Competitive Bidding in Construction Contracting

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Competitive bidding and accurate cost estimation allow state departments of transportation (DOTs) to make effective use of budgeted funds to deliver construction projects. However, the different bidding procedures and practices in use affect the market competition in competitive bidding. For many state DOTs, including Michigan DOT (MDOT), obtaining precise estimations, especially for traffic control and maintenance items, is a challenging task. In addition, state DOTs need effective metrics and methods for reviewing unbalanced bids and for advanced bidding tendency monitoring. To fill these gaps, the research presented in this report aims to improve the competitiveness of construction bidding in Michigan and to develop new methods and tools for post-bid analysis and cost estimation, especially for traffic control items. The research objectives are pursued through (1) a literature review and nationwide survey on construction bidding and estimating, (2) competitive analysis of construction bidding in Michigan and in peer states, (3) bidding experiments of various strategies for pre-bid information releases, and (4) data analytics and tool development for bidding tendency monitoring, unbalanced bid detection, and competition evaluation. Leveraging the results of a national survey, literature review, industrial reports, data analytics, and bidding experiments, we synthesize recommendations for MDOT to improve the competitiveness and estimation accuracy of construction bids in Michigan. The recommendations include, but are not limited to, the following: (1) Engineer's Estimate (EE), awarded average unit prices, and the list of eligible bidders should not be released together to prospective bidders prior to bidding; (2) the developed tool can be used to assist MDOT in systematically performing post-bid analysis and evaluations, such as unbalanced bid detection, bidding tendency monitoring, and competition assessment; and (3) bid-based estimation can be used in cost estimation, although it needs to be improved in certain respects.</td></tr>
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EXECUTIVE SUMMARY

The purpose of competitive bidding is to encourage competition among bidders so that the owner can receive competitive prices for construction projects. There are many variations in the implementation of competitive bidding, particularly regarding the level of detail (e.g., list of eligible bidders, awarded historical average unit prices, and Engineer's Estimate of total cost) of the information provided by the owner. These variations may lead to different levels of competition in construction bidding. In this context, the overall goal of this research project is to identify best practices for competitive bidding on the part of state Departments of Transportation (DOTs) and then develop recommendations to improve the competitiveness of construction bidding in Michigan in particular. Additionally, this study aims to address the challenges in construction estimation and post-bid analysis, e.g., inaccurate estimation in traffic control and maintenance, a lack of appropriate metrics for identifying unbalanced bids, and a lack of effective methods/tools for monitoring patterns in bidding and assessing the level of competition.

To accomplish these research objectives, the research team undertook a comprehensive literature review to uncover similar studies regarding competitive bidding and construction estimation. The team then surveyed state DOTs to elicit information on current construction bidding and estimation practices. The survey results indicated that bid-based estimation is still the primary estimation method but that it is not as reliable as other methods in terms of estimation accuracy. In terms of bidding tendency monitoring, the team conducted another survey within Michigan DOT to gather opinions on the prerequisites for effective implementation of a Geographic information system (GIS) in bidding tendency monitoring. Based on the national and MDOT survey results and an extensive literature review, the team developed a method and tool for post-bid analysis. This tool is capable of automatically detecting unbalanced bids, performing bidding tendency monitoring, and carrying out competition evaluation. In an attempt to investigate the impact of information release on bid competitiveness, bidding experiments were carried out in which 36 undergraduate students of Western Michigan University (WMU) were invited to participate. The results of the experiment show that releasing a list of eligible bidders to prospective bidders prior to bidding may reduce the competitiveness of construction bidding. Disclosing both awarded average unit prices of pay items and the Engineer's Estimate of the total cost to bidders may lead to higher mark-up ratios, which are always in a reasonable of the

Engineer’s Estimate. Finally, the research team developed recommendations for bidding and estimation of highway construction projects in Michigan. Some of the recommendations include not releasing the list of eligible bidders, the awarded average unit prices, or Engineer’s Estimate to prospective bidders prior to bidding, and improving the accuracy of bid-based estimation by (1) cleaning the data by removing outlier unit prices of pay items, (2) using a combined approach rather than relying solely on bid-based estimation, and (3) taking into account inflation.

Chapter 1. INTRODUCTION

In recent years, departments of transportation (DOTs) have been experiencing significant cost escalation of their construction projects over time. According to the U.S. Labor Department, the annual inflation rate was approximately 1.77% over the period, 2010–2019. In contrast, the annual growth rate of the national highway construction cost index (HCCI) averaged 3.31% over the same period (Federal Highway Administration, 2020). (The HCCI measures price changes over time in the highway construction industry.) Moreover, the Michigan HCCI saw an average growth rate of 4.29% during the same period (Liu et al., 2020), indicating even higher price increases in Michigan compared to the already-high national average. These price increases in highway construction bring negative impacts to the construction program of the Michigan Department of Transportation (MDOT), such as a reduction in the number and scale of projects that can be delivered within budget constraints. The rise in bid prices may be attributable to such internal factors as prices of materials, labor, and equipment, but also external market competitiveness conditions. At times, a low number of actual bids is received for MDOT's construction projects, resulting in less market competition and increased bid prices. In this context, how MDOT bidding practices and procedures affect the market competition and the contract price is unclear; for example, whether providing the average unit prices for each pay item bid encourages "bid creep." There is thus a pressing need for MDOT to investigate the impact of its bidding practices on bidding competitiveness so that improvements in bidding practices can be identified and applied to encourage competition and lower bid prices.

The accuracy of the cost estimate is a significant concern for owner agencies because of its impact on the final cost of a project. In practice, there are three cost-estimation methods widely used by state DOTs: the historical data approach (also named as bid-based estimation approach), the actual cost method, and the combined approach. However, there is no compelling evidence suggesting which is the most effective and accurate among them. Meanwhile, MDOT faces the challenging task of obtaining accurate estimations of traffic control items. For this reason, it requires cost-effective estimation methods to ensure realistic unit prices of pay items, e.g., for traffic control and maintenance. Furthermore, unbalanced bids on lump sum items, especially traffic control items, often occur in the bidding. MDOT thus needs effective methods for reviewing unbalanced bids, conducting advanced post-bid analysis, and monitoring bidding tendency.

1.1 OBJECTIVES

The research presented in this report aims to investigate the impact of various bidding practices on the level of competition in competitive bidding and to develop novel methods and tools for post-bid analysis and cost estimation, especially for traffic control items. To this end, the current practices of competitive bidding and cost estimation in various states, including Michigan, were identified to aid an understanding of the impacts of those bidding practices on bidding competition. Improvements in bidding practices were then identified to encourage competition and lower the bid price for MDOT construction projects. Specifically, this research sought solutions to the following questions:

1) Does providing contractors with the Engineer's Estimate of the total project affect the overall contract price?
2) Does providing the average unit prices for each pay item bid result in "bid creep" and keep contractor's bids artificially high?
3) Does publicizing the list of contractors who are eligible to bid affect the number of bidders and the number of "complimentary bids" the Department receives?
4) Does publicizing the list of contractors who are eligible to bid affect the number of subcontractors submitting bids to prime contractors?
5) Is MDOT's use of the Historical Data Approach to Cost Estimation effective? Is it cost-effective to increase staff in order to make use of the actual cost approach or a combined approach feasible?
6) Is there a way to ensure realistic unit bid prices for traffic control and maintenance unit prices? Can these items be accurately estimated?
7) What is an appropriate metric for unbalanced bid reviews?
8) What is an effective method for graphically-aided bidding tendency monitoring?

1.2 SUMMARY OF TASKS

These research objectives were pursued in eight tasks, as shown in Figure 1. **First**, bid data was collected from MDOT and other sources (e.g., other state DOTs and publications) for data analytics purposes, including competition analysis, bidder tendency analysis, unbalanced bidding analysis, and so forth. The **second step** was to gain an in-depth understanding of state-of-the-art practices concerning competitive bidding and cost estimation through surveys. As a **third step**, follow-up surveys/interviews were then conducted to solicit further information on bidding and estimation from select state DOTs whose bidding and estimation practices differ from those employed by MDOT. Various bidding and estimating practices identified in the surveys were compared qualitatively to identify the best practices. **Fourth**, a method was developed by which to monitor and report contractors' bidding tendencies.

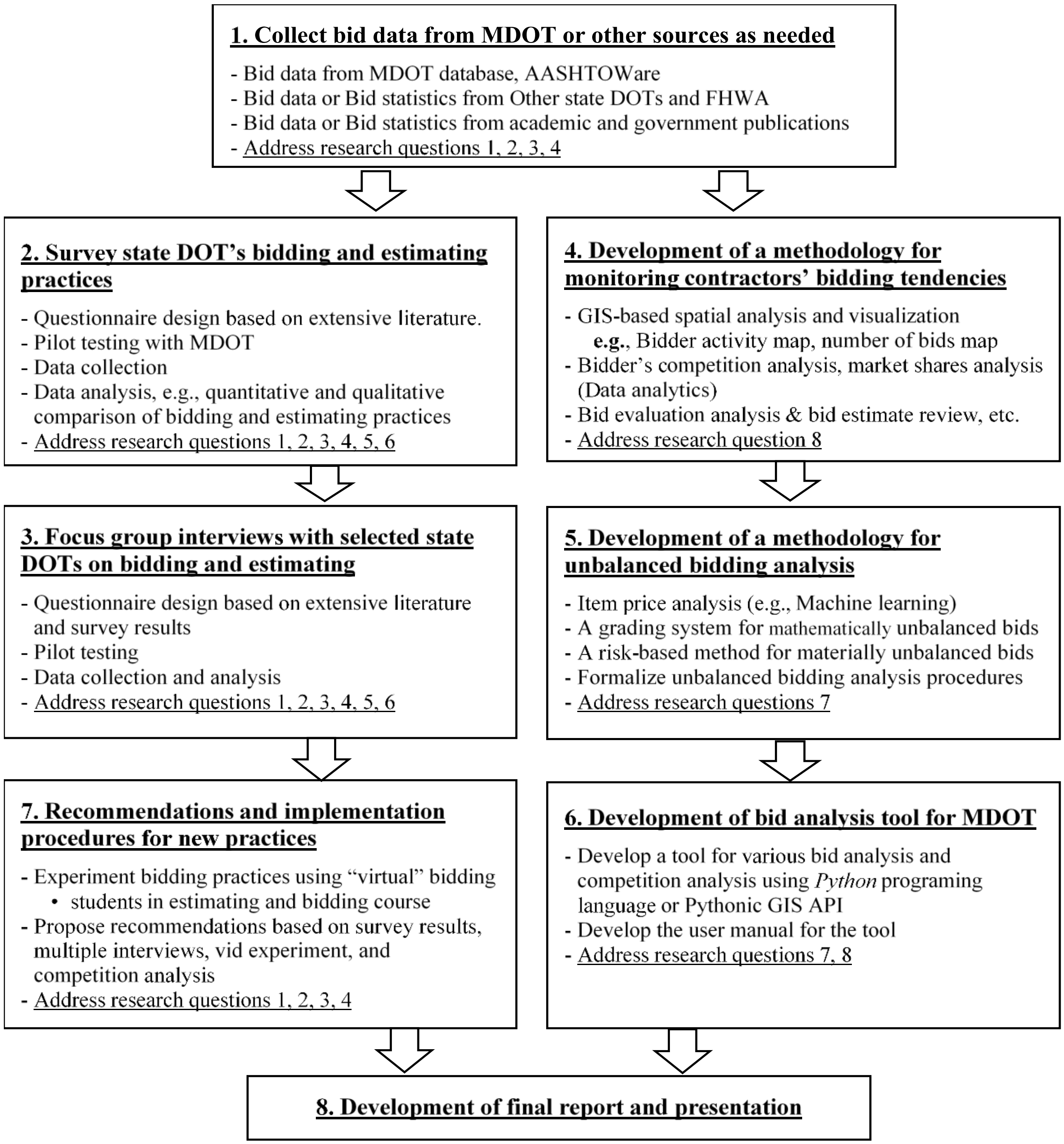


Figure 1. Summary of research tasks

As a **fifth step**, we developed an advanced approach for unbalanced bid analysis and competition assessment. Leveraging these methods, in the **sixth step**, a tool was developed by which for MDOT to perform post-bid analysis and reporting effectively. The research team conducted a bidding experiment to investigate the impact of information release on construction competition in the **seventh step.** We also developed recommendations for MDOT bidding and estimation practices that may improve the competitiveness and estimation accuracy of construction bids in Michigan. **Finally,** these recommendations were documented.

1.3 ORGANIZATION OF THE REPORT

A full description of the work performed in this research is provided in the chapters that follow. Chapter 2 reports on the survey and interview of other state DOTs' bidding and estimation practices. The survey sought to ascertain other state DOTs' best practices for construction bidding and estimation, garnering 30 valid responses (a 60% response rate).

Chapter 3 reports on the bidding tendency monitoring. An internal survey was first conducted with MDOT to solicit the requirements of tendency monitoring. Twelve valid responses were received, most from the contract management and estimation units. The survey results suggest the potential use of GIS for (1) post-bid analysis, (2) vendor analysis, and (3) bidding activity visualization. The findings also suggest that any such tools for bidding tendency monitoring would need to be user-friendly in order to be effective, especially for non-GIS experts. Given this, a visualization tool is developed for monitoring tendency, and its descriptions are presented in this chapter. Chapter 4 discusses unbalanced bidding analysis. Specifically, this chapter outlines the unascertained model and the risk-based approach to unbalanced bid detection. It further describes the advanced tool (i.e., MDOT Post-Bid Analysis tool) that the team has developed to aid in detecting unbalanced bids.

Chapter 5 presents the competitive analysis of construction bids in Michigan and in peer states, and a comparison of competitiveness is also provided. Chapter 6 describes the bidding experiments conducted to investigate how the information feedback from owner agencies may affect the competitiveness of construction bids. The recommendations on how the competitiveness of construction bids in Michigan can be improved are described in Chapter 7. In addition, this chapter also outlines several recommendations regarding post-bid analysis and cost estimation methods. It should be noted that the research team has developed an advanced computer tool, namely, the MDOT Post-Bid Analysis tool (MPBA). This tool is intended for post-bid analysis, including 1) tendency monitoring, 2) unbalanced bid detection, and 3) competition evaluation. The recommendations regarding post-bid analysis are provided based on the developed MPBA tool. Chapter 8 presents the conclusion of the report.

The questionnaires used for the nationwide and statewide surveys can be found in Appendix A and Appendix B, respectively. Appendix C summarizes the prequalified amount calculations for state DOTs. Appendix D provides one example of construction bids and the information released to bidders, which is used in the bidding experiment. Some results of the national survey and the bidding experiment are included in Appendix E and Appendix F, respectively. Appendix G is the user manual for the developed MDOT Post-Bid Analysis (MPBA) tool.

Chapter 2. SURVEY AND INTERVIEW RESULTS OF DOTS' BIDDING AND ESTIMATION PRACTICES

2.1. INTRODUCTION

A survey was conducted to identify state DOTs' current bidding and estimation practices and gain an in-depth understanding of their best practices. Specifically, the survey sought to obtain a better understanding of DOT's practices in terms of the following aspects:

- Bidding procedures and prequalification
- Bid evaluations, such as evaluating the reasonableness of bids and the level of competition
- Bid information release
- Construction estimation methods
- Bidding and estimating traffic control

2.2. SURVEY DESIGN AND ADMINISTERING

The research team developed the questionnaire in such a manner as to solicit responses well aligned with the objectives of the survey. The following five steps were followed by the research team in the development and administering of the survey:

1. Develop a draft questionnaire that takes into consideration the bidding and estimation practices identified in the literature review.
2. Obtain feedback from the Research Advisory Panel (RAP).
3. Conduct a pilot survey.
4. Finalize the questionnaire based on the findings of the pilot.
5. Distribute the survey to DOT representatives via the email list of the AASHTO Committee on Estimating and BidX Agency contacts.

The developed questionnaire is included in Appendix A. The survey was distributed to state DOT representatives and an FHWA representative on June 7, 2021, via email, and we continued to accept responses until July 15, 2021. Multiple reminders were sent out to increase the number of participants. In total, 30 participants completed the survey, an approximate response rate of 60%.

2.3. INTERVIEW DESIGN AND ADMINISTERING

After evaluating the survey responses, state DOTs participating in the survey were further invited for interviews to ask specific questions regarding their unique bidding and estimating practices. The questions were designed to gain a deeper understanding of the bidding and estimating practices that are different from MDOT's and used by other state DOTs. The questions were also finalized with the feedback of MDOT RAP. The follow-up interviews were conducted from October 4, 2021, to November 09, 2021. In the interview invitation, we provided them with options on how they could participate in the follow-up interview, such as answering our follow-up questions by email, phone call, online meeting, and the like. In total, we received 13 feedbacks via email, a response rate of 43%.

2.4. ANALYSIS OF SURVEY AND INTERVIEW DATA

This section discusses the results of the questionnaire survey and interviews. **It should be noted that MDOT's responses are not included in the quantitative survey results, but it is indicated by an asterisk (i.e., *) symbol on the figures**.

2.4.1. Participating state DOTs

As mentioned above, 30 responses were received for the national survey, including 29 state DOT representatives and one FHWA representative. Among those, thirteen DOTs participated in the follow-up interviews or surveys. The responding states are shown on the map (green color for the national survey and blue color for the surveys and follow-up interviews in Figure 2). As can be seen, the DOT representatives of one of Michigan's four neighboring states (Wisconsin) participated in the survey.

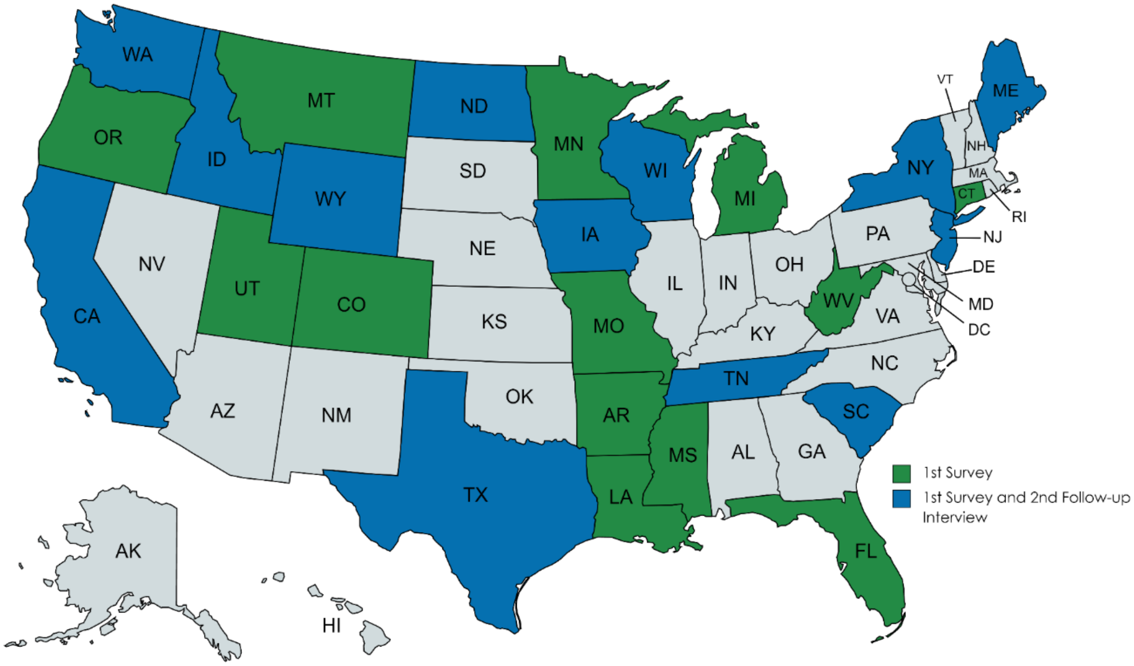


Figure 2. Geographic map of responding states

2.4.2. Bidding procedures and qualifications

One objective of the survey is to understand how DOTs advise and procure construction projects. A short answer question was asked to describe their bidding procedures, including such items as advertisement length, whether or not prequalification of contractors is used, and how and where bids are submitted. Their responses are summarized in Figure 3, Figure 4, and Figure 5.

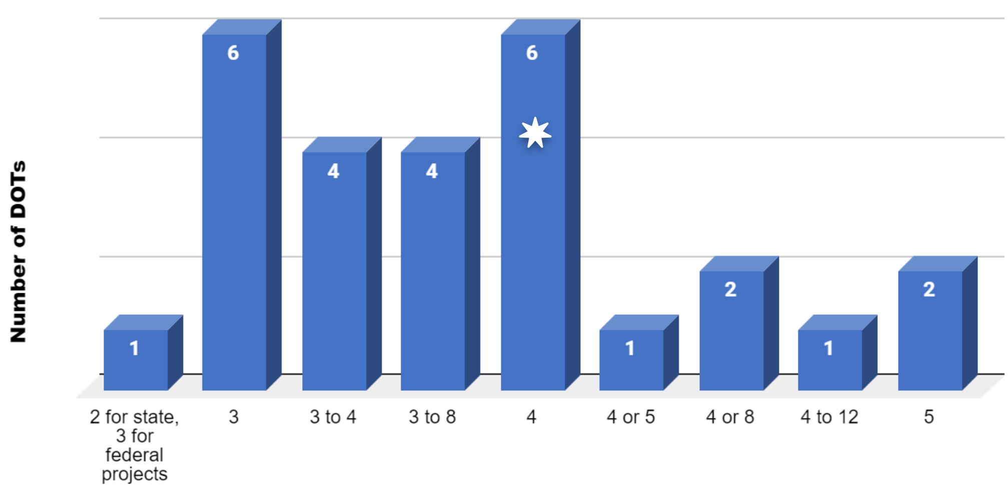


Figure 3. Advertisement length (in weeks)

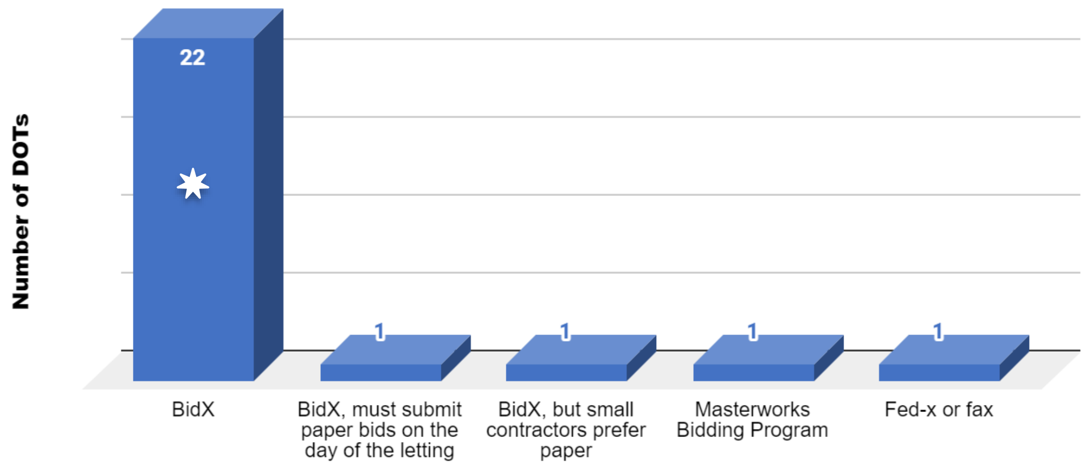


Figure 4. E-submission of bids (Y/N)

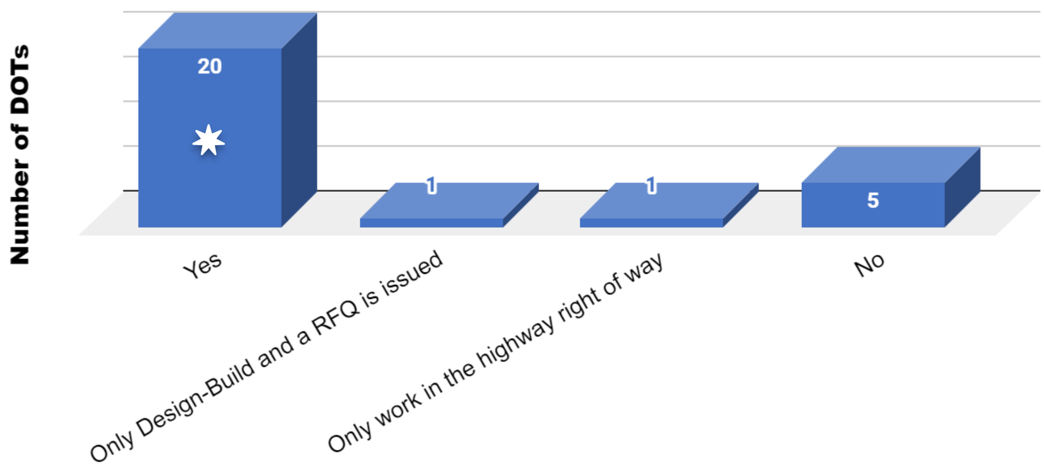


Figure 5. Prequalification (Y/N)

As shown in Figure 3, the majority of DOTs advise the construction project for about four weeks. Some DOTs may have a variable advertisement length (e.g., 4-8 weeks), depending on the complexity of the construction projects. For example, small and regular projects may have a 4-week advertisement, while the large and complex projects need to be advertised for a longer time, e.g., eight weeks. The four-week is a typical advertisement length for all participating DOTs.

Regarding how and where bids are submitted, 25 among 30 respondents indicated they take the e-submission of the construction bids via either BidX or Masterworks bidding program (see Figure 4). Only FHWA indicated they take the hard copy of construction bids via Fed-X or Fax.

The survey results regarding prequalification are presented in Figure 5. As shown in the figure, most DOTs conduct the prequalification of bidders prior to bidding. Alternatively, NY

DOT only performs prequalification for Design-Build projects, implying no prequalification for the traditional design-bid-build projects. Washington DOT requires contractors to be prequalified for construction work in the highway right of way. The reason for the prequalification is that it could ensure the quality of prospective bidders and allow DOTs to receive responsive bids.

There are five DOTs that do not prequalify the bidders, including Caltrans DOT, Idaho DOT, LaDOTD, Minnesota DOT, and Mississippi DOT. This non-prequalification practice could encourage small contractors to bid on construction projects to increase the level of competition in competitive bidding. On the other hand, this practice may have a negative effect on cost estimation, especially for DOTs who release the average unit price of historical projects to the public and use the historical data approach for cost estimation. The reason is that small contractors may introduce anomaly prices into historical data, leading to a bias in the average bid prices.

The respondents were also asked to describe how their agency determines whether or not a contractor can bid on a construction project. The majority of DOTs prequalify the contractors before allowing them to bid on their construction projects, as shown in Figure 6. In specific, the prequalification of contractors is typically conducted on ***an annual basis***. Most DOTs maintain a list of the prequalified bidders. If a bidder has not yet been prequalified for the construction work, they are usually required to file their prequalification application at least two weeks prior to bidding opening. In addition, the prequalification is generally conducted for various types/classes of construction work. Only the bidders prequalified for the work class/type of the new project are allowed to bid on the project.

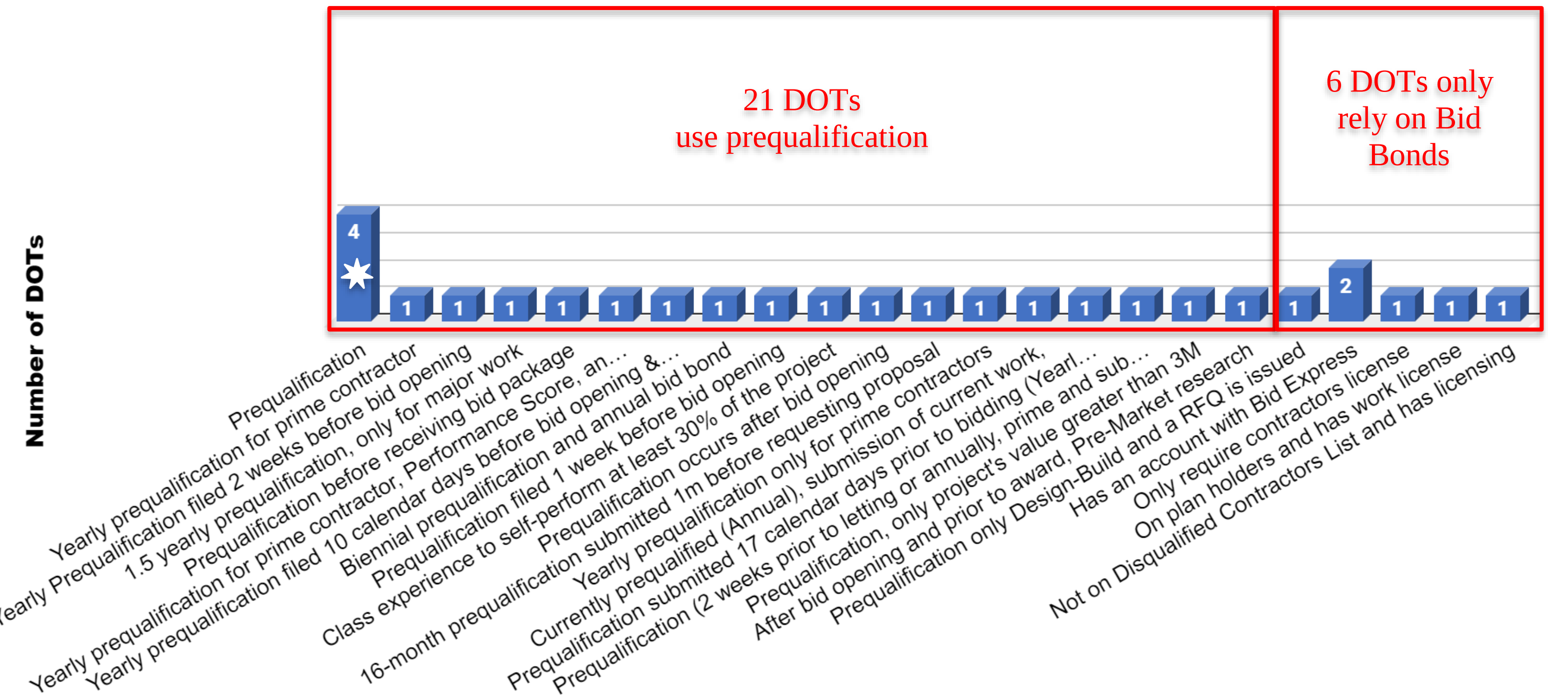


Figure 6. Qualifications for bidding

In the survey, the respondents were further asked how to determine the maximum amount contractor can bid on or the maximum amount a contractor can contract for at any given time. Generally, there are two methods to determine the bid and contract limits, namely (1) using the bonding capacity and (2) prequalified capacity (see Figure 7). For example, several DOTs do not have a maximum amount contractors can bid but ask contractors to secure bid and performance bonds from bonding companies for 100% of the contract amount, including South Carolina DOT, Maine DOT, Minnesota DOT, Mississippi DOT, Idaho DOT, Oregon DOT, Montana DOT, and FHWA. On the other hand, other DOTs use their own formulas in determining the total prequalified amount during the prequalification process. In addition, some DOTs subtract the outstanding work from the prequalified amount to determine the limits for each bid. For instance, North Dakota DOT calculates the prequalified amount by five times the stakeholder's equity. Alternatively, in the Washington DOT’s practice, the prequalified amount is the contractor’s net worth times a factor of 5 to 7.5.

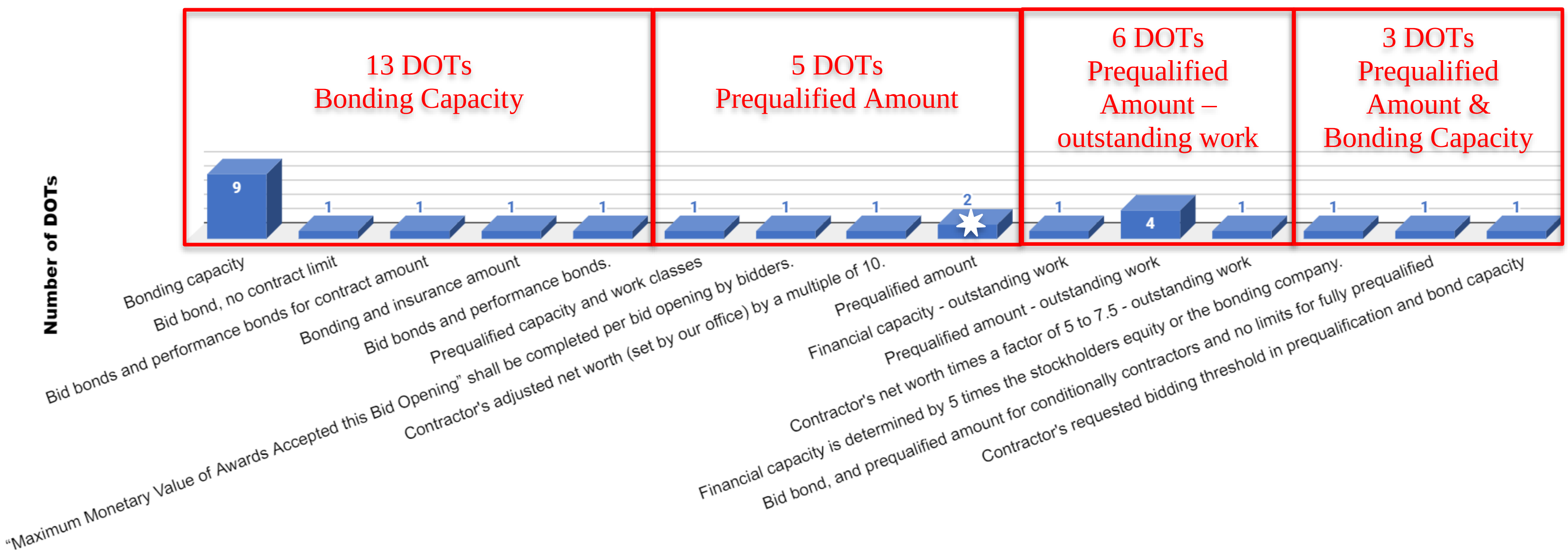


Figure 7. Bidding and contracting limit: survey results

In terms of funding sources, most DOTs receive federal aid for a large percentage (e.g., 80%–90%) of their construction projects. Only Caltrans DOT, South Carolina DOT, and Iowa DOT have about 30%–40% of their construction projects having federal aid (See **Figure 8**). For non-federal aided projects, sixteen DOTs indicated that the bidding procedure and practices differed from those for projects with federal aid (as shown in **Figure 9**). For example, the federal requirements on Disadvantaged business enterprises, Davis Bacon, and Federal Acquisition Regulation (FAR) are removed for non-federal aided projects (as shown in **Figure 10**). Oregon DOT and New Jersey DOT have specific state requirements but did not provide details on these requirements. LADOTD only requires the contractors to be properly licensed for non-federal aided projects. FHWA follows the federal acquisition regulation (FAR), as all their projects have some type of federal funding.

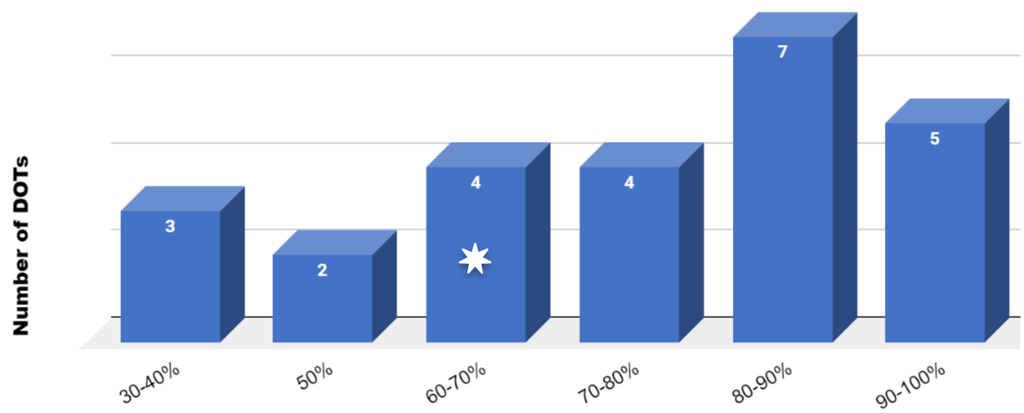


Figure 8. Federal aid percentage

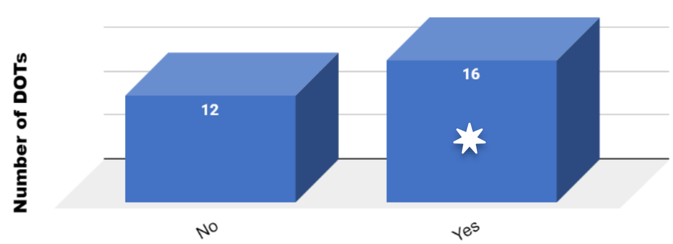


Figure 9. Different bidding procedures for non-federal aided projects (Y/N)

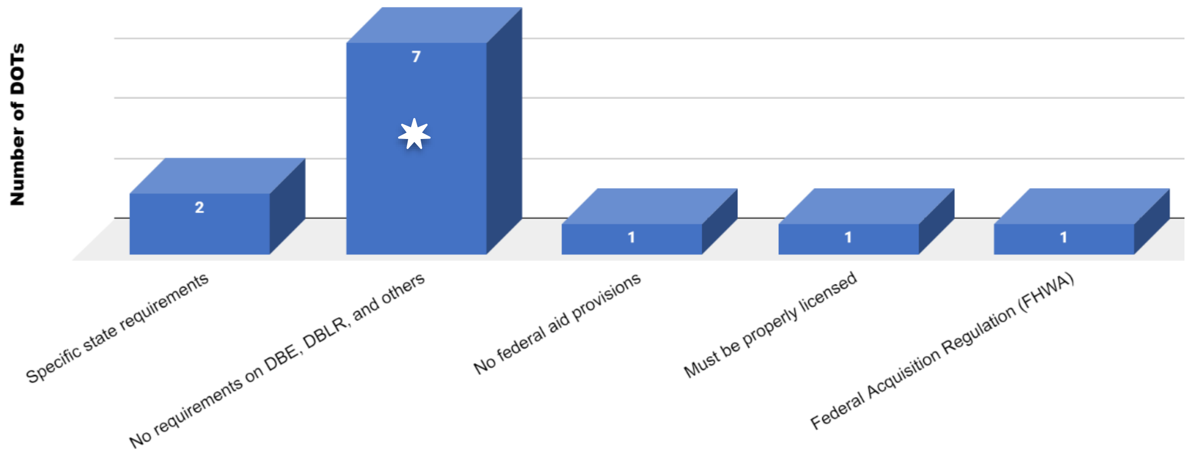


Figure 10. Procedures for non-federal aid projects

Competitive bidding is widely used for construction projects that are contracted and delivered by the traditional design-bid-build method. The respondents were then asked what percentage of projects let by your agency are not delivered by such conventional design-bid-build methods. As shown in Figure 11, most DOTs have less than 5 % of their construction projects for non-design-bid-build methods, such as the design-build method. Three DOTs, such as South Carolina DOT, West Virginia DOT, and Minnesota DOT, have approximately 10%. Non-design-bid-build projects account for about 15%–20 % for Utah DOT. Idaho DOT is allowed to use alternative contracting for up to 20% of our highway construction budget; however, they have not done any alternative contracting in the last few years, with only a total of 7 projects.

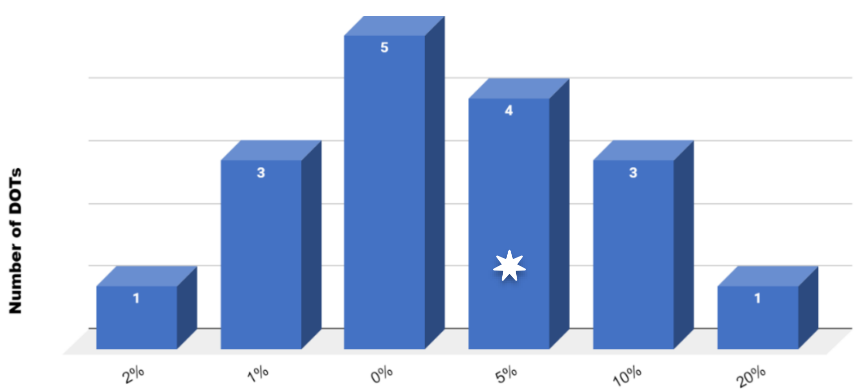


Figure 11. The percentage of projects awarded by the non-design-bid-build method

2.4.2.1. Follow-up interview and results regarding prequalification

In the national survey on bidding and estimation practice, the twenty-two respondents indicated that prequalification is used to qualify the contractors before allowing them to bid on construction projects. It should be noted that prequalification of contractors and subcontractors could ensure the quality of bids but may limit the level of competition for construction projects. For DOTs who do not practice prequalification, their specific bidding procedures could shed light on how to encourage competition while also ensuring bid quality. Also of note, Tennessee DOT reported that they conduct the prequalification for both prime contractors and subcontractors, while the others did not provide specific information in this matter. Minnesota DOT conducts qualifications on a project-by-project basis rather than carrying out an annual prequalification. As such, three follow-up questions were further posed to select DOTs to solicit further information on their prequalification process.

