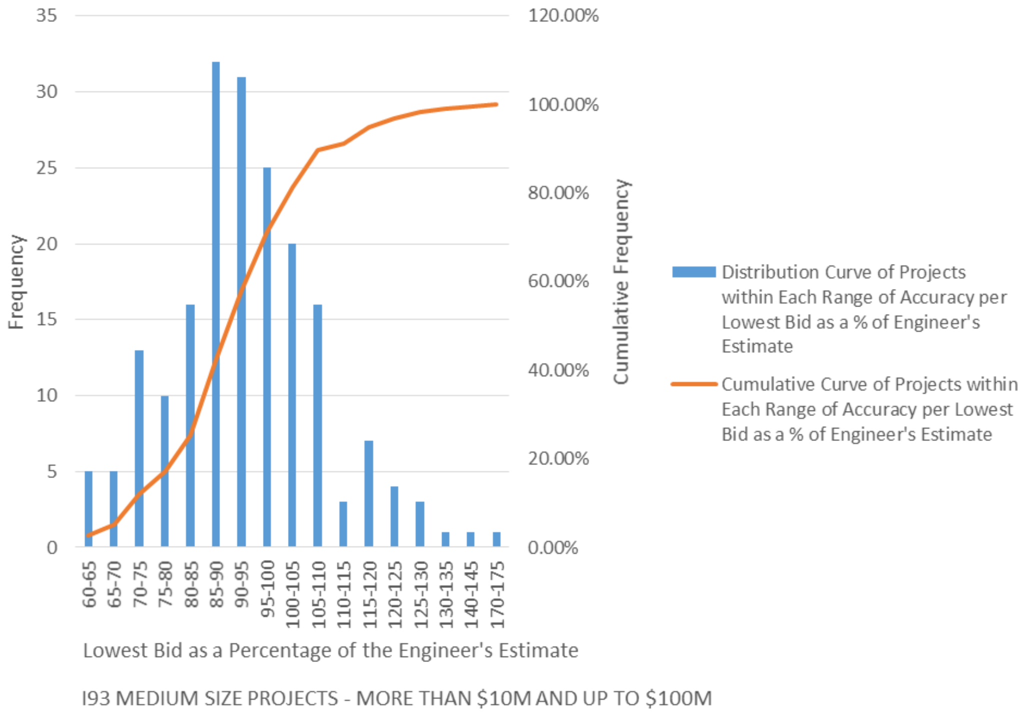

Figure 6 Medium size project distribution and probability curve per lowest bid as a percentage of the engineer’s estimate

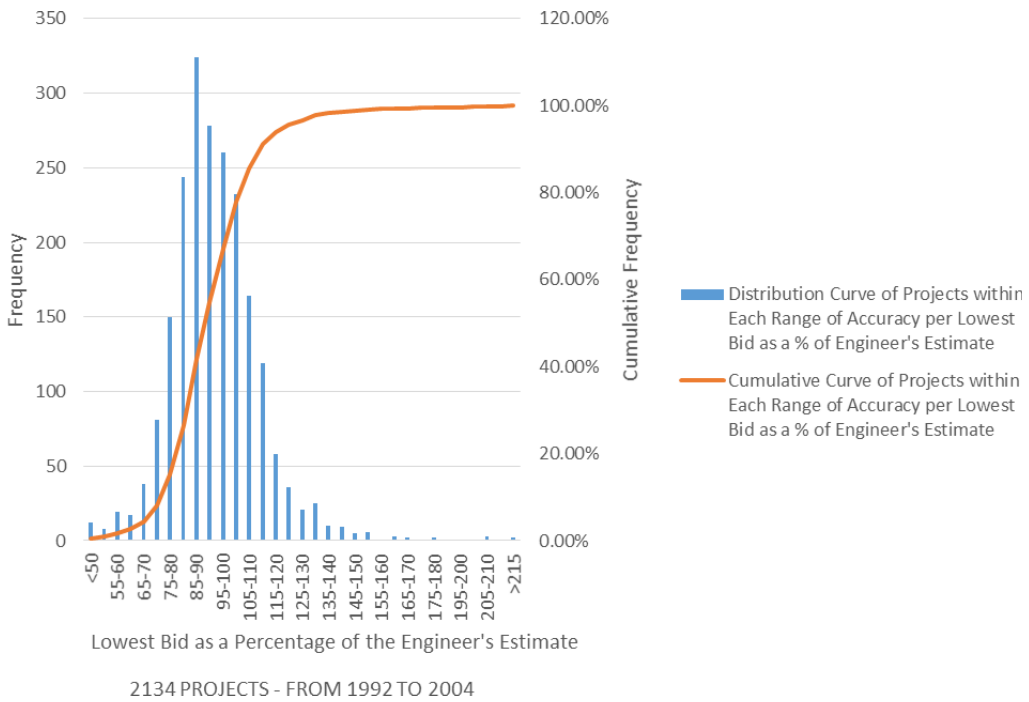

Figure 7 1992 - 2004 distribution and probability curve per lowest bid as a percentage of the engineer’s estimate

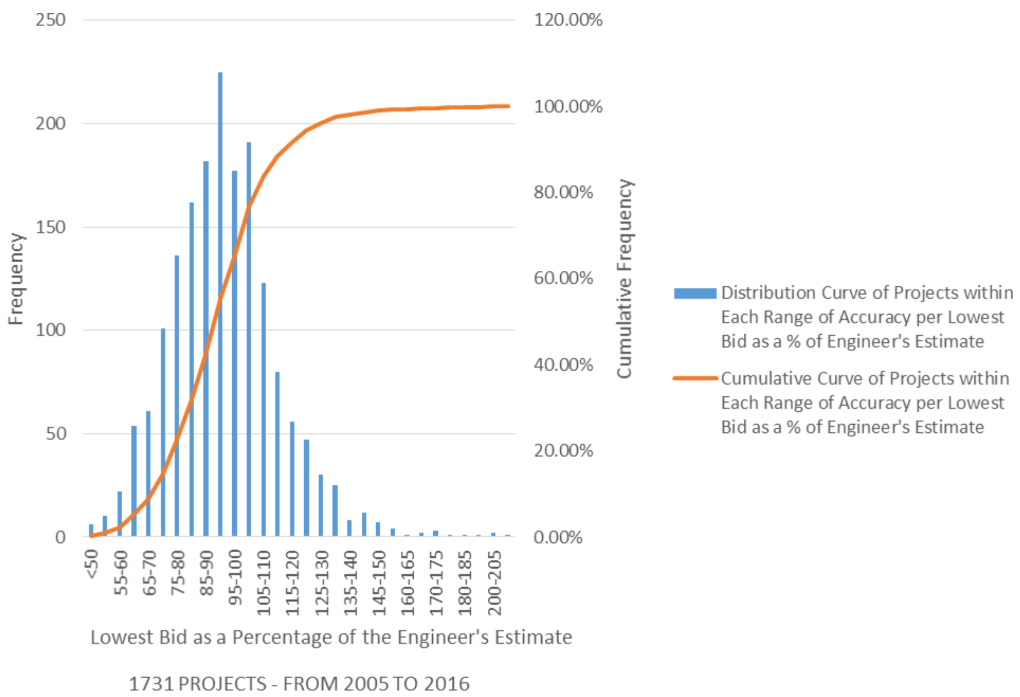

Figure 8 2005 - 2016 distribution and probability curve per lowest bid as a percentage of the engineer's estimate

