Procurement and Infrastructure Costs

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Abstract

Why is it so expensive to build and maintain U.S. infrastructure? In this paper we conduct a survey of infrastructure procurement practices across the 50 states. We survey both employees at each state department of transportation (DOT) and the road builders that win contracts to build and maintain roads. With this survey we are able to create a new dataset of procurement rules and practices across the U.S. and understand what actors on the ground think drives costs. We correlate the survey practices with a new, detailed dataset of *project-level* infrastructure costs. We find that two important inputs in the procurement process appear to particularly drive costs: (1) the *capacity* of the DOT procuring the project and (2) the lack of *competition* in the market for government construction contracts. Using novel administrative data from California, we find that DOT engineer assignment explains a meaningful share of road resurfacing costs.

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1 Introduction

The United States spends a large amount on infrastructure costs: state and local governments spent $266 billion on highways alone in 2022. The spending, on a per-project basis, is very high by international standards—over three times as high as other upper- and middle-income countries.[1] Despite the magnitude of the investment, there is a growing concern that the quality of infrastructure is declining (American Society of Civil Engineers, 2017; US Census Bureau, 2018). Not only are costs high, but there is substantial heterogeneity in spending and road quality across states.

Why is infrastructure construction and maintenance so expensive in the U.S.? One potentially important, but previously untestable, hypothesis, is that government procurement practices drive costs. Every federally funded road building and resurfacing project goes through a procurement process, usually an auction. The government does not typically build or repair roads; rather, it disburses and oversees contracts that private sector firms complete. In this paper, we collect and assemble new data on state DOT procurement and costs in order to begin to quantify the importance of procurement practices on realized costs. Further, we use detailed administrative data from one state in order to confirm the suggestive evidence from the survey, using a fixed effect analysis that exploits engineer assignment across projects. We find that DOT capacity and competition in the market for projects are important drivers of realized costs.

A vast literature shows, theoretically and empirically, that the design and implementation of procurement auctions have implications for total cost. While the existing literature provides evidence on specific programs in certain states for which rich data exist, there is no comprehensive dataset on highway procurement practices across states. As a result, the literature has major blind spots on areas that could be very important to infrastructure costs, but lack data or useful within-state variation for any empirical design.

We produce three new datasets to help fill this gap. First, we conduct a 50-state survey of state Department of Transportation (DOT) highway procurement practices. This project collects data on the procurement process to resurface highways in each state, using a survey based on the World Bank's Doing Business Procurement Module (Bosio et al., 2022). We survey two groups in each state who have complementary knowledge about state procurement: procurement officials at each DOT and contractors (i.e., road builders and engineers at private firms). The survey asks specific questions about processes, all which can be related to potential cost drivers in the procurement process.

Second, to study procurement cost drivers, we need detailed data on the realized costs of the state

[1] NYU Transit Costs Project (`https://transitcosts.com/executive_summary/`).

DOT projects. To this end, we create a new dataset on *project-level* costs for each state. We collect this data state-by-state. While some states make this sort of data publicly available, others we obtain via public records requests. Then, we match the contract data with project plans and bid lettings, in order to create a cost per mile measure that is comparable across states.

Third, we assemble administrative data on the construction industry that completes projects and the public sector industry that manages projects. This includes data on employment and payroll for state DOTs, data on market structure for road construction companies, and data on approved subcontractors (disadvantaged business enterprises) for a subset of states. We also include non-procurement cost drivers, such as weather and population density. We show that the cost data we collect is correlated with observables that should drive costs (weather, road usage, labor costs).[2]

With the survey data, we can produce summary statistics on what experts think is driving costs. With the three datasets together, we can correlate specific procurement practices with cross-state data on resurfacing costs, with the acknowledgment that correlation is not causation. We assess a variety of sets of hypotheses on procurement cost drivers with the data, including corruption, the absence of competition, insufficient controls for quality, a lack of transparency about the process, and the capacity of the state DOT.

We start with the experts. Here, the evidence points to two broad patterns:

1. **State DOTs have limited capacity.** In the survey, there is broad agreement that state DOTs have become more understaffed and that reliance on consultants drives up costs. Survey respondents attribute a lack of details in project plans to both a lack of time or experience of DOT engineers and the use of consultants. When there is not enough specificity in the plans the risk to the contractor increases, increasing bids. Moreover, whenever the scope of a project changes this initiates a costly and time-consuming renegotiation process. Survey respondents agree that such changes are a major contributor to costs. We confirm that the state DOT workforce has been shrinking with administrative data on public sector employment.