1) Is prequalification required for both prime (general) contractors and subcontractors?
2) If there is no prequalification process, are there any steps to ensure bidders' capacity and qualifications, such as specific requirements on performance bonds or verification of bonding capacity?
3) Do you determine contractors' qualifications on a project-by-project basis?

The national survey results also revealed that several DOTs employ their own formula to determine the max capacities of bid and contract. The research team posed two additional questions to solicit information on their specific formula, as follows:

1) How is a contractor’s maximum bid capacity in dollars determined? Do you have any specific formula to calculate the max bid capacity?
2) How do you determine what type of construction work a contractor can bid on? How do you assess their capacity in dollars for each kind of work?

Figure 12 presents the follow-up interview results regarding the prequalification. It shows that **two** state DOTs, namely West Virginia DOT and Tennessee DOT, prequalify both prime and sub-contractors. The **eighteen** DOTs do the prequalification only for prime contractors. The reason is that the prime contractors enter a contract with DOTs and are responsible for executing the contract. The responsibility and risks related to subcontractors are transferred to prime contractors. Prequalification of sub-contractors by state DOTs may cause a challenge for prime contractors to secure the services of sub-contractors and discourage competition.

For **six** state DOTs that do not use prequalification (e.g., Caltrans DOT, Idaho DOT, LaDOTD, Minnesota DOT, Mississippi DOT, and NYS DOT), the bid bond and performance bonds are typically required to be the full amount of estimated cost and contract prices, respectively. Contractors can bid on construction projects as long as the required construction bonds are secured from the surety companies.

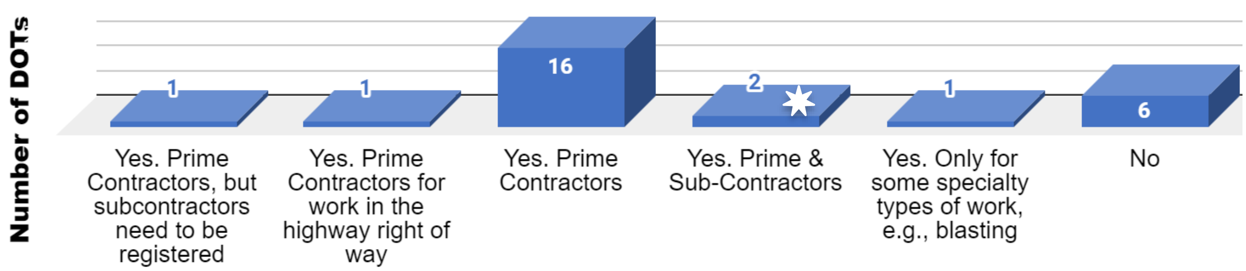


Figure 12. Prequalification of prime contractors and subcontractors

In terms of bid and contract limits, **thirteen** DOTs take the bonding capacity as the limit, and another **two** DOTs use the contractors' required thresholds in the prequalification and the bid submission. The remaining **twelve** DOTs use different ways to determine the limits (see Figure 13). Generally, the prequalification amount is based on the net worth and various factors. Most DOTs qualify contractors in work categories but usually do not set the dollar limit for each category, such as Iowa DOT, Florida DOT, Wyoming DOT, Utah DOT, West Virginia DOT, and Maine DOT. On the other hand, Wisconsin and Washington DOTs have their own formulas to determine the limits for each work class. The research team reviewed the prequalification amount calculations and summarized them in **Appendix C**. On the contrary, Texas DOT does the prequalification without any work class/type/category.

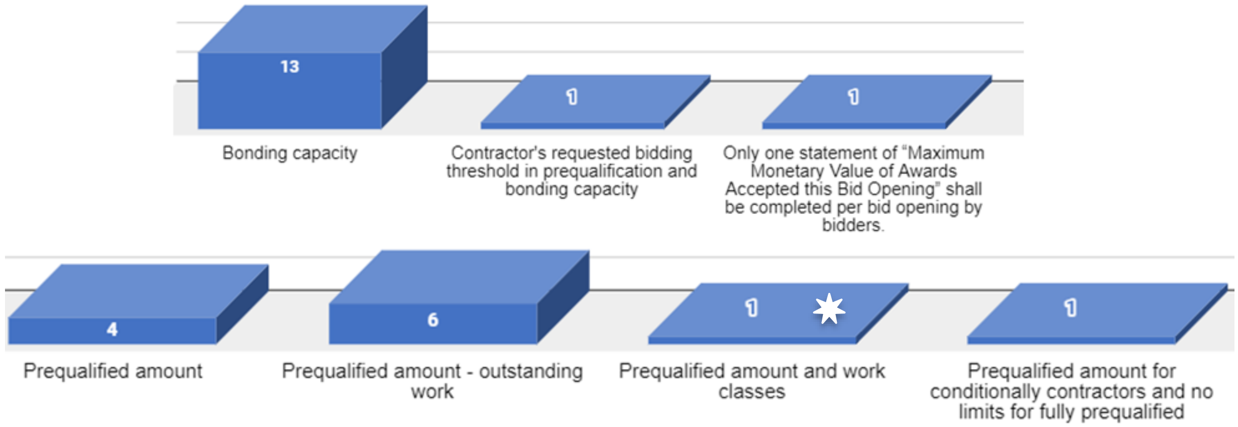


Figure 13. Bid limit and contract limit: follow-up interview

In terms of prequalification frequency, only Minnesota prequalifies contractors for historic properties on a project-by-project basis, and other DOTs use **annual prequalification**. With annual prequalification, the bidding eligibility is determined on a project-by-project basis throughout the following two steps:

- Certify the amount of uncompleted work when requesting bid documents or to be added to the bidders' list.
- Eligibility depends on the prequalification amount and uncompleted work.

For example, Washington DOT requires contractors to be qualified for various work classes, and each work class is given a rating. The contractors must be able to self-perform 30% or more of the project, and the 30% or more of the project is the cost percentage of pay items for which the contractors are prequalified. They must also have a contract capacity greater than the total project estimate plus uncompleted work for the department. Lastly, the work class ratings need to be greater than the value of various classes of work within EE.

Wisconsin DOT is different from Washington DOT, as its prequalification is assigned <u>at the contract level</u>. For instance, a prequalified bridge contractor cannot bid on an asphalt pavement contract. This bridge contractor with a maximum rating of $2 million cannot bid on contracts whose price is worth more than $2 million subtracted by their outstanding work.

Alternatively, Tennessee DOT considers the delay of current work in determining the bid and contract limits. They usually look at why the contractor is behind schedule on projects and whether or not the projects could be completed on time. Then, they will also contact the bidder to discuss their workload capacity in making this determination.

2.4.3. Bid evaluations

Bid evaluation refers to the process of comparing and evaluating bids to determine which proponent the construction project will be awarded to in consideration of bid price, bidder's quality, work experience, and the like. The survey had a dedicated section to solicit information on this aspect of current practice. The respondents were given a short answer question on what criteria your agency uses to determine if a bid is incomplete, irregular, and/or non-responsive. Typically, the criteria are specified by DOTs in the advertisement, including (1) failing to complete the "Non-Collusion and Debarment Certification, (2) adding any provisions reserving the right to accept or reject an award, (3) failing to acknowledge all addenda, (4) failing to include verification of all signatures and bid bond certification, (5) not bidding all items, and (6) failing to submit any other required documents such as DBE quote. In addition to these, Florida DOT considers unbalanced, high, and low bids as non-responsive bids.

When incomplete, irregular, and non-responsive bids are identified, they are usually rejected by most DOTs, as shown in **Figure 14**. Only five DOTs make a practice of evaluating the severity of incompleteness and irregularity and then asking for clarifications from the bidders, these being Colorado DOT, Mississippi DOT, New Jersey DOT, one of the anonymous respondents, and Maine DOT. It should be noted that most DOTs currently receive electronic bids via BidX. As such, it is rare for DOTs to receive these types of irregular bids.

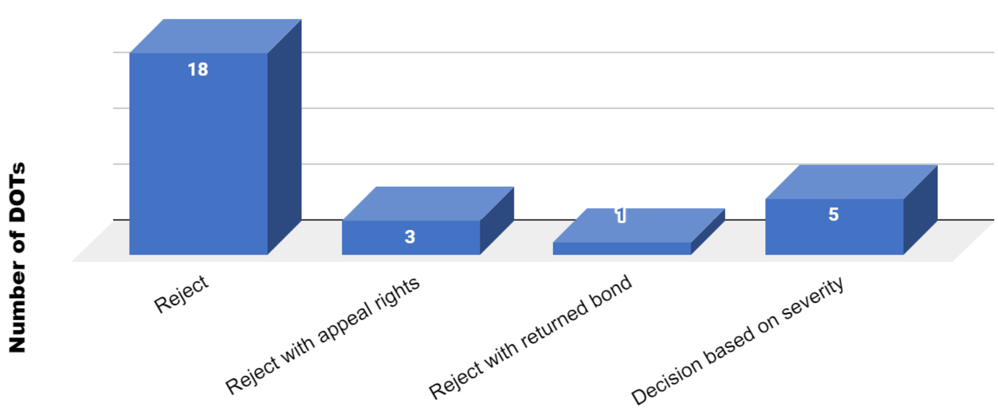


Figure 14. Decision on incomplete, irregular, non-responsive bids

Ideally, the total bid prices of bidders should closely follow the Engineer's Estimate of the total cost, for example, within plus or minus 10% of the Engineer's Estimate. In practice, DOTs use various criteria to determine reasonable bids when over Engineer's Estimate (see Figure 15). Ten DOTs use a fixed percentage of the Engineer's Estimate (i.e., ± 10%). On the contrary, another five DOTs make the judgment on difference percentages considering the number of bids. The difference percentages vary depending on the number of received bids, e.g., ±10% when there are five bidders and ±5% when there are ten bidders. These DOTs include North Dakota DOT, South Carolina DOT, one anonymous respondent, Minnesota DOT, and West Virginia DOT.

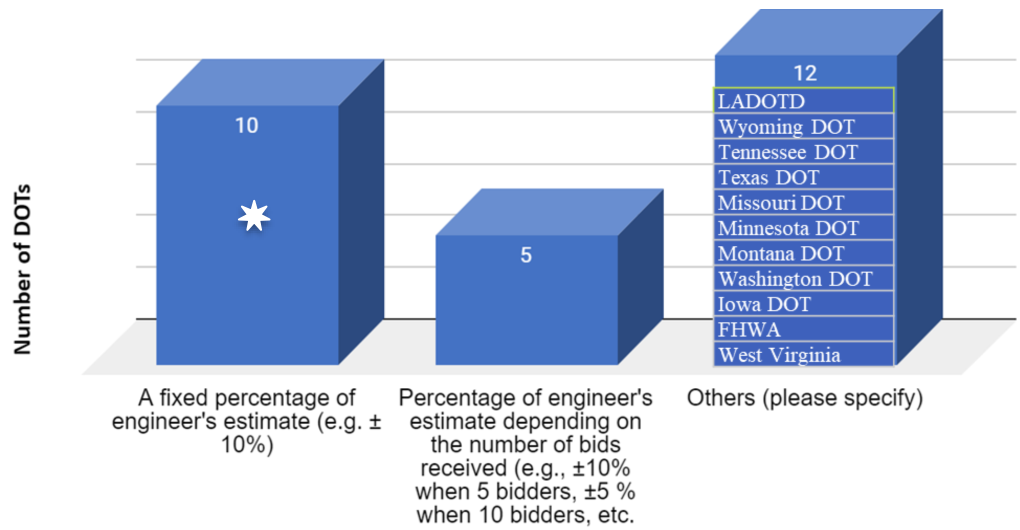


Figure 15. Criteria of the reasonableness of bids whose total prices exceed the EE

As shown in Figure 15, twelve DOTs reported the use of other criteria. For example, FHWA uses ± 15% from the engineer's estimate. Montana DOT uses 25% for small projects and 10% for large projects. Washington DOT asks for justification from bidders when more than 10% and $50,000 over. Other DOTs (e.g., Iowa DOT, Wyoming DOT, and Texas DOT) tend to perform a bid review analysis and look for multiple indicators and patterns to determine the reasonableness of bids. These indicators consist of how close the bidders are to each other, the percentage compared to other bidders, market fluctuations since the Engineer's Estimate was made, and how "critical" it is that the project is awarded now rather than being rejected and re-let.

When the bids are determined to be unreasonable, the majority of DOTs reject all bids, as shown in Figure 16. Some DOTs need to conduct a bid review and get approval for the rejection from the bid review committee and/or transportation commission.

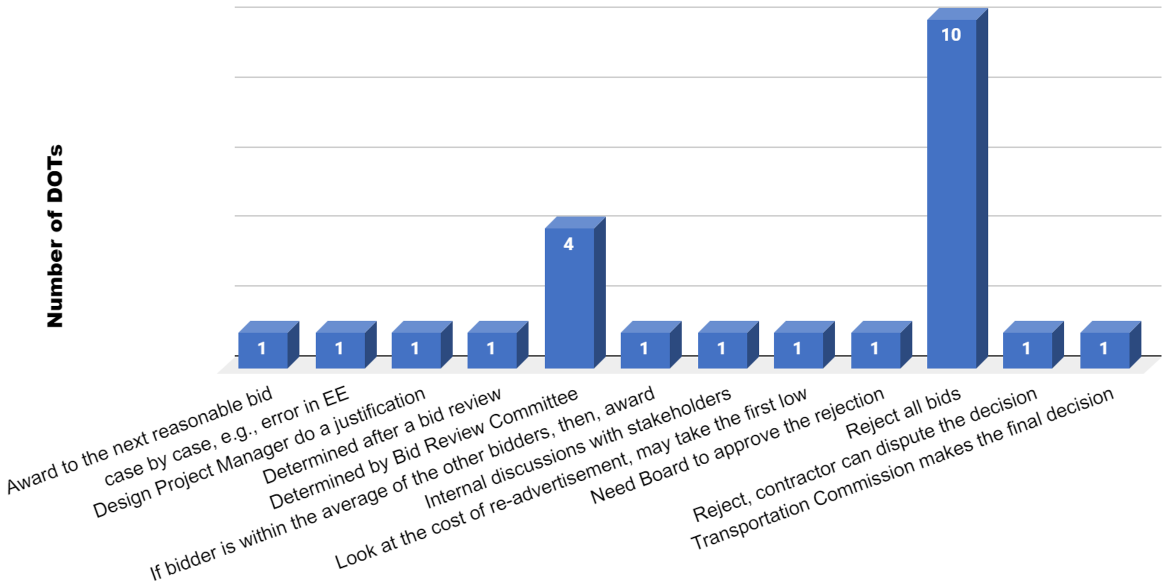


Figure 16. Procedure when the bids are determined to be unreasonable

In terms of bidding tendency monitoring, respondents were asked whether they have a procedure or tool to monitor contractors' bidding tendencies. Almost half of the state DOTs gave positive feedback on this question and indicated they are using or will use AASHTOWare software, including Preconstruction, Estimation Module, Data Analytics, BAMS, and DSS (see Figure 17).

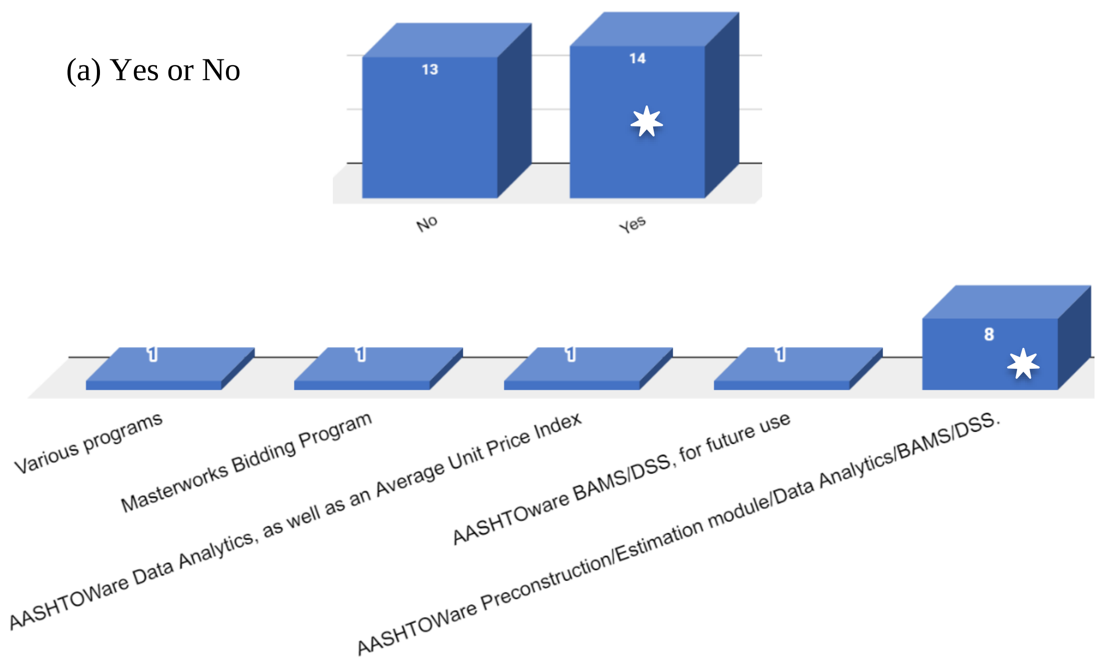


Figure 17. Bidding tendencies monitoring: (a) Y/N and (b) procedure

Unbalanced bid analysis is also widely performed by many DOTs (see **Figure 18**). For example, most DOTs have manual bid reviews by either bid review committees or cost estimation units. Four DOTs use AASHTOWare data analytics, including Iowa DOT, Texas DOT, West Virginia DOT, and Wisconsin DOT. Five DOTs (e.g., Florida DOT, North Dakota DOT, Wyoming DOT, Caltrans DOT, and Minnesota DOT) developed an in-house spreadsheet for detecting unbalanced bids.

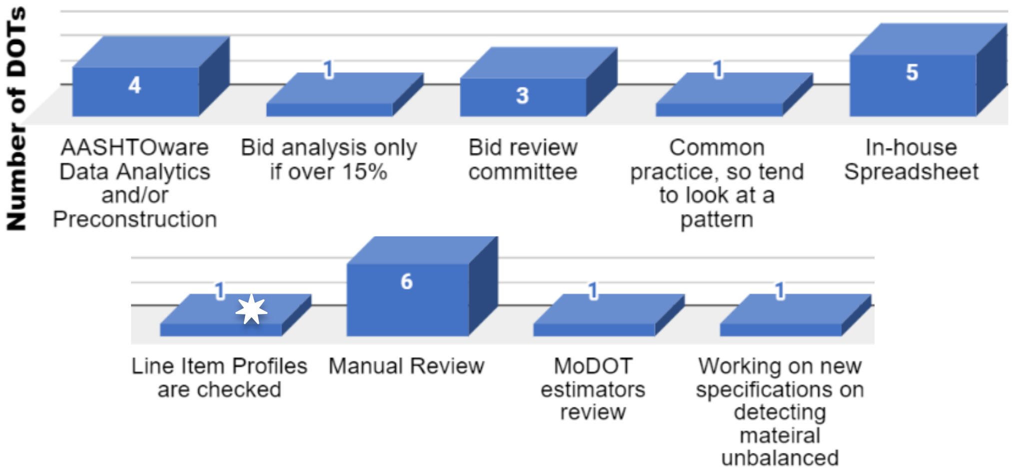


Figure 18. Unbalanced bid analysis procedures

The survey also sought to understand how other DOTs detect possible collusion during the bidding process. A short-answer question was asked to the respondents to describe their detection method. Eleven DOTs do not have a formal procedure or monitor bid collusion (see **Figure 19**). Six DOTs use AASHTOWare (e.g., data analytics, DSS, and SAS) to look for some indicators of bid collusion. The other DOTs in the survey do a manual review by the bid review committee.

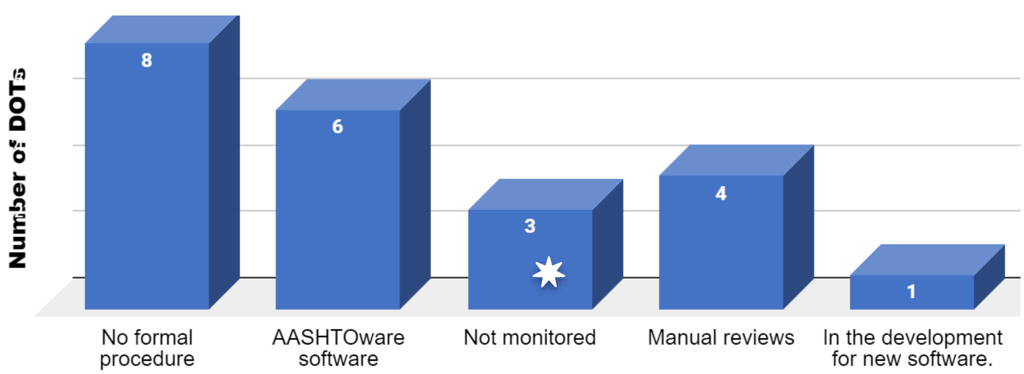


Figure 19. Bid collusion detection procedure

As indicated by the construction cost index, DOTs have been experiencing cost escalation for construction projects. Thus, the respondents were asked whether they had seen an increase in unit bid prices. Except for Caltrans DOT, all DOTs in the survey experienced a price increase (see **Figure 20**). Furthermore, one question is posed to gain an understanding of the cause of the price increase, i.e., What does your agency primarily attribute the increased unit bid prices to? Table 17 in APPENDIX E tabulates the various factors driving cost inflation as reported in the survey. Most DOTs in the survey attributed the cost increase to the supply chain disruption and shortages, either material or labor. The pandemic is claimed to be the primary reason for supply chain disruption and cost escalation in recent years. Florida DOT believes the price increase is attributed to the market condition, and North Dakota and Mannie DOT indicated the low-level competition partially causes it.

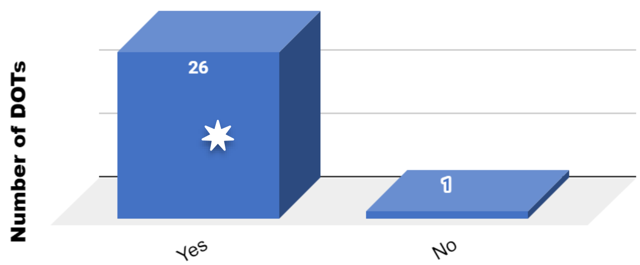


Figure 20. Increase in unit bid prices

2.4.3.1. Follow-up survey and results regarding bid evaluation

State DOTs established their own criteria and procedures for evaluating construction bids. The national survey participants did not provide details on their specific criteria, such as tendency monitoring, unbalanced bid analysis, and competition evaluations. Consequently, we followed up with their responses by raising four questions to the participating DOTs.

1) What are the specific criteria for determining whether or not bids are reasonable?
2) What software do you use for determining bidding tendencies? What analysis do you perform?
3) What specific criteria and analysis do you perform for an unbalanced bid review?
4) What specific analysis is performed to detect collusion?

Iowa DOT reported a comprehensive list of factors determining **whether bids are reasonable when over the engineer's estimate**. These factors include 1) sufficient competition, 2) emergency and safety projects, 3) re-letting could not likely result in a low bid, 4) an error in EE, and 5) awarding the contract is in the public's best interest. We solicited more information on their reasonable bid evaluation criteria in the follow-up survey. For example, sufficient competition is turned out to be determined by the FWHA guideline, i.e., the number of bids and percentage difference of awarded price from the engineer's estimate. They further evaluate the cost saving of re-lettings by 1) changing pay items, 2) changing the project scope, 3) project repackaging, 4) project period adjustments, and 5) project delay. In summary, the bids are believed to be reasonable when 1) there are no improvements in bidding competition in re-letting and 2) the project is urgently needed.

Fourteen DOTs indicated they monitor bidder tendencies in the national survey. Among them, ten use AASHTOWare software, such as Data Analytics, BAMS, and DSS. As revealed by the research team's literature review and indicated by state DOTs, AASHTOWare software Data Analytics is still in the development phase. The bidding tendencies are usually monitored by observing 1) the bidder's win/lose ratio, bidding activities in regions, and swapped patterns in winning the project, as shown in **Figure 21**. Some indicators and patterns that deserve attention include 1) identical bids, 2) win/loss patterns, and 3) repeating patterns (see **Figure 22**). On the other hand, this result justifies the tendency monitoring method and tool developed in this study, described in Chapter 3.

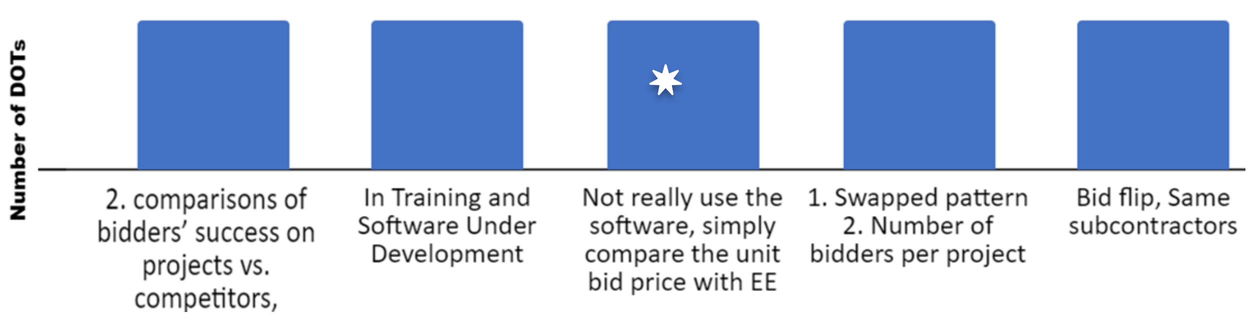


Figure 21. DOTs' bidding tendency monitoring: procedure

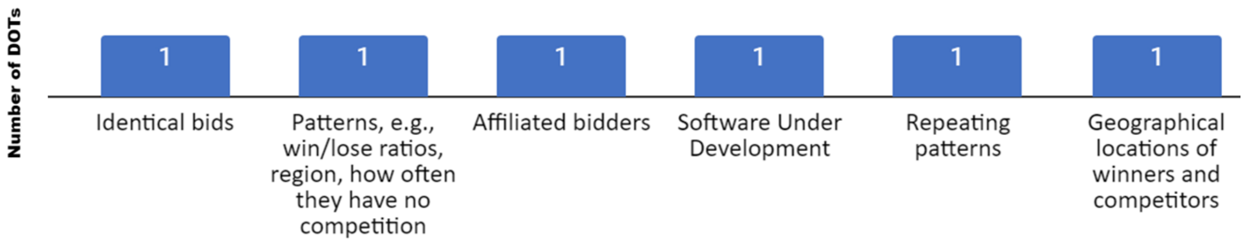


Figure 22. DOTs' bidding tendency monitoring: indicators/patterns

Figure 23 presents the summary of DOTs' unbalanced bid analysis drawn from the follow-up survey of selected state DOTs. The manual review is the most common practice. For example, 11 state DOTs manually compare the unit prices of pay items line by line (i.e., pay item by pay item). High price differences, e.g., 10%, and up to 50%, are indicators of unbalanced bids. When high price differences are identified, DOTs will further compare the prices with historical price trends; verify the quantities; then do a bid flip analysis. The bid flip analysis is to see whether bidders' ranking will change when quantities change.

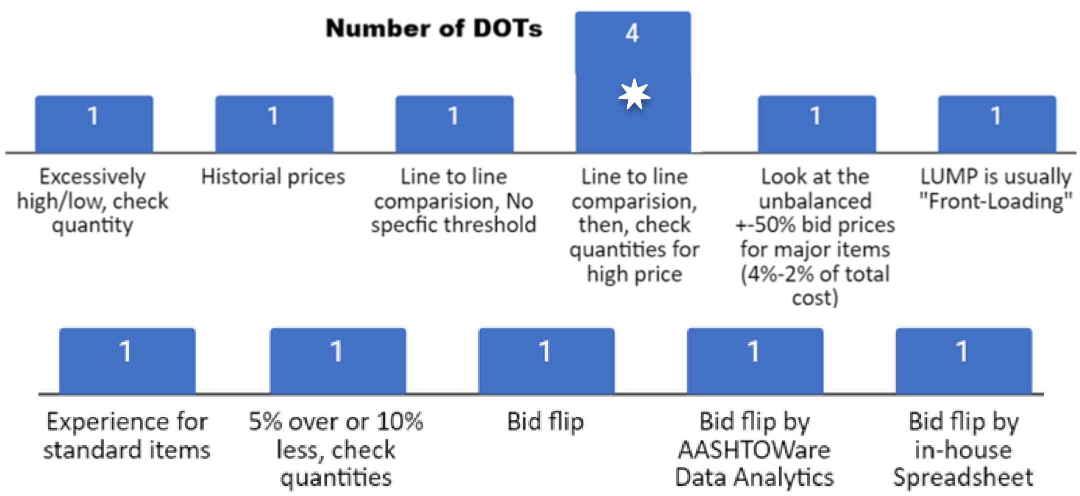


Figure 23. DOTs' unbalanced bid analysis: indicators/patterns

In summary, DOTs usually use different thresholds for the price difference. When there is a significant price difference, they do the quantity verification to avoid materially-unbalanced bids. Also, pay items creating the opportunity for advance payment (i.e., a concern for "front-loading") are flagged. The pay items are those that can be completed at the beginning of the construction work, and their prices are excessively high.

2.4.4. Bid competition assessment

Another significant area in construction procurement and bid evaluation is the level of competitiveness of bids. One of the main purposes of competitive bidding is to encourage competition among the bidders so that the owner agency could benefit from low construction cost, high quality, and shortened project duration. DOTs usually need to assess the level of competition for their construction projects and make efforts to improve the level of competition. There are various methods in competition evaluation.

In the survey, the respondents were given a short-answer question to describe what criteria they use to determine adequate competition. The most widely-used measure is the number of bidders used by 9 DOTs, as shown in **Figure 24**. Most DOTs strive to get at least three bidders, which is considered competitive (see **Table 18** in APPENDIX E).

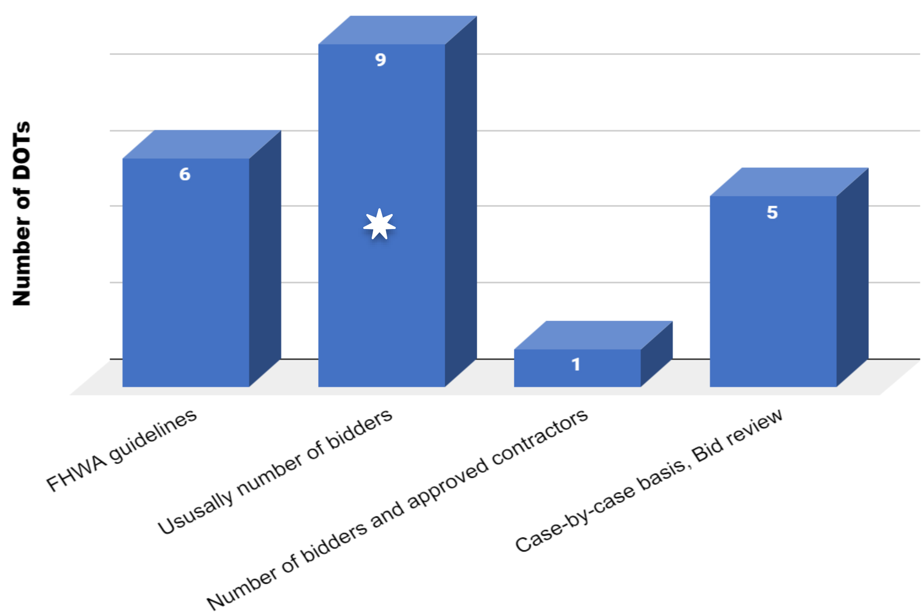


Figure 24. Criteria for adequate competition

Six DOTs adopt the FHWA's guideline on Preparing Engineer's Estimate, Bid Reviews, and Evaluation to assess the competition, as shown in **Table 19** of APPENDIX E. The remaining respondents consider the number of bidders along with other factors, such as 1) plan holder list, 2) available approved contractors, 3) particular project conditions, and 4) geographical location. Montana DOT also considers expert judgment in the competition evaluation (see **Table 20**, APPENDIX E). A comprehensive case-by-case review is preferred by Missouri DOT, Caltrans DOT, Maine DOT, Minnesota DOT, and Montana DOT. Other factors are usually considered to justify the competition level when the number of bids is less than three.

When the level of competition in competitive bidding is not sufficient, state DOTs follow specific guidelines to reject or award construction projects. The guidelines describe when the bids should be rejected or awarded in general. For example, most DOTs (in **Table 21**, APPENDIX E) will reject the bids if they believe the re-letting at a different time and/or re-packaging of the projects will encourage competition, e.g., more bidders or lower prices. Several strateties will be carried out to improve the competition in re-leting, such as soliciting information on why contractors did not bid and revising the projects accordingly (in **Table 2223**, APPENDIX E). Otherwise, the winners have to justify the **reasonableness** of their bid in terms of the bid prices. The Engineer's Estimate is often used as the first criterion in the justification. When the bid price is within 10% of EE, the bid is considered to be reasonable. A cost justification will be needed when the number of bids is fewer than three and the bid price is more than 10% higher than the Engineer's Estimate. Otherwise, a reasonable winner can be selected for the award, as shown in **Table 23**. Encouraging competition in re-let

DOT	Procedures for Encouraging Competitions
Mississippi	Typically single bidders with more than 10% over the state estimate are rejected and re-bid. Often we make **changes to the project** or delay the re-bid to a more favorable time. In those limited markets, there is a limit to how much work any one contractor can bid and complete.
Wyoming	Based on percentage over/under Engineers Estimate (which considers the number of prospective bidders). Non-bidding contractors will be **surveyed** to verify why they decided not to bid. If a change can be made in the proposed project to accommodate more bidders, the Commission may reject bids to make said changes and re-let.
Idaho	We may call contractors on **the plan holders list to see why they did not bid**. We may adjust the work window to the next season or allow for more flexibility for the contractor. We will look at our proposal to see if there is anything that might limit contractors from bidding. Often, **the 95% Idaho Resident preference** is the only reason that **out-of-state contractors** do not bid on state-funded contracts. We may change it to federal, in rare instances.
Tennessee	We make sure that the **advertisement** is in multiple locations and sent to the Tennessee Road Builders Association for a more widespread competition area. We also provide alternates with different work types in a geographic area that may be on the border of a known single bid area.

Table 2322 of APPENDIX E.

The respondents were then asked whether the agency usually obtains adequate competition for construction projects by the criteria. All respondents, except Iowa DOT, have sufficient competition for their construction projects (see **Figure 25**).

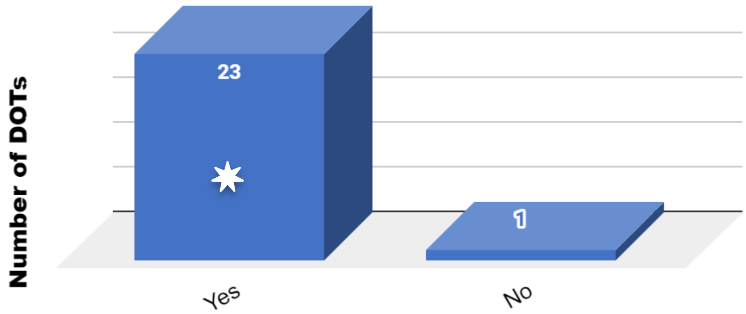


Figure 25. Sufficient competition (Y/N)

In terms of the average number of bids per project, sixteen DOTs receive about 4 to 6 bids, while the other nine DOTs only have 1 to 3 bids per contract (see **Figure 26**). It should be noted that six DOTs do not prequalify contractors. Among those six DOTs, NYS DOT, Caltrans DOT, Mississippi DOT, and LADOTD DOT reported that they, on average, have about 4 to 6 bids per contract; the other two (e.g., Minnesota DOT and Idaho DOT) have 1-3 bids per contract. It implies that prequalification actually does not reduce the number of bids and does not discourage the competition.

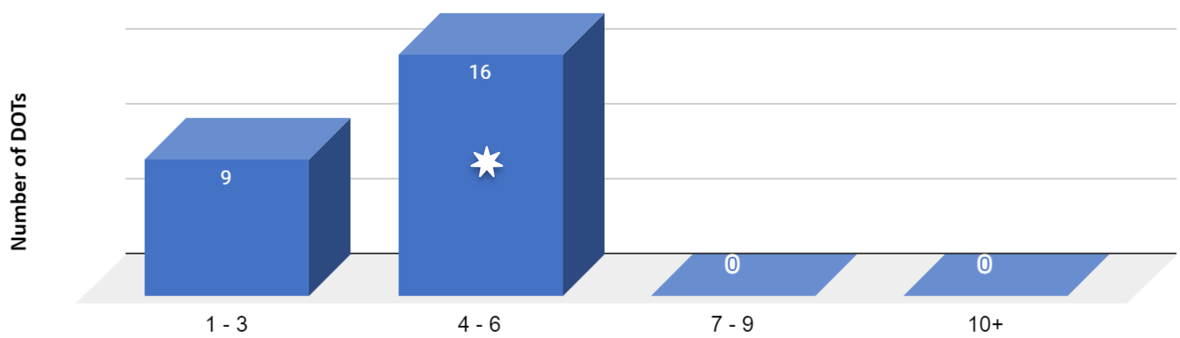


Figure 26. The average number of bids per contract

2.4.5. Bid information release

The survey also sought to determine what information is released to contractors before and after bidding. A multiple-choice question was asked to the respondents about what information will be released to prospective bidders prior to bidding. Sixteen DOTs provide a range of the estimated project cost to prospective bidders so that they can better understand the project size (see **Figure 27**). Twelve DOTs make a practice of disclosing the identities of approved bidders (i.e., the bidder list). The average unit bid price of the first three bidders for the historical projects in the past three years is given by eight DOTs. Four DOTs actually disclose the historical unit price of the Engineer's Estimate to prospective bidders: Minnesota DOT, Oregon DOT, Utah DOT, and Texas DOT. Only **Texas DOT** and **Caltrans DOT** provide pre-bidding Engineer's Estimates for total project cost to prospective bidders. It should be noted that MDOT also releases the Engineer's Estimates for total project cost before bidding.

As a common practice, three pieces of information are usually released to prospective bidders: (1) a range of the estimated project cost, (2) average unit bid price from bidders (e.g., the first three low bidders) in previous lettings, and (3) identity of approved bidders or bidder list.

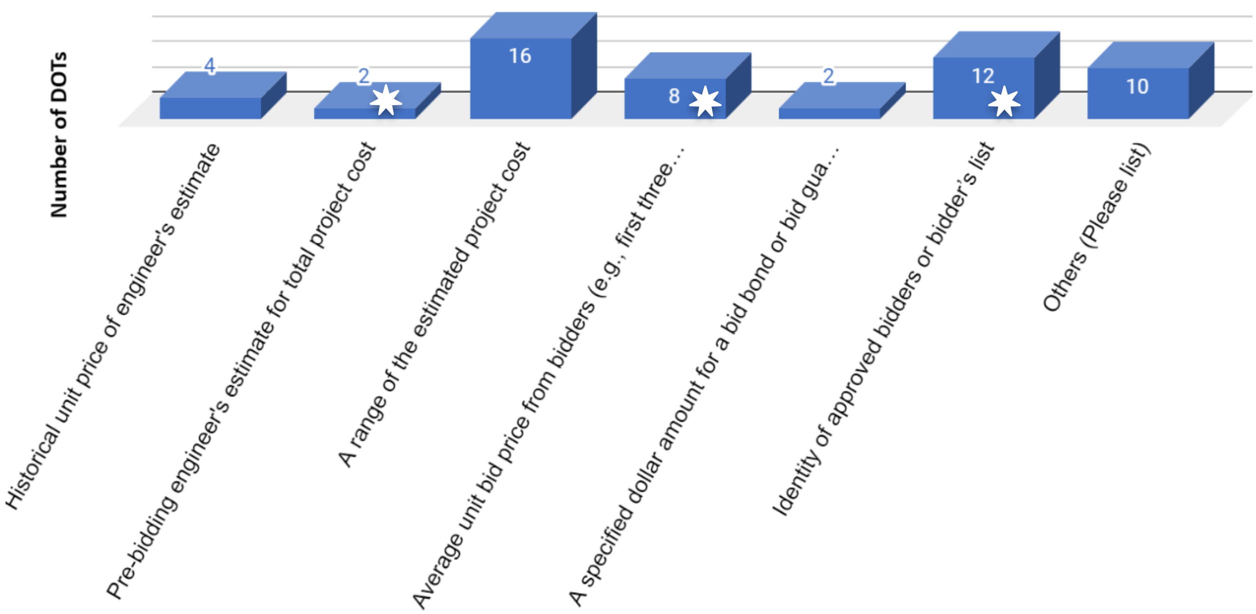


Figure 27. Information released prior to bidding

The other information in **Table 24** (in APPENDIX E) is also released before bidding. For example, Texas DOT provides the line item price of the Engineer's Estimate (which turned out to be a wrong response in the follow-up survey). Florida DOT releases 'Total authorized budget,' another form of the Engineer's Estimate for the total cost. 'Total authorized budget' sheds light on the DOT's project cost expectation. Several DOTs also disclose plan holder lists to the bidders.