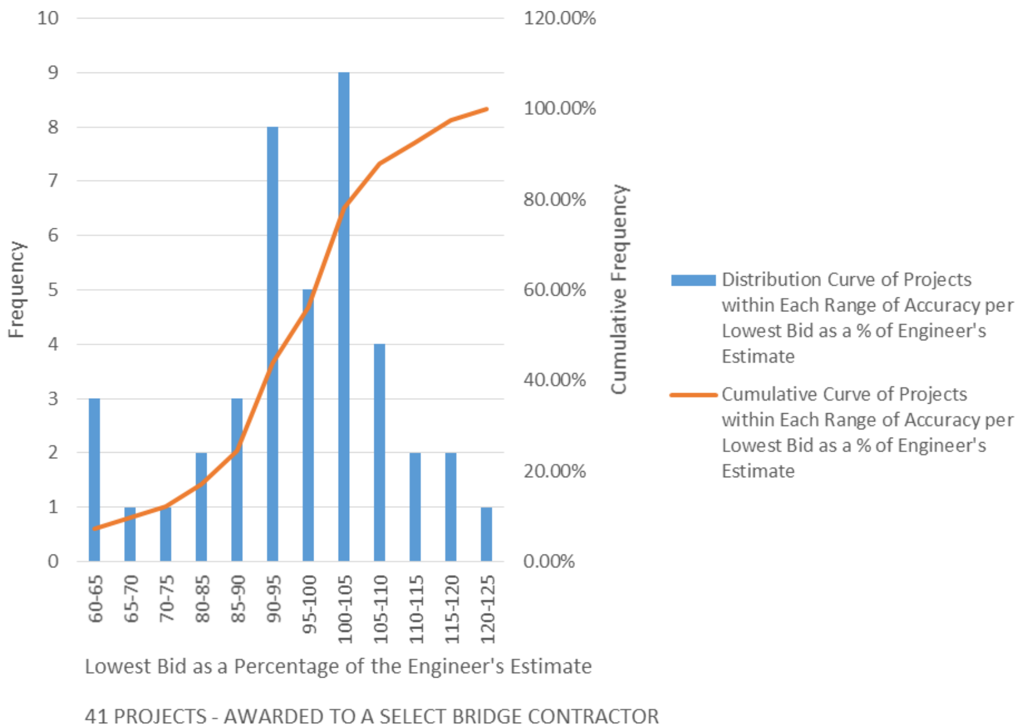

Figure 9 Select bridge contractor distribution and probability curve per lowest bid as a percentage of the engineer's estimate

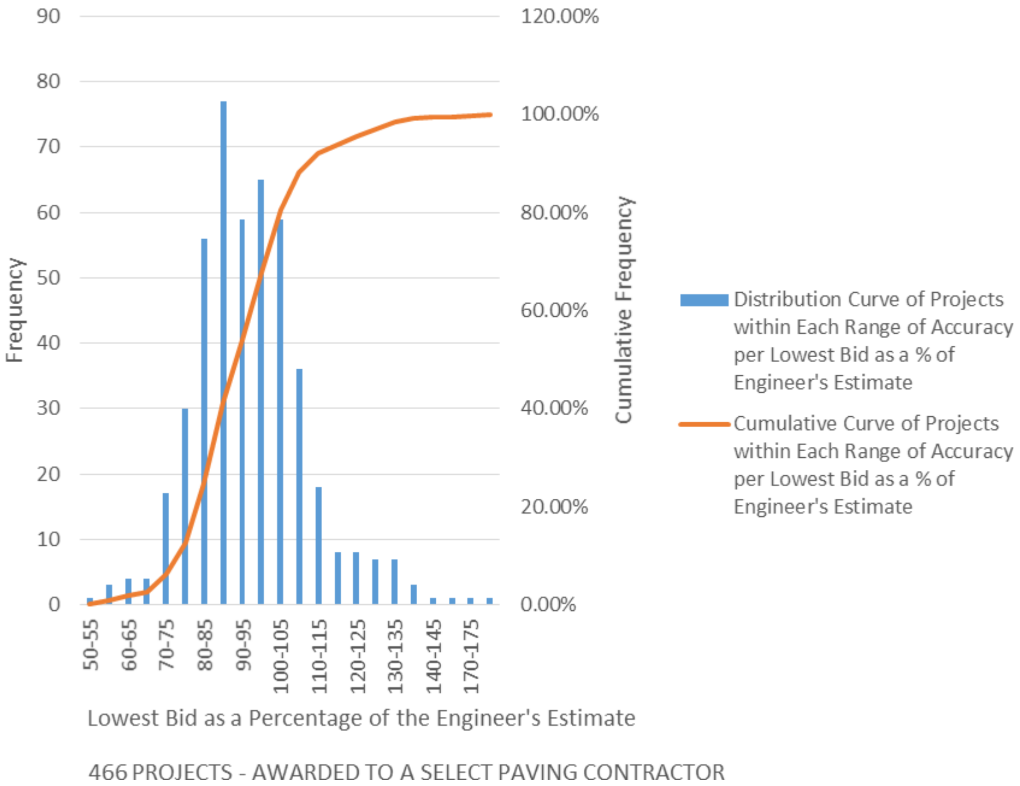

Figure 10 Select paving contractor distribution and probability curve per lowest bid as a percentage of the engineer's estimate