2. **There is not enough competition.** A lack of competition for contracts is a oft-cited cost driver from procurement officials. This was also mentioned by contractors, but at the subcontractor level. We show, with external data on the highway construction industry, that concentration in the industry seems to be rising. Most states have experienced a loss of construction firms, and an increase in size of the remaining firms, in the last 10 years.

[2]Strikingly, publicly available data on aggregate resurfacing costs from the Federal Highway Administration does not correlate well with observable cost drivers like weather or road quality. We compare this dataset to our own in Appendix B.2.

Given the stated cost drivers from the survey respondents and confirmation of the two patterns using external data, we proceed to the correlations with realized costs. Both procurement practices and costs vary widely across states. While most state-level procurement practices do not correlate with realized costs, the correlations that emerge are consistent with the cost drivers that the experts identify.

First, we find evidence that state capacity correlates inversely with costs in a several ways. States that flag concerns about consultant costs have higher costs—a one standard deviation increase in reported consultant costs is associated with an almost 20% increase ($70,000) in cost per lane-mile. States where contractors and procurement officials expect more change orders have significantly higher costs: one additional change order correlates with $25,000 in additional cost per lane-mile at the mean. Frequent change orders could directly lead to higher costs through delays and costly renegotiation; they could also be a downstream symptom of poor administrative capacity at a state DOT—many contractors reference poor-quality project plans made by third-party consultants. Consistent with this hypothesis, the quality of the plans provided by the DOT also correlate with costs: costs are lower when the DOT provides both detailed project plans and predicted unit costs, and higher if the DOT only provides a total estimated contract value.

More directly, we find that states with (perceived) higher quality DOT employees have lower costs. A state with "neither low nor high quality" employees has almost 30% higher costs per mile than one that rates the DOT employees as "moderately high quality", all else equal. Finally, when we measure capacity using external data we show that states with higher DOT employment per capita have lower infrastructure costs. A one standard deviation increase in DOT employment per capita is correlated with 16% lower costs.[3]

We also find compelling evidence of the relationship between competition and costs. In the survey data, we find that states that do outreach to increase the bidder pool have significantly lower costs, highlighting both the importance of competition and the role the DOT can play in order to increase competition. A one standard deviation (12 percentage point) increase in bidder outreach is correlated with a 17.6% decrease in costs. At the mean, this translates to a decrease in costs of $65,000 per lane-mile and $1 million at the project level. We also find that limits on the amount of work that can be subcontracted is positively correlated with costs. Restrictions on subcontracting can decrease competition by limiting the set of potential prime contractors that can complete the project. Lastly, using our project-level cost data, we find that an additional bidder on a project is associated with 8.3%

[3]Here, the capacity measure is from administrative data on public sector Highways employment from the census (US Census Bureau, 1997-2021).

lower costs, or a savings of approximately $30,000 per lane-mile ($460,000 for the average project).

We confirm the suggestive evidence on the role of DOT capacity with data from one large state DOT—Caltrans, California's Department of Transportation. Here, we are able to observe the DOT engineer who manages the project, from inception to completion, as well as the DOT engineer who communicates with the contractor through the construction phase of the project. We also observe details about the project (length, type of work, location) and a variety of project outcomes (number of bidders, winning bid, realized cost, duration). We use a fixed effects analysis in order to understand how much of variation in realized costs can be explained by the individual engineer that is assigned to manage the project.

Our preliminary analysis suggests that replacing a construction engineer at the 95th percentile of the cost distribution with a median engineer would reduce costs by $24,000 per mile, or $220,000 per project, at the mean. Caltrans completes 60 resurfacing projects per year, on average, so this effect scales to a savings of over $13 million per year. In ongoing work, we will be able to use this rich personnel data to decompose the role of the DOT engineer in the pre-bidding and bidding stages (i.e. the role of the project manager before construction begins), with the role of the engineer during the construction phase (i.e. the engineer on the ground managing the contractor).