After bidding, most DOTs make all bidders' identities and unit bid prices public, usually in the form of bid tabulation. As for Engineer's Estimate (See **Figure 28** and Table 25), fourteen DOTs post total project cost, while nine DOTs give the unit price of each line item. This practice provides the opportunity for contractors to collect each pay item's unit price for future use.

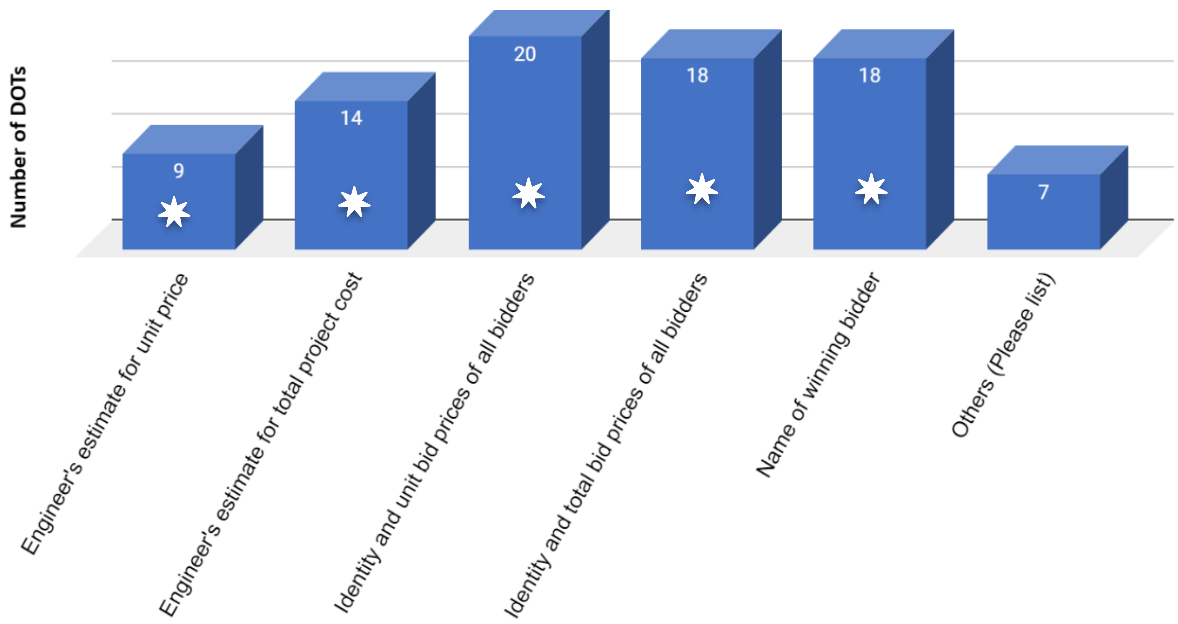


Figure 28. Information released after letting

FHWA's Preparing Engineer's Estimate, Bid Reviews, and Evaluation guidelines suggest keeping the Engineer's Estimate confidential. This is because the nondisclosure of the Engineer's Estimate could, to some extent, help to prevent bid collusion. In the survey, sixteen respondents reported that they have regulations regarding the nondisclosure of the Engineer's Estimate (see **Figure 29**). These DOTs usually do not publicize the Engineer's Estimate. These regulations restrict the release of the Engineer's Estimate.

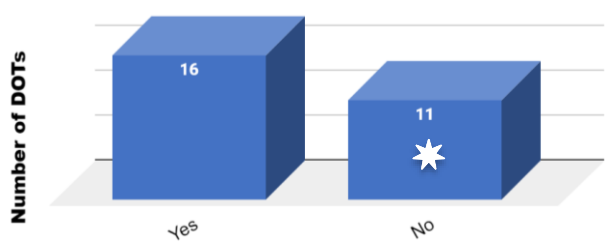


Figure 29. Regulations regarding the disclosure of the Engineer's Estimate (Y/N)

2.4.5.1. Follow-up survey and results regarding information release

Throughout the multiple-choice selection questions, the national survey clearly showed the information released by the participating DOTs before and after the bidding. Some state DOTs did mention other details that they provided to bidders. For example, Texas DOT indicated they provide "Line item engineer's estimate" before bidding. However, FHWA suggests this information should be confidential from the bidders. Thus, Texas DOT was followed up to confirm their response and get further details on their practices.

- Is "Line Item Engineer's Estimate" historical price or the price for the current project?

The follow-up survey revealed that Texas DOT provides 1) Historical unit price of engineer's estimate, 2) Pre-bidding engineer's estimate for total project cost, 3) Average unit bid price from bidders (e.g., first three low bidders) in previous lettings, 4) A specified dollar amount for a bid bond or bid guarantee, and 5) Identity of approved bidders or bidder's list. 'Line item engineer's estimates' is actually not given to the bidders before bidding.

In summary, sixteen provide a range of project costs and bidder's list. Three DOTs give the dollar amount for a bid bond. Bidders could further calculate project costs using the bid bond. Three (e.g., Texas, California, and Michigan DOTs) among 30 DOTs give the total project cost.

2.4.6. Construction estimation methods

Accuracy in cost estimation is always a significant concern for owner agencies. Inaccurate cost estimates may lead to cost overruns and create difficulties in budget planning. In practice, there are three estimation methods: the historical data approach, the actual cost approach, and the combined approach. Among these, the actual cost approach is believed to generate higher accuracy and to alleviate contractor collusion and bid-rigging problems; however, it is time-consuming and demands a significant workforce. This survey also sought to explore which estimation method is widely used by DOTs and how to improve the accuracy of construction estimation with reasonable estimation efforts. The respondents were given a multiple-choice question to indicate which estimation method they used in their current practice. According to the responses in **Figure 30**, the historical data approach is the most widely-used one, and **twelve** DOTs employ this method for cost estimation. Only **four** DOTs—Missouri DOT, Tennessee DOT, Idaho DOT, and one of the anonymous respondents—use the actual cost approach. Others use the combined approach, which is intended to strike a balance between estimation effort and accuracy. In this method, major cost items are estimated using the actual cost method, whereas the minor items can be estimated by a historical data approach to reduce the estimation effort required.

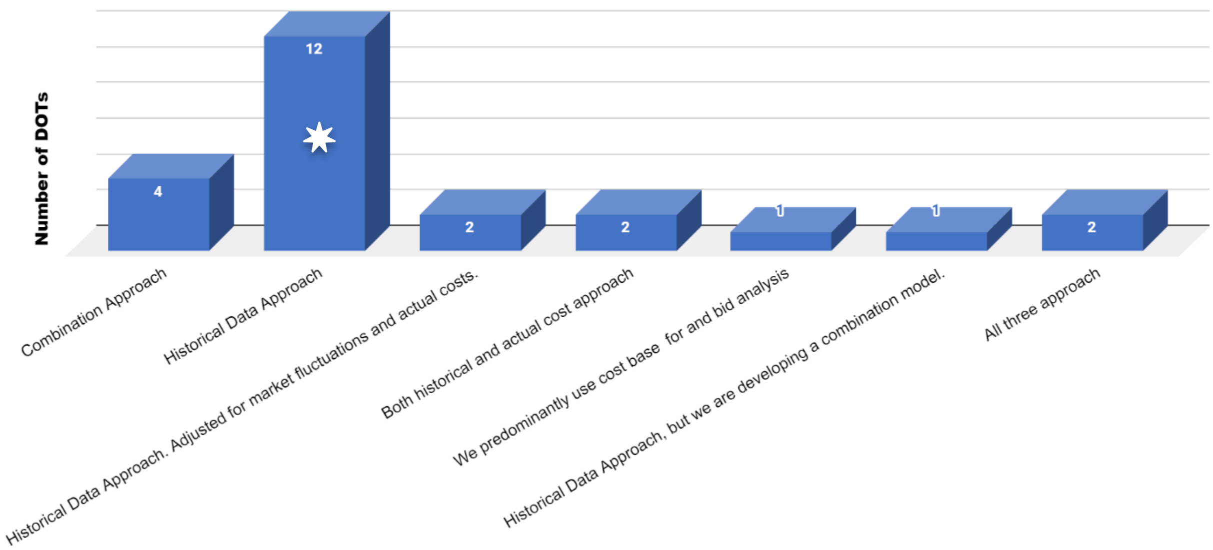


Figure 30. Estimation approaches

The accuracy of engineers' estimates, to a certain degree, depends on the efforts spent on an estimation. Some states are larger than others, and their number of estimates might be different. The workload is a significant factor to consider when DOTs select the estimation method. In the survey, we asked, "How many estimates does your agency prepare monthly?". Ten DOTs have about 20-40 estimates per month, as shown in **Figure 31**. Four DOTs, including Florida DOT, Caltrans DOT, West Virginia DOT, and Tennessee DOT, can do more than 60 estimates per month. We also sought information on their efforts per estimate, estimate accuracy, and the number of estimators. For one estimate, it takes about up to 40 hours, as shown in **Figure 32**. We do see the 160, 4000, and 640 hours. However, it is not reasonable. They may be inputted by mistake.

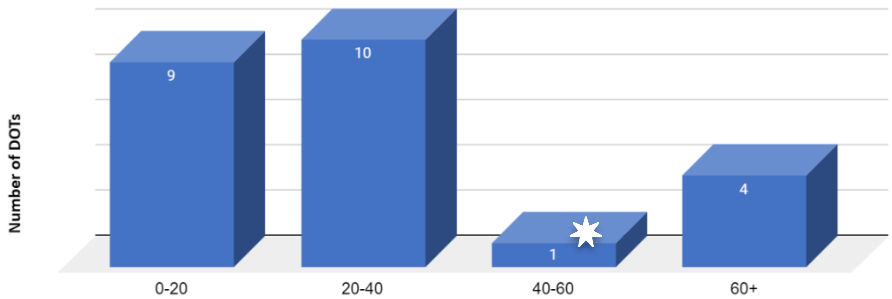


Figure 31. Number of estimates per month

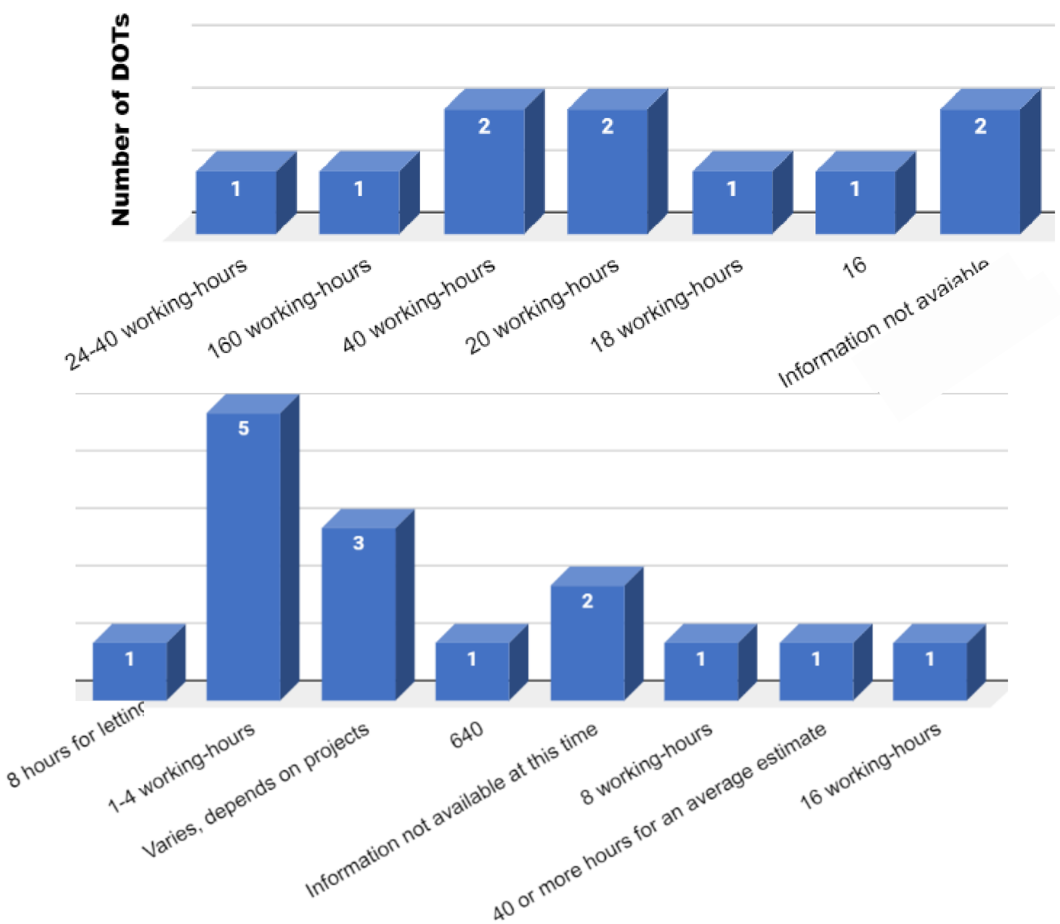


Figure 32. Number of working hours for one estimate

DOTs usually have 1-4 estimators (see Figure 33). Idaho has up to 10 estimators, even though they have up to 20 estimates per month. Minnesota DOT, Wisconsin DOT, Utah DOT, and Iowa DOT have four estimators, and their monthly estimates are 0-20, 20-40, 2-40, and 40-60, respectively.

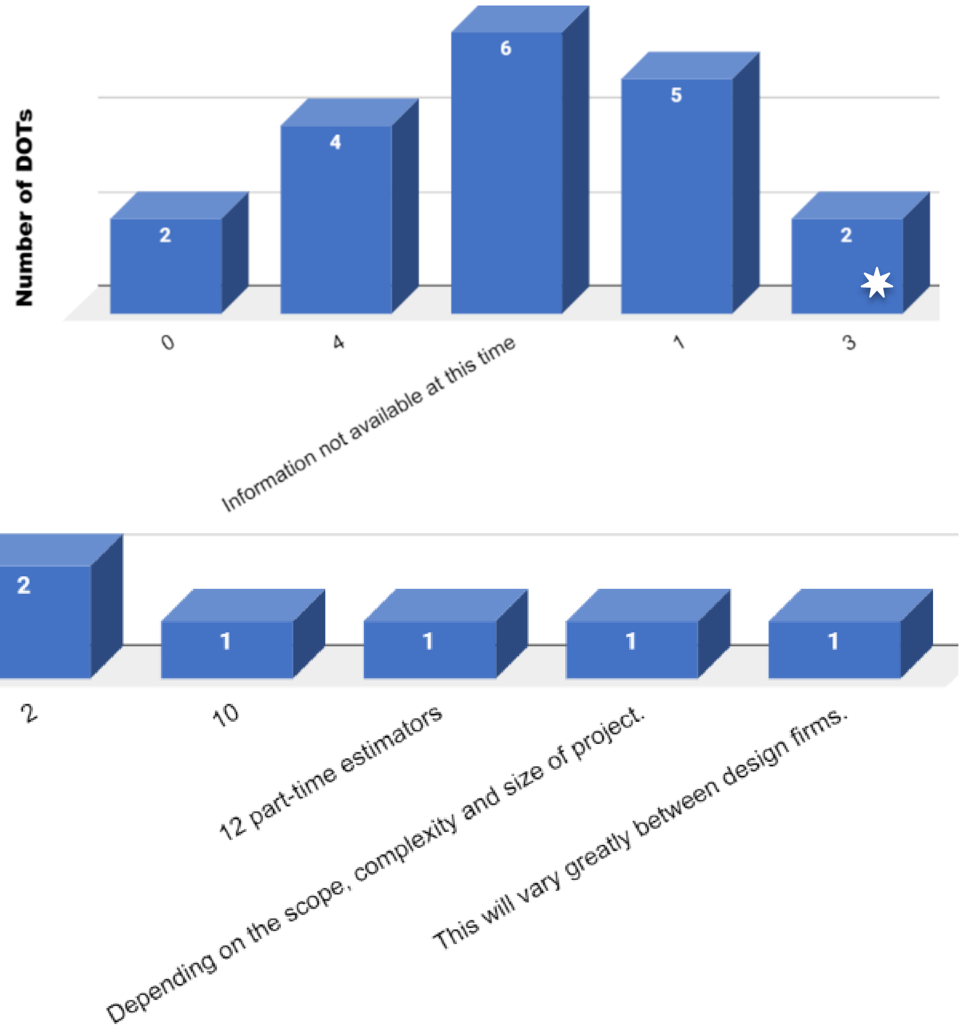


Figure 33. Number of full-time estimators

Given the heavy workload in cost estimation, the historical-based data approach is still the primary method for preparing an engineer's estimate. The accuracy of an engineer's estimate is usually measured by its comparison with the lowest bid. In an attempt to identify the estimation accuracy, we asked the participating DOTs to describe your agency's typical low bid results compared to your engineer's estimates. **Table 26** in APPENDIX E tabulates the responses, showing that 17 DOTs are in the acceptable range specified by FHWA, i.e., 50% of the projects within 10% of EE. These 17 DOTs use different estimating methods. Two DOTs reported they were not in the acceptable range with their historical data-based estimation method.

We also sought the estimate accuracy from DOTs by raising, "How close does the final actual construction cost track to the engineer's estimate and initial contractor bid price?" The responses are summarized in **Table 27**, APPENDIX E. Final costs are in the range of 102-110%

of the low bids for most DOTs, and Iowa sometimes seems to have a significant cost overrun. This finding implies that the historical data approach, in general, could generate engineer's estimates with acceptable accuracy. It should be noted that the cost overrun herein means the final project cost is higher than the contract price (e.g., awarded price or the bid price of the selected contractor). It is not the same as the bid price is higher than the engineer's estimate, as shown in **Figure 34**.

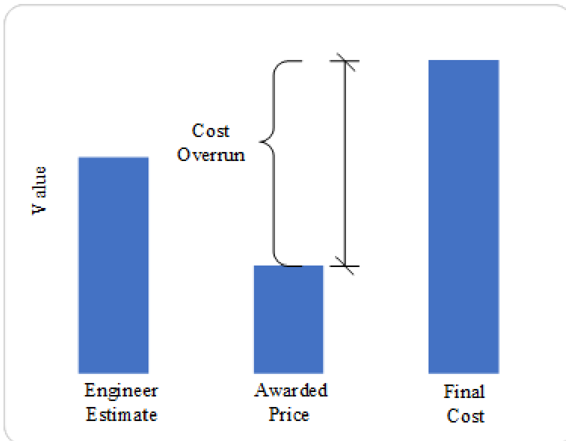


Figure 34. Cost overrun definition

One challenge in preparing an engineer's estimate is related to the cost estimation of lump sum items. One of the reasons is that LSUM items are usually used to account for the cost of construction activities that are difficult to measure. We solicit information regarding LSUM items in the survey, e.g., what items are bided using LUSM items. Twenty-six DOTs use LSUM items, and the other participating DOTs did not provide their responses to the question (see **Figure 3534**). In terms of criteria for Lump-Sum items, the standard specification is emphasized by state DOTs (see **Table 28**, Appendix E). Their standard specification clearly defines the LSUM items.

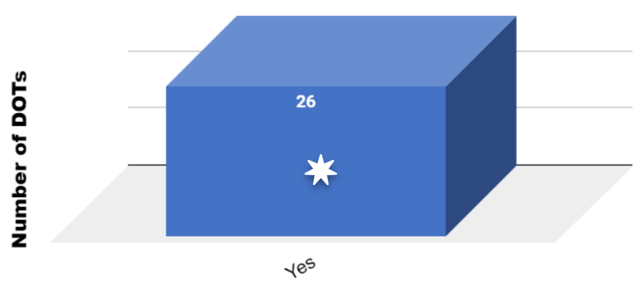


Figure 35. Use of LSUM items (Y/N)

Figure 3635 shows the typical LSUM items used by DOTs and the number of DOTs that use them. The most common LSUM item is mobilization, used by 15 DOTs, and traffic control is the second most common one with 10 DOTs. Six DOTs use LSUM items for clearing and grubbing. The LUSM items are defined to account for the cost items that are hard to measure.

Figure 36. Count of DOTs for LSUM items

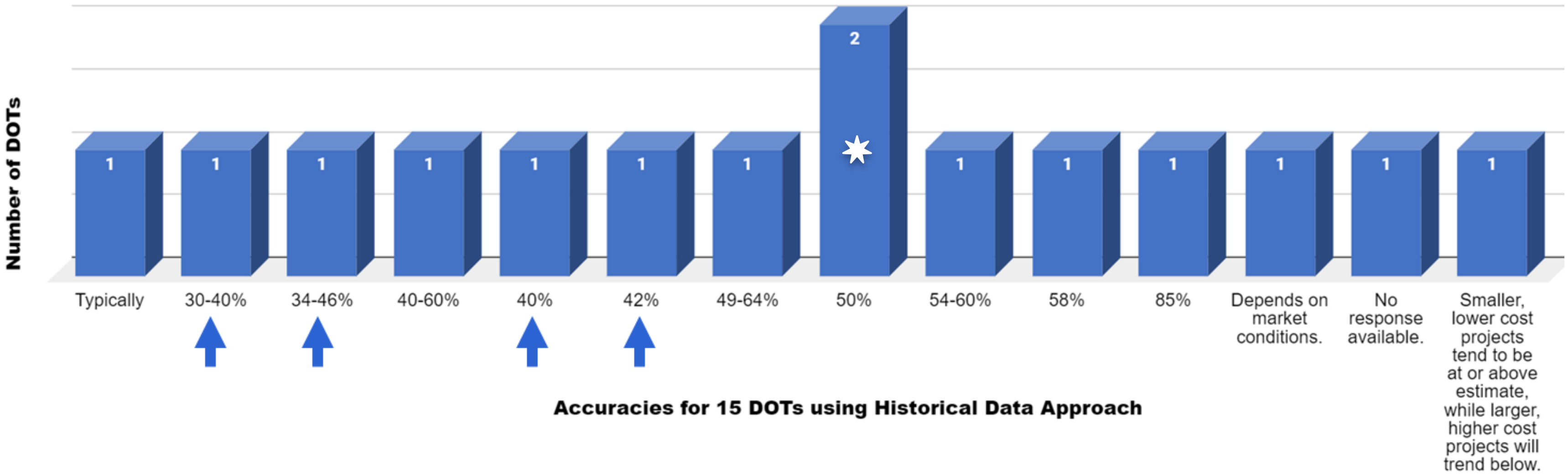
2.4.6.1. Follow-up survey and results regarding estimation methods

One of this study's research objectives is to get insights into the cost-effectiveness of cost estimation methods. The follow-up survey further solicits information regarding the efficiency or accuracy of three estimating methods. Three follow-up questions were raised to the participating DOTs, as follows.

1) How many equivalent man-hours are required to prepare one estimate, using the actual cost approach or historical data approach, respectively? What percentage of the low bids fall within plus or minus 10% of the engineer’s estimate?
2) What percentage of the construction bids does the lowest bid fall within or minus 10% of the engineer’s estimate when utilizing the actual cost-based or historical data approach, respectively? What percentage of the low bids fall within plus or minus 10% of the engineer’s estimate?

Figure 3736 summarizes the follow-up survey results regarding the historical data approach. The historical data approach has lower accuracy, as 4 out of 15DOTs reported less than 50% of their projects are not in the acceptable range of 10 percent difference from EE. Regarding estimating efforts, most DOTs take about 4 hours to do one estimate. However, it should be noted that the estimates can vary from a few bid items to hundreds of bid items, and estimates with the mid-range number of bid items (50-100) can vary in preparation time, as indicated by Caltrans DOT. The same estimating approach (i.e., historical data approach) takes Idaho DOT 4 hours up to 3 days to prepare one estimate. It is challenging to determine the man-hours to prepare an estimate. The survey results should be taken with caution.

Iowa DOT reported using the automated item pricing functionality in AASHTOware PROJECT Preconstruction only takes moments for the system to generate prices; however, some pay items without sufficient price histories need to be estimated manually. Lump sum items always require more review. Complex projects with numerous items in these categories may take several hours to prepare and review. In addition, there are extra efforts required to maintain the price history database.



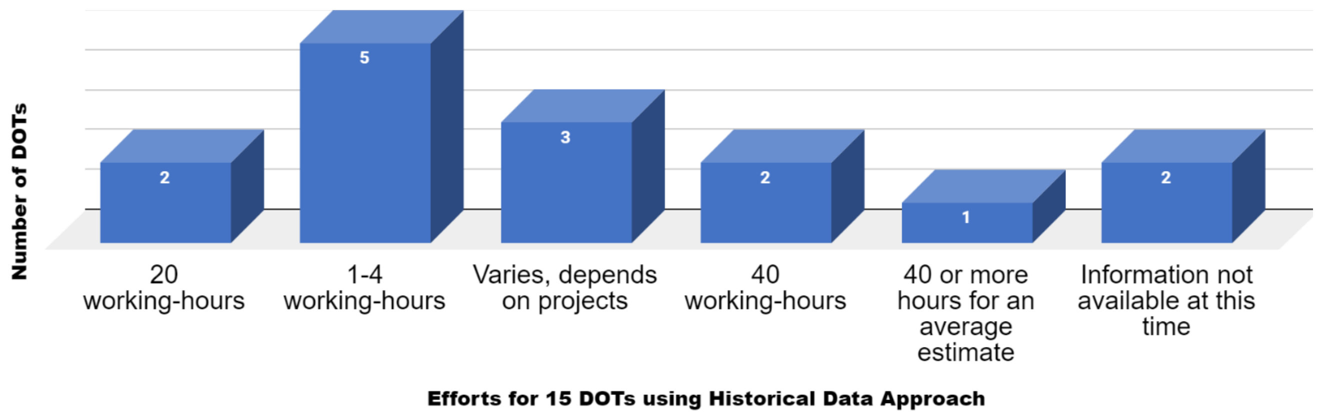


Figure 37. Historical data approach: a. Efforts and b. Accuracies

Two DOTs using the historical data and actual cost approaches reported their accuracy is always in the acceptable range. The historical data and actual cost methods take about 8-16 hours to prepare one estimate (see Figure 3837). The combination approach is used by Florida DOT, Oregon DOT, Utah DOT, and FHWA. Their accuracy is also acceptable according to the FHWA's estimation accuracy guideline. However, the combination approach demands more working hours in a range of 18-160 hours.

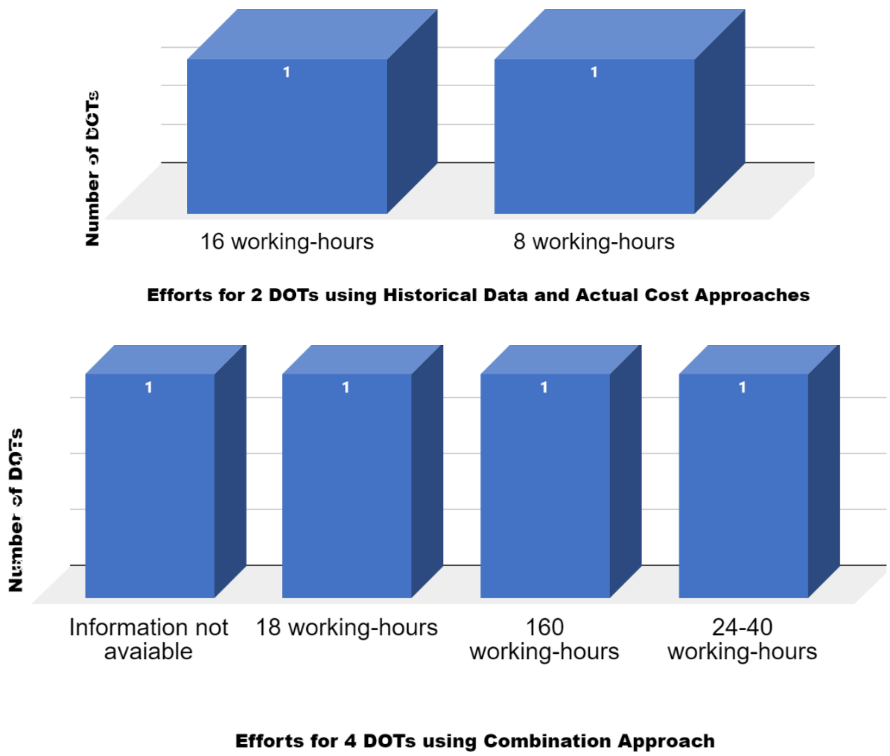


Figure 38. Estimating efforts: Actual cost approach vs. Combination approach

2.4.7. Bidding and estimating traffic control

Traffic control and maintenance is another concern of state DOTs, as it is challenging to estimate and bid this work precisely. This study thus aims to provide a method for bidding and estimating traffic control and maintenance. The national survey was designed to solicit information regarding this matter. The participating DOTs were asked to briefly describe how traffic control and maintenance are estimated and bid. The survey responses are tabulated in **Table 29** (APPENDIX E) and Figure 3938.

In terms of estimating, ten DOTs look at the historical data to determine a percentage on top of the total bid amount and then use the percentage for estimation, such as Mississippi DOT, South Carolina DOT, Wyoming DOT, and Tennessee DOT. Alternatively, Arkansas and Wisconsin DOTs estimate traffic control and maintenance using a fixed percentage (e.g., 2-4%). The other ten DOTs, including Maine, Oregon, North Dakota, Idaho, West Virginia, Missouri DOTs, and FHWA, use the traffic control plan for a detailed estimation, i.e., calculating quantities based on the plan and then multiplying them with historical unit prices.

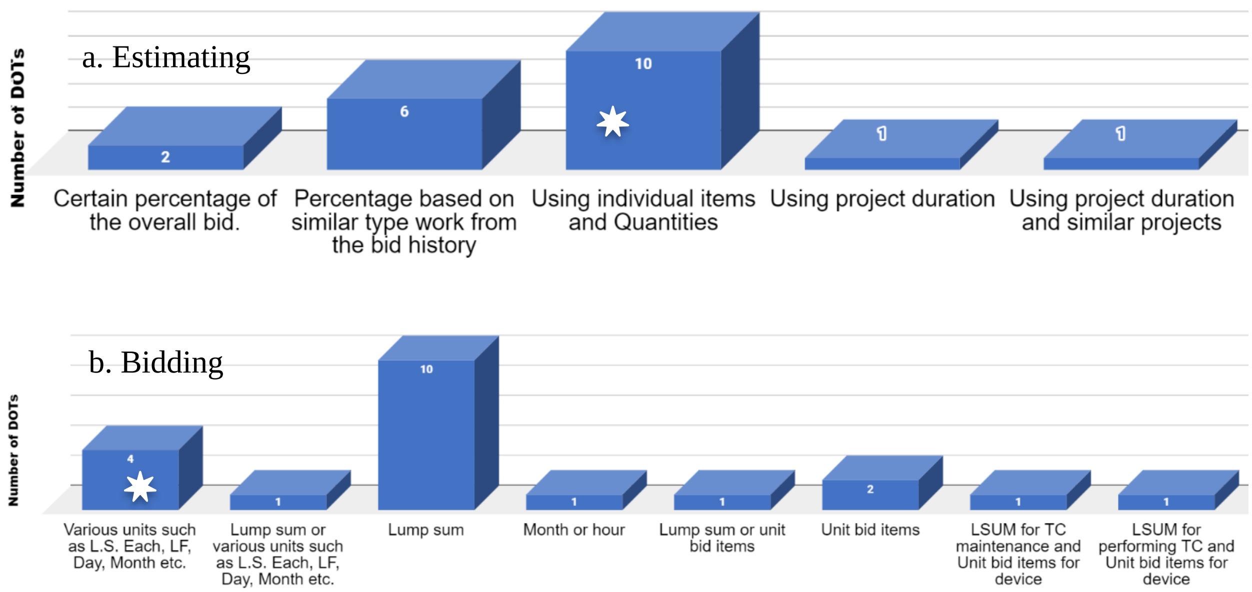


Figure 39. Traffic control and maintenance: a. Bidding, b. Estimating

In terms of bidding, three typical methods used by DOTs include 1) unit bid items, whose quantities are prepared by DOTs and whose unit prices are bid by contractors, 2) LSUM items, which require the contractors to bid on the total amount, and 3) combination of both. Ten DOTs use individual items and quantities from the traffic control plan to estimate traffic control and maintenance, representing the most prevailing method. Six DOTs, on the other hand, estimate the cost via a percentage. The percentage here is determined based on the work type of similar work in the past and bid history. Alternatively, two DOTs take a fixed percentage of the estimated total project amount, e.g., 2-4%. The remaining DOTs use the project durations along with a daily rate.

Following this, the participating DOTs were asked to describe the basis of payment for traffic control and maintenance and the payment schedule. Eighteen DOTs use the percentage of work completed to pay for the traffic control and maintenance work (see **Table 30** in APPENDIX E). The others make the payment based on the completed quantities, as they use the unit bid items in bidding this work.

In the last part of the survey, the survey participants were asked about Mobilization, General Conditions, and/or Safety-Security, i.e., do they have any standard items for those work? Twenty-four DOTs have standard pay items for mobilization, and 12 DOTs do not use pay items for general conditions and safety-security, as shown in **Figure 4039**. Most DOTs established a payment schedule for mobilization. For example, Minnesota's first progress payment covers 25% of the estimated amount; 50% will be paid when 10% of the project is completed, and the remaining will be paid when the contractor completes 25% of the project. The detailed responses regarding the payment for mobilization, general conditions, and/or safety-security are tabulated in **Table 31**, Appendix E.

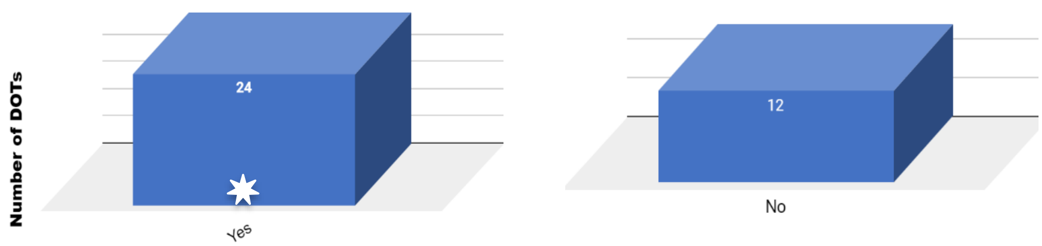


Figure 40. Standard items for mobilization (left) and general conditions (right), Y/N

2.4.7.1. Follow-up survey and results regarding traffic control

Some state DOTs, such as Maine DOT, North DakotaDOT, and so forth, use unit bid items for traffic control and maintenance. They are followed up to obtain more specific information on their practice related to traffic control. One question was further raised to the participating DOTs to solicit more information on their traffic control, i.e., how do you estimate traffic control and maintenance based on a detailed traffic control plan?

Iowa DOT responded, "We estimate traffic control as either a lump sum or as individual items and quantities basis. When the project is estimated using individual items and quantities, then a detailed traffic control is done for bidding. When it is estimated using a lump sum method, the detailed traffic control may or may not be done based on the needs of the project." Maine DOT asks the contractor to supply the traffic control and erosion control plans between award and construction begin.

Chapter 3. BIDDING TENDENCY MONITORING

3.1. INTRODUCTION

As revealed in the national survey, fourteen DOTs do have specific procedures to monitor the contractor's bidding tendencies. State DOTs use AASHTOWare software to review the bidder's win/loss ratio. In particular, DOTs look for specific patterns (e.g., swapped/repeating patterns) in the bidder's activities. One of the objectives of this study is to propose an effective method of graphically-aided bidding tendency monitoring. In this respect, an MDOT internal survey was conducted to identify the potential of GIS in bidding tendency monitoring and to gain an in-depth understanding of the requirements and/or needs of GIS-based bidding tendency monitoring.

3.2. MDOT INTERNAL SURVEY DESIGN AND ADMINISTRATION

The research team developed the questionnaire in such a manner as to solicit responses well aligned with the objectives of the survey. The research team followed the following five steps in the development and administering of the survey:

1. The questionnaire was developed based on a review of the literature regarding bidding tendency monitoring (see Appendix B).
2. Obtain feedback from the Research Advisory Panel (RAP).
3. Conduct a pilot survey.
4. Finalize the questionnaire based on the findings of the pilot.
5. Distribute the survey with the support of the project manager at MDOT.

The survey was distributed to MDOT representatives via email on August 19, 2021, and we continued to accept responses until September 22, 2021. One reminder was sent out to increase the number of participants. In total, 12 participants from the contract management and estimation units of MDOT completed the survey.

3.3. ANALYSIS OF SURVEY DATA

This survey aims to understand how MDOT could apply GIS in the bidding and estimation practices, especially in bidding tendency monitoring. A question was asked about whether they use GIS in their daily tasks, and all participants indicated that GIS is not used in the current MDOT's bidding practices.

Another question was then asked about how you could use GIS in the daily bidding and estimating activities. None of them answered they would use it, and one suggested that GIS may be more cumbersome to use in bidding and estimation. This implies that the majority did not know how GIS could be applied in their bidding practices. This may be due to the fact that most of the respondents are engaged primarily in bidding and estimating and are unfamiliar with GIS applications/tools, and that GIS is too complex for non-GIS specialists to use.

Furthermore, we asked how the GIS tools could be used for bidding tendency monitoring, particularly whether AASHTOWare Project Data Analytics is currently being used by MDOT for this purpose. Only **two of the twelve** responses reported GIS could potentially be used for (1) post-bid analysis, (2) vendor analysis, and (3) bidding activity visualization. One noted that GIS could merely provide **spatial visualization**.

Given that MDOT is using AASHTOWare Project Data Analytics for the bidding tendency monitoring, a question was posed to participants asking for one sample of bidding tendency reports generated using Data Analytics. One participant provided a price-quantity chart of Item 2050016, and this response indicates that the current bidding tendency monitoring in MDOT is limited to price trend visualization.

The survey results, in turn, suggest that a user-friendly tool would be required to assist MDOT staff in bidding tendency monitoring. Such a tool should satisfy several requirements as follows:

1) Providing spatial visualization of vendor activities
2) Providing spatial visualization of post-bid analysis
3) Easy-to-use for non-GIS specialists.

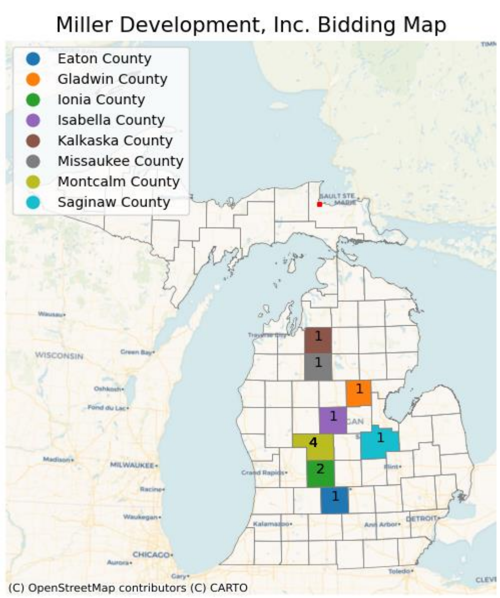
3.4. BIDDING TENDENCY MONITORING TOOL

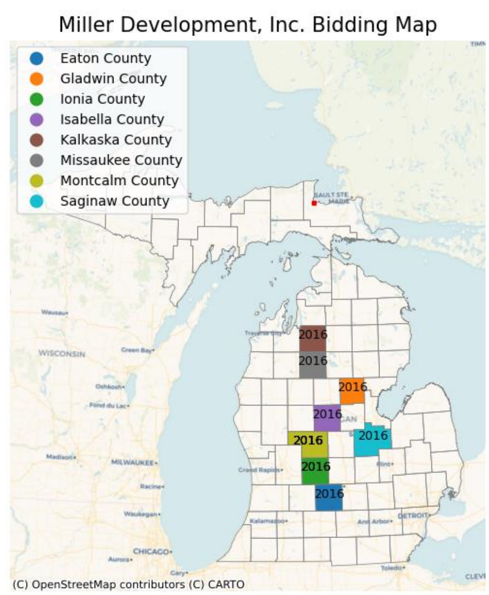
Given the identified needs, the research team developed a post-bid analysis tool that can be used to monitor the bidding tendency. The tool's user manual is attached in Appendix G. The developed tool can automatically generate various maps and charts that assist the users in visualizing the bidding tendency. These maps and charts are summarized in Table 1. Essentially, the bidders' tendencies are systematically monitored in three respects, including (1) their competitors, (2) temporal patterns, and (3) spatial patterns. That is, how the bidder's activity evolves temporally and spatially, as well as against its competitors.

The developed tool also allows the users to visualize the price trends, similar to the one sample of bidding tendency provided by the MDOT staff using Data Analytics. The price trends are described in the unbalanced bid analysis (i.e., Chapter 4), as they are highly related to and can be applied in unbalanced bid detection.