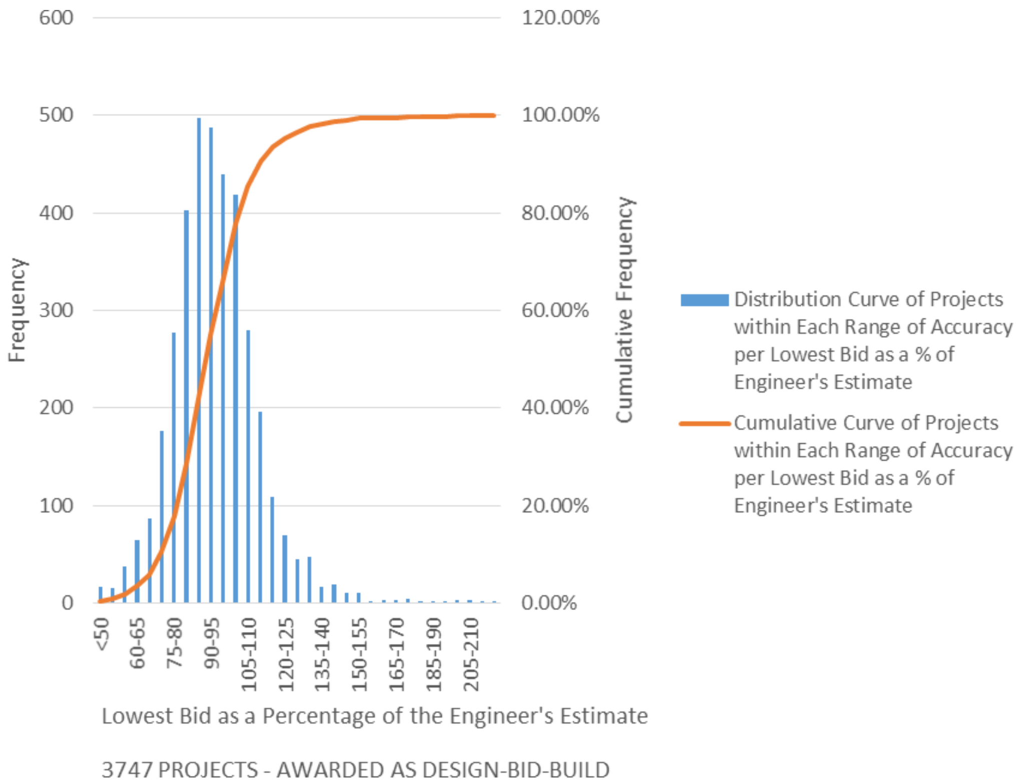

Figure 11 Design-bid-build distribution and probability curve per lowest bid as a percentage of the engineer's estimate

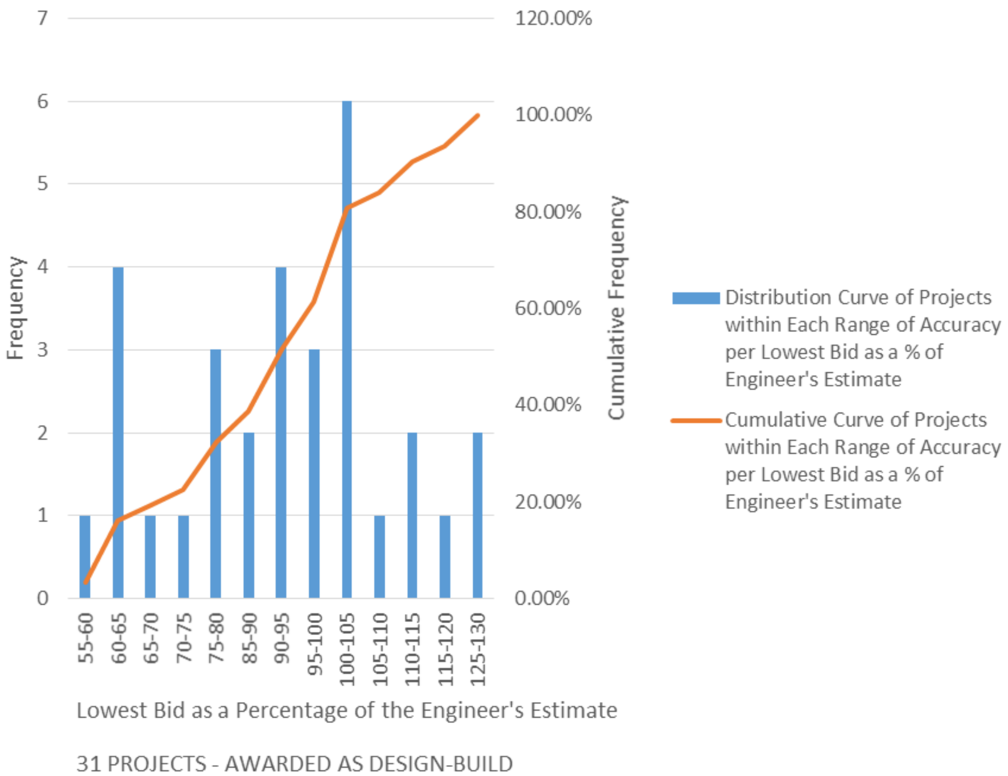

Figure 12 Design-build distribution and probability curve per lowest bid as a percentage of the engineer's estimate

3. Small size projects (<$10M) and medium size projects ($10M-$100M) were analysed and included 3664 small size projects and 193 medium size projects. For small size projects, 11.84% of the engineer's estimate came within the ±5% range of the lowest bids, 31.77% within the ±10% range, and 50.73% within the ±15% range. For the medium size projects, 11.31% of the engineer's estimate came within the ±5% range of the lowest bids, 34.35% within the ±10% range, and 52.11% within the ±15% range.
4. Time periods from 1992 to 2004 and from 2005 to 2016 were analysed and included. For the time-period spanning from 1992 to 2004, 2134 projects were used, and for the time-period spanning 2005 to 2016, 1731 projects were used. From 1992 to 2004, 11.72% of the engineer's estimate came within the ±5% range of the lowest bids, 32.84% within the ±10% range, and 52.23% within the ±15% range. From 2005 to 2016, 12.01% of the engineer's estimate came within range of 95 to 105 (±5%) of the lowest bids, 30.73% within the ±10% range, and 49.06% within the ±15% range.
5. Two respected contractors, included a bridge contractor and a paving contractor, with years of industry experience were selected and included. 41 projects contracted to the selected bridge contractor were used, and 466 projects contracted to the selected paving contractor. For the select bridge contractor, 23.53% of the engineer's estimate came within the ±5% range of their bids, 46.95% within the ±10% range, and 71.54% within the ±15% range. For the select paving contractor, 13.61% of the engineer's estimate came within the ±5% range of their bids, 36.70% within the ±10% range, and 53.64% within the ±15% range.
6. Design-bid-build and design-build project delivery methods were evaluated and included. For design-bid-build, 3747 projects were used, and for design-build, 31 projects were used. For design-bid-build projects, 12.09% of the engineer's estimate

came within the ±5% range of the lowest bids, 32.73% within the ±10% range, and 51.71% within the ±15% range. For design-build projects, 21.37% of the engineer's estimate came within the ±5% range of the lowest bids, 35.61% within the ±10% range, and 56.69% within the ±15% range.

The second set of charts (Figure 13 to 23) descriptively show the likelihood that the engineer's estimate will come within range of the amount paid at completion as represented by the following probability curves showing the ranges and the probability of engineer's estimate falling within range.

1. All the projects were analysed and included only completed projects for a total of 3865 projects. For all the project completed, 10.06% of the engineer's estimate came within the ±5% range of the amount paid at completion, only 27.71% of the engineer's estimate came within the ±10% range of the amount paid at completion, and 43.15% of the engineer's estimate came within the ±15% range of the amount paid at completion. Overall, 39% of the projects had overruns, and 59% of the projects came in below the engineer's estimate.
2. Bridge and roadway project types were analysed and included. 41 bridge projects were used, and 37 roadway projects were used. For 41 of the bridge projects, 58 % of the projects had overruns, and 39% of the projects came in below the engineer's estimate. For the 37 roadway projects, 51% of the projects had overruns, and 49% of the projects came in below the engineer's estimate.
3. Small size projects (<$10M), and medium size projects ($10M-$100M) were analysed and included. 3664 small size projects were used, and 193 medium size projects were used. For the small sized projects, 37% of the projects had overruns, and 60% of the