Related Literature. This paper contributes to a burgeoning literature on the U.S. construction industry, and infrastructure construction in particular. Goolsbee and Syverson (2023) have documented a large and long decline in construction sector productivity. Kroft et al. (2022) show that construction firms have considerable market power: in both the labor and the product market. On the infrastructure side, Brooks and Liscow (2023) find suggestive evidence that increases in costs in road building in the later part of the 20th century were driven by citizen voice, which delay the process, instead of increases in materials or labor costs. Mehrotra et al. (2021) find that input prices are more important for resurfacing. This paper adds one important piece to the understanding of the interaction between the DOT and the private sector: the procurement process.

There is also a small, but growing, literature on the supply side determinants of procurement costs. Our findings on the role of competition contribute to a debate on the relationship between the number of bidders and costs in the procurement setting. Carril et al. (2022) and Coviello and Mariniello (2014) both study the effect of procurement publicity requirements, though in different settings (US Department of Defense and local procurement in Italy, respectively). Coviello and Mariniello (2014) find that increased publicity increases auction participation and lowers costs to the government; larger and less local firms are more likely to win auctions that are publicized. However, Carril et al. (2022) find that while publicity increases the number of bidders, with lower winning bids, ex-post contract performance decreasing, leading to delays and cost overruns. Finally, Allende et al. (2023) use a natural experiment to study the effect of an increase in auction participation on prices in public procurement of pharmaceuticals in Chile, and find that the entry of an additional bidder decreases costs by about 10%.

Our paper is inspired by Bosio et al. (2022), which surveys procurement practices and law across *countries*. They find that correlations between procurement practice and outcomes highlight the importance of public sector capacity, while regulations only become more useful in countries more vulnerable to corruption. We do not find any role for corruption as a cost driver in the U.S. context. However, public sector capacity remains important in our setting.

Our finding that procurement costs are highly correlated with DOT capacity is consistent with a literature on bureaucratic competence and capacity, both in the United States and abroad. Best et al. (2023) finds that variation across individual procurement officials and the organizations that manage them can explain nearly 40% of the variation in prices paid for goods in Russia. In a stylized model of the procurement process, they show how this plays out, showing that a bureaucracy can drive up prices by imposing higher contract fulfillment costs and by imposing higher participation costs, thereby reducing the number of bidders.[4] The Best et al. (2023) model, however, does not consider the bureaucrat's effort after the auction, which we are able to study with our fixed effect analysis by using data on the engineer involved in pre-bidding and bidding (the project manager) and the engineer involved in the construction phase.

In the U.S. setting, Decarolis et al. (2020) study bureaucratic competence across federal agencies, and find that increases in competence, as measured by internal agency surveys, leads to less delays, less renegotiation, and lower costs in federal procurement. Warren (2014) finds that retirement-induced increases in procurement officer workload, also in the federal government, increase the risk of renegotiation and contract costs. The striking decrease in state DOT employment over the last 20 years, especially in the wake of the Great Recession, may have contributed to rising costs (US Census Bureau, 1997-2021).

2 Data and Background

We embark on an ambitious data collection effort to study the relationship between DOT procurement practices and realized costs. First, we design and implement a survey to collect data on procurement

[4]Similarly, Bandiera et al. (2009) find that different agencies in Italy pay very different prices for the same products.

rules and practices from procurement officials and local contractors in each state. Second, we assemble project-level cost data on state road resurfacing projects via public records requests from state DOTs and manual inspection of bid lettings. Third, we collect administrative data on employment in state DOTs and market structure of the road building industry, merging these with state-level observables that may affect construction costs.

2.1 The Procurement Survey

We follow the general framework of the World Bank Doing Business "Contracting with the Government" survey, which collected data on the procurement laws and practices of 187 countries (Bosio et al., 2022). In the Doing Business project, each survey respondent is given a case study, which is an example road resurfacing project. They are then asked questions about the rules and practices that would dictate the procurement process of the project. Our case study and a description of the survey follows.[5]

2.1.1 Case Study

The case study describes a standard project contracted by a state DOT. The project entails resurfacing 5 miles of a flat two-lane road that is part of the National Highway System (but is not an Interstate). The road would extend from the outskirts of a medium sized city into the surrounding rural area, with an asphalt overlay of 1 inch. The estimated value of the contract is between $1 to $5 million.