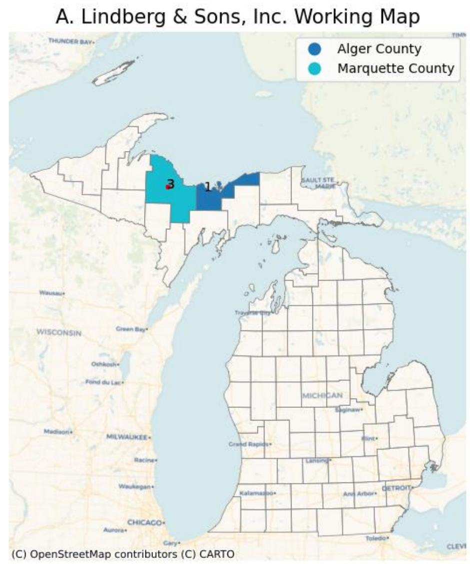
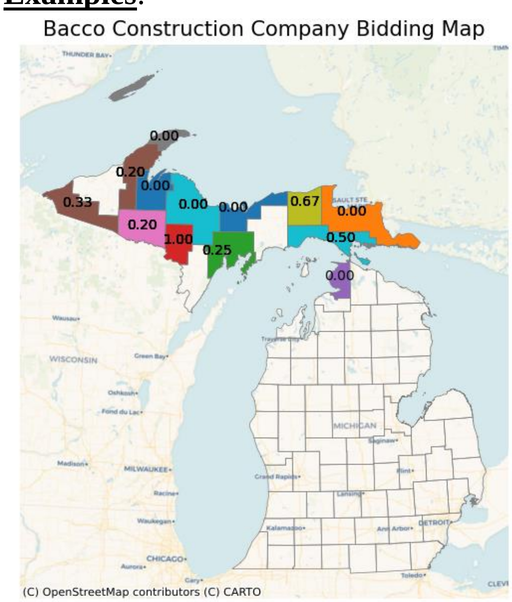
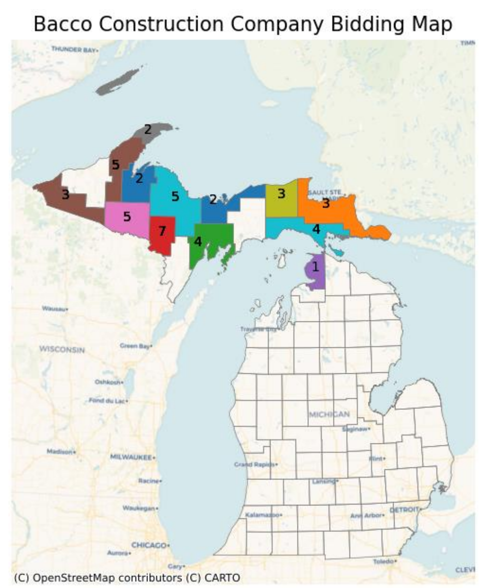
Table 1. Visualization for bidding tendency

<table>
<tr><th>ID</th><th>NAME</th><th>DESCRIPTION</th></tr>
<tr><td>1</td><td>Bidding Activity Map (with time)</td><td>Graphically displays the number of bids of a single selected bidder for each county. The bidder's facility is also shown as a spot. When "Time" is checked, it shows the average time of bidding activities.

<u>Examples</u>:




</td></tr>
</table>

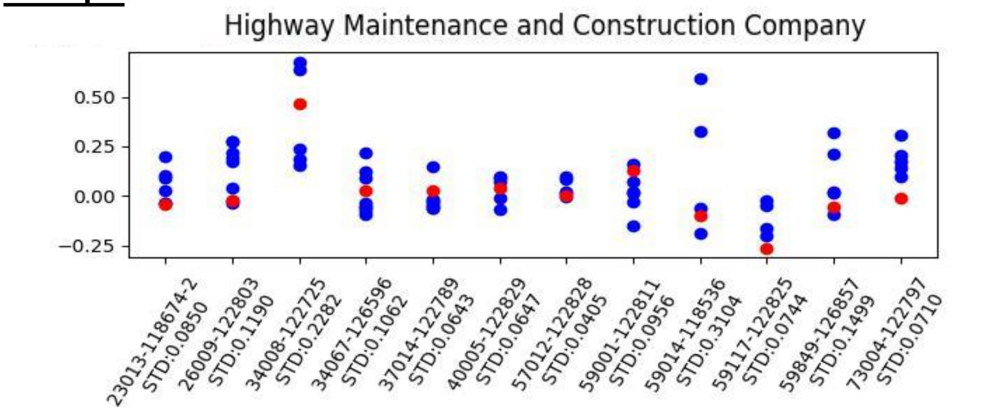
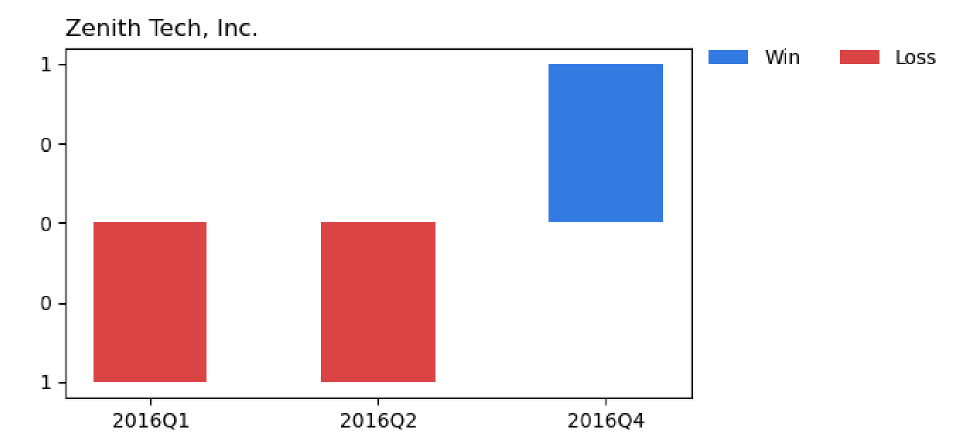
2	Working Activity Map (with time)	Graphically displays the number of wins of a single **selected** bidder for each county. The bidder's facility is also shown as a spot. When "Time" is checked, it shows the average time of the winning activity. **<u>Example</u>**: 
3	Spatial Win/Loss Map	Provide the win ratio of a **selected** bidder for the specific regions. <u>This map can assist in determining whether each bidder's wins appear reasonable for specific regions</u>. **<u>Examples</u>**: 

<table>
<tr>
<td>4</td>
<td>Bidder Competition (Win/Loss) Map</td>
<td>
Provide the bidding win/loss ratios between a single selected bidder and its one or more competitors.

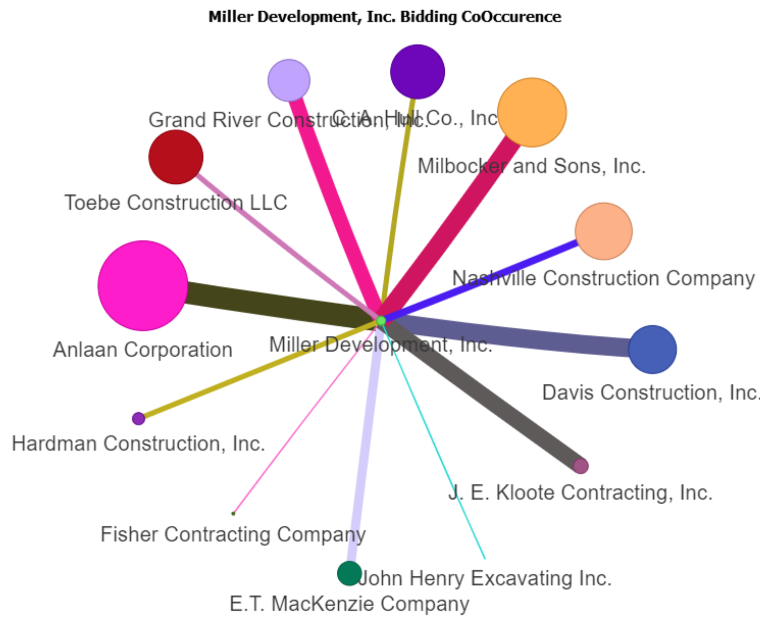
<u>This map can assist in determining whether each vendor's wins versus losses ratio appears reasonable in head-to-head competitions with specific competitors</u>.

<u>Examples</u>:

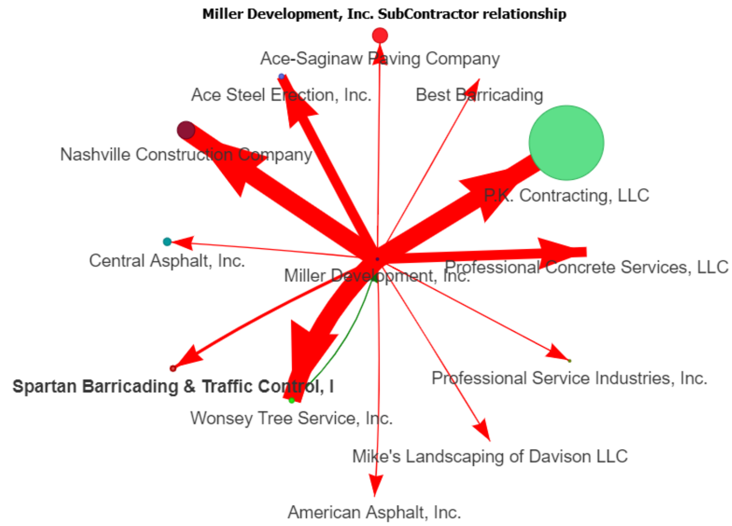
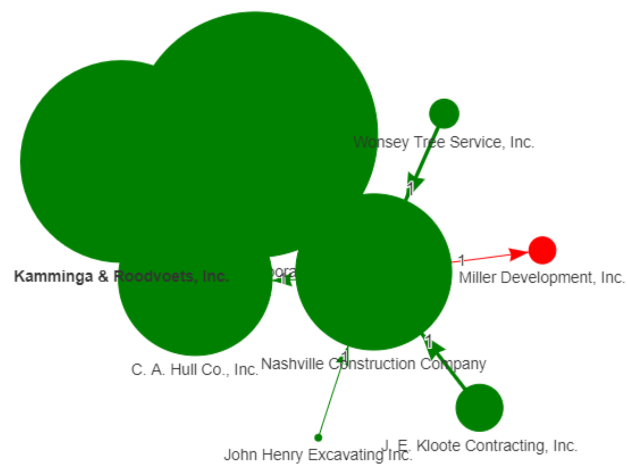

</td>
</tr>
</table>

5	Bid Spread/Variation Over Time Chart	Provides a graphic display of the extent to which the total bid prices of a single **selected** bidder and its competitors diverge from the Engineer's Estimate of the total cost **over time**. The x-axis shows (1) the contract number and (2) the standard deviation (STD) of its bid price differences <u>The bids are not statistically reasonable if the STD is greater than 0.28</u>. The STD can assist in determining whether bid prices appear reasonable, and the bids can then be studied to determine the cause(s) of the deviations. **<u>Example</u>**: 
6	Bidder Win/Loss Over Time Chart	Provides the number of wins and losses for a **selected** bidder over time. <u>This chart can assist in determining the competitiveness of a single selected bidder over time</u>, e.g., which quarter or year the bidder was competitive or non-competitive. **<u>Example</u>**: 

<table>
<tr>
<td>7</td>
<td>Bidding Co-occurrence Map</td>
<td>Graphically displays the statistics of the competing activities of a single selected bidder, e.g., who are its competitors (i.e., nodes), how many bids each competitor has (i.e., node size), and how many competitions (i.e., link thickness) it had with each competitor.

<u>Example</u>:


<u>This chart can determine the specific/main competitors of a selected single bidder</u>; then, whether the bidder's wins versus losses ratio appears reasonable in head-to-head competition with specific competitors can be investigated.</td>
</tr>
</table>

8	Subcontracting Map	Graphically displays the subcontracting activities of a single **selected** bidder, e.g., who are its subcontractors (i.e., **nodes**), how many contracts and subcontracts each contractor has (i.e., **node size**), and how many projects (i.e., **link thickness**) it worked with each subcontractor. **<u>Example</u>**: 
9	Competing and Subcontracting Map	Graphically provides the competing and subcontracting relationship of <u>all historical bidders</u>, e.g., who are later turned to be its **subcontractors** for the **competed projects** (i.e., **nodes**), how many bids each **subcontractor** has (i.e., **node size**), and how many bids (i.e., **link thickness**) the winning vendors subcontracted the work to its competitors. <u>The arrow is pointing to the subcontractors</u>. **<u>Example</u>**:  <u>This chart can identify the bidders who had competition relationships for specific projects while the winners of the projects then subcontracted the work to their competitors. It can be used to identify potential improper bidding behavior.</u>

Chapter 4. UNBALANCED BIDDING ANALYSIS

An unbalanced bid refers to an offer with unusually high or low prices for some pay items that do not reflect the reasonable construction cost. There are a number of reasons why a bidder may practice unbalanced bidding, such as (1) to gain a competitive advantage, (2) to achieve higher profits, or (3) to obtain the payment earlier. In practice, it is challenging for owners to detect unbalanced bids. This is due to the fact that there is no clear boundary between “unbalanced bid” and “balanced bid.” Furthermore, a large number of models have been developed by prior studies to assist contractors in unbalancing bids, such as linear programming models (Stark 1968), Fuzzy Mathematical Programming (Inuiguchi and Ramik, 2000), and a risk-based model (Afshar and Amiri, 2010b).

The widely used method for unbalanced bid detection is to compare the bid prices of pay items with the Engineer’s Estimate or the average bid price of all bidders and screen the price differences using certain criteria, such as ±15% from the Engineer’s Estimate. When the price differences exceed the threshold, the pay items are considered to be unbalanced. As revealed by AASHTO Subcommittee on Construction Contract Administration (2010), MDOT applied a percentage, i.e., a plus or minus 15% from the Engineer’s Estimate, and the threshold value of $1,000 for the difference amount in the comparison. In addition, MDOT checks the bidder’s historical bids for respective pay items as a secondary screening. However, these methods are constrained by the accuracy of the Engineer’s Estimates and cannot effectively detect materially and mathematically unbalanced bids (An et al., 2017).

4.1 UNBALANCED BID DETECTION

In light of the preliminary review of various detection methods and current DOT practices, this study proposed a three-step approach to unbalanced bidding analysis, as shown in Figure 4140. This method consists of (1) an unascertained model for mathematically unbalanced bid detection, (2) a risk-based method for materially unbalanced bid detection, and (3) pay item data visualization to get the insight into pay item prices. To start with, the unascertained model scores the bids to detect mathematically unbalanced bids. The Engineer's Estimate is used as the evaluation criterion to analyze the bid price of pay items in the unascertained model. Following this, a risk-based method is then applied to investigate the impact of quantity variations on the total bid prices and detect materially unbalanced bids. In addition, pay item data visualizations are presented to gain insight into the construction bids. Finally, unbalanced bids can be identified based on synthesizing the results described above. The overview of the unbalanced bid detection method is illustrated in Figure 4140 and is described in detail in this section.

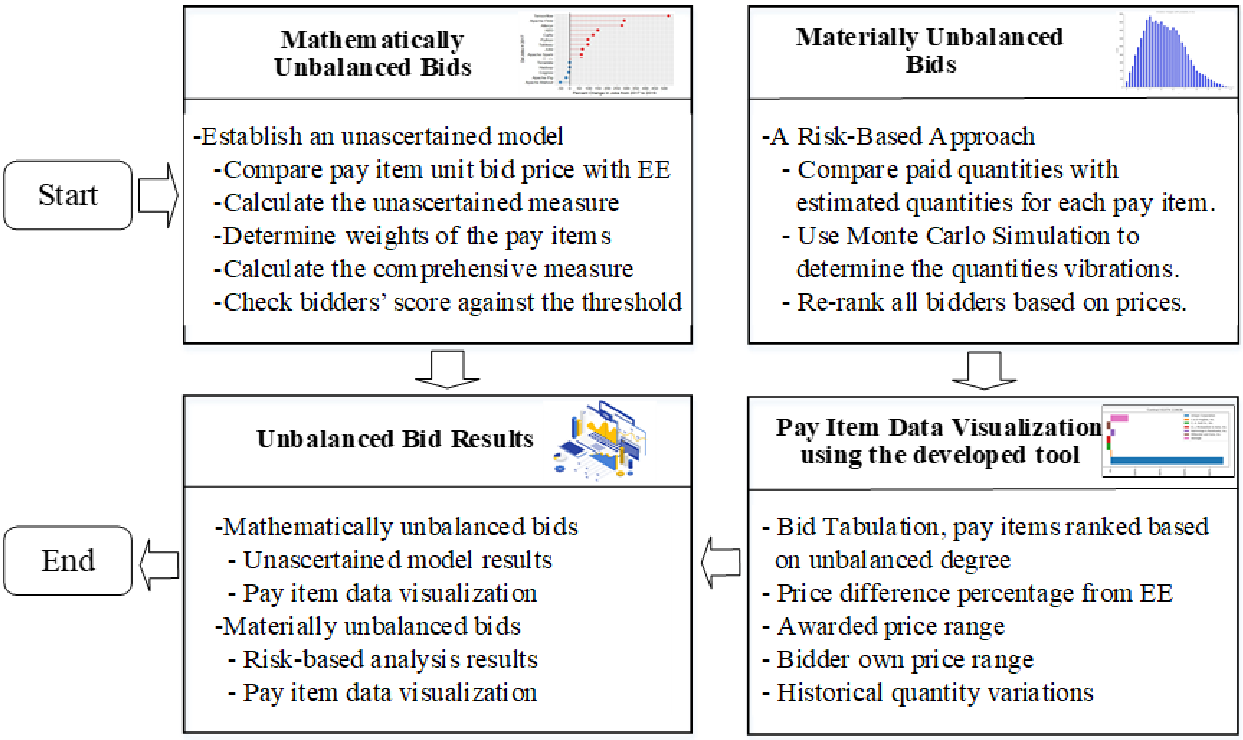


Figure 41. Developed unbalanced bid detection steps

4.1.1 Unascertained model for mathematically unbalanced bids

Theoretically, the unascertained model measures the degree of bidders' bid price deviation from the selected evaluation criterion. When the Engineer's Estimate is chosen as the criterion, the deviation herein is the ratio of the bidder's bid price to the Engineer's estimated price. The unascertained model evaluates the construction bids based on the price deviations and scores them for unbalanced bid detection purposes (An et al., 2018).

To start with, the unascertained model categorizes a bid into five different deviation grades. The five grades include (1) unbalanced (low price), (2) relatively unbalanced (low price), (3) reasonably balanced, (4) relatively unbalanced (high price), and (5) unbalanced (very high price). The degrees of a bid belonging to each grade are calculated using Eq. (2). Then, a score of the entire bid is calculated by weighing the degrees of each grade, as expressed in Eq. (1).

The score of a bid ranges from 0 to 1, and the greater value indicates a more balanced construction bid. For example, the value of 1 implies that all pay items in the construction bids are balanced. When the score for a bid is below a specific threshold (e.g., 0.75), it is considered to be unbalanced.

$$S = \sum_{i=1}^{5} a_i \mu_i \tag{1}$$

$$\mu_i(x) = \sum_{j=1}^{n} w_j \mu_{i,j} \tag{2}$$

$$\mu_{i,j}(x_j) = \begin{cases} 1 & x \le 0.7 \\ \dfrac{0.8 - x}{0.8 - 0.7} & 0.7 < x \le 0.8 \end{cases}, \quad i = 1$$

$$\mu_{i,j}(x_j) = \begin{cases} \dfrac{x - 0.7}{0.8 - 0.7} & 0.7 < x \le 0.8 \\ \dfrac{0.9 - x}{0.9 - 0.8} & 0.8 < x \le 0.9 \end{cases}, \quad i = 2$$

$$\mu_{i,j}(x_j) = \begin{cases} \dfrac{x - 0.8}{0.9 - 0.8} & 0.8 < x \le 0.9 \\ 1 & 0.9 < x \le 1.1 \\ \dfrac{1.2 - x}{1.2 - 1.1} & 1.1 < x \le 1.2 \end{cases}, \quad i = 3$$

$$\mu_{i,j}(x_j) = \begin{cases} \dfrac{x - 1.1}{1.2 - 1.1} & 1.1 < x \le 1.2 \\ \dfrac{1.3 - x}{1.3 - 1.2} & 1.2 < x \le 1.3 \end{cases}, \quad i = 4$$

$$\mu_{i,j}(x_j) = \begin{cases} \frac{x - 1.2}{1.3 - 1.2} & 1.2 < x \le 1.3 \\ 1 & 1.3 < x \end{cases}, \quad i = 5 \tag{3}$$

where a_i denotes the weight for each grade, and the deviation grades in this study include three: [unbalanced, relatively unbalanced, reasonable balanced, relatively unbalanced, and unbalanced]. Their weights are [0.6, 0.8, 1, 0.8, 0.6]. μ_i represents the degree of the bid belonging to one of five grades and can be calculated using Eq (2); x is the ratio of the bidder's bid price to the Engineer's Estimated (An et al., 2018).

n is the number of pay items in a bid; j denotes the index of pay items in a bid; A construction bid consists of multiple pay items, and the deviation of each pay item needs to be evaluated using Eq. (3) in the unascertained model. Each deviation in a bid is considered to be one factor in the whole bid evaluation. Entropy weight is then used to determine the weight of each factor, expressed in Eq. (4).

$$w_j = v_j \sum_{j=1}^{m} v_j \tag{4}$$

$$v_j = 1 + \frac{1}{\ln n} \sum_{i=1}^{n} f_{i,j} \ln f_{i,j} \tag{5}$$

$$f_{i,j} = \frac{x_{i,j}}{\sum_{i=1}^{n} x_{i,j}} \tag{6}$$

where w_j denotes the weight for each pay item and $x_{i,j}$ is the ratio of the bidder's bid price to the Engineer's Estimate for the j^{th} pay item in the i^{th} bidder.

4.1.2 Risk-based method for materially unbalanced bids

Afterward, a risk-based method is developed to identify materially unbalanced bids, capitalizing on Monte Carlo Simulation. A materially-unbalanced bid is usually proposed by the bidders who identify the uncertainty in pay item quantities and tend to make use of inaccurately-estimated quantities for higher profits. In this regard, this study used a risk-based method to detect materially-unbalanced bids. The concept here is that the quantity uncertainty or variations of pay items are modeled using statistical distribution based on historical quantity data (i.e., actual quantities and estimated quantities of pay items). For a new bid, the quantities of its pay items are simulated by randomly sampling quantity variations from the fitted distributions. The quantity simulations could be conducted multiple times (i.e., 500); then, the simulated quantities could be used to further statistically determine the bid prices for each bidder. Given the statistical bid prices for each bidder, the materially-unbalanced bids can be identified.

Figure 4243Figure 42 shows the steps of the materially-unbalanced bid detection. This process **starts** with data preparation, i.e., linking the estimated quantities (in the bidding data) and actual estimated quantities (in the construction payment) of pay items that were awarded in the past. **Then**, the percentages of quantity variations between the actual and estimated quantities are calculated for all pay items. Table 2 provides the statistics of quantity variations for several pay items awarded in 2016. For example, the pay item "5010057 HMA, 5E3" has been awarded and paid 132 times, and its quantity variation averaged 2.2%. This implies that this item's actual quantity is 2.2% more than the estimated quantity. The standard deviation of quantity variations is 0.10, indicating the actual quantity is usually close to the estimated quantity.

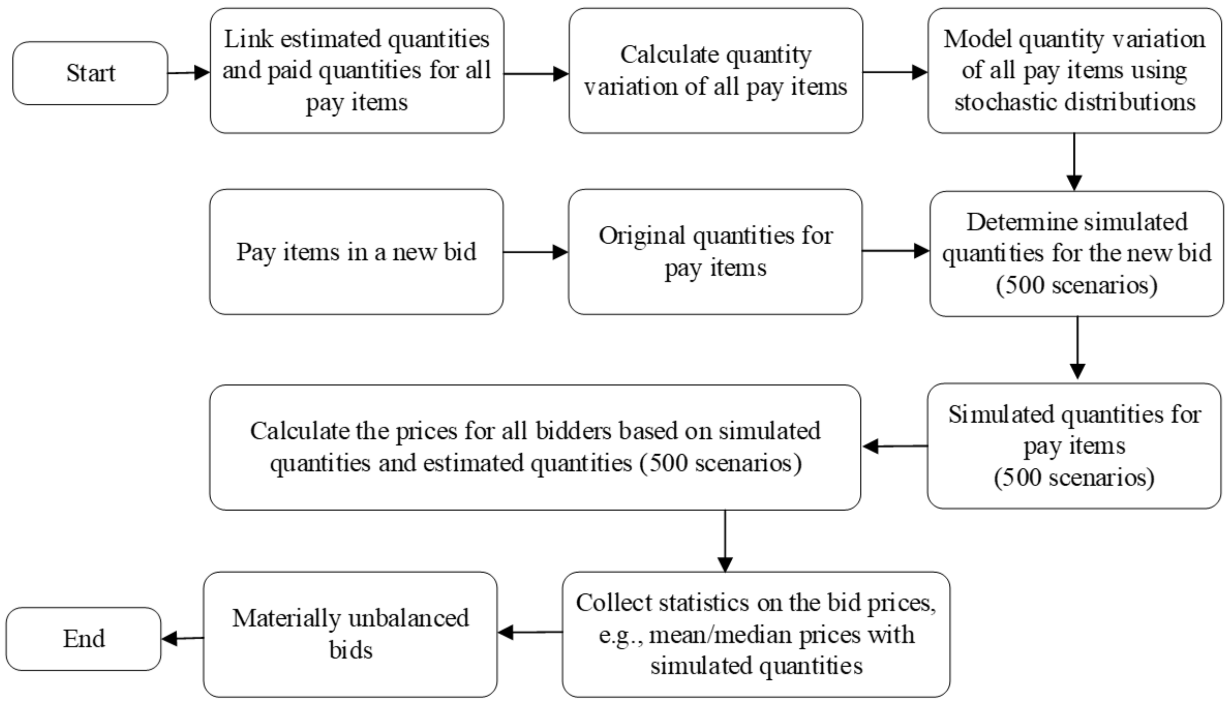
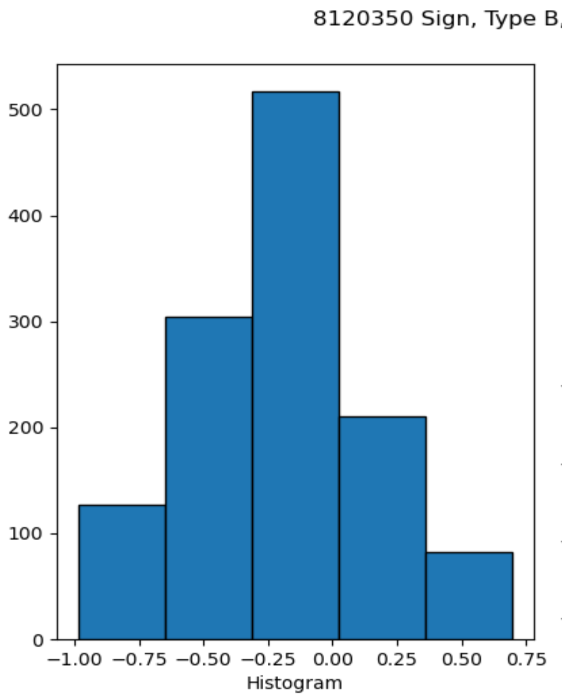


Figure 42. Risk-based unbalanced bid detection steps

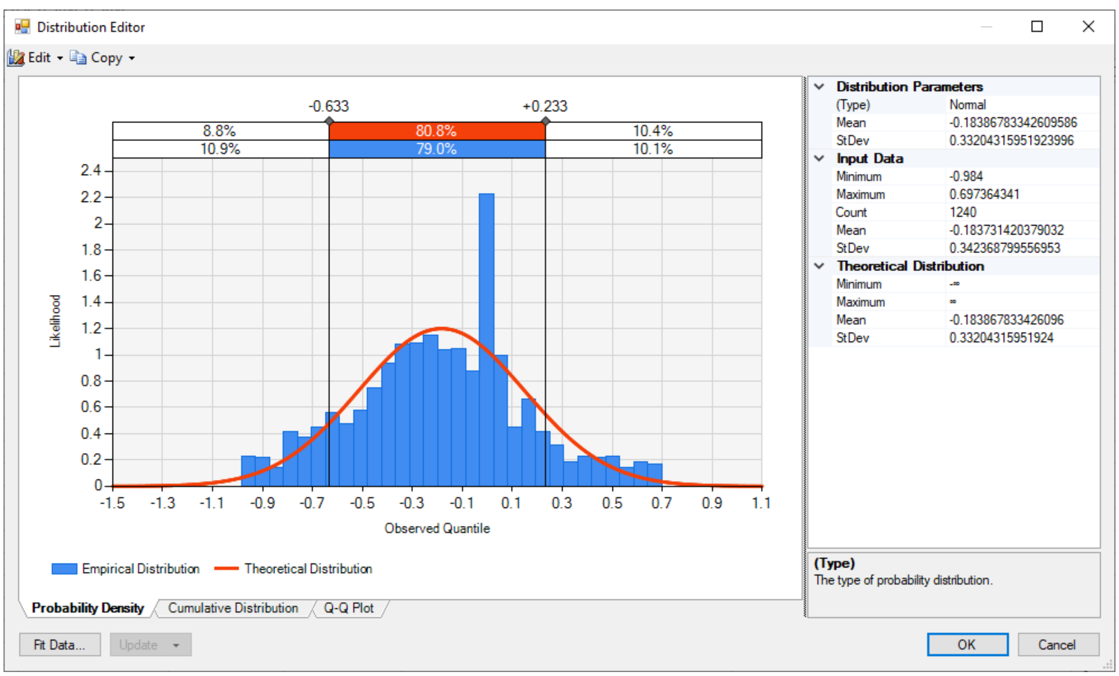
Table 2. Historical quantity variations for selected pay items in 2016

Item	Item Description	Count	Mean	Median	STD
8120350	Sign, Type B, Temp, Prismatic, Furn	1240	−18.4%	−16.8%	0.34
8120310	Sign Cover	614	−30.8%	−31.1%	0.43
8110042	Pavt Mrkg, Ovly Cold Plastic,12in, White	10	43.0%	16.6%	0.96
8120351	Sign, Type B, Temp, Prismatic, Oper	1237	−18.5%	−17.1%	0.34
6020021	Conc Base Cse, Nonreinf, 9 inch	21	4.1%	4.9%	0.51
5010057	HMA, 5E3	132	2.2%	1.4%	0.10
5010515	HMA, 5E3, High Stress	75	6.8%	5.2%	0.13
5010005	HMA Surface, Rem	505	−3.3%	0.0%	0.20
5010045	HMA, 3E3	64	6.4%	3.8%	0.14
5010509	HMA, 4E3, High Stress	41	4.5%	5.1%	0.11
5010061	HMA Approach	502	0.9%	0.0%	0.32
8060040	Shared use Path, HMA	26	8.7%	6.1%	0.16
5010025	Hand Patching	483	−21.8%	−24.4%	0.50
8110231	Pavt Mrkg, Waterborne, 4 inch, White	478	−6.8%	−2.8%	0.26
7120010	Patch, Full Depth	24	17.3%	15.4%	0.74
5010002	Cold Milling HMA Surface	475	−1.1%	−0.5%	0.07
8110233	Pavt Mrkg, Waterborne, 6 inch, White	467	−1.9%	−1.7%	0.06
2050016	Excavation, Earth	451	−2.7%	0.0%	0.11
2040020	Curb and Gutter, Rem	435	3.5%	1.0%	0.16
2080036	Erosion Control, Silt Fence	434	−36.8%	−40.5%	0.43

Following this, quantity variations are modeled using probability distributions. The least-square algorithm is used to fit the distribution and tested for the fitness. Taking the pay item “8120350 Sign, Type B, Temp, Prismatic, Furn” as an example, its quantity variations in 2016 are used to plot the histogram (as shown in Figure 434241), which gives a general idea of the potential distribution. The least-square algorithm informs that Normal distribution (−0.18, 0.332) is the best fit for the quantity variations of 8120350. The distributions are then used in determining the potential quantities for the new construction bid.



a) histogram and box plot



b) Fitted distribution

Figure 43. Quantity variations of “8120350 Sign, Type B, Temp, Prismatic, Furn”

With simulated quantities from statistical distributions, the total bid prices of all bidders are calculated, and their price statistics, such as max, min, mean, and so forth, are determined. The mean and median simulated prices of all bidders are compared and ranked. When the original lowest bid's price is no longer the lowest in the simulated prices, the construction bids are considered to be materially unbalanced.

4.2 UNBALANCED BID DETECTION TOOL

The developed tool can automatically generate various charts that assist the users in visualizing the pay item data. These charts are summarized in Table 3. The user manual of the tool is attached in Appendix G.

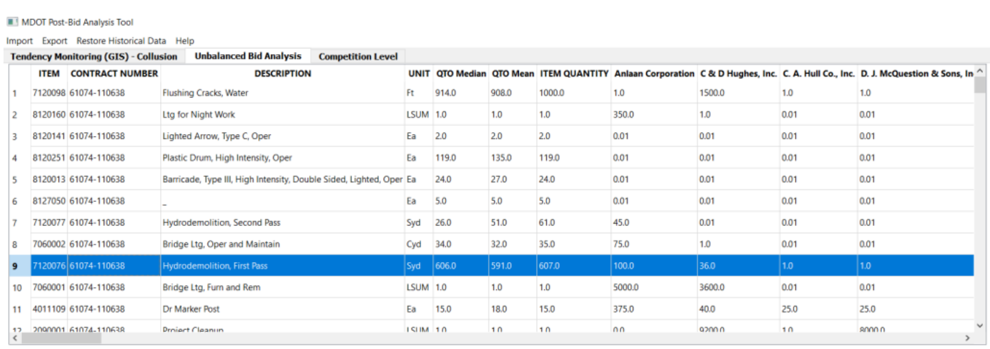
Table 3. Unbalanced bid analysis: data visualization

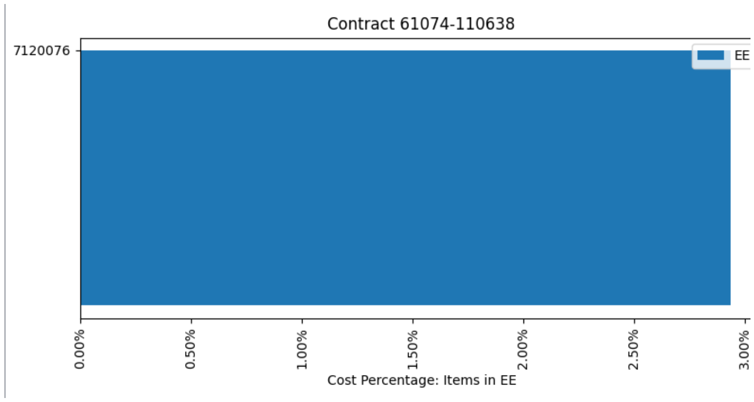
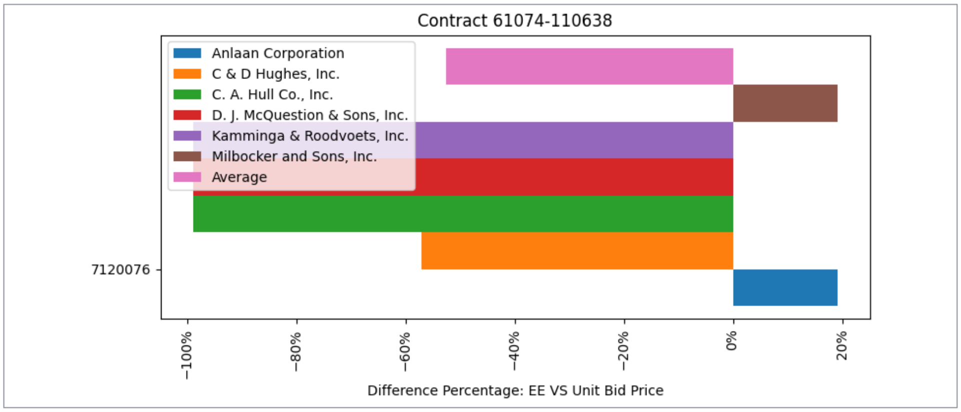
<table>
<tr><th>ID</th><th>NAME</th><th>DESCRIPTION</th></tr>
<tr><td>1</td><td>Bid Tabulation</td><td>Provides a summary of pay items for the imported contract, e.g., unit, price, description, bidder's price, and so forth. Importantly, the pay items are ranked in descending order of the degree of imbalance (which is calculated by the developed algorithm). The sum of the degree of imbalance of all pay items is equal to 100.

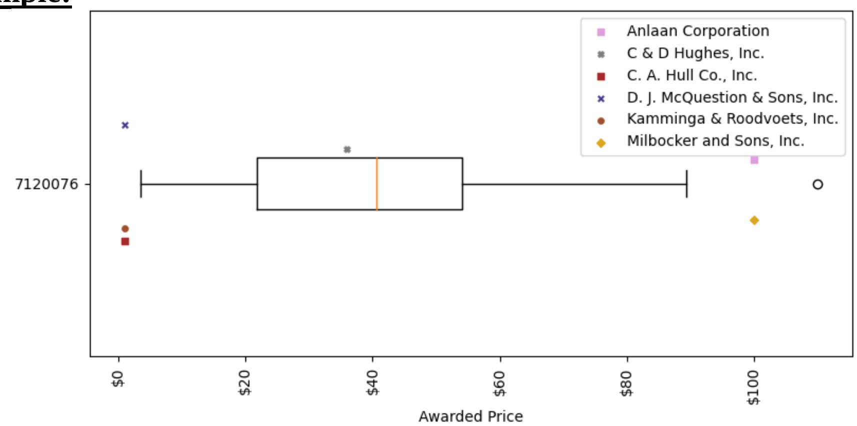
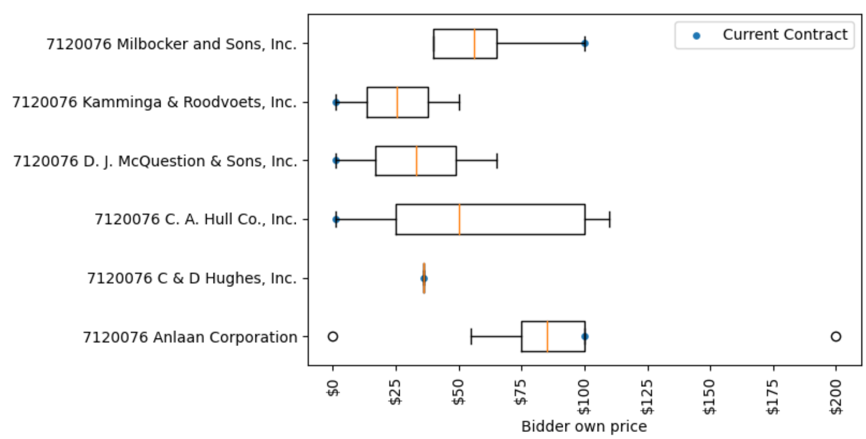
This table is interactive, and the user can click each pay item to visualize its specific information, e.g., its price difference between bidders and Engineers, awarded historical price range, each bidder's historical price range, historical quantity variation, and cost percentage in total Engineer's Estimate.