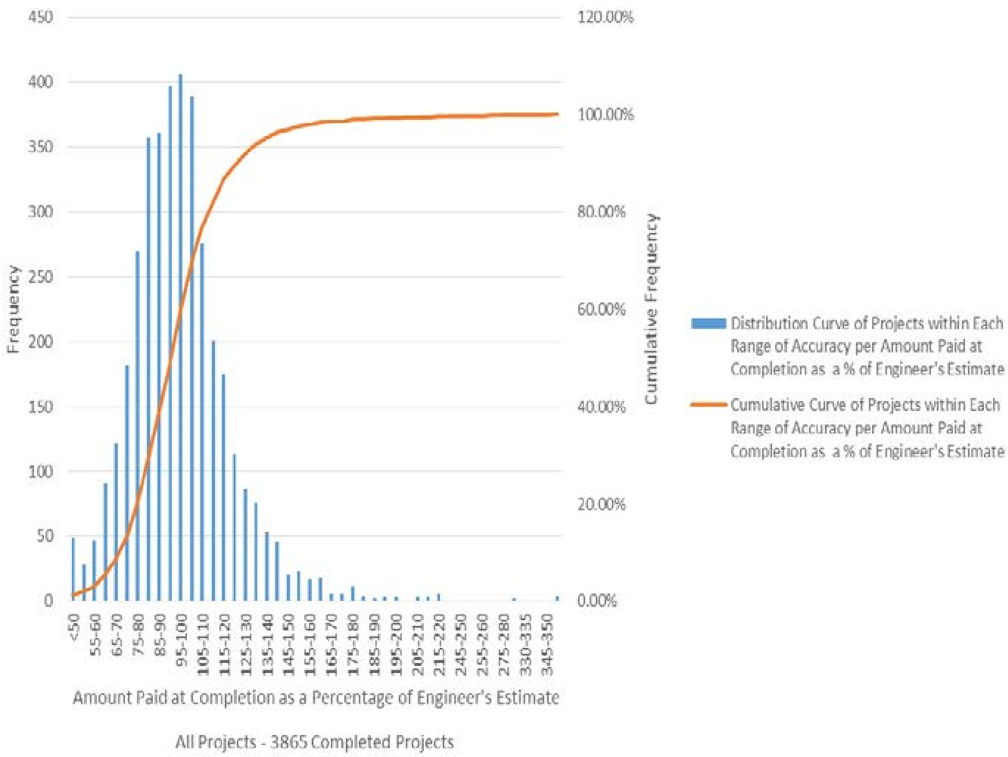

Figure 13 Overall distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

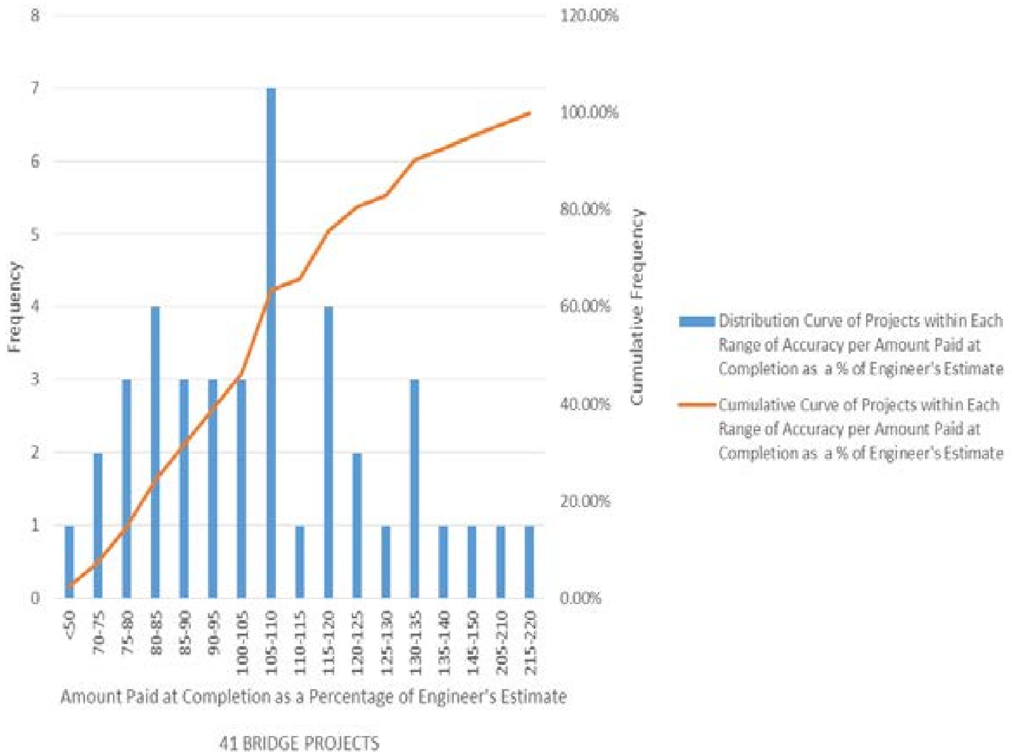

Figure 14 Bridge distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

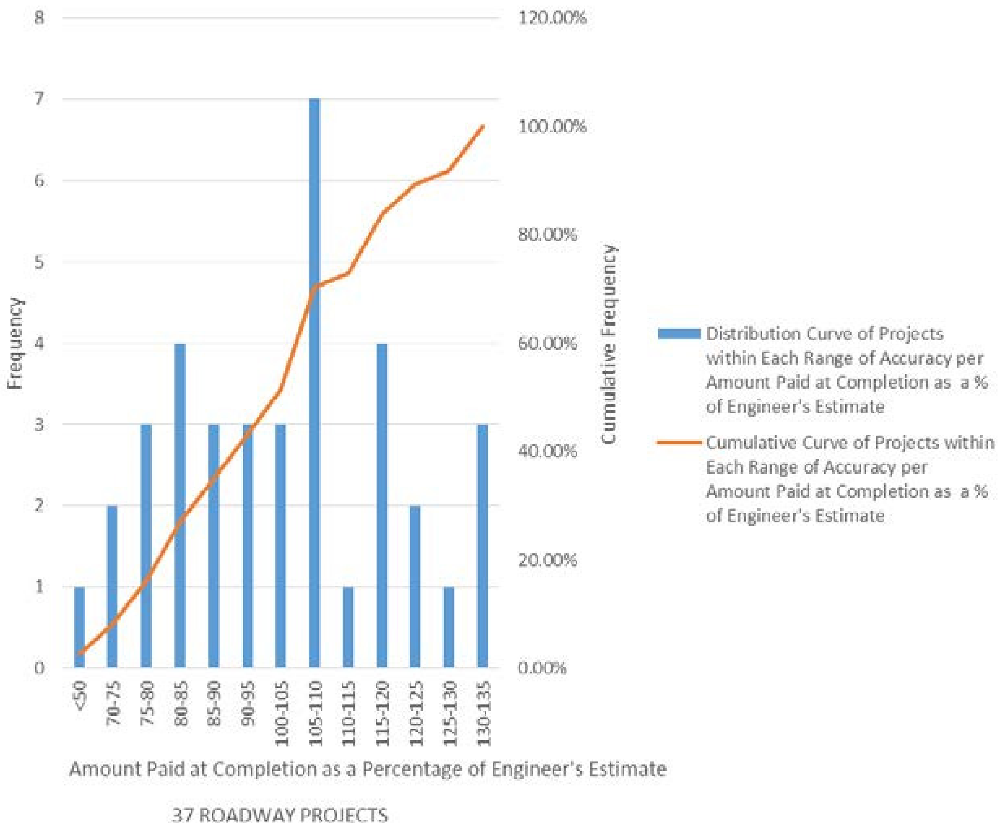