We choose to focus on resurfacing because it is both the biggest category of state highway spending and the most easily comparable across states. Although highway-building projects can be more complicated and involve more discretion (which would be interesting from a procurement perspective), many states are not building new highways. In fact, between 2004 and 2014 the rehabilitation of roads increased from 47% to 72% of total capital outlays on state and local highway spending. This means that at the same time, road expansion and new construction fell from 53% to 28% of outlays. Therefore, because we are interested in what drives costs for state DOTs broadly, we focus our case study on the most common type of project.

Two consequences flow from this choice of case study. The first is that we are able to largely abstract away from issues of litigation and "citizen voice" because—though there may be competition to receive resurfacing dollars—resurfacing projects rarely arouse organized opposition. This allows us to focus on procurement itself. The second is that our results have a greater chance of external

[5] The full survey is found in the Appendix.

validity because, however challenging procurement is for resurfacing, it is likely even more challenging for more complicated projects.[6]

2.1.2 Short Procurement Primer

In this section we provide a brief overview and timeline on the state DOT procurement process for a standard resurfacing project (like the one described in the case study). We provide more details in the Appendix.

1. **Pre-bidding:** Before the bidding starts, the DOT plans the project. The agency determines the scope of the work, and a DOT design engineer (or a consultant hired by the DOT) draws up the project plans and estimates the project cost. Along with design, the pre-bidding phase typically includes environmental review and right-of-way permitting/coordination.

2. **Bid Letting:** Once the plan of work is approved, a call for bids is posted. The DOT has discretion over when and where to post the call for bids, and over any bidder outreach efforts. The bid letting should include the detailed project plans and the engineer's estimate from the planning (pre-bidding) stage. It will always include an itemized list of the quantity of each item needed to complete the project. Depending on the state, bidders may have to have completed a pre-qualification process, and they may have to pay a small fee in order to receive access to the project plans.

3. **Submitting Bids and Project Award:** Each interested contractor prepares and submits the bid to the DOT. All contracts for resurfacing projects are awarded via a unit bidding process, where the contractors total bid is the aggregation of their bid on each component of the project (Figure 1). The lowest bid wins, unless the DOT determines there is a reason to exclude a bid (due to a bid being infeasibly low, for example).

4. **Construction:** Once the contract is awarded, the DOT and the contractor determine the work start date. The contractor then performs the construction, though they may subcontract parts of the project to other private firms (see Section 4.2.1 for more details on subcontracting). The

[6] One might wonder about the extent to which survey participants actually consider the case study, versus other types of projects, when answering questions. We are able to gain insight into this by comparing answers to two of our questions (Question 16 and Question 17 in Appendix F.), which are essentially identical, except that one asks about the case study, while the other asks about a more complicated design-build project. We asked about the number of change orders, and, for the case study question, the mean response was 3.80, while the design-build question, the mean response was 4.39. The fact that respondents expected more change orders on the more complicated project is suggestive evidence that respondents were attentive to the nature of the case study.

DOT inspects the contractor's work, coordinates permitting and road closure, and negotiates changes to the scope of the work as needed through a process known as "change orders".[7]

Figure 1: Contract Award and Unit Bidding

ARKANSAS
BY JOB REPORT

Oman Systems, Inc

Job No: 061084 | County: HOT SPRING | 100

Low Bidder: ROBERTSON CONTRACTORS, INC. | Low Bid: $7,045,842.59 | Letting: 01/1

				1st Bidder ROBERTSON CONTRACTORS, INC.	2nd Bidder MANHATTAN ROAD & BRIDGE CO.	3rd Bidder KIEWIT INFRASTRUCTU RE SO. CO.	4th Bidder MOBLEY CONTRACTORS, INC.	State Average
PayItem	Description	Quantity	Unit	Unit	Unit	Unit	Unit	Unit
201011	CLEARING	25.000	STA-M	$800.00	$1,428.00	$3,500.00	$1,320.00	$1,318.16
201111	GRUBBING	25.000	STA-M	$800.00	$1,428.00	$3,500.00	$880.00	$903.49
401011	TACK COAT	406.000	GAL	$3.50	$3.50	$3.50	$3.68	$2.68
405161	MINERAL AGGREGATE IN ACHM BASE COURSE (1 1/2")	109.000	TON	$74.56	$74.56	$74.56	$78.29	$59.35
405402	ASPHALT BINDER (PG 64-22) IN ACHM BASE COURSE	5.000	TON	$120.00	$120.00	$120.00	$126.00	$205.32
406161	MINERAL AGGREGATE IN ACHM BINDER COURSE (1")	1472.000	TON	$76.44	$76.44	$76.44	$80.26	$62.09
406402	ASPHALT BINDER (PG 64-22) IN ACHM BINDER COURSE (1") (MINIMUM BID $120.00)	74.000	TON	$120.00	$120.00	$120.00	$126.00	$318.00
407162	MINERAL AGGREGATE IN ACHM SURFACE COURSE (1/2")	1832.000	TON	$78.88	$78.88	$78.88	$82.82	$65.82
407432	ASPHALT BINDER (PG 64-22) IN ACHM SURFACE COURSE (1/2") (MINIMUM BID $120. 00)	109.000	TON	$120.00	$120.00	$120.00	$126.00	$347.13
412001	COLD MILLING ASPHALT PAVEMENT	1289.000	S.Y.	$4.25	$5.20	$23.64	$16.49	$3.06