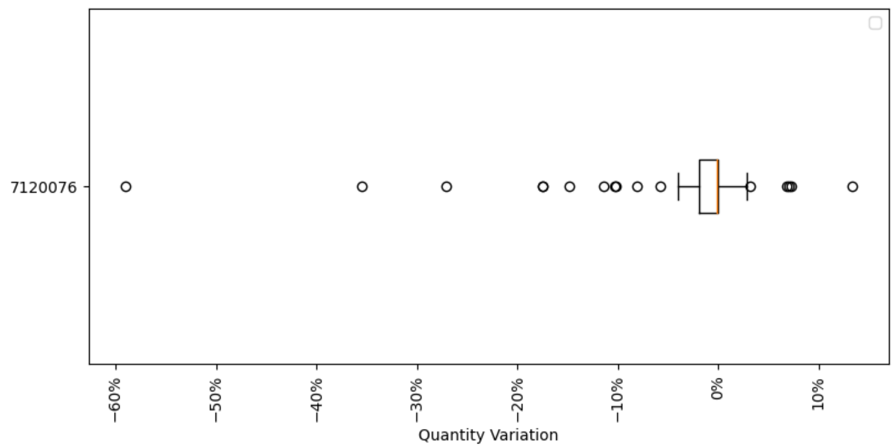
<u>This table can assist in investigating individual pay items that are potentially unbalanced or warrant special attention.</u>

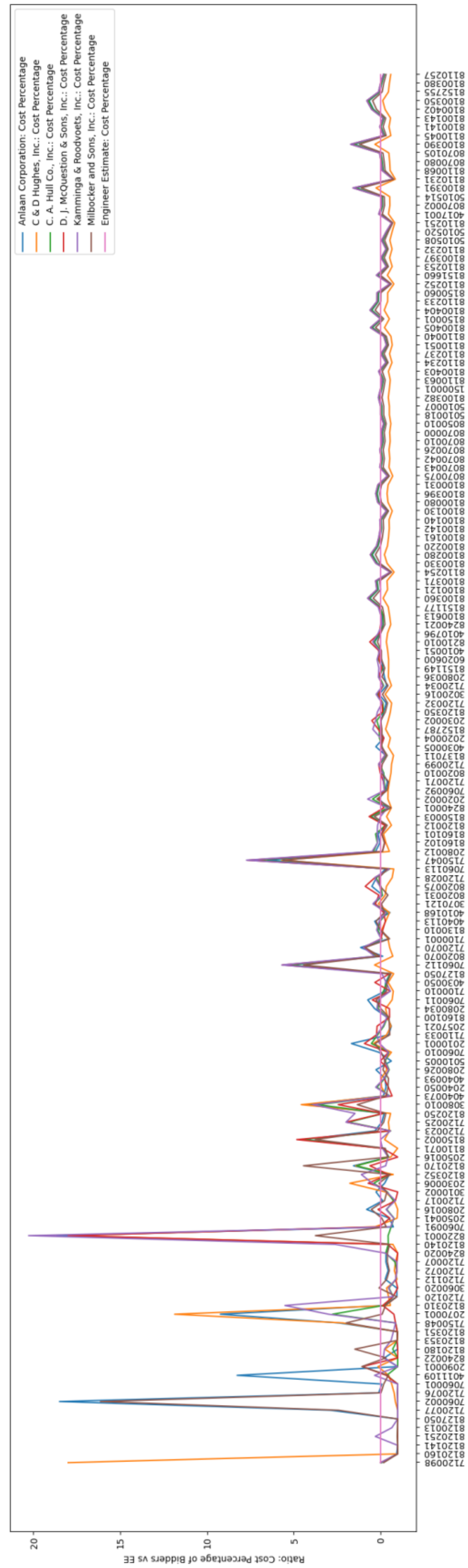
<u>Example:</u>


MDOT Post-Bid Analysis Tool
Import Export Restore Historical Data Help
Tendency Monitoring (GIS) - Collusion | Unbalanced Bid Analysis | Competition Level
<table>
<tr><th></th><th>ITEM</th><th>CONTRACT NUMBER</th><th>DESCRIPTION</th><th>UNIT</th><th>QTO Median</th><th>QTO Mean</th><th>ITEM QUANTITY</th><th>Anlaan Corporation</th><th>C & D Hughes, Inc.</th><th>C. A. Hull Co., Inc.</th><th>D. J. McQuestion & Sons, In</th></tr>
<tr><td>1</td><td>7120098</td><td>61074-110638</td><td>Flushing Cracks, Water</td><td>Ft</td><td>914.0</td><td>908.0</td><td>1000.0</td><td>1.0</td><td>1500.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td>2</td><td>8120160</td><td>61074-110638</td><td>Ltg for Night Work</td><td>LSUM</td><td>1.0</td><td>1.0</td><td>1.0</td><td>350.0</td><td>1.0</td><td>0.01</td><td>0.01</td></tr>
<tr><td>3</td><td>8120141</td><td>61074-110638</td><td>Lighted Arrow, Type C, Oper</td><td>Ea</td><td>2.0</td><td>2.0</td><td>2.0</td><td>0.01</td><td>0.01</td><td>0.01</td><td>0.01</td></tr>
<tr><td>4</td><td>8120251</td><td>61074-110638</td><td>Plastic Drum, High Intensity, Oper</td><td>Ea</td><td>119.0</td><td>135.0</td><td>119.0</td><td>0.01</td><td>0.01</td><td>0.01</td><td>0.01</td></tr>
<tr><td>5</td><td>8120013</td><td>61074-110638</td><td>Barricade, Type III, High Intensity, Double Sided, Lighted, Oper</td><td>Ea</td><td>24.0</td><td>27.0</td><td>24.0</td><td>0.01</td><td>0.01</td><td>0.01</td><td>0.01</td></tr>
<tr><td>6</td><td>8127050</td><td>61074-110638</td><td>_</td><td>Ea</td><td>5.0</td><td>5.0</td><td>5.0</td><td>0.01</td><td>0.01</td><td>0.01</td><td>0.01</td></tr>
<tr><td>7</td><td>7120077</td><td>61074-110638</td><td>Hydrodemolition, Second Pass</td><td>Syd</td><td>26.0</td><td>51.0</td><td>61.0</td><td>45.0</td><td>0.01</td><td>0.01</td><td>0.01</td></tr>
<tr><td>8</td><td>7060002</td><td>61074-110638</td><td>Bridge Ltg, Oper and Maintain</td><td>Cyd</td><td>34.0</td><td>32.0</td><td>35.0</td><td>75.0</td><td>1.0</td><td>0.01</td><td>0.01</td></tr>
<tr><td>9</td><td>7120076</td><td>61074-110638</td><td>Hydrodemolition, First Pass</td><td>Syd</td><td>606.0</td><td>591.0</td><td>607.0</td><td>100.0</td><td>36.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td>10</td><td>7060001</td><td>61074-110638</td><td>Bridge Ltg, Furn and Rem</td><td>LSUM</td><td>1.0</td><td>1.0</td><td>1.0</td><td>5000.0</td><td>3600.0</td><td>0.01</td><td>0.01</td></tr>
<tr><td>11</td><td>4011109</td><td>61074-110638</td><td>Dr Marker Post</td><td>Ea</td><td>15.0</td><td>18.0</td><td>15.0</td><td>375.0</td><td>40.0</td><td>25.0</td><td>25.0</td></tr>
<tr><td>12</td><td>2090001</td><td>61074-110638</td><td>Project Cleanup</td><td>LSUM</td><td>1.0</td><td>1.0</td><td>1.0</td><td>0.0</td><td>9200.0</td><td>1.0</td><td>8000.0</td></tr>
</table></td></tr>
</table>

2	Cost Percentage of Pay Item in Engineer's Estimate	Provide the cost percentage of a selected pay item in Bid Tabulation. <u>It can assist in identifying the items that have the greatest dollar impact on the total awarded contract dollars in a specified period and market</u>. 
3	Diff Percentage from Engineer's Estimate	Provide the graphic display of bidders' price difference percentage from the Engineer's Estimate for a selected pay item. <u>This table can assist in investigating individual pay items that are potentially unbalanced or that otherwise warrant special attention.</u> **<u>Example:</u>** 

4	Awarded Price Range Chart	Provides (1) summary statistics for **awarded** historical bid prices of a selected item and (2) a comparison between item prices on the imported contract and historical item prices and standard deviations. <u>It can assist in identifying the items whose prices are significantly different from **historically awarded prices** and that thus warrant special attention in bid evaluation. These outliers are removed from the historically awarded prices using the standard deviation method.</u> **<u>Example:</u>** 
5	Bidder Price Range Chart	Provides (1) summary statistics for the **bidder**'s historical prices of a selected item and (2) a comparison between item prices on the imported contract and the bidders' historical item prices and standard deviations. <u>It can assist in identifying the items whose prices are significantly different from **bidders'** historical **normal** prices and that warrant special attention in bid evaluation. It should be noted that outliers are removed from the **bidders'** historical **normal** prices using the standard deviation method.</u> **<u>Example:</u>** 

6	Historical Quantity Variation	Provides summary statistics for the **percent quantity variation of a selected item.** <u>It can assist in identifying the items whose quantities are highly variable and that warrant special attention in bid evaluation, especially for materially unbalanced bids.</u> **<u>Example:</u>** 
7	Unbalanced Bid Analysis Results	Provides a summary of unbalanced bid analysis results For example: (1) whether the bid is an unbalanced bid or not (which is concluded through different methods, e.g., (an unascertained model for mathematically unbalanced bids and risk-based analysis for materially unbalanced bids), (2) Number of bidders within 10% of Engineer's Estimate, (3) Cost Percentage of Identical Items, (4) Percentage of Identical Items, (5) Number of bids that this group of bidders competed together, (6) Prob. to Be Lowest, (7) Percentage from Total Engineer's Estimate, (8) Number Percentage: Items Within 5% of Engineer's Estimate (9) Cost Percentage: Items Within 5% of Engineer's Estimate, (10) Number of Unbalanced Items via MDOT, (11) Cost Percentage of Unbalanced Items via MDOT, (12) Unascertained Score: Entropy & Percentage <u>The summary concludes the bid unbalance analysis and provides a basis for further manual review and analysis on the part of the bid review team.</u>



Price Similarity Chart of Construction bids in a contract

Chapter 5. COMPETITIVE ANALYSIS

This chapter presents the competitive analysis of construction bidding and the comparison of the **relative competitiveness** in Michigan and peer states, including Ohio, Iowa, Idaho, Wisconsin, Minnesota, and Indiana. Competitiveness is a general concept to measure the ability of a business, a country/region, or an entity to compete for the work and reflects its performance. The competitiveness of construction bids can be evaluated using different metrics, as shown in Figure 4443 and Figure 4544. The metrics in this study include (1) the number of bids per contract, measuring the competitiveness at the project level, (2) the ratio of the lowest bid amount divided by the Engineer's Estimate of the total project (the smaller ratio, the more competitiveness), (3) bid spread: the ratio of the second-lowest bid amount divided by the lowest bid amount (the smaller the ratio is, the more competitive the bid is), (4) the standard deviation of all bid variations from the lowest bid, which measures the bid spread (the smaller of the standard deviation, the more competitiveness), (5) the percentage of contracts whose awarded prices are lower than the Engineer's Estimate, and (6) the number of contractors, which provides an implication of general market competition. The bid data for the peer states is retrieved from Bid Express (Bid Express, 2022).

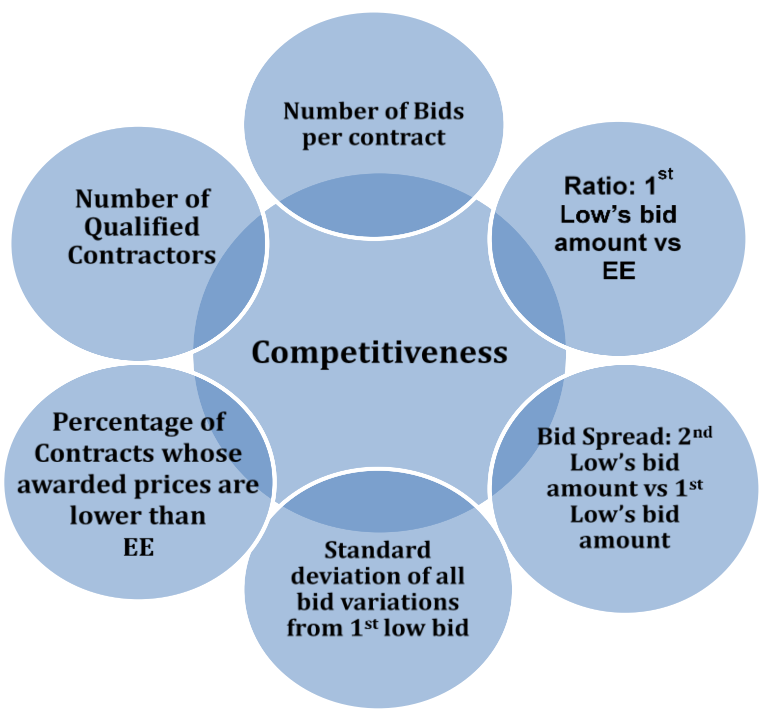


Figure 44. Competitiveness of construction bids

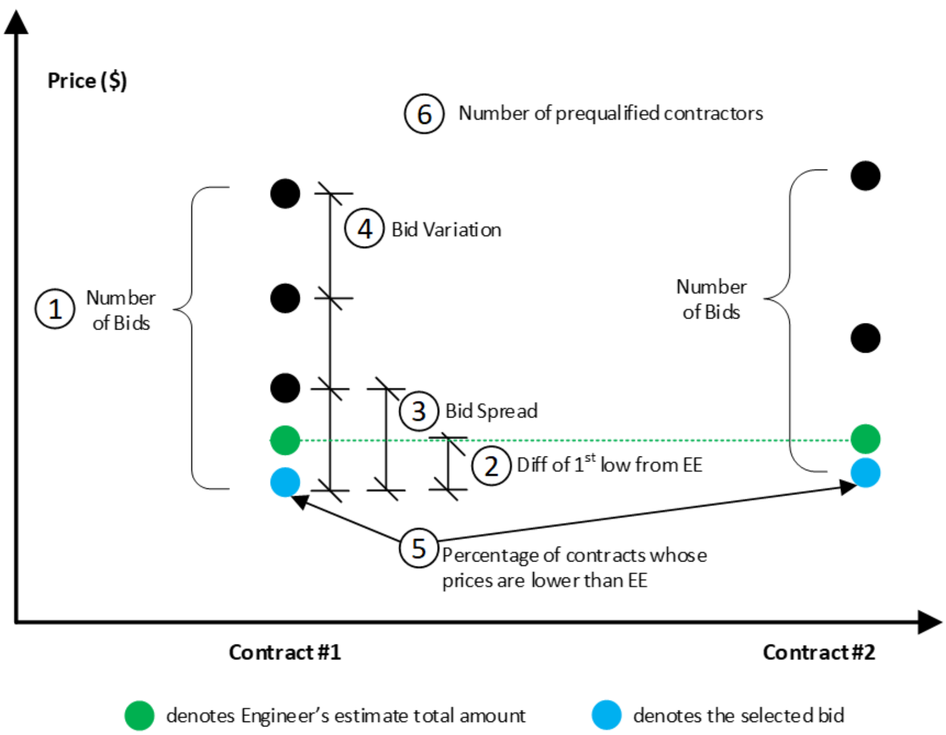


Figure 45. Relative competitiveness measurement: definition

5.1 NUMBER OF BIDS PER CONTRACT

The number of bids per contract is the most widely used metric for evaluating the level of competition in construction bidding. As revealed in the nation-wide survey, all the survey participants take the number of bids per contract in the competition evaluation. As such, this metric was employed to measure MDOT's bidding competitiveness quantitatively and make a comparison among different states. The number of bids per contract is retrieved from the 2016 bid data of both Michigan and neighboring states. The bid data for many state DOTs are published at Bid Express Lettings and readily downloaded for competitive analysis. Figure 4645 shows the box plots of the number of bids per contract for Michigan and for peer states. Their statistics are tabulated in Table 4.

The table shows that the number of bids per contract in Michigan averages 3.92, which is higher than the peer states. This implies that the competitiveness in Michigan is higher than that in peer states. To validate this finding, a Mann-Whitney U test is used to test the difference in the number of bids between Michigan and peer states. It should be noted that the Mann-Whitney U test is a nonparametric test of the null hypothesis (e.g., no significant difference) for two specified populations. The statistical results revealed that the number of bids in Michigan is significantly higher than in Idaho (*U*=291, 063.5, *pvalue*=0.048) and in Wisconsin (*U*=54, 331.5, *pvalue*=0.002). Michigan is not significantly different from Ohio (*U*=277,718.0, *pvalue*=0.490), Iowa (*U*=218,774.0, *pvalue*=0.129), Minnesota (*U*=14,795.0, *pvalue*=0.083), Indiana (*U*=182,287, *pvalue*=0.722), *and* Washington (*U*=43,088.5, *pvalue*=0.822). However, Michigan's number of bids is lower than North Dakota's (*U*=79,382.0, *pvalue*=0.0001). In conclusion, the competitiveness in Michigan is higher than in Idaho and Wisconsin and similar to the one in Ohio, Iowa, Minnesota, and Indiana.

Table 4. Number of bids per contract: statistics

	Michigan	**Ohio**	**Iowa**	**Idaho**	**Wisconsin**	**Minnesota**	**Indiana**	**North Dakota**	**Washington**
Count	746	786	650	823	312	165	483	182	117
Mean	3.92	3.85	3.81	3.54	3.42	3.90	3.78	4.88	3.91
STD	2.16	2.15	1.93	1.54	2.13	1.83	2.04	2.99	2.23
Min	1	1	1	0	1	1	1	2	2
25%	2	2	2	2	2	2	3	2	2
50%	3	3	4	3	3	4	4	4	3
75%	5	5	5	4	4	5	6	7	5
Max	14	14	12	10	10	9	13	18	12

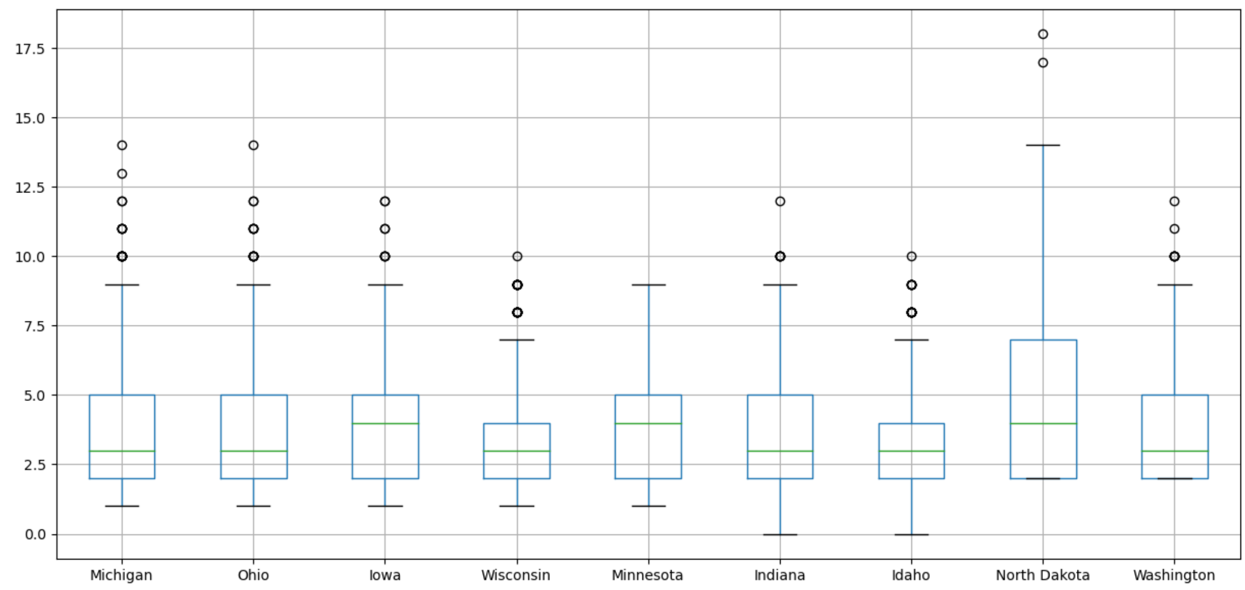


Figure 46. Number of bids in Michigan and peer states.

5.2 RATIO BETWEEN THE LOWEST BID AND THE ENGINEER'S ESTIMATE

Ideally, the total price of the lowest bid should be within 10% of the Engineer's Estimate. FHWA recommends that more than 50% of construction projects' awarded prices be within 10% of the Engineer's Estimate. This recommendation is used to measure the accuracy of the Engineer's Estimate. On the other hand, the price percentage difference of the lowest bid from the Engineer's Estimate could also be used to measure competitiveness. When the competitiveness is high, the price percentage difference should be less than one but more than 0.9. The price differences are calculated for 2016 construction bids in Michigan and peer states. Their descriptive statistics are summarized in Table 5. Figure 4746 shows the box plots of these price differences.

Table 5 shows that price differences in Michigan average 96%, lower than 98% in Ohio and 98.8% in Washington but higher than 87.5% in North Dakota. The result implies that Michigan's competitiveness is higher than in Ohio and Washington but lower than in North Dakota. A Mann-Whitney U test is used to test the difference in bid spreads between Michigan and Ohio. The statistical results revealed that the price difference in Michigan is significantly lower than in Ohio (*U*= 267588.0, *pvalue*= 0.008*)*, higher than in North Dakota (*U*= 88540.0, *pvalue*= 0.000*)*, and similar within Washington (*U*= 44502.0, *pvalue*= 0.495*)*. These statistical results support the finding described above.

Table 5. Percentage price difference between Engineer's Estimate and the lowest bid

	Michigan	**Ohio**	**North Dakota**	**Washington**
Count	732	706	182	117
Mean	0.96	0.98	0.875	0.988
STD	0.173	0.192	0.225	0.217
Min	0.387	0.463	0.302	0.581
25%	0.856	0.871	0.733	0.845
50%	0.945	0.963	0.843	0.945
75%	1.029	1.057	0.965	1.072
Max	2.149	2.263	1.951	1.998

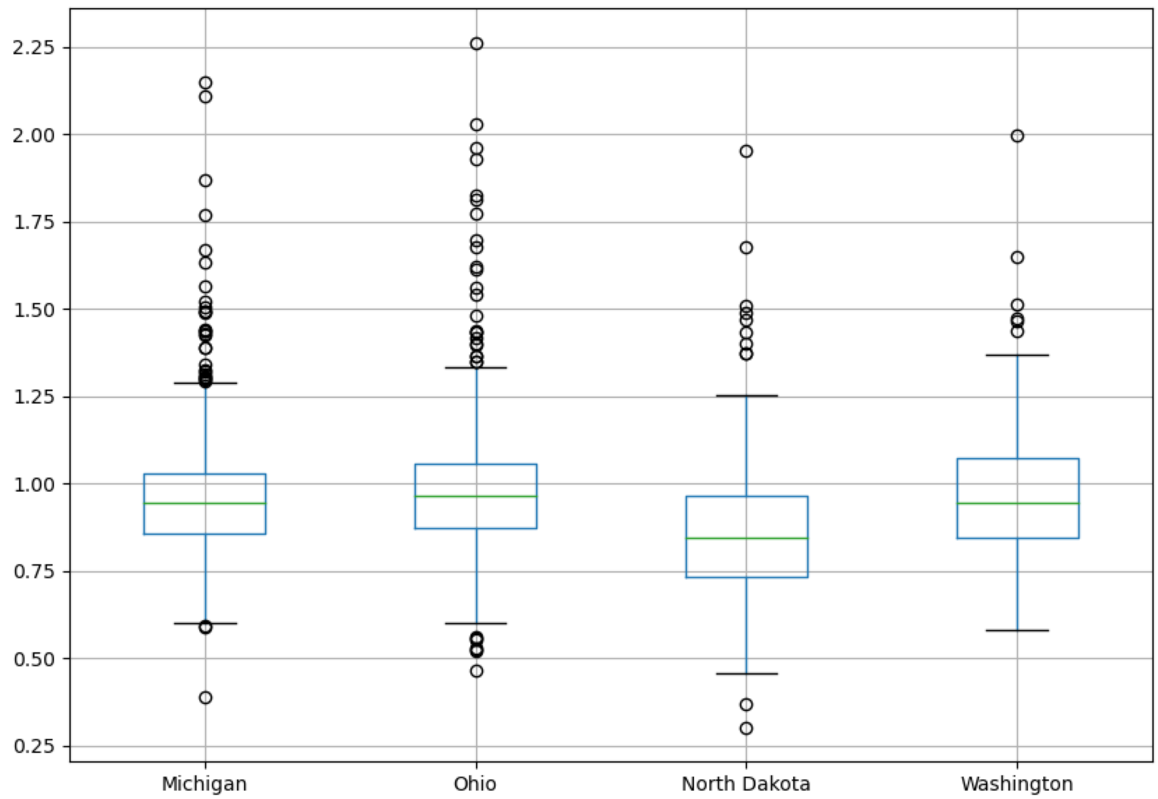


Figure 47. Percentage price difference between Engineer's Estimate and the lowest bid.

5.3 BID SPREAD

Bid spread refers to the percentage difference between the second-lowest bid bidder's total amount and the lowest bidder's total amount. The lower bid spread implies more competitiveness in the bidding, especially between the winner and the second-lowest bidder. The bid spreads are then calculated for all 2016 bids in Michigan and the peer states, including Iowa, Wisconsin, Minnesota, and Indiana. The statistics of bid spreads are summarized in Table 6. Figure 4847 presents the box plots with descriptive statistics (e.g., max, min, 0.75 quantile, median, and 0.25 quantile). The table shows that bid spreads in Michigan average 9.3%, lower than 14% in Iowa, 10.6% in Minnesota, and 13.2% in Indiana. This indicates that competitiveness is higher in Michigan than in these other states. A Mann-Whitney U test is used to test the difference in bid spreads between MDOT and peer state DOTs. The statistical results revealed that the bid spreads in Michigan are significantly lower than in Iowa (*U*=206319.0, *pvalue*=0.000) and Indiana (*U*=113123.0, *pvalue*=0.000). Michigan is not significantly different from Minnesota (*U*=10706.0, *pvalue*=0.739) and Wisconsin (*U*=33628.0, *pvalue*=0.407). These statistical results support the finding described above.

Table 6. Bid spread of Michigan and peer states

	Michigan	Iowa	Wisconsin	Minnesota	Indiana	North Dakota	Washington
Count	711	580	248	145	426	178	116
Mean	0.093	0.140	0.092	0.106	0.132	0.086	0.129
STD	0.124	0.225	0.124	0.164	0.173	0.101	0.152
Min	-0.398	0.000	0.000	0.001	0.000	0.000	0.000
25%	0.022	0.033	0.019	0.028	0.034	0.020	0.031
50%	0.056	0.077	0.053	0.056	0.076	0.055	0.071
75%	0.119	0.165	0.113	0.111	0.161	0.119	0.148
Max	0.980	2.762	0.935	1.185	1.368	0.684	0.776

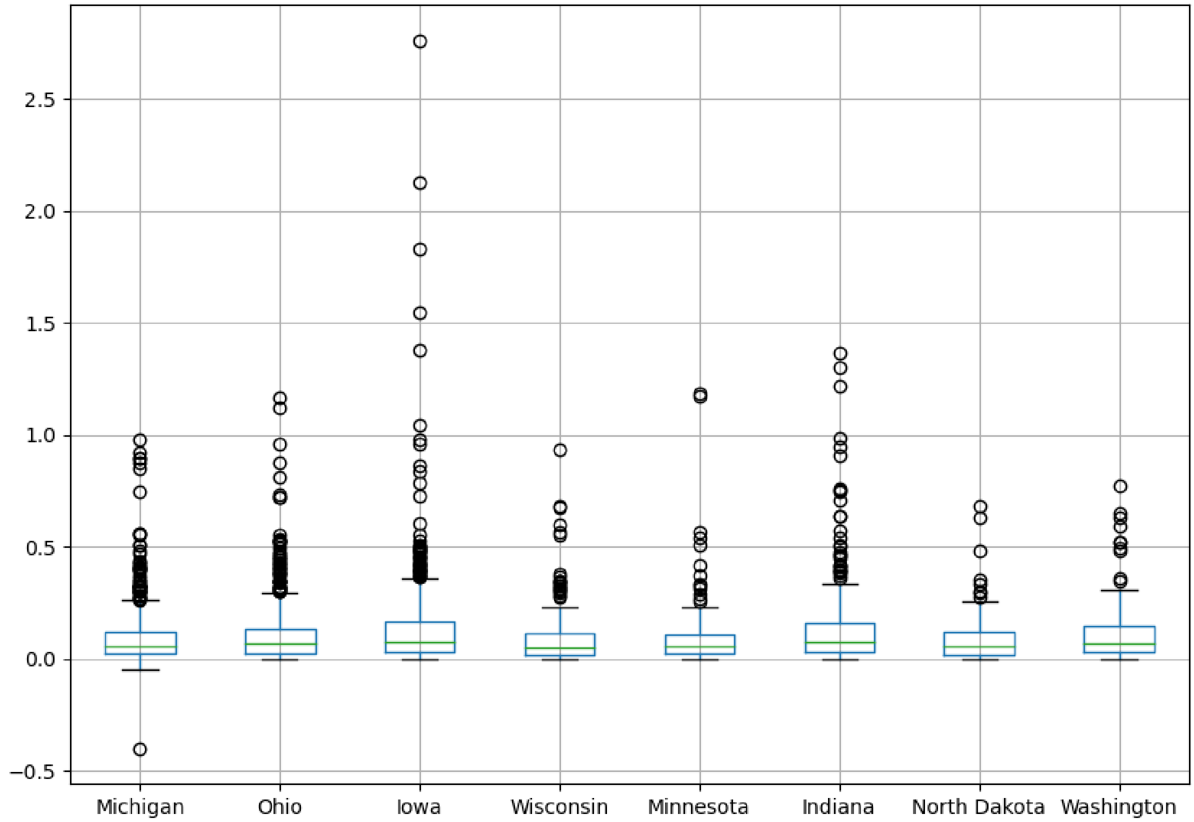


Figure 48. Bid spread of Michigan and peer states.

5.4 BID VARIATIONS: STANDARD DEVIATION OF PRICE DIFFERENCES FROM THE LOWEST BID

Bid variations herein refer to the standard deviations of all bidders' price differences from the lowest bid. The lower bid variation, to certain degrees, implies higher competitiveness in the bidding. The bid variations are used to compare the competitiveness of construction bids in Michigan and peer states. The bid variations are calculated for all 2016 bids in Michigan and the peer states, including Iowa, Wisconsin, Minnesota, and Indiana. The statistics of bid variations are summarized in Table 7. The box plots of all bidders' price differences from the lowest bid are shown in Figure 4948. Bid variations in Michigan averaged 0.123, which is lower than those in peer states. For example, Iowa's bid variation was 0.203, with Wisconsin of 0.115, Minnesota of 0.156, and Indiana of 0.188. A Mann-Whitney U test is used to examine the difference in bid variations between MDOT and peer state DOTs. The results revealed that the bid spreads in Michigan are significantly lower than in Iowa (*U*= 221991.0, *pvalue*=0.000), Indiana (*U*= 119971.0, *pvalue*=0.000), and Minnesota (*U*= 12693.0, *pvalue*= 0.009). Michigan is not significantly different from Wisconsin (*U*= 34151.0, *pvalue*=0.252). The results suggest that the competitiveness in Michigan is higher than in Iowa, Indiana, Minnesota, North Dakota, and Wisconsin and similar to that in Wisconsin.

Table 7. Bid variations of Michigan and peer states

	Michigan	**Iowa**	**Wisconsin**	**Minnesota**	**Indiana**	**North Dakota**	**Washingt on**
Count	711	592	254	148	437	178	116
Mean	0.123	0.203	0.115	0.156	0.188	0.142	0.157
Min	0.000	0.000	0.001	0.014	0.000	0.002	0.002
25%	0.057	0.078	0.048	0.069	0.075	0.063	0.078
50%	0.097	0.142	0.084	0.109	0.130	0.097	0.129
75%	0.148	0.237	0.133	0.176	0.204	0.169	0.188
Max	1.233	2.669	1.110	0.850	1.635	1.557	0.790

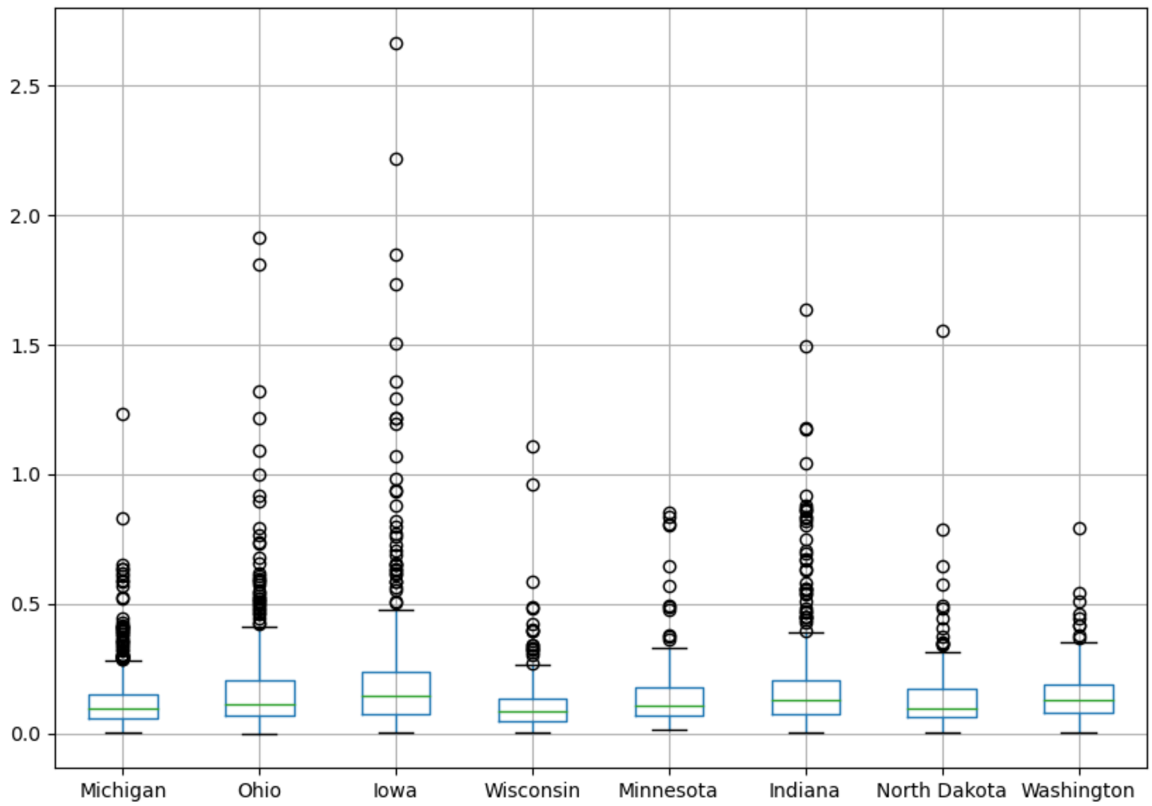


Figure 49. Bid variations of Michigan and peer states.

5.5 Percentage of Contracts Whose Awarded Prices Are Lower Than EE

Another indicator of the competitiveness of construction bids is the percentage of contracts whose awarded prices are lower than the Engineer's Estimate. Such percentages are used to shed light on the bidding competitiveness. The higher percentage means more contracts whose awarded price is lower than the Engineer's Estimate and higher bidding competitiveness. The percentages are calculated for all 2016 bids in Michigan, Indiana, North Dakota, Ohio, and Washington. The percentage and the number of bids are summarized in **Figure 505049**. For example, in 2016, 35 contracts in Michigan received only one bid, among which 31.4% of contracts' prices were lower than the Engineer's Estimate. In contrast, Indiana DOT had 37 contracts with only one bid; among these, 35% of contracts' prices were lower than the EE. A Student's t-test is used to examine the difference in percentage between MDOT and peer states. It should be noted that the Student's t-test is a test of the null hypothesis (e.g., no significant difference) for two normally-distributed populations. The percentage of Michigan and Indiana were found to be normally distributed based on the findings of the Shapiro–Wilk test. The t-test results revealed that the percentage in Michigan is not significantly different from Indiana (T= 0.868, *p-value*= 0.395), Ohio (T= -0.330, *p-value*= 0.744), and Washington (T= -0.725, *p-value*= 0.476). This means that Michigan's competitiveness does not significantly differ from those of Indiana, Ohio, and Washington.

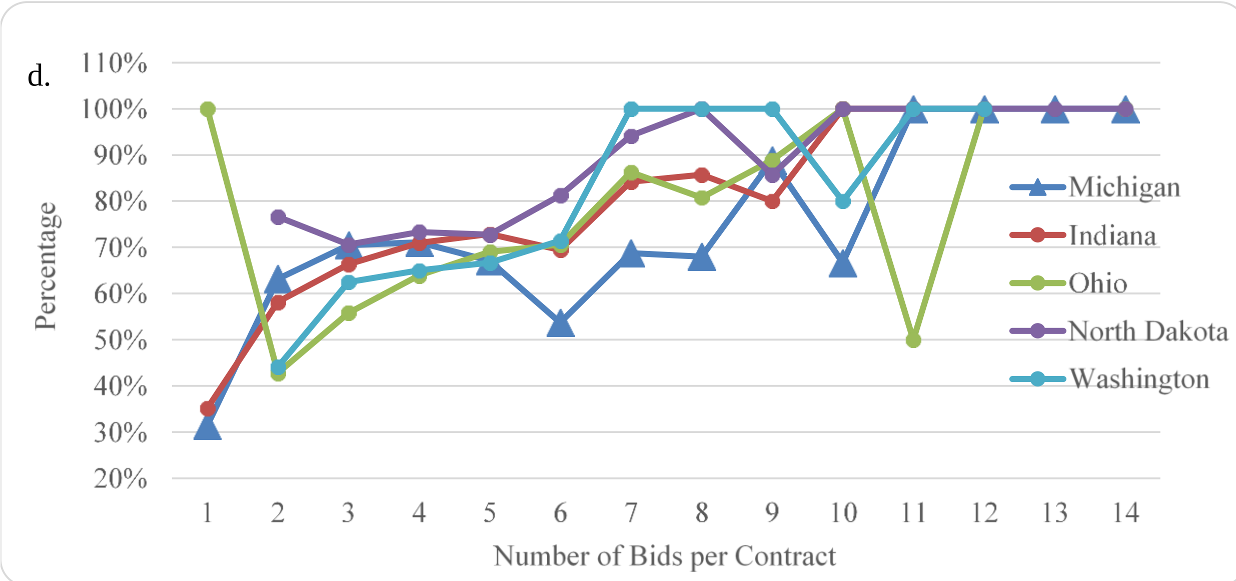


Figure 50. Percentage of contracts whose awarded prices are lower than the Engineer's Estimate: (a). Michigan, (b). Indiana, (c). North Dakota, (d). Other

It should be noted that North Dakota DOT had a minimum of 2 bids for all their projects awarded in 2016. The Student's t-test is also used to examine the difference in percentage between MDOT and North Dakota DOT. The statistical results reveal that North Dakota DOT's percentage is significantly higher than MDOT's (*T*= 2.479, *p-value*= 0.010*)*. This means that North Dakota's bids are more competitive than Michigan's.

5.6 NUMBER OF PREQUALIFIED CONTRACTORS

The last metric of the competitiveness of construction bids is the number of qualified contractors and the contractors who bid on construction projects. The number of contractors could imply an implication of general market competition. Technically, the more contractors, the more competition. The number of prequalified contractors and contractors who bided on projects is retrieved from the official website of state DOTs and summarized in Figure 515150.

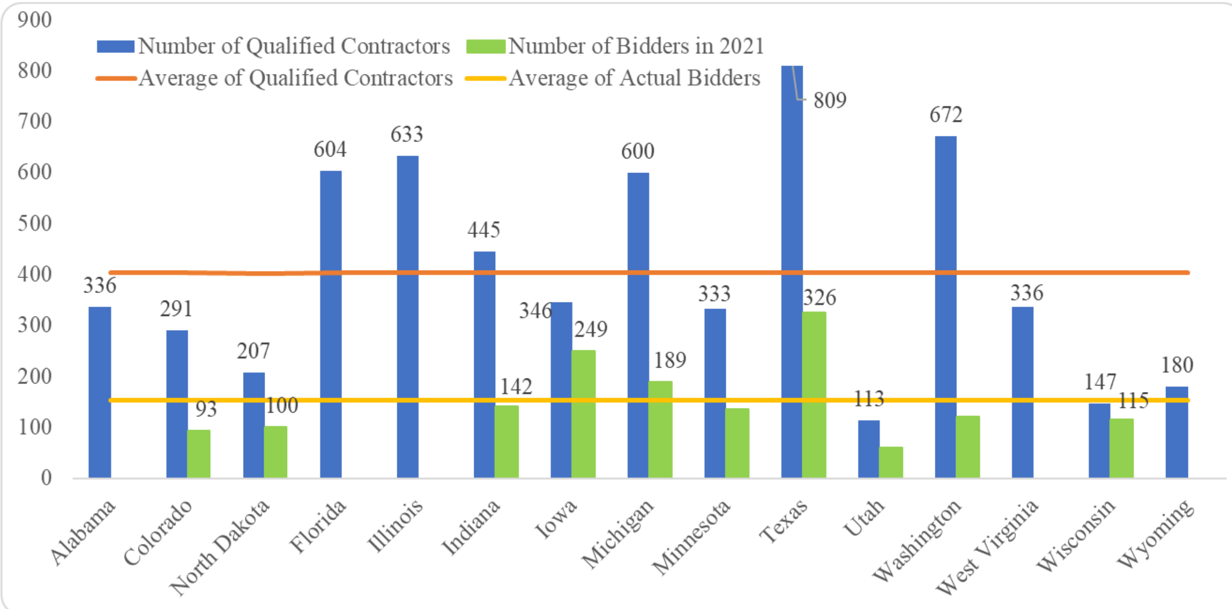


Figure 51. Number of prequalified contractors and contractors who bided on projects

For example, Texas has a total of 809 contractors; among these, only 326 contractors bid on the projects in 2021. It is followed by Illinois (633 prequalified contractors) and Michigan (600). One hundred eighty-nine of the contractors in Michigan actually bid in 2021. The number of qualified contractors in Michigan is higher than the average number of 403 for the identified states, and the actual number of bidders in Michigan (189) is higher than the average 153. It should be noted that the number of qualified contractors and actual bidders is not normalized for comparison, and the construction market size or state population is not considered in this analysis. Additionally, Michigan performs a prequalification for both prime contractors and sub-contractors. As such, the competitiveness drawn from the number of prequalified contractors is highly cautious.

5.7 Comparison of Main Pay Items

The competitiveness comparison above revealed that construction bids are more competitive in Michigan than in its peer states. For example, Michigan's bids are significantly more competitive than those in Idaho and Wisconsin, and Michigan is not considerably different from Ohio, Iowa, Minnesota, and Indiana. However, the highest level of competition does not necessarily correspond to the lowest contract price. Figure 5251 illustrates one example contract with two different sets of bids. Regarding the six competitiveness measurements, the bids on the right of Figure 52 are more competitive than those on the left. However, the left bidding may result in a higher contract price than the right one.