Figure 15 Roadway distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

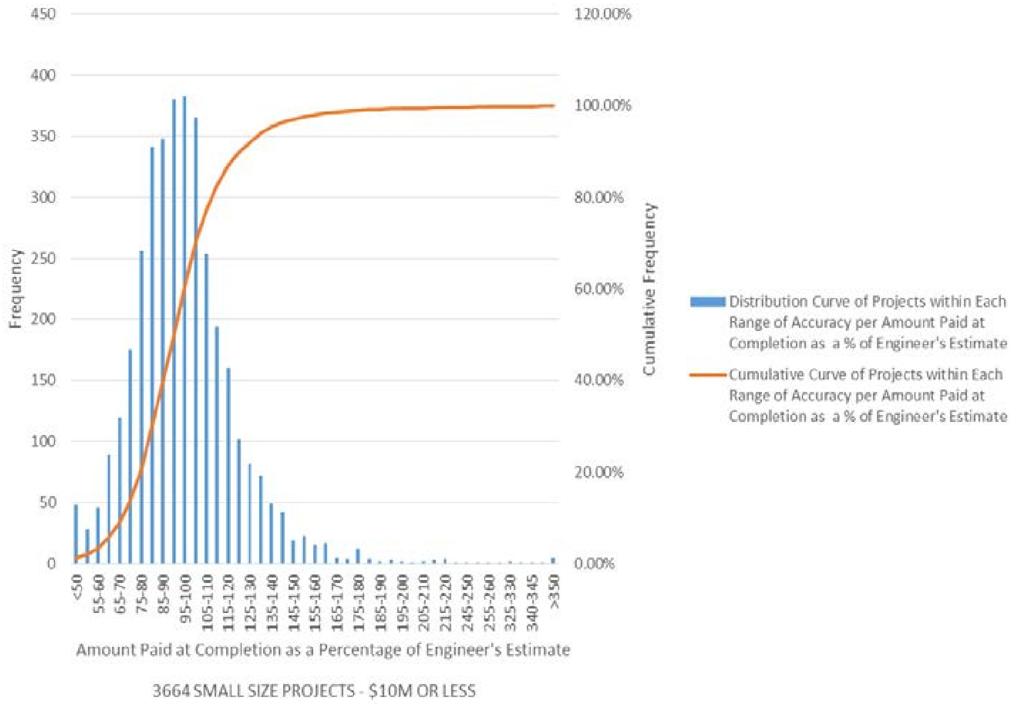

Figure 16 Small size project distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

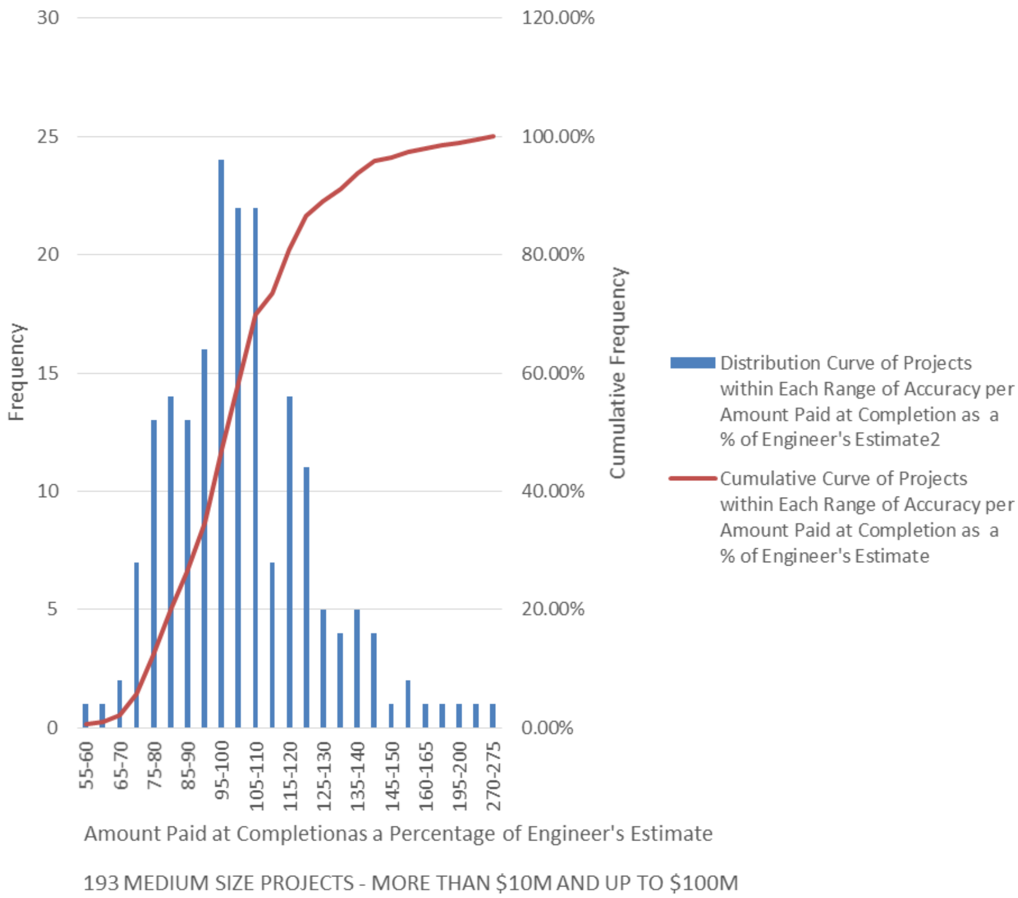

Figure 17 Medium size project distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