Notes: This figure shows an example of bids for a state DOT resurfacing project (this example is from Arkansas). Each contractor bids at the unit level, on a list of goods and services that are specified by the DOT. For example, in this project the DOT estimates that the contractor will need 406 gallons of tack coat and 5 tons of asphalt binder. The contractors' bids consist of a cost per item for each list on the unit bidding sheet, which are then multiplied by the quantities and aggregated. The contractor with the lowest bid wins the contract.

2.1.3 Survey Questions

The survey questions are organized roughly chronologically over the course of a typical project. They ask about a variety of features of the procurement and construction processes, all which have the potential to affect costs. Specifically, the questions we ask can be grouped into five broad sets of hypotheses:

1. **Transparency** Questions on the public availability of documents such as the, number of registered bidders, and details of past contracts all concern transparency.

2. **Competition** Questions on outreach, advertising, and the number of bidders are intended to collect information on competition.

3. **Quality** Questions on the bidder pre-qualification and bid screening focus on controls for quality in the procurement process.

4. **Capacity** Questions on renegotiation, changes in the project details, and payments all concern the capacity of the agency and the credibility of the contract.

5. **Corruption** Questions about bidder collusion, unethical contractor behavior, and improper state employee behavior concern corruption.

[7] Initial contract agreements specify precise plans and prices for each unit good that goes into a highway construction project. In the event of inaccurate plans or state authorities changing their minds, either party can initiate a legal process known as a change order to alter the terms of the contract to reflect current conditions.

We depart from the World Bank survey in asking free form questions about what the procurement officials and bidders think drives costs and asking directly about the capacity of the state DOT and the competitive environment for the bidders. We provide more details about the procurement process in the U.S. and the literature related to the above hypotheses in Appendix A.

2.1.4 Distribution

The surveys for the procurement officers and for the road builders and engineers (also known as contractors) are slightly different. This is sometimes as simple as question phrasing. For the contractor we ask, "To the best of your knowledge, how often does the agency do outreach to increase the bidder pool for highway construction projects?" To the procurement officer, who should know about the universe of projects, we simply ask "How often does the agency do outreach to increase the bidder pool for highway construction projects?" However, there are also questions that are group-specific. For example, we only ask the contractors about their expectations of the level of competition. Therefore, we launch the survey separately for procurement officers and for contractors. The sample and survey distribution method for each group is as follows.

Procurement Officers We collect contact emails for procurement officers from two sources: the state DOT websites and the American Association of State Highway and Transportation Officials (AASHTO), a trade association for DOT procurement officials.[8] We directly email the survey to these contact emails. Respondents follow a link to complete the survey via Qualtrics.[9]

Contractors We also collect contact emails for the contractors (road builders and engineers) from contractor trade associations and each state's public DOT website. Here we use public announcements of winning bidders or lists of pre-qualified firms. The contact information sometimes includes only the firm name and phone number, so we then google the firm to get the email address. As with the procurement officers, we email the contractors directly.[10]

Sample Appendix Figure C.1 shows the geographic distribution of survey respondents. We have 123 survey responses from procurement officials in 50 states plus the District of Columbia (a response rate of about 13.5%).[11] We summarize the survey responses at the state level, averaging responses

[8]Specifically, we use the contact lists for AASHTO's Maintenance, Construction, Design, Materials, and Planning committees.

[9]Survey distribution started on April 19, 2022, and ended on September 1, 2022.