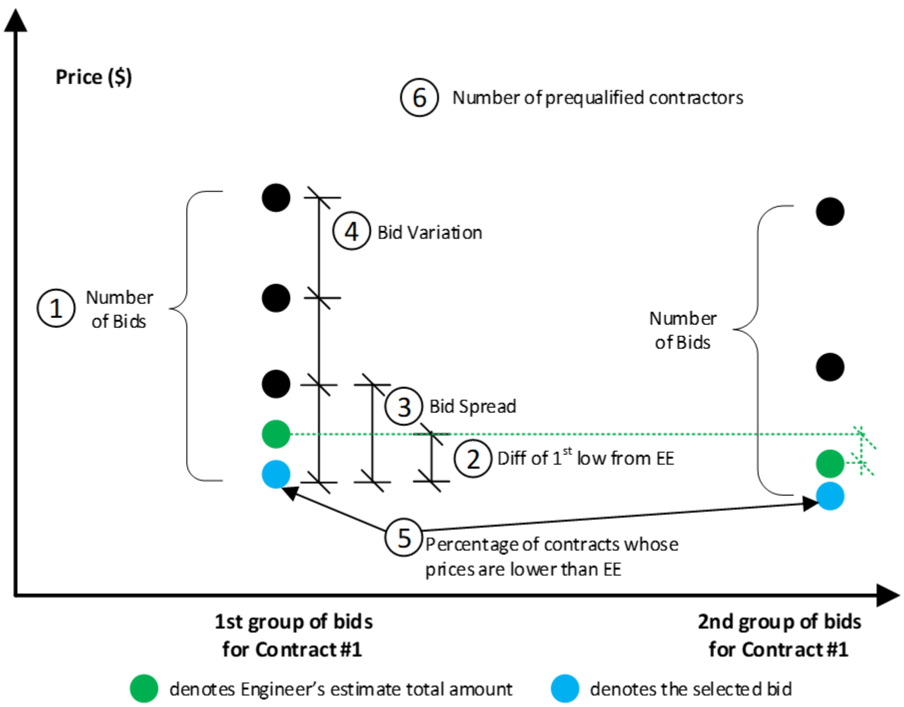


Figure 52. Relative competitiveness: higher competition but higher price

For this reason, this study compared the main pay items of Michigan with the ones of peer states in an attempt to reveal whether construction costs in Michigan are higher. In fact, State DOTs do have different pay items in managing the construction cost in the highway construction industry. For example, there are about six thousand pay items in MDOT 2020 item catalogs. Ohio defined 2,000 items. Theoretically, more pay items could lead to higher accuracy of construction estimation. The reason is that the pay items need to be designed to account for each construction item or activity with different work scope, construction method, resource requirements (e.g., crane), productivity, location, and unit cost.

This study selected Mobilization as one example in the cost comparison of the main pay items. It is because all state DOTs use this item to manage the mobilization-related cost. Figure 5352 presents the cost comparison of mobilization between Michigan and Ohio. The mobilization cost in Michigan averaged $148,198.47 in 2016, accounting for 7.77% of the total construction cost. The median mobilization cost is $54,800.00. It should be noted that MDOT uses 5% in estimating the mobilization and its maximum percentage is limited to 10% in the bidding evaluation. In contrast, Ohio's average mobilization cost was $47, 294.71, accounting for 3.6%, and its median was $20,000.00. The comparison results indicate that the absolute mobilization cost and percentage were much higher in Michigan than in Ohio. There are several possible explanations: (1) Michigan's construction work is more expensive than Ohio's due to internal factors such as higher labor, material, and equipment cost; (2) bidders in Michigan might also unbalance the mobilization pay item, leading to the higher cost percentage; and (3) releasing both the awarded average unit prices and the Engineer's Estimate prior to bidding may lead to more reasonable but higher prices in comparison with the Engineer's Estimate.

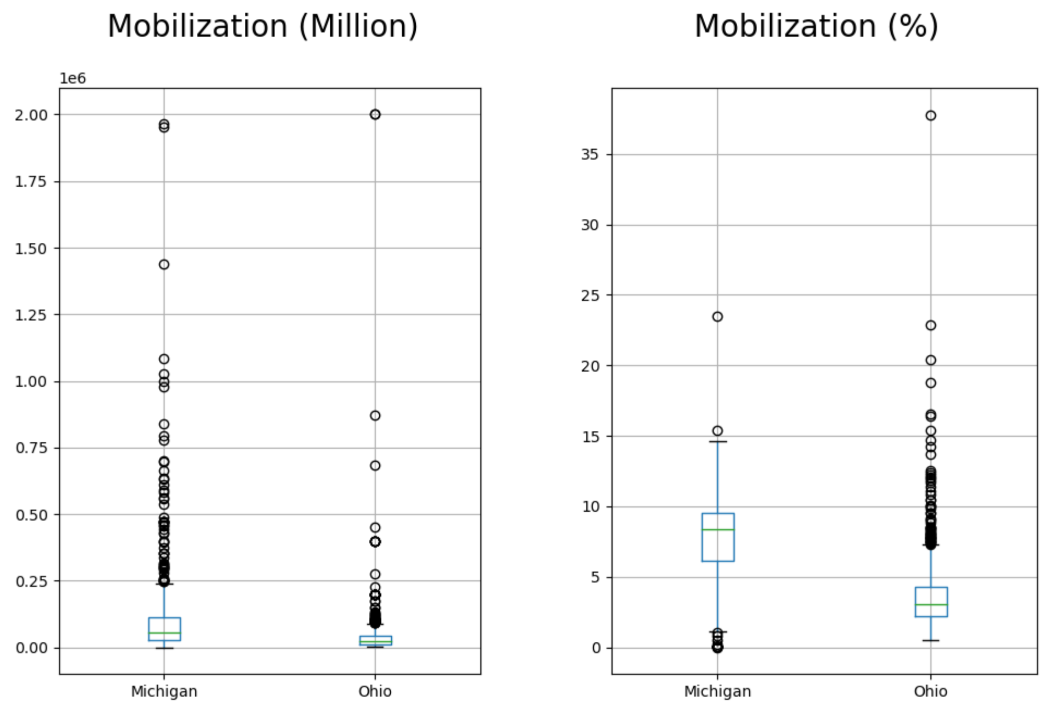


Figure 53. Pay item comparison: Mobilization

Many state DOTs also employ a maximum percentage in the bidding and estimating of the mobilization. For example, 10% of the contract amount is used by Iowa DOT, Manie DOT, Oregon DOT, and Wisconsin DOT (who require the justification when over 10%). In contrast, Minnesota DOT, Arkansas DOT, and Tennessee DOT use 5%, and NYS DOT limits the percentage to 4% of the bid. One interesting note is that contractors ofter estimate and bid the mobilization near the maximum percentage. For example, the mobilization in Arkansas is usually bid around 5%. <u>It implies that MDOT may consider reducing the max percentage for the LSUM items</u>.

Chapter 6. COMPETITIVE BIDDING EXPERIMENT

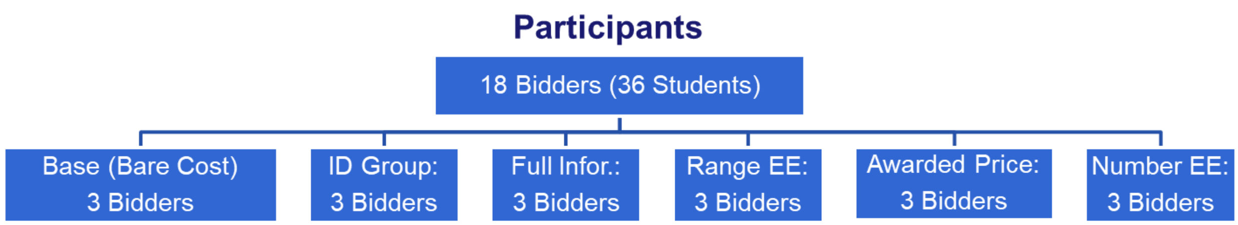
There are many variations in the implementation of competitive bidding across different agencies, for example, in the level of information release provided by owner agencies on (1) historical bids, (2) qualified bidders and owner's prices for new projects. As revealed in the national survey, the state DOTs release various information prior to bidding. Some typical examples include (1) a list of eligible bidders, (2) historically awarded average unit prices, and (3) the Engineer's Estimate of the total amount of the new project, either as an exact value or as a range. The variation in information feedback affects the competitiveness of bidders to different degrees. There has been extensive qualitative discussion on whether such information should be released to the bidders prior to bidding. Some claims a list of eligible bidders, for example, could potentially increase the number of subcontractors by revealing the identity of the prime contractors to subcontractors. In contrast, the other asserts that such information may provide opportunities for non-competitive bidding. This chapter presents the construction bidding experiment regarding information release in competitive bidding, i.e., whether such information should be released to prospective bidders and how such information may affect the competitiveness of construction bids, such as its effect on the contract price and on the number of bidders.

6.1 EXPERIMENT SETTINGS

The bidding experiment was carried out for the period of three weeks in April 2022. Figure 5453 presents the experiment settings, including (1) participants, (2) lettings and hypothetical projects, and (3) information disclosed to each bidder. These settings are described in this section.

Participants: It is challenging to obtain feedback on bidding strategies from contractors and engage actual contractors in the experiment. Alternatively, undergraduate students enrolled in the course of Construction Contract Spring 2022 at WMU were invited to participate in the bidding experiment and simulate the bidding behaviors of actual contractors. In total, there are 36 students in the course, and they are assigned randomly into 18 groups. One group represents one bidder or contractor and consists of two students.

Hypothetical construction bids: In an attempt to investigate how the given information affects the bid price, all bidders were invited to bid on 32 hypothetical projects. Bidding for these 32 projects occurs in eight lettings, and each letting has four projects. The projects are selected from the actual historical MDOT construction projects. They are selected based on (1) project size and (2) diversity of pay items. The project sizes range between $100,000 and $3,000,000, with an average of $500,000. Each project has about 20–40 pay items so that the bidders do not lose interest in preparing their bids because of tedious work on a large number of items. One example of the construction project is included in Appendix D. The bidders could determine on which projects they would bid.



Bidder ID	Letting 1				Letting 2-7				Letting 8			
	Project 1	Project 2	Project 3	Project 4	…	…	…	…	Project 29	Project 30	Project 31	Project 32
Bidder 1												
Bidder 2												
Bidder 3												
…												
Bidder 16												
Bidder 17												
Bidder 18												

Figure 54. Experiment settings

<u>Information that is released to bidders</u>: Bidders were given different information about the hypothetical bids of actual MDOT historical projects. For example, Bidders #1–#3 were provided the list of eligible bidders, while Bidders #4–#6 were given the full information, including (1) a list of eligible bidders, (2) Engineer's Estimate, i.e., the owner's price, and (3) the awarded average unit price of each bid item. Bidders #7–#9 received a range of owner's price, i.e., Engineer's Estimate. The awarded average unit prices were provided to Bidders #10–#12. Bidders #13–#15 were merely given the base information about the project, i.e., the bare cost of the construction project. The last group of bidders (#16–#18) is given the owner's price. In addition, all bidders were provided with the bare cost of the construction project. The bare cost is the direct cost of a contract, i.e., the sum of bare material cost, bare labor cost, and bare equipment cost. As such, they could determine the mark-up percentages for each project and calculate the total bid prices using the mark-up percentage and bare cost of each pay item.

Other settings: To mimic the actual bidding, the bidders were given a start-up fund of $400,000, and each bid they participated in costs 2.5% of the estimated bid price. As such, the bidders needed to select the projects they wanted to bid on in each letting in consideration of their available funds. The eight lettings were conducted in 3 weeks. After each letting, the lowest bid was determined to be the winner in each group given the same information. The winner's identity and the ranked bid amount were announced in the bid opening. In addition, all bidders were informed of the winner’s profit and their remaining available funds.

6.2 RESULTS OF THE EXPERIMENT

As the bare cost of each pay item in each construction project is disclosed to the bidders, they could add a specified mark-up percentage (**MUP**) to determine the total bid prices. The mark-up percentage could measure the competitiveness of each bidder, as expressed in Eq. (7). The value of an MUP could be in the range of -0.5 and 0.5, and the lower MUP indicates a more competitive bid. An MUP of 0 means a bidder bids at the bare cost without profit. When the value is less than 1, the bidder is actually bidding at a cost that is less than the actual construction cost.

$$\text{MUP} = \text{Total Bid Price} / \text{Estimated Bare Cost} - 1 \quad (7)$$

This study also investigates how the given information will affect the number of bidders, e.g., a list of eligible bidders. Some bidders (i.e., Bidders #1–#6) received a list of eligible bidders, and the others did not. This treatment is used to answer this question, and the measurement is the number of bidders. Bidders are supposed to select the ones among the 32 projects to bid in the experiment. The results of the experiment are included in Appendix F.

6.2.1 First Letting

Before the various bidding information is disclosed to all groups of bidders, bidders are required to bid on the first four projects in the first letting. All bidders had the same information, i.e., the bare cost of each project. They could determine their bidding strategy and mark-up percentage based on their experience. The first letting is to ensure all bidders do not significantly differ in bidding behavior and strategies. Meanwhile, it allows the bidders to be familiar with the bidding procedure. Table 8 tabulates the mark-up percentages of each project for each bidder. The table shows that the percentages are slightly different among all bidders, except Bidders #8-#10. For example, the averages of mark-up percentage are 11.79%, 11.24%, 4.15%, 9.78%, 10.68%, and 11.67%, for the six groups, respectively. Bidders #8-#10 are more competitive than other groups. To validate this, Mann-Whitney U-test was used to test the difference in mark-up percentage. The test results are summarized in Table 9. The statistical results show no significant difference among the bidders in the first letting, except for the bidders given with a range of total Engineer's Estimate. It is worth noting that Mann-Whitney U-test is used because the data is not normally distributed, as proved by the Shapiro-Wilk test.

Table 8. Mark-up percentage of all bidders in the 1st letting

ID		Mark-up Percentage				
		Project 1	Project 2	Project 3	Project 4	Average
Given the bidders' identity #1 (**ID**)	Bidder 1	10.00%	-10.00%	12.00%	18.50%	11.79%
	Bidder 2	12.00%	12.20%	28.85%	15.00%	
	Bidder 3	9.36%		8.71%	13.06%	
Given full information #2 (**Full**)	Bidder 4	12.00%		5.00%	8.00%	11.24%
	Bidder 5	20.00%		20.00%	20.00%	
	Bidder 6	7.02%		-0.85%	10.00%	
Given total EE #3 (**Range EE**)	Bidder 7	11.30%		3.00%	2.99%	4.15%
	Bidder 8	7.51%	3.21%		-5.91%	
	Bidder 9	10.11%	2.56%		2.57%	
Given average awarded prices of pay items #4 (**Awarded Price**)	Bidder 10	10.00%	8.34%		9.00%	9.78%
	Bidder 11	20.00%	20.00%		20.00%	
	Bidder 12	2.52%	2.84%	2.57%	2.51%	
Bare cost, excluding profit #5 (**Base**)	Bidder 13	5.34%	5.25%	6.04%		10.68%
	Bidder 14	8.41%	2.59%		8.45%	
	Bidder 15	20.00%	20.00%	20.00%		
Given total EE #6 (**Number EE**)	Bidder 16	10.00%		-15.00%	-3.00%	11.67%
	Bidder 17	28.04%	23.49%	10.04%	27.41%	
	Bidder 18	15.51%	10.19%	10.04%		

Table 9. Mark-up percentage in the 1st letting: Mann-Whitney U-test

Each Group Pair	Mann-Whitney U-test		Conclusion (Interpretation)
	U1	*P*-value	
Base vs. Full	43.5	0.822	not differ significantly
Base vs. Number EE	24.0	0.457	not differ significantly
Base vs. Awarded Price	42.5	0.8697	not differ significantly
Base vs. ID	63.0	0.322	not differ significantly
Base vs. Range EE	19.0	0.063	not differ significantly
Full vs. Number EE	26.5	0.63	not differ significantly
Full vs. Awarded Price	48.0	0.8	not differ significantly
Full vs. ID	56.5	0.6202	not differ significantly
Full vs. Range EE	63.0	0.051	not differ significantly
Number EE vs. Awarded Price	32.5	0.845	not differ significantly
Number EE vs. ID	38.5	1.0	not differ significantly
Number EE vs. Range EE	21.0	0.299	not differ significantly
Awarded Price vs. ID	67.5	0.397	not differ significantly
Awarded Price vs. Range EE	34.5	0.414	not differ significantly
ID vs. Range EE	84.0	0.0097	differ significantly

6.2.2 Competitiveness comparison among experiment groups

After the first letting, each bidder received their bidding information in the designed treatments. They could use the provided information in their bidding decision, such as bid or not on a specific project, the mark-up percentage, and the total bid amount. This section presents the results of the experiment for all lettings.

6.2.2.1 Mark-up percentage

Table 1012 summarizes the make-up percentages of each bidding group over eight lettings, the descriptive statistics of all groups of bidders is provided in Table 1110. The highest average MUP was 29.6% (from the group of bidders that received the awarded average unit price). This was followed by 16.3% (from the group of bidders given the full information, i.e., eligible bidders, awarded prices, and owner's prices). The lowest MUP was 0.9% (from the group of bidders that received only information about the bare cost of the construction project). The other groups' MUPs averaged 4.4%, 4.9%, and 5.2%, respectively. The notable findings are summarized below:

1) The awarded average unit prices could reduce the competitiveness of the bidders.
2) Full information release, to a certain degree, discourages competitiveness in construction bidding.

Table 10. Mark-up percentage over eight lettings

Group	Letting 1	Letting 2	Letting 3	Letting 4	Letting 5	Letting 6	Letting 7	Letting 8
ID	11.8%	2.9%	3.9%	−1.0%	1.0%	6.8%	5.5%	4.6%
Full Infor.	11.2%	16.0%	23.2%	27.0%	11.6%	11.1%	18.6%	11.4%
Range EE	4.1%	7.4%	10.0%	2.9%	1.9%	0.3%	6.8%	5.7%
Awarded Price	9.8%	89.3%	38.3%	43.8%	23.7%	13.7%	21.3%	−3.2%
Base	10.7%	2.9%	−0.7%	−1.9%	−2.2%	−1.3%	−0.5%	0.0%
Number EE	11.7%	19.0%	−15.3%	3.2%	6.7%	8.3%	3.8%	3.9%

Table 11. Descriptive statistics of mark-up percentage

Groups	Mark-up Percentage			
	Mean	**STD**	**Max**	**Min**
Bidder's identity (Bidders #1–#3)	4.4%	0.076	28.8%	−20.5%
Full information (Bidders #4–#6)	16.3%	0.142	96.5%	−7.3%
Range EE (Bidders #7–#9)	4.9%	0.146	38%	0.0%
Awarded Unit Price (Bidders #10–#12)	29.6%	0.576	251.8%	−8.7%
Base (Bidders #13–#15)	0.9%	0.0765	20%	−20.1%
Number EE (Bidders #16–#18)	5.2%	0.11	28%	−15.7%

In addition to comparing the average MRR, Mann-Whitney U-test was used to test the significant difference between each treatment group. The test results are summarized in Table 1211. The statistical results suggest that each additional item of information disclosed to the bidders affects the competitiveness (i.e., MUP) significantly, as their MUPs differ very considerably from the bidders who only receive the bare cost of the projects. One interesting finding is that the MUP of the bidders receiving the full information did not differ significantly from those who only received the awarded average unit prices. This implies that the awarded average unit prices play the most influential role in determining the prices in construction bidding. The bidders receiving the awarded prices offered greater MUP (i.e., 29.6%) and less competitive bids. Furthermore, the standard deviation of 0.576 was higher than those of any of the other groups, indicating that bidders in this group showed less consistency in their bidding. This finding implies that extra caution should be taken when providing the average awarded prices of highway construction bid items to prospective bidders prior to bidding.

Table 12. Significant differences between each group: Mann-Whitney U-test

Each Pair Group	**Mann-Whitney U-test**		**Conclusion (Interpretation)**
	U1	*P*-value	
Base vs. Full	4,240.5	0.00000000006	differ very significantly
Base vs. Number EE	1,091.0	0.00036	differ very significantly
Base vs. Awarded Price	4,298.0	0.00000001	differ significantly
Base vs. ID	4,374.0	0.00082	differ very significantly
Base vs. Range EE	3,956.0	0.0061	differ significantly
Full vs. Number EE	1,981.5	0.00044	differ very significantly
Full vs. Awarded Price	2,388.0	0.7008	**do not differ significantly**
Full vs. ID	1,205.0	0.000005	differ very significantly
Full vs. Range EE	3,900.5	0.000000001	differ very significantly
Number EE vs. Awarded Price	1,997.5	0.049	differ significantly
Number EE vs. ID	1,568.5	0.0927	not differ significantly
Number EE vs. Range EE	1,509.5	0.135	not differ significantly
Awarded Price vs. ID	2,094.0	0.0004	differ very significantly
Awarded Price vs. Range EE	2,011.5	0.0009	differ significantly
ID vs. Range EE	3,738.5	0.271	not differ significantly

The bidding experiments were carried out in eight lettings. The bid trends and spreads are examined through scatter plots and LOWESS curves, as shown in Figure 5554. The primary y-axis represents the trends of average MUP, whereas the secondary y-axis denotes the MUP of each bidder in each letting. The comparison results among the bidding groups are summarized below.

1) The MUP of the base group (i.e., yellow line) is continually decreasing from 10.7% to −2.2% over the first five lettings and then experiences a slight increase from −2.2% to 0.9% in the last three letting. This finding implies that bidders receiving no additional information from the owner always competitively bid in an attempt to win the projects.

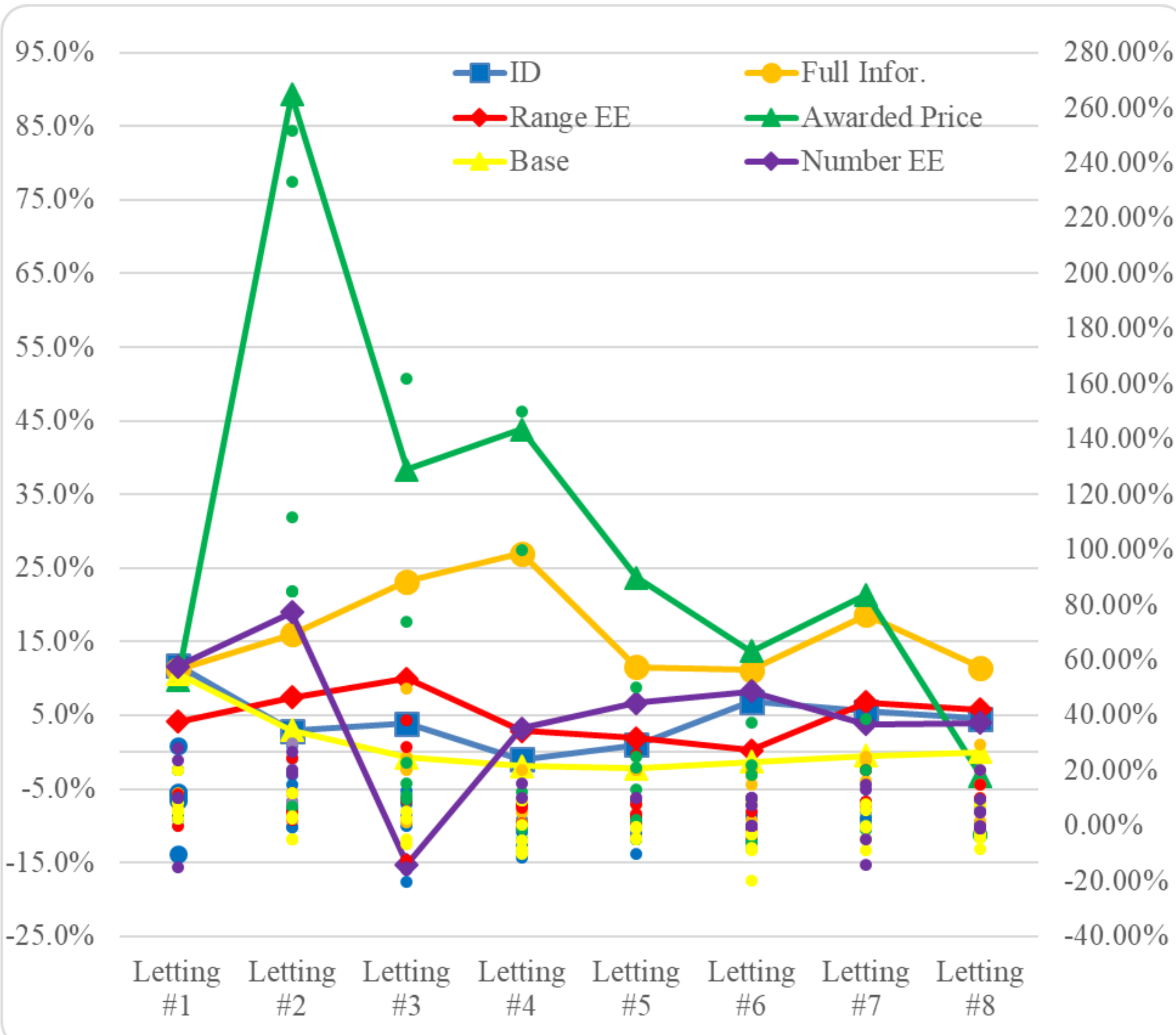


Figure 55. Bid spread and trends in the eight simulated lettings

2) The MUP of the bidders with the awarded average unit prices (i.e., green line) significantly increased in the 2nd letting. This is simply because this group of bidders was attempting to base their price on the awarded average unit prices. However, the awarded average unit prices are high because of the extremely high price of certain pay items awarded before. Again, this finding implies that the owner agency should have caution in releasing the awarded average unit prices. At least, the accuracy of the awarded average unit prices should be improved by excluding unusual prices.
3) The group of bidders with full information actually bid more competitively than the group with awarded average unit prices. This may be due to the fact that these bidders considered both the awarded average unit price and the Engineer's Estimate of the total cost in their decision-making. They attempted to propose prices close to the awarded average unit price while within a reasonable range of the owner's expectations. In short, the EE and awarded average unit prices could cause bid creep to a certain degree.
4) The MUP trends of the other three groups (e.g., purple, blue, and red lines) are experiencing fluctuations, implying the changes in the bid strategy of each group. These groups are less competitive than the base group, and statistically, there are no significant differences among these three groups.
5) All bidders consider their given information in determining the bid prices and change their bidding strategies over the eight lettings. As shown in the figure, all bidders, except those in the base group, increased their mark-up percentage after the first letting. The base group is steadily decreasing their mark-up percentage as they did not receive any information regarding the bidder identity, awarded average unit prices, and Engineer's Estimate and tend to be competitive in the bidding. Although there were increases in the first four letting, all bidders also made an effort to decrease the MUP.
6) The bidders from different groups significantly differ in terms of competitiveness. For example, the bidders with the full information are less competitive, with an average MUP of 16.3%.

6.2.3 Number of bidders for ID group and No ID group

Many state DOTs release the list of eligible bidders before the bidding. This information may affect the number of bids received for construction projects. In the experiment, the list of eligible bidders is disclosed to different groups. There are, in total, six bidders who received the list of eligible bidders, including Bidders #1–#3 and Bidders #4–#6. In contrast, the remaining groups of bidders (another 12 bidders) did not have this information. The former group herein is named the ID group, while the other is called the No ID group in this study. After the eight lettings, the number of bids received for each construction project is collected and compared to investigate how the eligible bidder list affects the bidding. The percentage of the number of bidders is calculated and compared between these two different treatment groups. The percentage herein is defined as the number of bidders who bid on the project divided by the total number of bidders in its group.

Figure 5655 shows the percentage comparison between the ID group and the No ID over the eight lettings. In the first three lettings, the percentage of the ID group is 100% means all six bidders decided to bid on the given construction projects. The percentage of the No ID group is 75%, meaning only 9 of 12 bidders competed on the same projects. For most lettings, the number of bids in the ID group is more than the No ID group. To validate this finding, a Mann–Whitney U-test was used to test the difference between the two groups. The statistical results (U = 166.5, p-value = 0.403) show that the number of bidders does not differ significantly between the two groups.

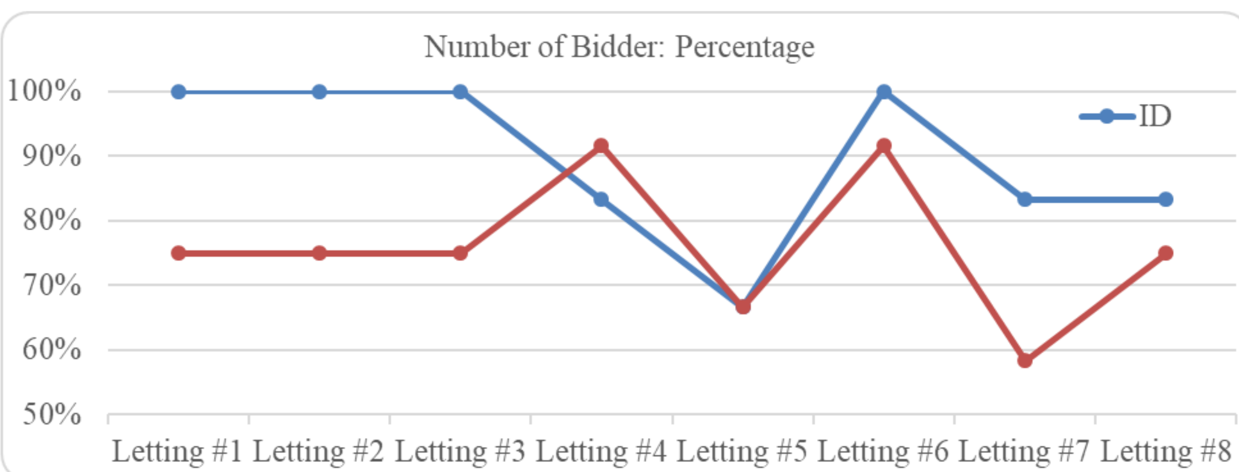


Figure 56. Percentage of the number of bidders: ID vs. No ID

This study also compared the mark-up percentage between the two groups as a way of evaluating the impact of the eligible bidder list on the total bid price. Figure 5756 shows the MUP trends over the eight lettings. The results show that the MUP of the ID group is consistently higher than the one of the base group. The reason may be that the No ID groups tend to be more competitive when they do not know the identity of the proponent against whom they are competing. On the other hand, the ID groups are less competitive, especially when they are aware of limited competitors. The primary y-axis in Figure 5756 represents the trends of average MUP, whereas the secondary y-axis denotes the MUP of each contract from each bidder.

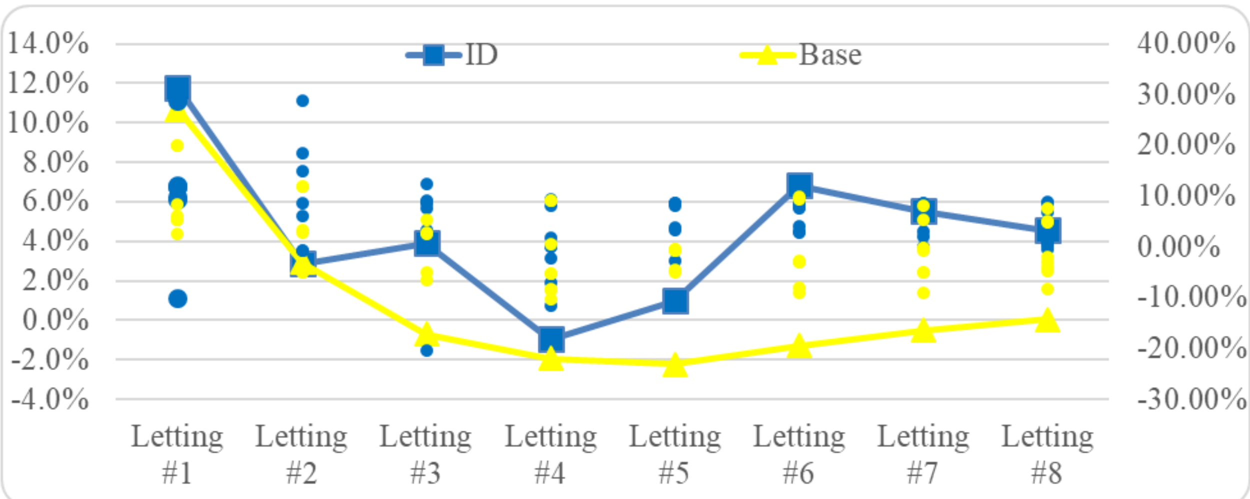


Figure 57. Mark-up ratio: ID vs. No ID

Chapter 7. RECOMMENDATIONS

This chapter presents the recommendation regarding competitive bidding and construction estimation based on the results of national surveys, follow-up interviews, competitive analysis, and bidding experiments.

7.1 BID INFORMATION RELEASE

The national survey results revealed that typical information released to prospective bidders prior to bidding includes (1) the list of eligible bidders, (2) a range representing the Engineer's Estimate total amount, and (3) awarded average unit prices of pay items. MDOT provides additional information, including the Engineer's Estimate in the accuracy of thousands, to the bidders. The competitive analysis results indicated that construction bids in Michigan are more competitive than, or as competitive as, that in peer states in many respects, including (1) the number of bids per project, (2) the ratio between the lowest bid and Engineer's Estimate, (3) bid spread, (4) bid variation, (5) a percentage of contracts whose bid prices are lower than the Engineer's Estimate, and (6) the number of prequalified contractors. It is worth noting that the highest level of competition does not necessarily correspond to the lowest contract price. One general note here is that the difference between Engineer's Estimate and the lowest bid depends on the accuracy of the Engineer's Estimate. In this respect, more than 50% of construction projects' Engineer's Estimate is within 10% of the lowest for most DOTs, as revealed by the survey results. Construction bids in Michigan are as competitive as that in peer states.

However, the results of the experiment suggest that, when both the awarded average unit price and the Engineer's Estimate of the total cost are disclosed to the bidders, the MUPs are proven to be always in a reasonably high range with an average of 16.3%. The awarded unit price group attempted to bid at the average unit prices; their MUP trends experienced a decrease in the eight lettings and averaged 29.6%. Consequently, it is recommended that the awarded average unit prices be disclosed with **high caution**, and the **Engineer's Estimate and awarded average unit prices should not be released together** to bidders before bidding.

The list of eligible bidders did not significantly affect the number of bids received per project. However, the MUPs from the bidders knowing the identity of their competitors are less competitive than those from the bidder (receiving no additional information from owners). In light of this, a reasonable practice would be for the list of eligible bidders to not be released to the bidders prior to bidding. Alternatively, the plan holder list may be disclosed to the bidders.

7.2 BIDDING PROCEDURES AND QUALIFICATIONS

The survey results also revealed that some bidding procedures and practices could encourage the competitiveness of construction bids, especially in terms of the number of bids per project. This section describes these best practices regarding letting time, project packaging, project types in a letting, and so forth, and they could be applied to MDOT's practice.

1. *Advertisement*: The advertisement should be placed at multiple locations and sent to the State Builders Association for a higher level of competition.
2. *Prequalification:* The prequalification could ensure the quality of prospective bidders. On the other hand, prequalification may discourage small contractors from bidding, decreasing competition in competitive bidding. Most DOTs prequalify the prime contractors, with several DOTs doing the prequalification for prime contractors and subcontractors (e.g., West Virginia, Tennessee, and Michigan). The data analytics shows that the number of bids per project in Michigan is higher than the peer states, implying that MDOT's prequalification process did not limit competition and can be used in the future. Conservatively, it is recommended only to prequalify prime contractors.
3. *Letting time*: The contractors have limited resources and capacities, so the letting time and project time could be determined for a more favorable time for contractors, especially key contractors, for the proposed construction work. This practice could encourage more bidders to compete for the projects and more competitions. It should be noted that letting time herein refers to the period between the start of advertisement and the bid opening.
4. *Project packaging* or *tie to another project:* It is recommended that multiple similar project bids in the same bid opening should be avoided. As such, the contractors could manage limited resources in preparing the bid and carrying out the construction work if awarded.
5. *Re-let*: When the level of competition is not sufficient and re-letting is the option, MDOT could make exert efforts in re-letting, for example, checking the letting time; adjusting the work window to the next season, allowing for more flexibility for the contractor; calling contractors on the plan holders list to see why they didn't bid. These practices could shed light on how to encourage competition in re-letting.

7.3 Post-bid analysis

Competitive bidding is the most widely used method for construction procurement, and it is intended to invite competition in order to lower the construction cost for owners. The owner agencies, such as state DOTs, can perform a post-bid analysis to evaluate the bid competition, detect unbalanced bids, and identify any non-compliant construction bids. The post-bid analysis is essentially a quality assurance procedure for the competitive bidding process.

Regarding bidding tendency monitoring, most state DOTs merely conduct a manual review of the bidders' win/loss ratio against their competitors and bidders' win/loss ratio by region. Unbalanced bid detection is limited to a line-to-line comparison for the price difference. State DOTs use various thresholds for the price difference in unbalanced bid analysis, such as 5% in Wisconsin, 15% by FHWA, 50% in New Jersey, and so forth. When a larger price difference is identified for specific pay items, their quantities are then verified in order to avoid any materially unbalanced bids.

Alternatively, this study developed a post-bid analysis tool that allows MDOT systematically monitors bidding tendencies. The maps and charts described in Chapter 3 can provide in-depth insights into the bidding tendency. The data visualization includes (1) Bidding/working activity map, (2) spatial win/loss map, (3) bidder's win/loss ratio map against its competitors, (4) bid spread/variation over time, (5) bidder's win/loss over time, (6) bidding co-occurrence map, (7) subcontracting map, and (8) competing and subcontracting map. The tool also offers data visualization of a selected pay item in a contract for unbalanced bid analysis, such as (1) difference percentage from the Engineer's Estimate, (2) historical awarded price range, (3) bidder's normal price range, and (4) historical quantity variation.

It is worth noting that the tool can provide various visualizations of bidding data. However, the user should use the tool to look for special bidding patterns, which can be indicators of any potential improper bid tendency, unbalanced bids, and insufficient competition. These patterns are described in the following subsections.

7.3.1 Patterns/indicators in tendency monitoring

The patterns and indicators in Table 13 can be considered in bidding tendency monitoring and they can be identified using this developed tool. Essentially, the tendency could be monitored in three respects: competitor, temporal, and spatial.

Table 13. Bidding tendency monitoring: Patterns and indicators

Spatial-temporal-competitor		Indicators
Bidder/ Competitor	Bid spread/variation over time	• Standard deviation of total bid price percentage differences from the lowest in a contract > 0.28 • A clear gap between the winner and other competitors (Complementary bid? Extremely high price?) • Prices are close but have the same increment
	Bid is identical or similar to the Engineer's Estimate for a given project	• More than 70% of pay items are identical?
	Competing, affiliation, and sub-contractor relationship	• Competitors turn out to be subcontractors or affiliated

	Bidder's win/loss ratios against its competitor (s)	• **The same group** of bidders competed for a series of contracts
		    o Bid rotation?
		    o Any spatial allocation?

Temporal (Time)	Key vs. Sporadic bidder	• A sporadic bidder never wins against a specific competitor
	Bidder's win/loss over time	• A contractor may have a limit of work capacity each year, e.g., five projects. When reaching this limit, it may give a complimentary bid
	Bidder's own price range over time	• Extremely high or low prices, unbalanced prices?
Spatial	Bidding/Work Activity or win/loss ratio for a specific area	• Win ratio for sporadic bidders in specific regions = 0 • Any spatial allocation? Frequent bidders in a specific area that is far from their facility never win?
	Spatial visualization: Number of bidders per county	• A list of bidders for a specific area, bid rotation?

7.3.2 Patterns/metrics for unbalanced bids

Unbalanced bids can be detected using the tool developed in this study. Table 14 shows some indicators for unbalanced bids. Once these indicators are identified using this tool, the bids are most likely unbalanced. These indicators could provide a basis for further manual review and analysis on the part of the bid review team and for the verification requests issued to bidders.

Table 14. Unbalanced bids: patterns and metrics

Name	Indicators
Unascertained Score	When the score is less than 0.75, it is considered to be unbalanced. This score is the proposed unbalanced bid metric from an unascertained model.
Risk-based analysis for materially unbalanced bids	When the printed result of materially-unbalanced bids on the graphic user interface is true, the bids are considered to be unbalanced. The risk-based analysis considers the historical quantity variations in recalculating the total bid prices and re-ranking the bidders. If the original lowest bid is not the lowest price with the quantity uncertainties, then it is considered to be materially unbalanced.
Number Percentage: Items Within 10% of EE	50% It gives the percentage of the number of items within 10% of the Engineer's Estimate unit price.
Cost Percentage: Items Within 10% of EE,	50% It gives the percentage of the cost of items within 10% of the Engineer's Estimate unit price.
Number Percentage of Unbalanced Items via MDOT existing method	50% It gives the percentage of the number of items that exceed the threshold of (1) price percentage difference of 15% from the Engineer's Estimate of unit price, and (2) price difference amount of $10,000 from the Engineer's Estimate.
Cost Percentage of Unbalanced Items via MDOT existing method	50% It gives the percentage of the number of items that exceed the threshold of (1) price percentage difference of 15% from the Engineer's Estimate of unit price, and (2) price difference amount of $10,000 from the Engineer's Estimate.

7.3.3 Patterns/metrics for unreasonable bids

Table 15 shows additional indicators for unreasonable bids, which typically include unbalanced bids and inadequate bid competition. The indicators could be identified using this tool and taken into consideration in establishing the reasonableness of construction bids, providing a basis for further manual review and analysis on the part of the bid review team.