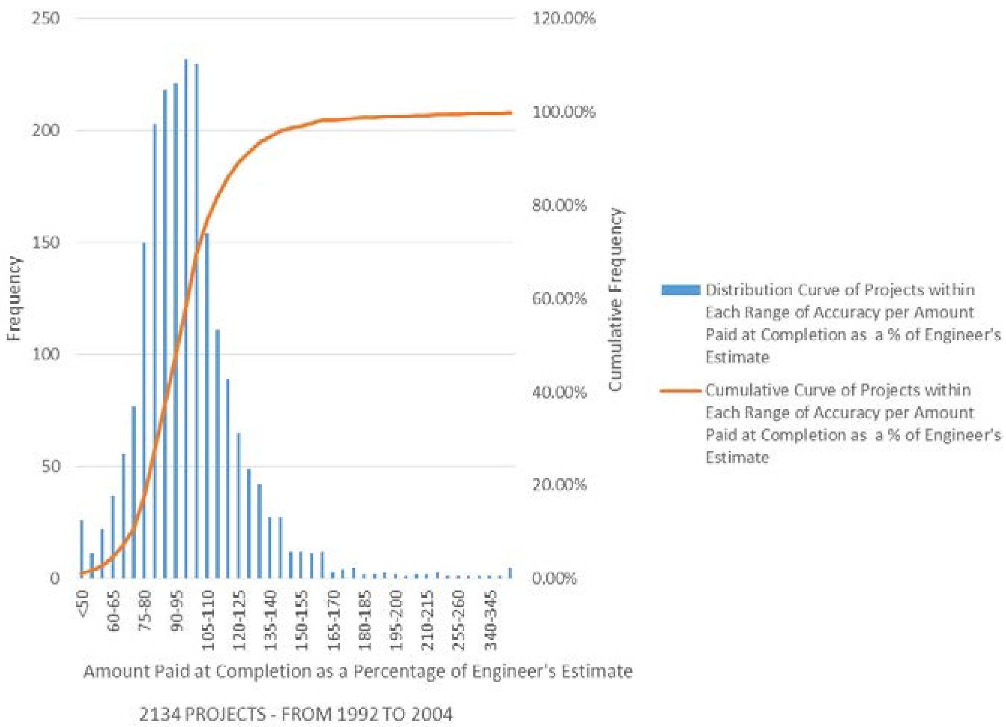

Figure 18 1992-2004 distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

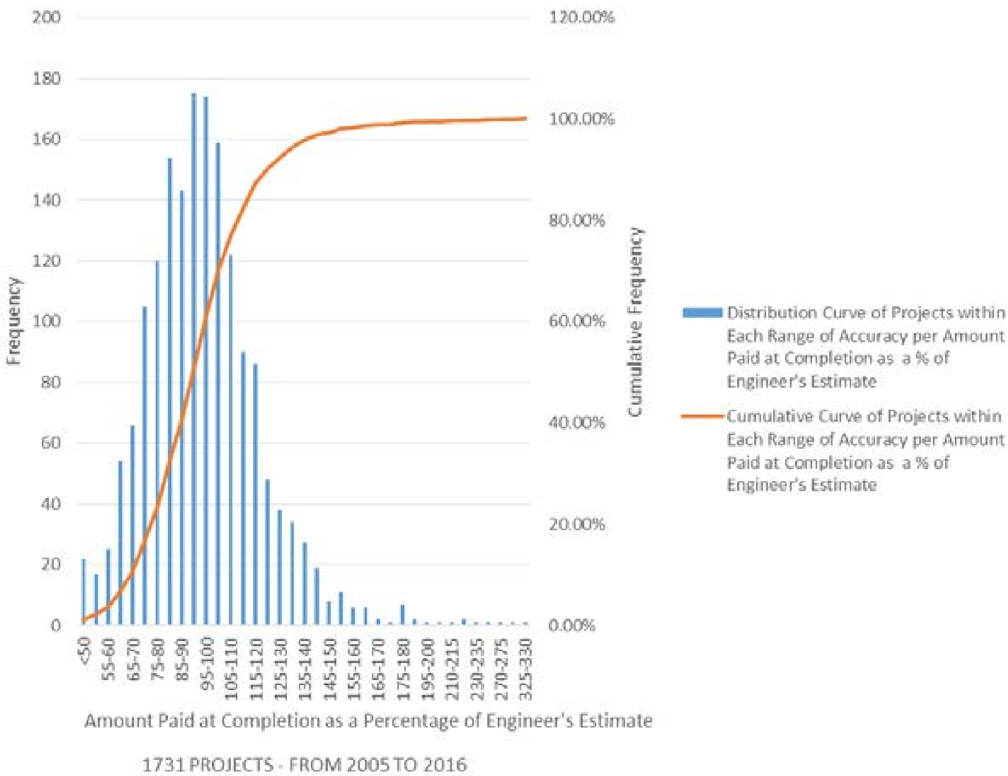

Figure 19 2005-2016 distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

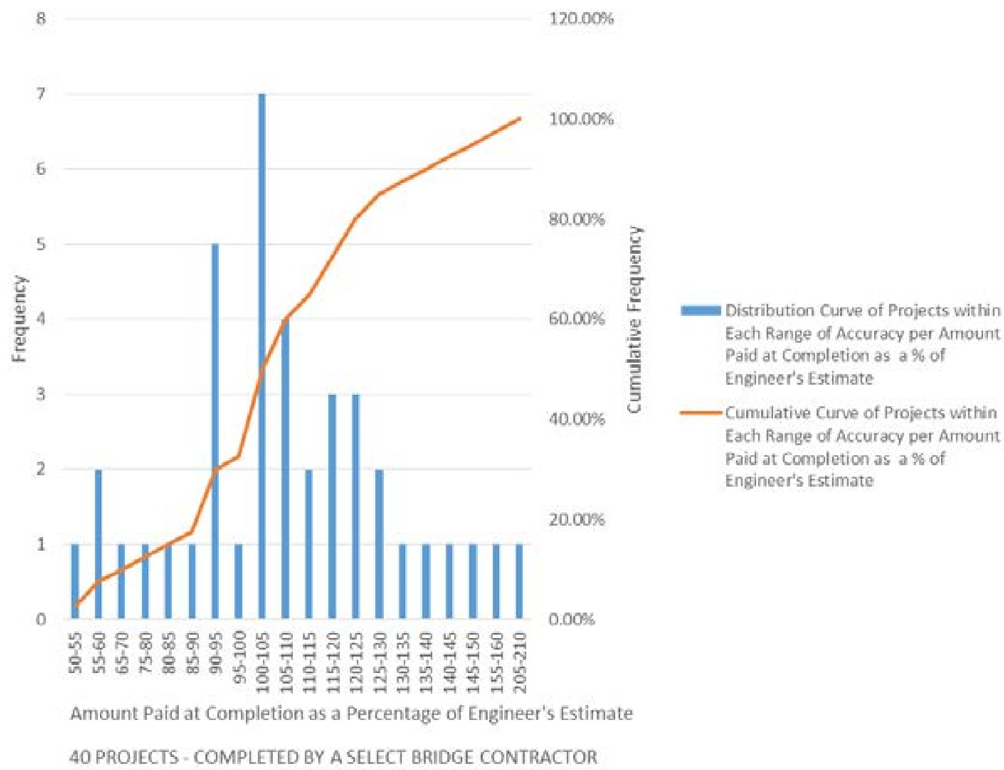

Figure 20 Select bridge contractor distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