[10]Survey distribution started on June 9th, 2022, and ended on October 27, 2022.

[11]Ten procurement official respondents were not original email targets, and thus are not included in the response rate. Of these, nine respondents received our survey through original email targets sharing the survey. One respondent used

within each state. On average, we have 2.5 responses per state, though this ranges from 7 responses in Utah, to only one response in 12 states. On the contractor side, we have 211 survey responses from 47 "primary" states (a response rate of about 3%).[12] The firms we survey often operate in many states, but we ask them to consider their primary state of operation while answering the survey. On average we have 4.5 responses per state, though this ranges from 20 responses in Texas, to only one response in 8 states.

2.2 Project-Level Data on Costs

We collect project-level cost data by requesting administrative data from each state DOT. Unfortunately, there was no such comprehensive dataset already; the federal DOT does not require states to report project-level costs on federally funded projects.[13] Most research on the topic uses aggregate (state-level) spending from the Federal Highway Administration (FHWA), but we need detailed project-level data in order to facilitate a comparison of similar projects across states.

We compare our data with the FHWA data in Appendix B.2, and find that our data correlate with well-established cost drivers (i.e., weather, road quality), while the FHWA data does not. The FHWA data is submitted by the states, and each state can determine how to account for projects over categories and time. Therefore, there are concerns over different norms across states in categorization of work-type or in the accounting of multi-year projects. The comparison bolsters our confidence that the project-level cost data is the right dataset for our purposes and will be a useful resource for future research.

We have project-level cost data from all 50 states. These data generally include the winning bid for the contract, a brief description of the project (or at least a project identifier we can link to the bid letting or project plans), the final cost of the project, the award date, and the completion date.[14] We also collect data on the scope of each project, allowing us to calculate cost per lane mile.[15]

To facilitate cost comparisons across projects and states, we construct a sub-sample of projects meeting predetermined criteria. Our goal is to create a sample of projects that are similar to the project described in the survey case study. Specifically, we randomly select 5 projects from each state

an advertisement that we posted on LinkedIn.

[12]Four contractor respondents were not original email targets, and thus are not included in the response rate. These respondents received our survey through original email targets sharing the survey.

[13]An exception is for projects funded in the ARRA, but this is 10 years before the period of interest.

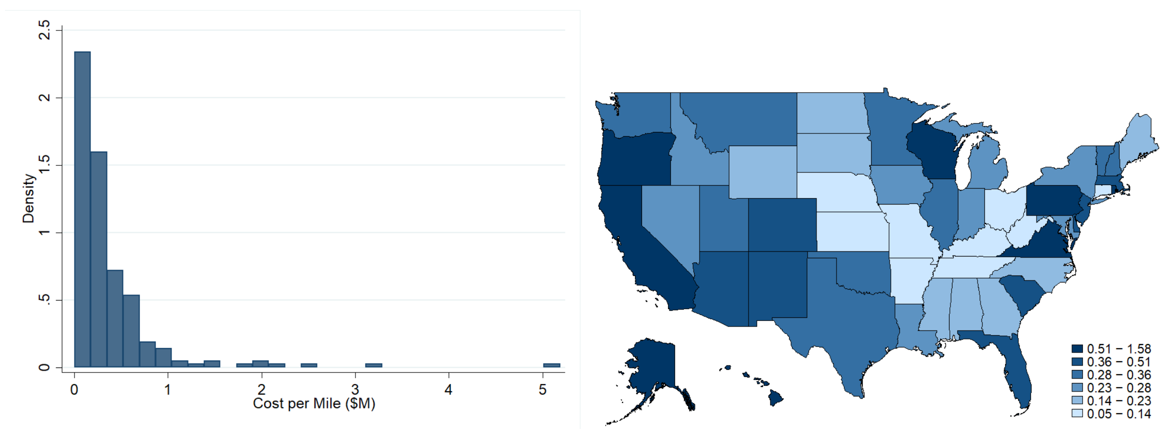
[14]For some states, we only observe the winning bid. However, for 75% of states we observe both the winning bid and the realized cost. Appendix Figures B.1 and B.2 show that there is a tight relationship between bids and realized costs for these type of projects.