Table 15. Unreasonable bids: Patterns and metrics

Name	Indicators
Number of bidders within 10% of EE	< 1 When no bid is within 10% of the Engineer's Estimate of the total cost, please look further at the competition assessment results. If the level of competition is inadequate, the bids are considered to be unreasonable.
Cost Percentage of Identical Items,	> 70% It gives the percentage of the cost of items that have identical prices from the bidders, indicating potential improper bidding tendency or a scenario in which the bidders may have the same subcontractors for the subcontracted work.
Number Percentage of Identical Items,	> 70% It provides the percentage of the number of items that have identical prices from the bidders.
Number of bids that this group of bidders competed together,	> 1 It means this group of bidders competed together for multiple projects, and their win/loss ratios should be further examined for any potential bid rotation.
Percentages from Total EE	It provides the percentage of the lowest bid amount divided by the Engineer's Estimate of the total cost.

7.4 BID COMPETITION ASSESSMENT

In practice, bid competition can be assessed by different measurements, including (1) the number of bids per project, (2) the price difference between the lowest bid and the Engineer's Estimate, and (3) the bid variations among the received bids. State DOTs typically consider these measurements in the bid competition evaluation; however, it should be noted that the number of bids per project is the most common factor used by state DOT because of its simplicity. The threshold for the adequate competition is typically three. When there are more than three bids, DOTs consider the level of competition to be sufficient. FHWA's 2004 guidelines on assessing competition consider all three factors and define a clear threshold; for example, the lowest bid should not exceed the Engineer's Estimate when only one bidder exists. However, the latest 2021 guideline removed the specific thresholds and merely provided a set of factors that could be considered. The factors in the 2021 guidelines include (1) the number of bids, (2) the difference between the lowest bid and the Engineer's Estimate, (3) the difference between the lowest bid and other bidders, (4) bid variation, (5) project type and competition for the work type, (6) letting time, (7) other bidding opportunities, (8) availability of subcontractors, and (9) potential DBE.

This study conducted a quantitative competition analysis to determine the threshold of adequate competition based on MDOT bid data. The proposed competition assessment includes three factors: (1) the number of bidders, (2) the ratio between the lowest bid and the Engineer's Estimate, and (3) bid variation. Their thresholds are summarized in Table 16. The construction bids have to satisfy two of the three criteria to consider competitive. For example, the number of bidders should be more than the average number in the specific county where the project is located. The ratio between the lowest bid and the Engineer's Estimate should be less than the maximum value calculated by the linear trend fitted in Figure 5857. Figure 5857 presents the line plot of the ratios of the lowest bid amount divided by the Engineer's Estimate of the total cost against the number of bids. Finally, the bid variations of the construction bids should be less than 0.28.

Table 16. Criteria of competition assessment

Step	Criteria	Threshold	Sufficient
1	Number of bidders	> Average number	Satisfying at least two criteria
2	Lowest's price/EE	See Figure 5857	
3	Bid spread/variation	<= 0.28	

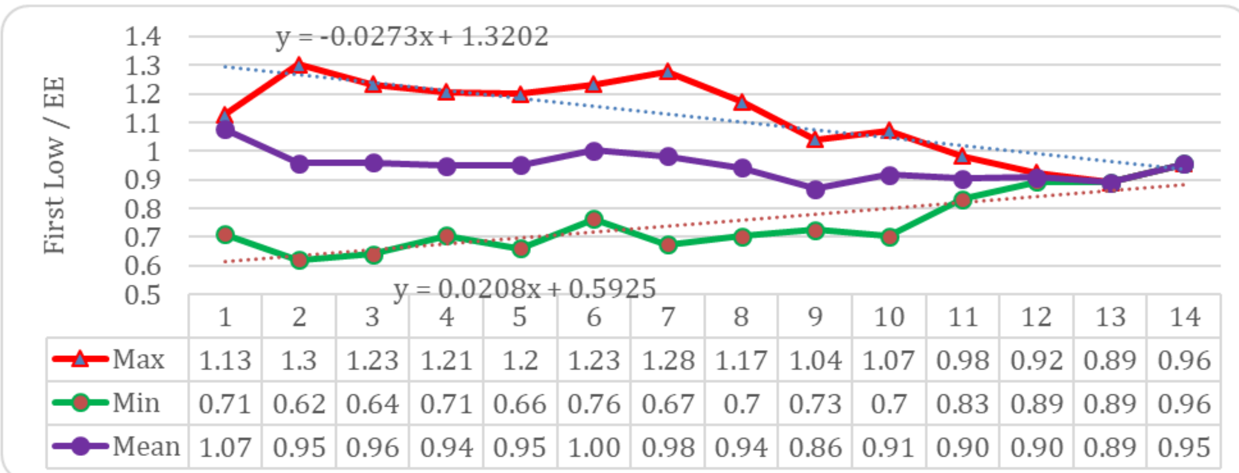


Figure 58. Max and min ratio between the lowest bid and EE

These criteria were applied to the construction bid data from 2016, with the result that 29 bids (i.e., 3.9% of the 750 total construction bids for 2016) were found to fail to satisfy the competition criteria.

7.5 Construction estimation methods

Three cost-estimation methods are widely used by state DOTs: the historical data approach, the actual cost method, and the combined approach. Among these, the actual cost approach is believed to generate higher accuracy in estimates, which alleviates contractor collusion and bid-rigging problems; however, it is time-consuming and demands a significant workforce.

The research team solicited information on estimation methods through the national survey. The survey results and recommendations are summarized below.

1. *Primary estimation method:* The historical data approach or bid-based estimation is still the primary method for estimating the highway construction project.
2. Eleven out of 15 DOTs using the historical data approach such as MDOT can achieve the acceptable range of federal recommendations, i.e., at least 50% of their projects within ± 10% of the Engineer's Estimate.
3. It is recommended that the historical data approach could be used as the primary estimation approach.
4. The accuracy of bid-based estimation could be improved in three respects. **First**, advanced data analysis of pay item unit prices, e.g., data cleaning techniques, can be developed to clean the outliers out of the historical data. **Second**, machine algorithms could be explored to predict the unit price of both Lump SUM and unit bid pay items, especially in the context of high inflation. Some potential algorithms include random parameters models, linear regression (Linear), ridge regression, Bayesian ridge, stochastic gradient descent (SGD) regression, passive-aggressive (PA) regression, and ensemble machine learning. **Third**, the bid-based estimation method could be further extended into a combined approach, where major bid items could be estimated or verified using the actual cost approach. Herein, the major items are defined as those whose cost accounts for more than 3% of the total estimated amount. **Fourth,** the quantity discount would be applied to the larger volume of items. **Lastly**, the construction cost index could be used to adjust the unit price of major items as a way of accounting for inflation; further the cost index-based estimation method could be further explored.

7.6 BIDDING AND ESTIMATING TRAFFIC CONTROL

The extensive literature review and survey results show that traffic control items are priced in three ways in DOTs' current practices: (1) Lump SUM, (2) unit price, and (3) a combination of both. Each has its pros and cons; for example, the unit price method minimizes the efforts in adjusting quantities as work progresses; however, it requires DOTs to monitor and document pay item usage regularly. According to the traffic control survey (Johnson et al., 2001), most states (43% of thirty-five states) use the combination of Lump SUM and unit price method. Only ten of the thirty-five responding states use a lump sum method for traffic control items, where the contractors are responsible for estimating the quantity of traffic control items. Conversely, DOTs should provide quantities of traffic control pay items for unit price contracts. In practice, state DOTs, including MDOT, face a challenging task in obtaining accurate estimations of traffic control pay items. This is partially due to the fact that (1) contractors may change the control plan on which DOTs prepare traffic control estimates, (2) DOTs do not know the construction schedule, and (3) the payment schedule of traffic control LSUM items (i.e., upfront payment) may encourage unbalanced bid prices or unrealistic prices of these items, creating the challenges in the bid-based estimation. With various different bidding and estimation practices in use for traffic control items, the best practices to avoid cost overruns remain unclear.

Leveraging the extensive literature review and our national survey results, the recommendations regarding traffic control are summarized below.

1. *Estimating*: The engineer should use historical data from similar types of projects to estimate the traffic control devices needed for the project. According to the survey of state DOTs conducted as part of this study, ten DOTs reported using individual traffic control items, while six DOTs used a percentage based on a similar type of project/work from the bid history. As such, for MDOT to accurately build the capacity to accurately estimate the price for traffic control pay items, we recommend the following steps:
    - Step 1: Collect cost data in the field – MDOT should track pay item details, such as quantities and costs used in construction projects, for at least two years to establish cost data of traffic control items. This information will be used in the future to estimate the price for traffic control pay items accurately.
    - Step 2: Establish a relationship between the cost data and historical traffic control data (e.g., the uses of specific devices, size, location, and type of project in the traffic control plan) – it is imperative to create decision criteria for comparing new and past projects in order to estimate the price for traffic control in the new project. Historical data collected in step 1 can be used to establish such criteria.
    - Step 3: Extract new traffic control data from the detailed traffic control plan - generate a new estimate. With traffic control pay items identified in the traffic control plan, the estimate for the new project can be generated.

- Step 4: Verify the estimated cost using percentage - historically, minor traffic devices and traffic regular control accounted for 4.96% of total cost in 2016. The estimate generated in step 3 can be used to determine the percentage of traffic control compared to the total project cost. This will be used as a step to verify the reasonableness of the traffic control pay items estimate.

2. *Bidding*: MDOT should adopt a method that allows for control of project cost while ensuring sufficient flexibility for contractors to execute the necessary traffic control to ensure motorists' safety and mobility as they traverse work zones. As such, MDOT should use Lump SUM as well as Unit Bid Item approaches as appropriate, based on a case-by-case method to determine project appropriateness. Specific items to consider when deciding on the most appropriate approach should include but are not limited to 1) how well the scope of work can be defined, 2) the level of risk for major changes, 3) how well the sequence of work can be defined, and 4) how well the use of detours can be defined. In addition, MDOT should use a combination of Lump SUM and Unit Bid Item approach. Below are specific recommendations for each approach.
    a. Lump SUM – This approach should be limited to small projects whose scope can be well defined. A rate schedule for covering additional traffic control for work that is outside of the contract should be included in the bid. This will allow flexibility for adjustment when and if substantiated.
    b. Combination of Lump SUM and Unit Bid Items – the survey conducted as part of this study indicated that eight DOTs use a combination of Lump SUM and Unit Bid Item approaches for bidding traffic control. The combined approach will allow MDOT to minimize the potential oversight (inspection) burden associated with the use of the Unit Bid Item approach only. In the combined approach, MDOT should identify specific items that can be bid as Lump SUM and those that should be bid using the Unit Bid Item approach. This approach should be used for complex projects. Contractors should specify quantities and devices they anticipate to use as well as their corresponding rates for some pay items. MDOT should use historical data from similar past projects to assess the reasonableness of the estimates.

c. The maximum bid amount may not be specified in the pay item description. The reason is that the traffic control cost varies significantly from project to project. As shown in Figure 5958, the cost percentage of traffic control LUSM items averaged 4.96% for Michigan in 2016, with a standard deviation of 0.07. In addition, The maximum amount may encourage the contractors to bid high on these items.

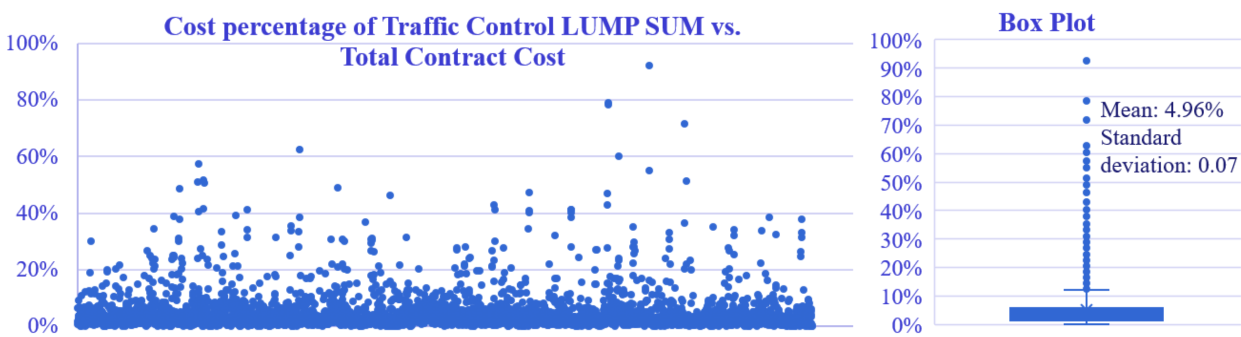


Figure 59. Traffic control LSUM item: cost percentage in awarded contract prices.

Chapter 8. CONCLUSION

The main goal of this study was to encourage the competitiveness of construction bids in Michigan, thereby mitigating the cost escalation of highway construction projects. To this end, a national survey of state DOTs was first conducted to solicit information on their construction bidding and estimation practices, i.e., how state DOTs advertise and estimate projects and conduct the bidding process. The survey results revealed that MDOT has similar procedures and practices to their peer states for competitive bidding and construction estimation. The notable differences between MDOT and peer state DOTs, as identified in the survey results, are twofold. First, other state DOTs do not release the Engineer's Estimate in any form to the bidders prior to bidding. Second, a few of the peer state DOTs use different estimation methods, such as actual cost and/or combined approaches.

Given these significant differences, this study compared the competitiveness of construction bids between Michigan and peer states based on data from 2016. The competitiveness was compared using a number of different metrics, namely, (1) number of bids per contract, (2) ratio between the lowest bid and the Engineer's Estimate, (3) bid spread, (4) bid variation, (5) the percentage of contracts whose prices are lower than the Engineer's Estimate, and (6) the number of qualified contractors. Although the bidding and estimation practices were found to differ from one state DOT to another, construction bidding in Michigan proved to be more competitive than, or at least as competitive as, that in the peer states.

This research project developed an approach and tool for post-bid analysis through which unbalanced bids can be identified, and through which bidding tendencies can be monitored from three perspectives: spatial, temporal, and opponent. Additionally, the metrics and patterns underlying unbalanced bids and bidding tendency monitoring were discussed. The developed tool can be useful for performing analysis and data visualization, providing evidence and indicators for post-bid evaluation.

Given that state DOTs typically release various information (e.g., list of eligible bidders, Engineer's Estimate of the total cost, and awarded average unit prices) to bidders before and after bidding, bidding experiments were also conducted to investigate the effect of information release on the competitiveness of construction bids. In the bidding experiment, competitiveness was measured based on the markup percentage. The results of the experiment indicated that DOTs should not disclose the list of eligible bidders when the level of competition is limited (e.g., the number of bids is fewer than or equal to three), but should disclose the awarded average unit prices of pay items, along with the Engineer's Estimate, to the bidders. In addition, the number of bids and complimentary bids was also examined and compared between the experimental groups.

Finally, notable findings and recommendations for construction estimation were formulated based on the survey results. For example, the actual cost approach was found to be superior to the bid-based estimation approach in terms of accuracy. Most of the state DOTs employing this approach (11 of the 15 using the bid-based estimation) achieved an acceptable accuracy level. An examination of MDOT's bid data for 2016 also indicated that MDOT's bid-based estimation approach satisfies the accuracy threshold recommended by the FHWA (i.e., that at least 50% of projects should have an awarded price within 10% of the Engineer's Estimate). As such, it is recommended that MDOT can continue using the bid-based estimation approach, though there are opportunities to make improvements.

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APPENDIX A: NATIONWIDE SURVEY ON BIDDING AND ESTIMATION PRACTICES

Cover Letter

Hello!

The Michigan Department of Transportation (MDOT) is interested in understanding how other agencies like yours have advertised, awarded, and estimated construction projects. MDOT has contracted with Western Michigan University (WMU) to analyze their estimating, advertising, bidding practices to develop better procedures.

The survey WMU developed will take about 30 minutes to complete. If you think another person in your agency is best suited to respond to this survey, please do not hesitate to forward this link to them. If possible, please complete the following survey by July 15, 2021.

Should you have any questions, you can contact Dr. Hexu Liu at (269) 276-3201 or email hexu.liu@wmich.edu.

Thank you!

How are construction projects advertised and awarded?

Bid Advertisement

1. Describe your agency’s bidding process (including such items as advertisement length, prequalification of contractors, how and where bids are submitted).
   ____
   ____

2. How does your agency determine whether or not a contractor can bid on a project,
   ____
   ____

3. How does your agency determine the maximum amount a contractor can bid on or the maximum amount a contractor can contract for at any given time.
   ____
   ____

4. What percentage of projects let by your agency have Federal aid?
   ____
   ____

5. Does your agency have different bidding requirements and procedures if Federal Aid is not being used?
   ☐ Yes
   ☐ No
   If yes, what are these bidding requirements and procedures?
   ____
   ____

6. What percentage of projects let by your agency is not delivered by traditional design-bid-build methods?
   ____
   ____

Bid Evaluation

7. How does your agency determine if a bid is incomplete, irregular and/or non-responsive?
   ____
   ____
   ____

8. What does your agency do when it is determined that a bid is incomplete, irregular and/or non-responsive?

____
____

9. What criteria does your agency use to determine whether or not bids are reasonable when over the Engineer's Estimate?
   ☐ Percentage of Engineer's Estimate (e.g., +5%)
   ☐ Percentage of estimate depending on the number of bids received
   (e.g., ±% of Engineer's Estimate when there are more than 3 bidders)
   ☐ Others (please specify) __________________________________

10. Does your agency have a procedure or tool to monitor contractors' bidding tendencies?
    ☐ Yes
    ☐ No
    If yes, briefly describe how contractor's bidding tendencies are monitored (especially note if a computer program is used).
    ____
    ____
    ____

11. How does your agency analyze bids that appear to be unbalanced? Briefly describe how this analysis is performed (especially note if a computer program is used).
    ____
    ____

12. Have your agency seen an increase in bid prices?
    ☐ Yes
    ☐ No
    If yes, what does your agency primarily attribute this to?
    ____
    ____

Bid Information Feedback

13. What information is disclosed to prospective bidders for projects prior to bidding?
    ☐ Historical unit price of Engineer's Estimate
    ☐ Pre-bidding Engineer's Estimate of total project cost
    ☐ A range of the estimated project cost
    ☐ Average unit bid price from bidders (e.g., first three low bidders) in previous lettings
    ☐ A specified dollar amount for a bid bond or bid guarantee
    ☐ A percentage of the bid submitted for a bid bond or bid guarantee
    ☐ Identity of approved bidders or bidder's list
    ☐ Others (*Please list*)_______________________

14. What information is released to prospective bidders after letting?
    ☐ Engineer's Estimate of unit price
    ☐ Engineer's Estimate of total project cost
    ☐ Identity and unit bid prices of all bidders
    ☐ Identity and total bid prices of all bidders
    ☐ Name of winning bidder
    ☐ Others (*Please list*)________________________

15. Are any state laws or regulations in effect regarding the disclosure or nondisclosure of the Engineer's Estimate of historical unit price and of the pre-bidding total price?
    ☐ Yes
    ☐ No

16. Explain how possible collusion is detected within the bidding process.
    ____
    ____

Bid Competition

17. What criteria does your agency use to determine whether adequate competition was obtained?
    ____
    ____

18. Does your agency usually obtain adequate competition for the construction project in accordance with the criteria in Question 14?
    ☐ Yes
    ☐ No

19. What is your procedure when there is not adequate competition?
    ____
    ____

20. What is the average number of bids you received per project in the past five years?
    ☐ 1 – 3
    ☐ 4 – 6
    ☐ 7 – 9
    ☐ 10+

21. If you are able to share your bid tabulation/statistics and bid data of main items and lump sum items for the past five years, please upload the documents or a document with links.
    ☐ Upload

How are construction projects estimated?

Cost Estimation Practice

22. What is the primary estimating approach used by your agency (e.g., actual cost, historical data approach, etc.)?
____
____
____

23. How many estimates does your agency prepare monthly?
☐ 0–20
☐ 20–40
☐ 40–60
☐ 30 or more

24. In your opinion, how much manpower does it take to obtain an estimate using your agency's current method?
☐ Approximate annual workload____
☐ Approximate full-time equivalent estimators___________________________________

25. Please describe your agency's typical low bid results compared to your Engineer's Estimates.
____
____

26. How close does the final actual construction cost track to the Engineer's Estimate and initial contractor bid price?
____
____

Estimation of Lump Sum Items

27. Does your agency use lump sum pay items, and how do you determine what items of work they will be used on?
____
____

28. What items of work are normally bid as lump sum?
____
____

29. Briefly describe how traffic control and maintenance are **estimated** and **bid**.
____
____

30. Describe the basis of payment for traffic control and maintenance and the schedule for payment (e.g., is it based on a percentage of work completed?).
____
____

31. Does your agency have standard pay items for Mobilization, General Conditions, and/or Safety-Security?
☐ Yes
☐ No
If Yes, describe the basis of payment and schedule of payment.
____
____

Further Contact Information

32. Can we contact you for further details about the information you provided in the questionnaire if needed?
☐ Yes
☐ No

33. Contact information

Name: ________________________
Title: ________________________
Email: ________________________
Phone: ________________________
Agency Name: ___________________

APPENDIX B: SURVEY ON GIS USE FOR BIDDING TENDENCY MONITORING

MDOT has contracted with Western Michigan University (WMU) research team to investigate the impact of bidding practices on competitive bidding and develop a novel approach and tools for bid analysis and cost estimation. Among the goals, the research intends to develop a novel approach for monitoring contractors' bidding tendencies. Currently, MDOT presents bidding results in portable document format (pdf) and Excel spreadsheets. Visualizing such reports spatially would provide a more straightforward representation of and insights into the level of competition and bidding tendencies of bidders. Geographical Information Systems (GIS) can be used to report and visualize bidding information as they contain spatial (location) attributes. This survey intends to establish the needs for GIS application in bidding practices at MDOT. Based on your position at MDOT, your feedback is very crucial to establish the needs for GIS application by responding to the following questions:

1. Do you use Geographical Information Systems (GIS) in your daily bidding and estimating tasks? Yes/No

If YES

a. For what specific bidding/estimating information (databases) and activities do you apply GIS? ___________________________
b. What specific GIS software do you use?

   ☐ ESRI's ArcGIS, ☐ Caliper's Maptitude, ☐ QGIS, ☐Other ________________

c. Do you use a stand-alone GIS tool? Yes/No (explain) ___________________________
   ☐ ArcGIS Desktop, ☐ ArcGIS Pro, ☐ ArcGIS online, ☐ ArcGIS Enterprise,

   ☐Other__________________
d. In what ways could the current application of GIS you use in your daily bidding/estimating tasks be expanded/improved?
   ____

If NO

a. Why are you not using GIS?
   ____
b. If you had an opportunity to use GIS in your daily bidding and estimating activities, what would you use it for?
   ____

c. What specific bidding/estimating information (data) would benefit from GIS application? How? ____

d. Which stand-alone GIS tool could be used for bidding and estimating?
☐ ArcGIS Desktop, ☐ ArcGIS Pro, ☐ ArcGIS online, ☐ ArcGIS Enterprise, ☐Other

(explain why this specific tool is selected) ______________________

2. Please explain how GIS tools could be used for bidding tendency monitoring, particularly whether **AASHTOWare Project Data Analytics** is currently being used by MDOT for this purpose.

____

____

____

3. Do you think the GIS application will merely provide spatial visualization?

☐ Yes

☐ No

4. If Yes to Question 3, do you think image-based map visualization will work for the MDOT rather than the GIS app?

☐ Yes

☐ No

5. Do you have any additional suggestions on GIS application to construction bidding and estimating activities at MDOT?

____

6. Would you please provide one sample of bid reports generated using **AASHTOWare Project Data Analytics**? A link will be provided to upload files.

____

7. Please provide your:

Name:_____________________________________

Title:______________________________________

Office/Region:_________________________________

Phone:_____________________________________

Email:_____________________________________

APPENDIX C: STATE DOTs' PREQUALIFICATION AMOUNT CALCULATION

Michigan[1]

Rule 41. The assets as determined from the financial statement shall be used in computing the overall financial rating of a bidder:

$$\text{Overall financial rating} = WC \times 9 + D_{C\&T} + NV_{C\&T} \times 4$$

Where:

- WC = Working capital
- $D_{C\&T}$= Depreciation expense on construction and transportation equipment
- $NV_{C\&T}$= Net construction and transportation equipment values

(a) Working capital, either positive or negative, multiplied by 9.

(b) Depreciation expense on construction and transportation equipment in the amount of 1½ times this allowable amount of depreciation, as recorded on the bidder's books of account and also shown in the space provided in the prequalification questionnaire for the same fiscal year as covered by the prequalification statement, multiplied by 9.

(c) Net construction and transportation equipment values multiplied by 4. This value is the bidder's equity in such equipment less the long-term portion of the obligation on this equipment.

R 247.42 Ratings: The overall financial rating is expressed as a number truncated to the number of thousands to identify a numerical rating in any given work classification. For example, an overall financial rating of $1,000,000 is converted to 1,000, and a financial rating of $1,105,000 is converted to 1,105.

$$Overall\ financial\ rating = \frac{given\ value}{1000}$$

Bidders may be given a full numerical rating, which is equal to the bidder's overall financial rating, or a partial numerical rating, contingent upon the results of an evaluation of the bidder being made by the department under these rules.

[1] https://www.michigan.gov/documents/mdot/MDOT_Construction_Prequalification_Administrative_Rules_516649_7.pdf?

Iowa[2]

The contractors shall meet the Iowa Department of Transportation (IDOT)'s prequalification requirements. They can only work on the contract whose amount does not exceed the difference between the maximum prequalification amount and the bidder's amount of uncompleted work currently under contract. The maximum prequalification amount of a contractor is calculated as follows:

$$\text{Maximum Prequalification Amount} = (CURRENT + NONCURRENT + LL) \times F$$

<u>Where:</u>

$$\text{CURRENT} = \text{current assets minus current liabilities}$$

$$\text{NONCURRENT} = \begin{cases} \dfrac{\text{noncurrent assets} - \text{noncurrent liabilities}}{2} & \text{if} > 0 \\ \text{noncurrent assets} - \text{noncurrent liabilities} & if < 0 \end{cases}$$

$$\text{LL} = \text{approved authorization to loan letter}$$

$$\text{F} = \text{experience factor}$$

→ The Department will qualify Contractors into three categories:

1) <u>Individually Prepared Statement</u>.

- An Individually Prepared Statement is a "Contractor's Financial -Experience - Equipment Statement" that the prospective bidder has completed. Suppose the statement has been compiled by a CPA but does not contain a CPA review or audit of the financial portion of the statement. In that case, it is still considered an Individually Prepared Statement.
- When an Individually Prepared Statement is submitted to the department, the maximum prequalification amount will be $400,000.

2) <u>CPA Reviewed Statement</u>.

- A CPA Reviewed Statement is a "Contractor's Financial -Experience - Equipment Statement" that includes a current CPA review of the financial portion of the statement. The review must be completed by a CPA either registered to practice in Iowa or registered in another state having reciprocal arrangements with Iowa.

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[2] https://www.iowadot.gov/erl/current/gs/content/1102.htm

- When a CPA Reviewed Statement is submitted to the department, an experience factor (F) ranging from 0.0 to 12.5, depending on the prospective bidder's past performance with projects let by the department, will be used in the prequalification formula. A prospective bidder, who has been qualified to submit proposals with this type of statement, shall be limited to individual proposal sizes that do not exceed the lesser of $2 million or the maximum prequalification amount minus the bidder's amount of uncompleted work currently under contract. Any combination of proposals, however, may total more than $2 million - as long as that total does not exceed the maximum prequalification amount minus the currently uncompleted work.

3) <u>CPA Audited Statement.</u>

- A CPA Audited Statement is a "Contractor's Financial - Experience - Equipment Statement" that includes a current CPA audit of the financial portion of the statement. The audit must be completed by a CPA who is either registered to practice in Iowa or registered in another state having reciprocal arrangements with Iowa.
- When a CPA Audited Statement is submitted to the department, an experience factor (F) ranging from 0.0 to 12.5, depending on the prospective bidder's past performance with projects let by the department, will be used in the prequalification formula. A prospective bidder, who has been qualified to submit proposals with this type of statement, shall be limited to work that does not exceed the maximum prequalification amount minus the bidder's amount of uncompleted work currently under contract. However, a prospective bidder shall be considered to have an "Unlimited" bidding capacity with the department if they were awarded over $50 million of work (including that from other Contracting Authorities) during their past fiscal year and have a prequalification limit, by the formula, over $100 million.

→ The maximum prequalification amount may be increased for a CPA Reviewed or CPA Audited Statement by providing an Authorization to Loan form and/or by obtaining an equipment appraisal. The Authorization to Loan form and equipment appraisal would be subject to the following respective restrictions:

1. The Authorization to Loan shall not exceed $1 million. The Authorization to Loan shall be signed by a duly authorized officer of a banking institution.
2. The equipment appraisal shall be cross-referenced with the depreciation schedule and shall be accompanied by a signed certification letter on the appraisal company’s letterhead

→ A prospective bidder must complete contract work in the following categories in excess of the quantities listed below before qualification to submit proposals or receive awards for projects involving larger quantities than those listed. The contract work may be done as a contractor or subcontractor.

Work Category	Amount	Unit
PCC Pavement	100,000	Square Yards
Grading	500,000	Cubic Yards
Bituminous Pavement	50,000	Tons
Bridges	200,000	$
Culverts	100,000	$
Other classes of work	No Fixed Maximum	

Texas[3]

The department will examine and determine based on the submitted information and advise the contractor of its approved bidding capacity.

1. For a bidder submitting a Confidential Questionnaire and audited financial information, the amount of the bidding capacity will be determined by multiplying the net working capital by a factor determined by the department based on the expected dollar volume of projects to be awarded and the number of bidders prequalified by the department.
    a. If this calculation results in a positive amount that is not greater than $1,000,000, the bidder will receive a bidding capacity of $1,000,000 if the bidder has positive net working capital and the bidder provides documentation of at least two years experience and four completed projects in the field in which the bidder wishes to bid. Bidding capacity determined under this paragraph applies to any project and is not limited to waived projects.
2. For a bidder submitting a Bidder's Questionnaire with no prior experience in construction or maintenance or a negative working capital position (i.e., financial statements indicate that current liabilities exceed current assets) will receive a bidding capacity of $300,000 for waived projects only.
3. For a bidder submitting a Bidders Questionnaire and compiled financial information, if the principals of the bidder have at least one year of experience in construction or maintenance and have satisfactorily completed at least two projects in these fields, the bidding capacity is $500,000 for waived projects only.
4. For a bidder submitting a Bidders Questionnaire and compiled financial information and the principals who have at least two years experience in construction or maintenance and have satisfactorily completed at least four projects in these fields, the bidding capacity is $1,000,000 for waived projects only. Those contractors possessing more than two years' experience will be granted an additional $250,000 in bidding capacity for each additional year of experience

3 https://texreg.sos.state.tx.us/public/readtac%24ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=43&pt=1&ch=9&rl=12

in construction or maintenance, with a maximum bidding capacity of $3,000,000 for waived projects only.

5. For a bidder submitting a Bidders Questionnaire and reviewed financial information and the principals of which have at least three years of experience in construction or maintenance and have satisfactorily completed at least six projects in these fields, the amount of the bidding capacity will be determined by multiplying the net working capital by a factor determined by the department based upon the expected dollar volume of projects to be awarded and the number of bidders prequalified by the department. In the event that this calculation does not result in an amount greater than $1,000,000, the bidder will receive a bidding capacity of $1,000,000. Bidding capacity determined under this paragraph is limited to waived projects only.

Florida[4]

MCR (Maximum Capacity Rating) shall be the total aggregate dollar amount of uncompleted work an applicant may have under contract at any one time as prime contractor and/or subcontractor. It is calculated by the following equation:

$$\mathrm{MCR} = \mathrm{AF} \times \mathrm{CRF} \times \mathrm{ANW}$$

Where:

- **AF** means the Ability Factor,
- **CRF** is the Current Ratio Factor,
- **ANW** represents the Adjusted Net Worth

1.1.3.1. Ability Factor

The Ability Score is determined by the **AF** as follows:

Ability Score	**AF**
64 or less	1
65-69	2
70-73	3
74-76	4
77-79	5
80-84	8
85-89	10
90-93	12
94-97	14
98-100	15

For new applicants and applicants who have not been qualified under this rule for more than two years, the Ability Score results from evaluations of the applicant's organization, management,

[4] https://www.michigan.gov/documents/mdot/MDOT_Construction_Prequalification_Administrative_Rules_516649_7.pdf?

work experience, and letters of recommendation. The maximum values used in determining the ability score for the contractor are as follows:

ABILITY SCORE	**Column1**
Organization and Management	Maximum Value
Experience of Principals	15
Experience of Construction Supervisors	15
Work Experience	
Completed Contracts	
Highway and bridge related	25*
Non-highway and bridge related	10
Ongoing Contracts	
Highway and bridge related	25*
Non-highway and bridge related	10
TOTAL	**100**

* Maximum value shall be increased to 35 if the applicant's experience is exclusively in highway and bridge construction.

If the contractor has been qualified under this rule within the last two years, and three or more Contractor Past Performance Reports are on file for projects completed for the department within five years of the application filing date and have not been previously used to determine an Ability Score, the Ability Score shall be calculated by adding the scores of these reports plus the average score from the previous application and dividing the sum by the number of scores used.

If the applicant has been qualified within the last two years, and the department does not have three or more Contractor Past Performance Reports on file for projects completed for the department within five years, then the Ability Factor (AF) from the applicant's last successful application shall be brought forward and used.

1.1.3.2. Current Ratio Factor

The current ratio is the number resulting from dividing the adjusted current assets by the adjusted current liabilities. The calculated current ratio ranges from 0.60 to 2.00. The maximum current ratio of 2.00 will be used for the CRF, even if the actual value is greater. The applicant will be denied qualification if its calculated current ratio is less than 0.60.

1.1.3.3. Adjusted Net Worth

The ANW must be a positive value for the applicant to be considered for qualification. The ANW used in the MCR formula will be the amount of capital and surplus (net worth) as adjusted.

1.1.3.3. MCR

The calculated MCR shall be rounded off according to the following scale:

Up to $500,000 – round off to nearest $10,000

Above $500,000 to $2,000,000 – round off to nearest $25,000

Above $2,000,000 – round off to nearest $50,000

Wyoming[5]

The following equation determines the prequalification amount (PA):

$$PA = AF \times NW$$

Where:

- **AF** means the Ability Factor
- **NW** represents the Net Worth

If the net worth comes from an unaudited financial statement, up to a maximum of $500,000, may be used for determining the prequalification rating. However, the net worth of an audited financial statement, regardless of the amount, will be used to determine the prequalification rating. Prequalification may be denied or revoked if the Contractor:

- Is declared in default while qualified in accordance with the applicable provisions of any contract issued by the department.
- Has been determined to have made false, deceptive, or fraudulent statements during the prequalification process.
- Has been and is currently under debarment or restricted from bidding by another government agency because of criminal acts or serious breach of contract.
- Has been disqualified for substantial reasons by another governmental agency.
- Has attempted to or has influenced Department policy through gratuities or gifts to WYDOT personnel or by employing Department personnel.
- F. Has, while qualified, demonstrated an inability to meet WYDOT requirements for specifications and contracts.

The Contractor's previous (three continuous years) and present job performance will be evaluated by using the Department's Contractor performance evaluation system to determine the current prequalification rating. Work performed by subcontractors shall be reflected in the Contractor's performance evaluation. Applicants who have not previously completed an application in the past will have an ability factor rating of 9 assigned to them.

Prequalification will be based on the following table:

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5 https://www.dot.state.wy.us/files/live/sites/wydot/files/shared/Construction/Prequalification/FORM%20PQ2%20Contractors%20Prequalification%20Form%20Rev._1-21%20Extended.pdf

FINAL PERFORMANCE RATING	ABILITY FACTOR
0 - 19	0
20 - 36	1
37 - 51	2
52 - 65	6
66 - 78	12
79 - 90	14
91 - 100	16

A Contractor with two or more Ability Factors within a one-year period of 6 or less will be given an ability rating of 6 or less.

Prequalification will be based off the following table:

First time qualifier and has never worked as a subcontractor	9
Worked as a prime	PQ-1 avg. rating past three year
Worked only as a subcontractor in the past three years	9
Worked as a prime and as a subcontractor	PQ-1 avg. rating past three year
Has worked in the past but not in the last three years as a prime Contractor or a subcontractor	9
Worked with in the last three years but not in the past two years	PQ-1 from three years ago

Utah[6]

Prequalification is required before submitting a proposal or bid on projects of more than $3,000,000 in Utah.

The prequalification amount is determined by the following equation:

$$PA = E \times A \times (B + C + D)$$

<u>Where</u>:

- **E** is Adjusted Equity;
- **A** is Contractor Performance Factor,
- **B** means the Experience Rating Factor (Yearly Finalized Contract Performance Rating),
- **C** indicates Financial Rating Factor, and
- **D** is Additional Experience Factor.

[6] https://drive.google.com/file/d/16puGlumNiuagC7qpBjHW_VNm5QRFp2b8/view

Wisconsin[7]

The following equations determine the Maximum Capacity Rating (MCR):

$$\mathrm{MCR} = 3 \times \mathrm{FA}$$

$$\mathrm{FA} = \mathrm{A} - \mathrm{L}$$

$$\mathrm{A} = 1.0 \times \mathrm{CA} + 1.0 \times \mathrm{CS} + 2.0 \times \mathrm{NBVC} + 0.6 \times (NCI + NCR + NBVP) + 1.0 \times NBV$$

$$\mathrm{L} = 1.0 \times \mathrm{CL} + 0.6 \times NCL$$

Where:

- **FA** is the financial factor that is determined by assets and liabilities;
- **A** and **L** represent the summation of the allowances for assets and the summation of deductions for liabilities, respectively;
- **CA** means the current assets,
- **CS** means cash surrender value of life insurance;
- **NBVC** is the net book value (GAAP Basis) of construction equipment;
- **NCI** and **NCR** indicate non-current investments and non-current receivables, respectively;
- **NBVP** means the net book value of plant and equipment, exclusive of construction equipment
- **NBV** is the net book value of real property;
- **CL** and **NCL** represent current liabilities and non-current liabilities, respectively.

[7] https://wisconsindot.gov/hccidocs/prequalification-policy-June2011.pdf

Washington[8]

Maximum capacity rating: "The total value of uncompleted prime contract works a contractor is permitted to have under contract with the department at any time". Washington DOT requires firms to pre-qualify when bidding on contracts over $500,000. When the amount of uncompleted work of a contractor exceeds its maximum capacity rating, the contractor is denied proposing bidding.

$$MCR = NW \times AF$$

$$Fn = F + (n-1) \times 0.5$$

$$5 \leq Fn \leq 7, \ \ NW \geq 50{,}000$$

- MCR = Maximum capacity rating
- NW = Reported net worth
- F = Factor = 5
- Fn = Factor with annual rate increase of (0.5/year)
- n = No. of years

The maximum capacity is determined by multiplying the contractor's reported net worth by a factor of 5.0. The factor may be increased to 7.5 at an annual rate of 0.5, on the condition that the contractor has maintained a satisfactory history and has completed a contract of $50,000 or more within the preceding prequalification year. The rating factor could be decreased by the department at any time if the contractor's performance becomes less than standard (herein standard means the acceptable quality of performance, meeting the demand, need, or requirement of contracts).

When establishing the maximum capacity rating, a bidding company that has established a leveraged ESOP (Employee Stock Ownership Plan) may use other values to replace the net worth: the lesser of the following values: (a) The adjusted net worth by subtracting any contra-equity or unearned compensation entry in the net worth section of the balance sheet which is directly related to the ESOP loan; (b) The company value as established by the company's most recent valuation for ESOP purposes provided the valuation was performed within the last twelve months which meets federal guidelines for ESOP-related valuations.

[8] https://app.leg.wa.gov/WAC/default.aspx?cite=468-16-140&pdf=true

West Virginia[9]

The running three-year average of a contractor's past project Factors and Evaluations scores will be taken to calculate a contractor's Performance Rating. The Performance Rating will be updated as described in the previous paragraph. Based on the Performance Rating, a contractor will be placed into one of five categories:

- "A" Contractors will be those with the highest Performance Ratings (9.0 to 10.0). Contractors in this category shall only be required to bond 75 percent of the contract price.
- "B" Contractors will be those with adequate Performance Ratings (8.0 to 8.9). Contractors in this category shall only be required to bond 90 percent of the contract price.
- "C" Contractors will be those with below average Performance Ratings (7.0 to 7.9). Contractors in this category shall be required to bond 102 percent of the contract price.
- "D" Contractors will be those with inadequate Performance Ratings (6.0 to 6.9). Contractors in this category shall be required to bond 125 percent of the contract price. These contractors will be placed on a six-month observation period. If the contractor does not improve to a "C" rating in six months, the contractor will be placed on a probationary period which will prevent them from bidding on new Division contracts until their Performance Rating returns to a C-level or better. If this is not accomplished within the second six-month period (probationary period), the contractor will fall to category "F".
- "F" Contractors (5.9 or less) will be barred from bidding and being approved as a subcontractor on any contract for two years from the date they are notified of their "F" rating.
- "N" Contractors are those who have submitted a new Application and received a certificate of qualification but have not yet performed work/been evaluated for work performed on a project. Contractors in this category shall be required to bond 102 percent of the contract price.