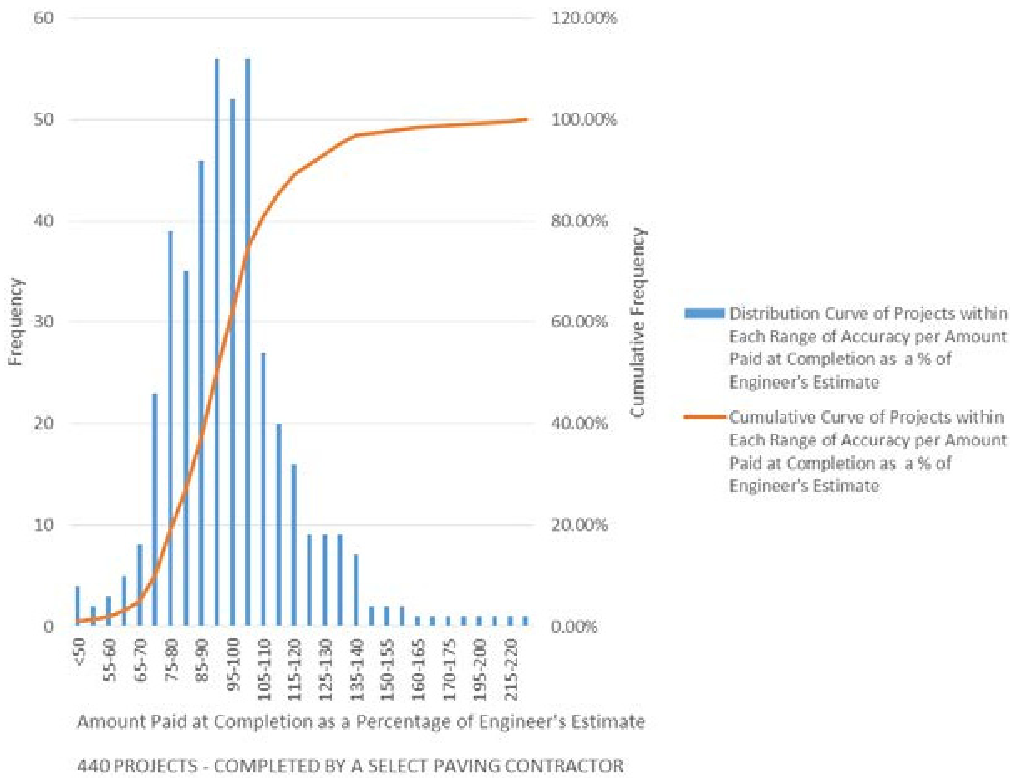

Figure 21 Select paving contractor distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

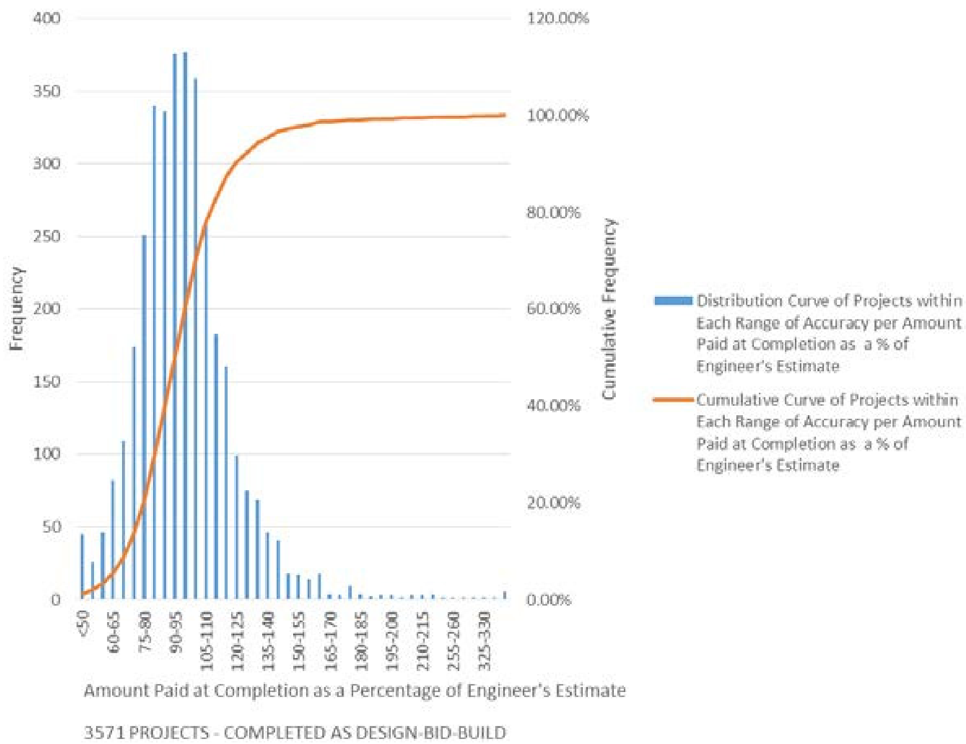

Figure 22 Design-bid-build distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

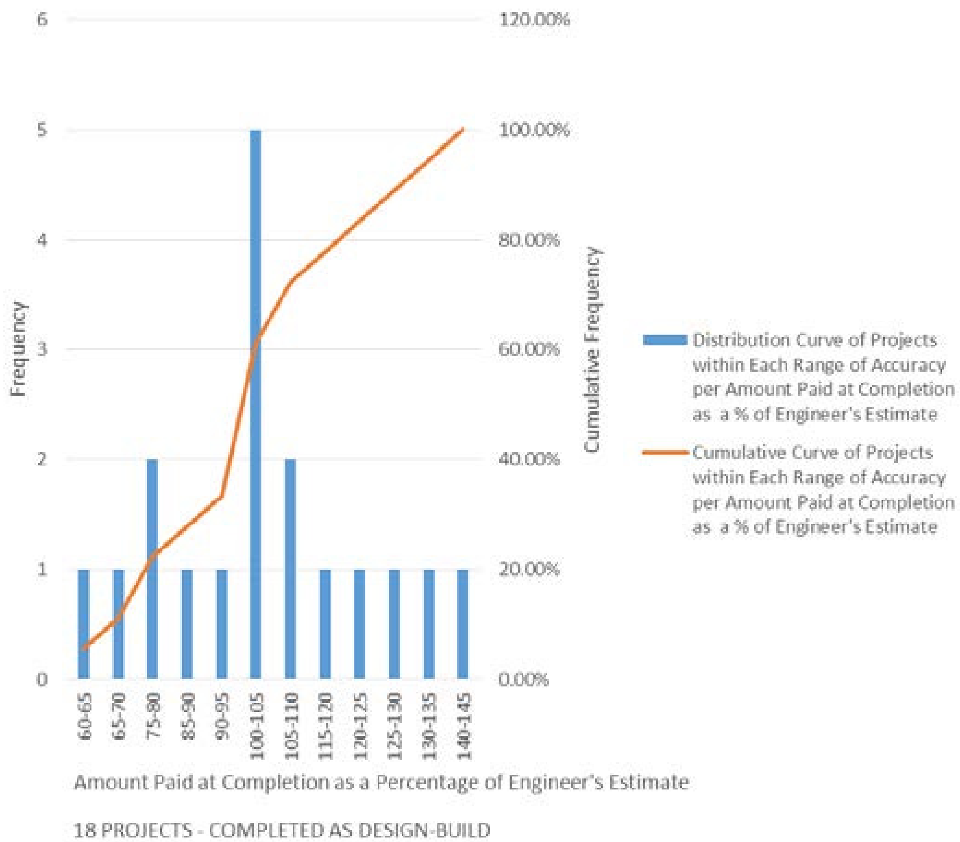

Figure 23 Design-build distribution and probability curve per amount paid at completion as a percentage of the engineer's estimate

projects came in below the engineer's estimate. For the medium sized projects, 49% of the projects had overruns, and 47% of the projects came in below the engineer's estimate.