Performance Rating Calculation

Performance Rating can be determined by using the equation below:

$$PR = 0.4 \times PES + 0.6 \times TPF$$

Where:

- PR = Performance Rating (rounded to the nearest tenth place)

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9 https://transportation.wv.gov/highways/contractadmin/prequalifications/Documents/WVDOHContractorPrequalificationApplication.pdf

- PES = Project Evaluation Score
- TPF = Total of Performance Factors

Performance Rating **PR** is the result of the sum of the project evaluation score **PES** multiplied by 0.4 and the Total of performance factor **TPF** multiplied by 0.6, The Performance Rating is rounded to the nearest tenth place.

Project Evaluation Score (PES) Calculation

Project Evaluation Score is based on an evaluation of a contractor by Division personnel with a series of objective, close-ended questions. Project Evaluation Score is the average score of all questions, **rounded to the nearest hundredth place** (See Project Evaluation Form).

It can be as equation as shown:

$$PES = \frac{\text{Sum of score of the questions}}{No. of\ questions}$$

Performance Factors (PF) Evaluation Score Calculation

Performance factors are based on data gathered from each project after the final estimate package has been approved. Performance Factors consist of the following:

PF Request for Additional Compensation and Claims (RACC) 15%

PF Penalty 30%

PF Time 30%

PF Compliance 15%

PF Safety 10%

PF Score = 0.15 PF RACC + 0.30 PF Penalty + 0.30 PF Time + 0.15 PF Compliance + 0.10 PF Safety

- **<u>RACC Performance Factor</u>**

RACC is categorized into three criteria.

A. Number of requests for additional payment submitted by a contractor that are not able to be resolved at or below the Regional Construction Engineer level.
B. Number of “Notice of Potential Claim” forms submitted by a contractor (Standard Specifications – Section 105.17).
C. Number of claims filed with the Claims Commission and/or Circuit Court by a Contractor against the Division and/or claims filed by the Division against a Contractor.

PF RACC is calculated by 1 minus the weighted RACCs and rounded to the nearest hundredth.

$$PF\ RACC = 1 - (0.25A + 0.50B + 0.75C)$$

- **<u>Penalty Performance Factor</u>**

PF Penalty will be determined by the total value of the applicable and paid items on the project and the total dollar amount of penalties. Pf Penalty equals 1.00 when there is zero disincentive.

A) Total Paid Dollar Amount of Applicable items

B) Total Dollar Amount of Penalties

PF Penalty is calculated by taking the difference of A and B over the value of A rounded to the nearest hundredth.

$$PF\ Penalty = (A - B)/A$$

- **<u>Time Performance Factor</u>**

PF Time is determined with two methods, one for a fixed completion date and one for working days.

1) Method one for the fixed completion date
   A = Fixed Completion Date-Notice to Proceed Date (current completion date with all approved Change Orders)
   B = Actual Completion Date - the Notice to Proceed Date

$$PF\ Time\ Damage = A/B$$

2) Method two for working days:
   A = Total number of working days contracted
   B = Total number of days charged

$$PF\ Time = A/B$$

- **<u>Compliance Performance Factor</u>**

PF Compliance is calculated by the following method. This factor is calculated based on the suspension of work by the Division's project supervisor or other entities due to a contractor's improper work or defective materials or negligence. Each occurrence of such suspension, partially or wholly, and regardless of duration, will be counted as a minus 1/3 of this factor. A contractor's score should not be impacted if zero events occurred or the events were the result of the Division.

A= Total number of events that resulted in a contractor being shut down by the Division or other entities

PF Compliance = $1 - (A/3)$

- **<u>Safety Performance Factor</u>**

Pf safety is based on contractor's **Experience Modification Rate (EMR**) provided. It's a numerical value of EMR

PF Safety Value	**EMR**
1	EMR ≤ 0.75
0.75	0.76 ≤ EMR ≤ 1.00
0.5	1.01 ≤ EMR ≤ 1.25
0.25	1.26 ≤ EMR ≤ 1.50
0	EMR ≥ 1.51

APPENDIX D: ONE EXAMPLE OF THE CONSTRUCTION PROJECTS IN THE BIDDING EXPERIMENT

Note: If you decide to bid on this project, please fill the cells in Green color;

Table 1 Bid Items

Item	Description	Item Quantity	Unit	Bidder's Unit Cost without profit	Unit Bid Price	Remark: i.e., How did you get this price	Total Bid Price	Awarded Average Unit Bid Price Q1	Awarded Average Unit Bid Price Q2	Awarded Average Unit Bid Price Q3	Awarded Average Unit Bid Price Q4
1500001	Mobilization, Max	1	LSUM	$ 18,650.00			$ -	$ 169,925.08	$ 85,992.04	$ 91,621.02	$ 326,208.83
5010050	HMA, 4E1	5409	Ton	$ 42.27			$ -	$ 59.90	$ 59.88	$ 53.35	$ 52.01
5047031	_	8366	Ton	$ 52.32			$ -		$ 87.74	$ 58.40	
8120140	Lighted Arrow, Type C, Furn	4	Ea	$ 175.00			$ -	$ 399.96	$ 368.32	$ 10,032.28	$ 506.01
8120141	Lighted Arrow, Type C, Oper	4	Ea	$ 0.01			$ -	$ 36.08	$ 24.94	$ 48.83	$ 38.51
8120170	Minor Traf Devices	1	LSUM	$ 2,360.90			$ -	$ 61,665.52	$ 38,582.84	$ 35,032.41	$ 116,301.81
8120231	Pavt Mrkg, Type NR, Tape, 4 inch, Yellow, Temp	5003	Ft	$ 0.56			$ -	$ 0.53	$ 0.71	$ 0.51	$ 0.59
8120250	Plastic Drum, High Intensity, Furn	10	Ea	$ 13.13			$ -	$ 16.49	$ 15.71	$ 14.95	$ 24.82
8120251	Plastic Drum, High Intensity, Oper	10	Ea	$ 0.01			$ -	$ 0.43	$ 0.60	$ 0.69	$ 1.09
8120350	Sign, Type B, Temp, Prismatic, Furn	448	Sft	$ 1.73			$ -	$ 3.47	$ 4.04	$ 3.52	$ 4.38
8120351	Sign, Type B, Temp, Prismatic, Oper	448	Sft	$ 0.01			$ -	$ 0.24	$ 0.22	$ 0.29	$ 0.25
8120370	Traf Regulator Control	1	LSUM	$ 2,875.00			$ -	$ 12,441.58	$ 13,143.31	$ 19,548.84	$ 33,624.70
8210005	Monument Box Adjust	15	Ea	$ 252.75			$ -	$ 275.49	$ 399.87	$ 338.27	$ 389.08
						Total Contract Price	$ -				
						Confidence Level for Wining the Project (e.g., 80%)					
List of Bidders for this project is unknown						**Owner's Price**	$ 888,208.10				
All bidders are eligible for this project, and each bidder will decide whether they will bid or not on this project.							**Low**	**High**			
						Owner's Price Range	$ 850,000.00	$ 900,000.00			

APPENDIX E: TABULATED NATIONAL SURVEY RESULTS

Table 17. Factors leading to the price increase

DOT	Factors Leading to the Price Increase
Arkansas	Current **materials shortages and labor shortages,** along with general inflation
Mississippi	Currently, we are seeing the largest unit price increases in any item containing steel (piles, sign posts, signal poles), traffic paint, and thermoplastic striping materials. We attribute these recent price increases to **supply chain disruption** caused by the COVID-19 pandemic and the severe winter weather in Texas, which disrupted many chemical plants.
Tennessee	Steel and epoxy shortages in supply and truck haulers are not enough to keep up with production.
Anonymous	Supply and demand were caused by politicians during the pandemic (Shutdowns, etc.)
Minnesota	Supply chain issues and commercial activity in the private sector
Oregon	
Idaho	**Supply shortages**, increased number of projects, busy schedules
LADOTD	The drop in construction employment may have been due to COVID-19-related issues, but the increase in items requiring resins, such as striping, was probably weather-related issues in Texas. For concrete and steel, some of this may have been due to **material shortages**, either **weather and/or global market conditions**.
Utah	The pandemic has caused some increases based on **availability issues**.
Missouri	Fluctuation in **material and fuel prices**
Colorado	Increases in fuel, material, and labor being passed through from the contracting community.
Washington	Most of the time, the increased unit prices follow the price of crude oil and diesel fuel.
Texas	Oil and Portland cement prices have been on the rise.
Florida	Market conditions.
Iowa	Economy and market conditions; contract requirements and restrictions in some instances.
FHWA	Supply chain issues, labor shortage, raw materials, timber, concrete, steel, etc
NYS	Unknown. But generally, I hear contractors complain about material price increases.
Wisconsin	We have not seen huge price jumps yet, but they are expected soon, and designers have been asked to increase their estimates. It is anticipated that asphalt prices and items sensitive to haul distances will rise as oil and fuel have. Asphalt contracts with less than 30,000 tons of asphalt have recently seen increased unit prices for asphalt mixes and mobilization. The increases are likely due to spreading the costs of mobilizing an asphalt plant or increased hauling costs in bringing the material from a permanent plant.

DOT	Factors Leading to the Price Increase
	Since the April 2021 Letting, we saw prices increase for some steel items, including piling and steel rail. Steel commodity prices remain high. Bid prices will likely increase. Proposal Management expects prices to remain high and would recommend construction estimates for piling and steel rail items to be increased.
North Dakota	It is not on all items, but the items that we have seen increases are primarily due to: 1. Procurement of labor and materials. 2. Competition.
Maine	Lack of competition. Contractor inefficiencies. Centralization of HMA plant locations. Lack of qualified personnel.
South Carolina	Wood, steel, and gas prices
Anonymous	Inflation
Wyoming	Inflation, COVID-19 complications, workforce, material supply

Table 18. Criterion in competitive bidding: number of bidders

DOT	Criterion in Competitive Bidding
Washington	We would like to get **three** or more bidders. This is not always possible on some of our smaller/more unique offerings.
North Dakota	We analyze all projects. If projects have **two** or fewer bidders, we scrutinize those bids closely.
Colorado	**Three** or more bids is considered to be representative of an adequate level of competition.
Texas	Number of bidders
LADOTD	Typically, if we have at least **three** bidders, it is considered to be competitive.
Idaho	We strive for at least **three** bidders, but it is not unheard-of having only one or **two** bidders. If we only have one bidder, we must evaluate the pricing closely to ensure reasonable prices.
FHWA	FAR and if we received **2** or 3 bids

Table 19. Criterion in competitive bidding: FHWA guidelines

DOT	Criterion in Competitive Bidding (number of bidders and bid differential)
Iowa	**FHWA guidelines** *Number of competitive bids* within 120% of low bid vs *low bid differential from estimate* 5 or more **vs.** 120% of Engineer's Estimate; 4 **vs.** 115% of Engineer's Estimate; 3 **vs.** 110% of Engineer's Estimate; etc.
WisDOT	WisDOT uses **FHWA's Guideline** on Preparing Engineer's Estimate, Bid Reviews, and Evaluation to assess Competition.
South Carolina	Based on **FHWA guidelines**
West Virginia	+5% for every competitive bid (low bid + 20 percent) and up to 120% of the Engineer's Estimate (5 or more competitive bids)
Utah	Utilizing a BVI report that shows the **number of bidders, the bid amounts, and the variable between bids**.

Table 20. Criterion in competitive bidding: number of bidders and other factors

DOT	Criterion in Competitive Bidding
Wyoming	Number of Bidders, **available approved contractors** that can do the type of work.
Minnesota	Number of bidders and **stratigraphy of bid spread**, commonality in pricing, use of subcontractors, price compared to EE, **look at plan holders list**, look at bidders to see if there are bidders missing you would expect, look at available contractors in regions, **unbalanced and complementary bids**
Florida	Number of bidders; **Amounts of bids**
Anonymous	Usually, the **number of bidders** and **the project scope** in the particular area
Oregon	Data of the **geographical location** by work type, some geographic areas have excellent, consistent competition vs. other same with work types.
Anonymous	Contractor Prequalification Process and Rules and Regulations within our Specification Book
Caltrans	Case-by-case basis
Maine	None
Montana	No set criteria. Judgment is used.
Mississippi	Unfortunately, we have several regions of the state with certain markets **dominated by a single bidder**. We do not have any formal policy for determining an adequate number of bidders.

Table 21. Reject and re-let procedures in the case of inadequate level of competition

DOT	Reject and Re-let Procedures
South Carolina	Reject the bid and re-let
NYS	Projects where we receive only 1–2 bids are reviewed. If the price is too high, may reject all bids
Minnesota	Look at re-letting option to see if this would result in savings and also look at award criteria for urgency of the project
Florida	Do a research to determine why.
Idaho	Revisit EE and consult industry for why they did not bid
Caltrans	Contractors taking out bid packages are contacted
New Jersey	Conducts a single bid survey when only one bidder submits a bid proposal.
Anonymous	Call contractors to find out possible project changes for more competition.
Idaho	Often, the reason for few bidders has to do with the **timing** of the bid opening. We look at the work windows in comparison to the time of bid opening, as well as the types of projects that are bidding that week. We try to avoid multiple similar project bids for one bid opening.
Tennessee	Possibly re-let with an alternate type of work (pavement surface types) to encourage competition within an industry that may only see one type of work.
Montana	Recommend rejecting bids and repackage the contract, or tie to another project.

Table 22. Encouraging competition in re-let

DOT	Procedures for Encouraging Competitions
Mississippi	Typically single bidders with more than 10% over the state estimate are rejected and re-bid. Often we make **changes to the project** or delay the re-bid to a more favorable time. In those limited markets, there is a limit to how much work any one contractor can bid and complete.
Wyoming	Based on percentage over/under Engineers Estimate (which considers the number of prospective bidders). Non-bidding contractors will be **surveyed** to verify why they decided not to bid. If a change can be made in the proposed project to accommodate more bidders, the Commission may reject bids to make said changes and re-let.
Idaho	We may call contractors on **the plan holders list to see why they did not bid**. We may adjust the work window to the next season or allow for more flexibility for the contractor. We will look at our proposal to see if there is anything that might limit contractors from bidding. Often, **the 95% Idaho Resident preference** is the only reason that **out-of-state contractors** do not bid on state-funded contracts. We may change it to federal, in rare instances.
Tennessee	We make sure that the **advertisement** is in multiple locations and sent to the Tennessee Road Builders Association for a more widespread competition area. We also provide alternates with different work types in a geographic area that may be on the border of a known single bid area.

Table 23. Award procedures in the case of inadequate level of competition

DOT	Award Procedures
North Dakota	We will review the bid to determine if it is a competitive bid. If so, we may award or reject and re-bid later.
Anonymous	We award projects that fall into our **approval guidelines**. (Single bids included).
Wisconsin	Only single bids have a **specific procedure**. Single bids with more than 10% over EE require review and concurrence from the Secretary's Office before award.
Texas	If the bid is determined to be **reasonable** based on the Engineer's Estimate, or there are extenuating circumstances (extremely **rural projects** can be difficult to get bids on), the project will be awarded.
Colorado	If fewer than three bids are received, a review of the low bid within **10%** of the engineer estimate is used. If over EE by more than 10%, a cost **justification** bid analysis is done. Assuming the cost justification supports continuing on with awarding the project, Agency's head/executive director approval is required.
LADOTD	If found to be **reasonable**, then award the contract
Oregon	Tend to award if within range of EE
Maine	Award determination is still made compared to the EE
Iowa	Evaluate additional award criteria; mentioned previously in this survey
FHWA	We follow the FAR. We can cancel or re-advertise, award, or go into **direct negotiations**
Washington State	Prior to bidding opening, if we do not have enough plan holders we send the ad to anyone qualified to try to get more competition. We may **delay the opening** or pull the project. We do not usually open bids until we have at least three plan holders; however, there are some areas of state where the market only supports two paving contractors. Whatever we do must take place before bidding open. Once bidding opens, if we have disclosed the bids of the only two bidders, we will not see as much competition in a re-bid.

Table 24. Additional information released prior to bidding

DOT	Information released
Florida	**Total authorized budget**
Texas	**Line item Engineer's Estimates**
New Jersey	We specify that a bid bond must be at least 50% of the total bid.
Montana	Past bid tabs are all posted
NYS	Plan holders list
Minnesota	Plan holders list
Idaho	Plan holders list
Tennessee	Plans, proposal, and bid file
Wyoming	No pricing info for each project is supplied; however, the STIP does include some loosely estimated values. **The average bid pricing** is available on our website
Iowa	Bid bond is the specified amount—a range of estimates may be determined based upon this as well as on historical unit prices and bidders list—that confidential bidders are allowed

Table 25. Additional information released after letting

DOT	Information Released after Letting
Minnesota	EE after contract award, Identity and unit bid prices for all bidders **after award,** and name of winning bidder after award
Tennessee	After the letting, the apparent low bids listing all bidders with the total overall bids are placed on our website. When proposals are **awarded** or rejected by the Commissioner (within 30 days after the letting), the summary of bids with all bidders and item bids, as well as the estimated cost sheet (with overall estimate total) with only the awarded bidder, is posted to our website.
Colorado	After the letting, the above items are provided. **After award,** when the NOA is issued, a bid tab is publicly posted with all the bidders' line item bid pricing and line item engineer estimate amounts.
Anonymous	We only release the bid tabs if the project is **awarded**.
Washington	What bidder listed to meet DBE, VOB, SBE, and other COA goals, and what subcontractors will be used.
Texas	Bidder unit prices are kept confidential until after projects have been **awarded**.
NYS	Unit prices are made public **after the award**

Table 26. Estimation accuracy: low bid results compared to Engineer's Estimate

DOT	Low Bid Results Compared to the Engineer's Estimates
Anonymous	Usually within the acceptable range
Tennessee	Usually, our low bid is within 10% of the EE and 5% of the overall bid letting estimate the total for all proposals in that scheduled letting
Minnesota	Typically are within 10% approximately 52% of the time
Wisconsin	Percentage of contracts within 10% of the low bid for the past three fiscal years: 2019 = 52%, 2020 = 49%, 2021 = 50%
Washington	Overall, we are close to our goal of bids coming in at estimate.
Caltrans	Over 85% were below the Engineer's Estimate
Missouri	We are **within the federal recommendation of 50% of the projects within 10%**
NYS	Generally close
Arkansas	50% of low bids fall within plus or minus 10% of the Engineer's Estimate
Florida	±10%
Utah	Approximately 80 to 90% of bids are within 10% of the Engineer's Estimate.
Wyoming	60% to 65% within ±10% of EE. Overall (annually) low bid is within ±5% of EE on a total estimated cost vs. total low bids
Oregon	Current year the average is −5.4% under the Engineers Estimate
Mississippi	From 2008 to 2020, 58% of our awarded bids have been within plus/minus 10% of the state estimates. This is based on 1,687 awarded contracts during that time period.
South Carolina	Bids cannot be higher than 10% of the Engineer's Estimate
FHWA	About 50% are within 15% of EE
LADOTD	Usually, the low bid is within the range of −25% to +10% of the EE over 50% of the time.
Idaho	In general, the bid is roughly 86% of the Engineer's Estimate. I believe that the districts guess high because they know it will have to go to the board if they are too low. This requires a justification memo, and there is always a delay to the award because there is only one Board meeting per month, and the deadlines to provide the memos are typically two weeks prior to the Board meeting.
Maine	It depends on the number of bidders and type of bidders. If the smaller contractors are bidding, we are at or below estimate. If only the larger contractors are left, we're typically 15%–30% over estimate
West Virginia	Approximately 40% of the low bids are within 10% of EE.
Iowa	Variable
Texas	Smaller, lower-cost projects tend to be at or above estimate, while larger, higher-cost projects will trend below.
Montana	Depends on market conditions

Table 27. Actual construction cost compared to Engineer's Estimate and initial bid price

DOT	Actual construction cost compared to Engineer's Estimate and initial bid price
South Carolina	The goal is to have **40%** of projects within **10%** of the estimate
Washington	Overall, we are close to our goal of final costs coming in within **10%** of bids.
Tennessee	Approximately within **5%** over the last six years
Mississippi	Historically, about **80%** of final project costs are less than **10%** over bid prices.
Wisconsin	In FY 2020, final costs program-wide were **2%** higher than the original contract amount. FY 2019 was **4.1%** higher, and FY 2018 was **4%** higher.
Idaho	In general, the bid is roughly 86% of the Engineer's Estimate. The actual construction cost is generally within **±5%** of the bid.
Maine	We build in a **3%** bump to the funding—this percentage has historically been sufficient to cover construction overruns
FHWA	Within 10% of the contract award amount
Iowa	It varies. $20 million annual program amount for post letting project costs out of an approximate $900 million annual highway improvement program.
Wyoming	This is not tracked through my office as projects are completed 1 to 5 years after the award
Caltrans	Information is not available at this time
North Dakota	Do not have that information available at this time.
Minnesota	No data for this question at this time
Colorado	No response is available.
LADOTD	That's something I wish we knew.
Montana	It is usually **higher** due to change orders.
Anonymous	**It varies** greatly on many factors: Weather, site conditions, unknown utilities, etc.
Utah	Approximately 30% of the UDOT projects require **additional funding** to meet the final actual construction cost in comparison to the initial Engineer's Estimate and contractor bid price.
Florida	Very close.
West Virginia	The final construction cost and the initial contractor bid price are tracked in our construction Management software (AASHTOWare Project SiteManager), and the Engineer’s Estimate and initial contractor bid price are tracked in our preconstruction software (AASHTOWare Project Preconstruction).

Table 28. Criteria for lump-sum items

DOT	Criteria for Lump-Sum Items
Iowa	Work that does not lend to individual measurement and with the scope that can reasonably be anticipated at bid letting.
Utah	(1) Not measured using a typical unit of measurement (such as foot, square yard, ton, each, etc.); (2) More abstract rather than specific work (like public information services); (3) Includes several types of work together
Mississippi	We have a very limited amount of lump sum items. They are typically items paid out over the length of the contract.
Washington	When the work is known, but it is difficult to define.
Idaho	There is a spec committee. We work with the AGC to determine what works best for the Department and the Contractor.
Caltrans	Subject matter experts decision
Montana	Past practice.
FHWA	Historical data
Wyoming	Non-standard items. We try to make new bid items if used more than once/twice.
Minnesota	Least amount of reward to track detail
Maine	Easily identifiable and described work
Texas	What items can have a unit of the lump sum is specified in our spec book.
Oregon	Standard specifications
Colorado	Based on how the work item is listed in CDOT's Standard Specifications. The unit of measurement for a work item is determined by the Standard and Specifications Unit and is used in the same manner on all projects.
Florida	Plan sets and descriptions.
Tennessee	Determined by our universal item listing and provided in the plans by the designers. The estimators will provide input on LS items that need to be broken into individual items.
Wisconsin	Based upon the specials. All contracts have mobilization and traffic, and all structure replacement contracts have structure removals and structure excavation.
Missouri	Standard pay items
South Carolina	It depends on the Item type

Table 29. Bidding and estimation for traffic control and maintenance

DOT	Bidding and Estimating for Traffic Control and Maintenance
Washington	Depending on the complexity, we handle it with either a lump sum traffic control or unit bid items.
Texas	Smaller, simpler projects may have a lump sum traffic control item, but most projects are based on sign days.
Minnesota	Lump-sum, based on work required—similar to contractor quotes, and cost base for crews
Caltrans	Paid as a lump sum: Construction Area Signs, Traffic Control System, Maintaining Existing Traffic Management System Element during Construction
Utah	It is a combination of a percentage of the overall total work and the type of work or level of impact on the traveling public.
Iowa	Estimated via historical bid prices on similar work, bid lump sum
Mississippi	These items are typically estimated as a certain percentage of the overall bid. Maintenance of Traffic is an LSUM item.
South Carolina	Use a percentage of the total cost and bid history, then use engineering judgments
Wyoming	Percentage based on similar type work from the bid history
Tennessee	Traffic Control is bid on a lump sum cost. We used similar projects previously and regression equations to come up with an LS amount based on the total estimated cost of the proposal. We modify based on phasing, locality (urban or rural), etc. I suspect that is how it is bid as well. The costs for maintenance work during construction and before the Project is accepted will not be paid separately but is incidental to the cost of the Work.
Arkansas	Mobilization is required to be 5% of the total project cost or less and is usually estimated and bid near 5%. Maintenance of traffic is usually 2%–4% of the project cost, depending on the size of the project. Roadway and Bridge Construction Control are usually 2%–4% of the cost of each of their respective categories.
Wisconsin	The Traffic Control bid item is a lump sum item with an Each unit for each project in the contract. Designers are expected to consider Traffic Control as a percentage of total bid and bid prices in their estimate. WisDOT's Similar Projects tool provides Traffic Control as a percentage of total bids and bid price amounts for awarded contracts, along with Mobilization percentages. https://wisconsindot.gov/Documents/doing-bus/eng-consultants/cnslt-rsrces/tools/estimating/similar-projects.xlsm
Montana	District Staff helps to determine this number.
Florida	Established procedures.
Colorado	No response was given.
Maine	Estimated based on individual items and quantities
Oregon	Have an overarching LS item for TPDT maintenance and individual items for all traffic control devices by unit price.

North Dakota	This is done using the detailed traffic control plan.
Idaho	Traffic control is typically estimated by providing a suggested traffic control plan using average unit prices versus the quantities for that plan. The bid is typically, but not always lump sum. Occasionally, we separate out items such as barrels, candlesticks, etc. TC maintenance is paid by the hour and has a specific requirement.
West Virginia	Traffic control items can be estimated and bid in various units, such as L.S. Site, Each, LF, Day, Month, etc. Please see section 636 of our specifications. (https://transportation.wv.gov/highways/contractadmin/specifications/2017StandSpec/Documents/2017_Standard.pdf)
Missouri	Typically, traffic control is identified in the bidding documents. Maintenance is not included
FHWA	Traffic Control is based on CPM from design as to staging requirements. Our agency does not do maintenance.

Table 30. Payment for traffic control and maintenance

DOT	Payment for Traffic Control and Maintenance
Utah	It is based on the percentage of work paid on each pay estimate.
Arkansas	The basis of payment is a lump sum, and periodic payments are made based on the percentage of work completed.
Texas	If traffic control is a lump sum, it is paid via percentage. If it is sign day, paid on actual days, the item is in place.
Idaho	Lump-sum items can be paid as a percentage of work completed. Maintenance is paid by the hour of documented and approved work.
South Carolina	Payment is based on the percentage complete
Minnesota	Payout curve based on percentage complete. If the bid exceeds spec allowance, excess payment is delayed to the end of the contract
Florida	Percentage of work completed.
Iowa	Proportionately as work is completed.
Oregon	The large LS item is paid on the percentage of work completed.
Caltrans	Yes, it is based on the percentage of work completed.
Mississippi	Yes, it is based on the percentage of other items of work completed.
Missouri	Payment on what is used and identified in the bidding documents
Maine	Based on actual items used. There is also daily maintenance of traffic item
Washington	Yes
FHWA	Flagger hours, Traffic Control Sup, % of work complete, etc.
West Virginia	See section 636 of our specifications. (https://transportation.wv.gov/highways/contractadmin/specifications/2017StandSpec/Documents/2017_Standard.pdf)
Wisconsin	The department will measure Traffic Control once for the contract acceptably completed and will not include work performed under other specific traffic control contract bid items per Standard Spec 643 (https://wisconsindot.gov/rdwy/stndspec/ss-06-43.pdf).
Tennessee	The Department will pay for accepted quantities, complete in place, at the contract prices as the lump sum payment for Traffic Control. It is full compensation for providing Temporary Workzone Lighting and all equipment, labor, and materials, and for furnishing flaggers and traffic cones, and for removing conflicting and incorrect pavement markings, as required, until Project completion (based on the percentage of work completed). The costs for maintenance work during construction and before the Project is accepted will not be paid separately but is incidental to the cost of the Work.
Montana	No. Units and unit price.
North Dakota	Traffic control is paid for as it is being used on the project. We pay for the actual devices that are used on the project.

Table 31. Payment for mobilization, general conditions, and/or safety-security

DOT	Payment for Mobilization, General Conditions, and/or Safety-Security
Utah	For **Mobilization,** it would be based on the percentage of the contract paid. We **do not do the other items**.
Idaho	Mobilization is paid as a lump sum. General conditions and safety-security are incidental to the contract.
Wyoming	**Mob only**. It is paid 10% at start up and then paid based on the percentage of work completed
Washington State	We have a bid item for **mobilization**, which is paid up front.
Mississippi	Mobilization is paid out in portions based on the **percentage of other items** completed. We do not have a general condition or safety/security item.
WisDOT	WisDOT does have **mobilization**, but not general conditions and/or safety items. WisDOT has a pay schedule for Mobilization based upon the following worksheet: https://wisconsindot.gov/Documents/doing-bus/eng-consultants/cnslt-rsrces/tools/estimating/ws6191.xls
Colorado	No response was given.
Montana	See our standard specs. https://www.mdt.mt.gov/business/contracting/
NYS	The contractor can bid what they want for mobilization, but it cannot be more than **4%** of the bid
Texas	These are paid based on the **percentage of project completed**.
Arkansas	Mobilization is paid by the lump sum, and we do not use the other two items listed above. Mobilization is paid using the following schedule: Percentage of Original Contract Amount Earned Percentage of Mob. Paid First progress estimates **25%;** 10% **50%;** 25% **100%**
Minnesota	Mobilization only -- LS with max % of contract limit. Payout according to spec allowance. If bid exceeds spec limit, excesses held to contract end. Do see multiple mobilizations on some projects on some contracts -- specifications developed to ensure payout is consistent with work progress to ensure no prepayment
Caltrans	Mobilization: Preparatory work that must be performed or costs incurred before starting work on the various items on the job site (Pub Cont Code § 10104). Payments for mobilization made under section 9-1.16D are in addition to the partial payments made under Pub Cont Code § 10261.
Maine	Of these, we only have mobilization. Half of the mobilization (up to **5%** of the contract amount) after award; half of the mobilization (up to **5%** of the contract amount) after **50%** complete; any remaining at contract close out
Oregon	GCs are to be spread amongst the items; mobilization is paid as a separate item up to **10%** of the total bid. Mobilization is paid out **50%** when **10%** is complete.

South Carolina	Payments for mobilization are included on the first and second payments. Each payment is for 1/2 of the lump sum price for mobilization.
Iowa	Mobilization is a lump sum. Payment for Mobilization will be as follows: A. Partial Payments. Partial payments may be made as follows: 1. Partial payment of mobilization will be made for each project within 30 calendar days after receipt of a signed contract. This partial payment will be either 10% of the contract price for this item or 1% of the original project sum, whichever is less. If the partial payment for a project is less than $1000, the Engineer will delay this partial payment until 5% of the awarded project total is earned. 2. When 5% of the original project sum is earned, either 25% of the contract price for this item or 2.5% of the original project sum, whichever is less, will be paid. 3. When 10% of the original project sum is earned, either 50% of the contract price for this item or 5% of the original project sum, whichever is less, will be paid. 4. When 25% of the original project sum is earned, either 100% of the contract price for this item or 10% of the original project sum, whichever is less, will be paid. B. Full Payment. Upon completion of all work on the project required by the contract, full payment will be made for this contract item, including any amount not paid as a partial payment. -- General conditions, safety/security, are incidental to other work on most contracts.
Tennessee	The Department will pay for Mobilization on a lump sum basis. The Department will make partial payments for Mobilization with the first and second partial pay estimates paid on the Contract. Payment will be made at the rate of 50% of lump-sum price for Mobilization on each of these partial pay estimates provided the amount bid for Mobilization does not exceed 5% of the total amount bid for the Contract. If the amount bid for the item of Mobilization exceeds 5% of the total amount bid for the Contract, the Department will pay 2-1/2% of the total amount bid on each of the first partial payment estimates, and that portion exceeding 5% on the last partial pay estimate. As an exception to the above, where the Work covered by the Contract is limited exclusively to the resurfacing of existing pavement, including projects involving the milling off of a portion of the existing pavement prior to the laying down of new asphalt cement concrete layer(s), the Department will pay the entire lump sum price for the item of Mobilization, less the retainage provided for in Title 54-5-121, TCA, with the first partial pay estimate paid on the Contract, provided the amount bid for Mobilization does not exceed 5% of the total amount bid for the Contract. If the amount bid for the item of Mobilization exceeds 5% of the total amount bid for the Contract, the Department will pay 5% of the total amount bid for the Contract on the first partial pay estimate, and the portion exceeding 5% on the last partial pay estimate.

APPENDIX F: MARK-UP PERCENTAGES IN THE BIDDING EXPERIMENT

	Letting 1 (Profit %)				Letting 2 (Profit %)			
ID	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7	Project 8
Bidder 1	10.0%	-10.0%	12.0%	18.5%	-0.7%	18.6%	-0.1%	-5.0%
Bidder 2	12.0%	12.2%	28.9%	15.0%	6.1%	9.8%	6.0%	-
Bidder 3	9.4%	-	8.7%	13.1%	1.6%	0.9%	-	-8.5%
Bidder 4	12.0%	-	5.0%	8.0%	24.0%	30.0%	20.0%	-
Bidder 5	20.0%	-	20.0%	20.0%	20.0%	-	-	-
Bidder 6	7.0%	-	-0.8%	10.0%	8.9%	8.1%	0.8%	-
Bidder 7	11.3%	-	3.0%	3.0%	5.0%	12.0%	2.1%	-
Bidder 8	7.5%	3.2%	-	-5.9%	24.7%	12.0%	0.0%	-
Bidder 9	10.1%	2.6%	-	2.6%	4.6%	3.8%	2.6%	-
Bidder 10	10.0%	8.3%	-	9.0%	111.9%	233.1%	251.8%	-
Bidder 11	20.0%	20.0%	-	20.0%	85.0%	85.0%	85.0%	20.0%
Bidder 12	2.5%	2.8%	2.6%	2.5%	-	7.0%	12.0%	1.8%
Bidder 13	5.3%	5.3%	6.0%	-	-	-5.0%	-5.0%	-5.2%
Bidder 14	8.4%	2.6%	-	8.5%	2.8%	-	3.4%	2.6%
Bidder 15	20.0%	20.0%	20.0%	-	11.9%	12.0%	11.0%	9.0%
Bidder 16	10.0%	-	-15.0%	-3.0%	19.0%	20.0%	-	10.0%
Bidder 17	28.0%	23.5%	10.0%	27.4%	27.0%	-	-	-
Bidder 18	-	-	-	-	-	-	-	-

APPENDIX F: MARK-UP RATIOS IN THE BIDDING EXPERIMENT

	Letting 3 (Profit %)				Letting 4 (Profit %)			
ID	**Project 9**	**Project 10**	**Project 11**	**Project 12**	**Project 13**	**Project 14**	**Project 15**	**Project 16**
Bidder 1	8.6%	7.7%	8.9%	8.5%	1.9%	8.2%	9.5%	8.4%
Bidder 2	9.0%	-	12.5%	6.8%	-	-2.3%	-7.0%	-4.0%
Bidder 3	3.4%	-20.5%	-	-5.9%	-11.6%	-	-5.9%	-6.6%
Bidder 4	25.0%	-	49.8%	30.0%	-	4.6%	1.2%	19.7%
Bidder 5	20.0%	-	20.5%	20.0%	96.5%	-	20.0%	19.8%
Bidder 6	1.2%	-	-	18.7%	-	-	-	-
Bidder 7	10.0%	9.4%	38.4%	20.0%	0.8%	6.4%	-0.4%	9.7%
Bidder 8	-	-12.6%	28.3%	-4.4%	0.3%	7.6%	0.0%	10.5%
Bidder 9	2.6%	0.0%	15.2%	3.1%	0.0%	0.0%	0.0%	0.0%
Bidder 10	74.1%	10.9%	-	11.0%	12.1%	-	9.8%	9.7%
Bidder 11	-	9.6%	161.9%	13.4%	-1.0%	-4.8%	-8.7%	-5.1%
Bidder 12	15.3%	23.0%	-	25.9%	100.0%	150.0%	130.0%	90.0%
Bidder 13	-5.0%	-6.6%	-	-5.0%	-5.2%	-5.4%	-8.6%	-
Bidder 14	5.3%	2.7%	2.5%	1.0%	0.5%	-10.4%	-8.2%	-9.1%
Bidder 15	-	-	-	-	9.0%	9.0%	9.0%	-
Bidder 16	-15.0%	-15.8%	-	-15.0%	0.0%	-	0.0%	9.7%
Bidder 17	-	-	-	-	-	-	-	-
Bidder 18	-	-	-	-	15.5%	10.2%	10.0%	-

APPENDIX F: MARK-UP RATIOS IN THE BIDDING EXPERIMENT

	Letting 5 (Profit %)				Letting 6 (Profit %)			
ID	Project 17	Project 18	Project 19	Project 20	Project 21	Project 22	Project 23	Project 24
Bidder 1	8.6%	8.6%	8.6%	8.6%	8.5%	8.6%	8.6%	8.2%
Bidder 2	-2.7%	3.9%	3.4%	-	2.9%	3.0%	4.0%	-
Bidder 3	-10.0%	8.0%	-12.2%	-13.8%	7.7%	7.9%	7.9%	7.7%
Bidder 4	-	-	-	-	18.1%	15.1%	-	12.8%
Bidder 5	20.0%	-	20.0%	20.0%	19.9%	20.1%	-	19.8%
Bidder 6	0.2%	7.7%	1.6%	-	2.1%	-0.6%	-	-7.3%
Bidder 7	3.1%	-4.6%	4.4%	-10.0%	-8.3%	5.0%	-5.1%	-6.4%
Bidder 8	26.0%	-	8.0%	-16.0%	0.0%	0.0%	-	13.3%
Bidder 9	0.7%	-100.0%	7.2%	0.0%	-1.4%	-0.3%	15.0%	-9.1%
Bidder 10	13.0%	2.0%	20.9%	-	8.7%	22.0%	-	8.2%
Bidder 11	-5.0%	-5.0%	-5.0%	5.0%	-5.8%	-6.0%	-6.0%	-6.1%
Bidder 12	25.0%	50.0%	40.0%	120.0%	18.4%	37.5%	65.8%	-
Bidder 13	-4.6%	-0.5%	-5.1%	-5.0%	-2.8%	-2.9%	-3.0%	-3.1%
Bidder 14	-0.8%	-0.7%	-0.6%	-0.5%	-8.0%	-9.0%	-20.0%	6.9%
Bidder 15	-	-	-	-	9.8%	9.3%	8.7%	-
Bidder 16	10.0%	0.0%	10.0%	-	10.1%	10.0%	10.0%	-
Bidder 17	-	-	-	-	-	-	-	-
Bidder 18	-	-	-	-	7.2%	9.9%	-	2.3%

APPENDIX F: MARK-UP RATIOS IN THE BIDDING EXPERIMENT

	Letting 7 (Profit %)				Letting 8 (Profit %)			
ID	**Project 25**	**Project 26**	**Project 27**	**Project 28**	**Project 29**	**Project 30**	**Project 31**	**Project 32**
Bidder 1	6.7%	8.6%	8.5%	8.5%	6.8%	8.6%	8.7%	9.0%
Bidder 2	0.2%	2.0%	3.1%	-	-0.6%	1.1%	0.7%	-
Bidder 3	5.4%	6.0%	5.9%	5.9%	0.3%	5.0%	4.9%	5.7%
Bidder 4	6.7%	20.0%	25.2%	20.0%	7.8%	10.0%	-0.5%	-
Bidder 5	-	20.0%	20.2%	-	15.0%	-	20.1%	19.7%
Bidder 6	23.8%	16.2%	15.4%	-	1.6%	29.5%	-	-0.2%
Bidder 7	-	-	-	-	-	10.0%	-2.1%	5.4%
Bidder 8	-	8.0%	20.3%	-2.0%	0.0%	15.0%	-	14.6%
Bidder 9	0.0%	8.8%	9.6%	2.8%	0.0%	5.2%	4.2%	5.0%
Bidder 10	-	-	-	-	-	-	-	-
Bidder 11	-0.1%	-1.0%	-1.6%	-1.0%	-3.5%	-3.0%	-3.2%	-3.1%
Bidder 12	38.6%	20.0%	-2.2%	118.0%	-	-	-	-
Bidder 13	-9.0%	-5.0%	-5.1%	-5.1%	-4.7%	-2.0%	-3.0%	-2.0%
Bidder 14	-0.3%	-0.2%	-0.7%	-7.9%	-8.3%	-4.0%	5.2%	-9.3%
Bidder 15	5.5%	8.0%	7.5%	6.3%	4.8%	7.6%	8.3%	7.8%
Bidder 16	-14.1%	-5.0%	14.9%	-	-0.8%	-	-0.9%	-2.0%
Bidder 17	-	-	-	-	4.8%	5.1%	9.4%	-2.7%
Bidder 18	-	13.0%	10.7%	3.1%	0.1%	20.3%	-	6.0%

APPENDIX G: USER MANUAL OF POST-BID ANALYSIS TOOL

MDOT Post-Bid Analysis Tool

USER GUIDE

Last updated on May 26, 2022

Available at https://docs.google.com/document/d/1u-2Ol3KAlLFSe9cwt0SUdQcdHDA5ALG7Tak-7eV5Sj4/edit?usp=sharing