4. Time periods from 1992 to 2004 and from 2005 to 2016 were analysed and included. For the time-period spanning from 1992 to 2004, 2134 projects were used, and for the time-period spanning 2005 to 2016, 1731 projects were used. From 2005 to 2016 projects were predominantly estimated using computer systems and estimating software and one would expect a high level of accuracy. However, there was not significant difference. For the period from 1992 to 2004, 39% of the project had overruns, and 58% of the projects came in below the engineer's estimate. For the period from 2005 to 2016, 37% of the projects had overruns, and 58% of the project came in below the engineer's estimate.
5. Two respected contractors, included a bridge contractor and a paving contractor, with years of industry experience were selected and included. 40 projects completed by the select bridge contractor were used, and 440 projects completed by select paving contractor were used. For the bridge contractor, 67% of the projects had overruns, and 33% of the projects came in below the engineer's estimate. For the paving contractor, 35% of the projects had overruns, and 62% of the projects came in below the engineer's estimate.
6. Design-bid-build and design-build project delivery methods were evaluated and included. For design-bid-build, 3571 projects were used, and for design-build 18 projects were used. On design-bid-build project, 37% of the projects had overruns, and 61% of the projects came in below the engineer's estimate. On design-build projects, 55% of the projects had overruns, and 33% of the projects came in below the engineer's estimate.

A t-test was conducted to evaluate if there is statistically significant difference between the two groups of 4062 projects (the lowest bid as a percentage of the engineer's estimate) and 3865 projects (amount paid at completion as a percentage of the engineer's estimate). Table 1 shows the result of the t-test.

Considering that the engineer's estimate is heavily relied upon and is expected to be reliable at predicting project costs, the analyses and findings have shown the reliability of the engineer's estimate under different dimensions or contexts.

The findings show the level of accuracy of the engineer's estimate on 4062 active and completed projects analysed based on the low bid as a percentage of the engineer's estimate. In addition, the findings show the level of accuracy of the engineer's estimate on 3865 completed projects analysed based on the amount paid at completion as a percentage of the engineers estimate.

The overall picture is that for the 4062 active and completed projects, and based on ±10% accuracy range, only 32% of the engineer's estimate came within range of the low bid. Also, the overall picture is that for the 3865 completed projects, and based on ±10% accuracy range, only 27% of the engineer's estimate came within range of the amount paid at completion.

Further analysis and characterization was conducted on project types (bridge and roadway), project sizes (small size and medium size), two time periods (1992 to 2004 and 2005 to 2016), two select contractors (a bridge contractor and a paving contractor), and two delivery methods (design-bid-build and design-build).

The intent for these characterizations was to further understand if the level of accuracy of the engineer's estimate is fundamentally different when it comes to different projects types,

Table 1 t-Test results

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Low Bid Amount As Percentage Of Engineers Estimate	3865	97.6774	32.72736	.52642
Amount Paid At Completion As Percentage Of Engineers Estimate	4062	94.2161	19.30712	.30293

One-Sample Test						
	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Low Bid Amount As Percentage Of Engineers Estimate	185.549	3864	.000	97.67736	96.6453	98.7095
Amount Paid At Completion As Percentage Of Engineers Estimate	311.012	4061	.000	94.21615	93.6222	94.8101

different project sizes, different time periods, different contractors, and different delivery methods.

Following the analyses presented in this research with the descriptive charts shown above and representing different contexts, it is evident that the engineer's estimate in most cases falls below or above the accuracy range of ±10% of the low bid or the amount paid at completion. The data show that only about 30% to 47% of the engineer's estimates fall with the ±10% accuracy range, which means that 53% or more of the engineer's estimate are inaccurate and are not reliable. This is a significant finding because when something is wrong or right 50% of the time, it is like tossing a coin – head or tail.

In the heavy civil sector, the engineer's estimate is the target estimate that contractors shoot for, and some are forced to change their bidding strategy to come close to the engineer's estimate, which this research indicates as missing the target most of the time. The engineer's estimate is relied on by contractors and owners, and when the engineer's estimate is wrong 50% of the time, it should be of concern to practitioners, and should call for a re-evaluation on how the engineer's estimate is prepared.

The descriptive charts indicate clearly that the engineer's estimate has a 50/50 chance of being accurate, which is a significant finding. The t-test validated this finding. As such, the engineer's estimate is used as a factor in comparing the low bids to the amount paid at completion of the projects. The t-test shows that there is a statistically significance difference, which indicates that the engineer's estimate is not reliable for use at predicting the lowest bid or the amount paid at completion of a project.

This is a significant finding which adds to existing literature on the accuracy of the engineer's estimate. The findings from this research is interesting and indicates how the problem extends to allocation of contingency on engineer's estimate – which has a 50% chance of being inaccurate. The research points to the need for use of proper classification of project types to understand their level of accuracy and which project types require more attention during estimate development. In addition, the research indicates that there is a knowledge gap in the cost estimating practice used to arrive at the engineer's estimate, and that the current method used to arrive at the engineer's estimate is not working.

From the literature, it is known that both the contractor and the owners rely heavily on the engineer's estimate, but the reliability of the engineer's estimate has been called into question, and in some cases the engineer's estimate has been considered misleading. The evidence and the analysis from this research supports the literature that the engineer's estimate is not reliable. The result of this research add to the dimension on the magnitude at which the engineer's estimate is inaccurate.

Conclusion

This study evaluated the reliance and reliability of the engineer's estimate and found that both owners and contractors rely heavily on the engineer's estimate for various reasons, which include the use of the engineer's estimate as a benchmark for funding requests and for projecting the cost to complete a project. The reliability of the engineer's estimate was evaluated within different contexts using the bid amount as a percentage of the engineer's estimate. Based on the set accuracy range and within different contexts, the data showed that only 11% to 23% of the bids came in within ±5% of the engineer's estimate, while 30% to 47% of the bids came in within ±10%, and 50% to

71% of the bids were within ±15% of the engineer's estimate. The engineer's estimate was further evaluated based on the amount paid at completion as a percentage of the engineer's estimate, and based on the set accuracy range and within different contexts, the study found that 35% to 67% of the projects were completed at costs higher than the engineer's estimate, while 33% to 62% of the projects were completed at a cost below the engineer's estimate. It can be seen from this study that about half of all the low bids were within ±15% of the engineer's estimate and more than 30% the projects were completed at a cost higher than the engineer's estimate. The study showed that most of the time the engineer's estimate failed to accurately come in within range of the low bid or accurately predict the cost at completion, and this calls for some recommendations. State DOTs are encouraged to spend the time to track and document the actual cost of efforts and resources that go into the construction of their project instead of using past bids or cost data books that do not reflect reality. Secondly, to arrive at a more accurate estimate, state DOTs are encouraged to use second estimates, which is a practice that is widely used by well-respected construction companies. Finally, State DOTs should re-evaluate their cost estimating practice, and learn to use the cost estimating practices found in highly reputable construction organizations.

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