[15]Some states include mileage in the data they provide. For many others we use the bid-lettings or project plans that are associated with the specific project. Specifically, we calculate the lane-mileage for each project, which takes into account both the length and width of the project.

that satisfy the following: 1) classified as "resurfacing," 2) started in 2018 or 2019, 3) length between 1 and 20 miles, and 4) state or U.S. highway (non-interstate) project. Along with facilitating more direct comparisons, focusing on a smaller number of projects in the sub-sample allows us to gather more detailed information about the nature of work for each project. We are able to fill in fields that are missing the larger datasets—such as the number of bidders for each project, the Disadvantaged Business Enterprise (DBE) threshold for the project, and any non-standard work that the project included—through examining the individual bid-lettings and project plans.

Figure 2 shows the distribution of cost per mile at the project level.[16] The majority of projects in the sub-sample (95%) cost under $1 million per mile; average cost is about $368,000 per mile, and the median is $226,000/mile. However, there is substantial variation in average costs across states. For example, cost per mile is twice as expensive in South Carolina than in the neighboring state of Georgia, at $376,000 and $189,000/mile respectively. Appendix Figure B.3 shows that the majority of the sub-sample contracts have a contract size of under $5 million, as was specified in the case study.[17]

Figure 2: Resurfacing Costs per Mile ($M)



(a) Project-Level Cost per Mile ($M)

(b) State-Level Cost per Mile ($M)

Notes: The figure on the left shows the histogram of project-level resurfacing costs per lane-mile. The figure on the right takes the average of project costs at the state level. There are 250 projects in the sample: 5 projects per state. Data collected by the authors.

We use cost per mile as our primary outcome of interest, though in the analysis we can consider other outcomes, such as project duration. This is a departure from some focus of the literature and policy discussion, which uses cost overrun as the measure of project success or costs. However, cost overruns only capture costs in excess of bids, which ignores an important input to the high cost of infrastructure procurement: the cost quoted by the contractor when they bid for the project. If all

[16]Our measure of cost per mile is the total cost of the project divided by the lane-mileage of the project.

[17]Appendix B.1 provides more details on data collection and descriptive statistics.

of the bids are high, a project with no cost overrun will still be expensive for the DOT to complete. Therefore, we use the *total* realized cost for our cost measure, which is the winning bid plus any changes that are incurred during the construction phase (i.e. the overrun).

3 Survey Descriptives

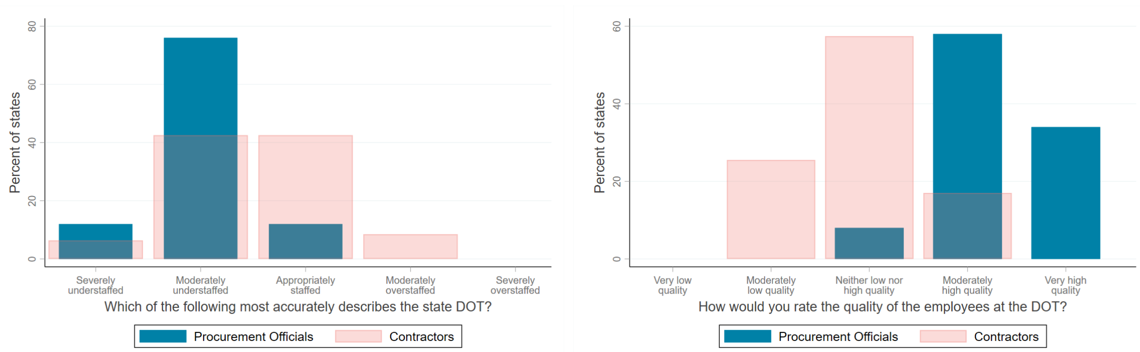
In this section we review some findings from the survey on the procurement process: where states agree, where there is substantial variation, and what respondents think drives costs.

3.1 State DOT Quantity and Quality

Figure 3 shows that procurement officials agree on a few key issues. First, they are understaffed. Almost 90% of respondents answered that their state DOT was severely (20%) or moderately (68%) understaffed. Figure 3(a) shows this summarized at the state level. Second, employee quality is relatively high. About 30% of the respondents rated the quality of the employees at the DOT as "very high", 51% at "moderately high," and 20% at "neither low nor high" (Figure 3(b)). Lastly, procurement officials agree that corruption is not a problem—almost 80% responded "very small" to "How large of a problem would you rate corruption?" (Figure C.2(a)).

Contractors, like procurement officials, are considerably more likely to think that state DOTs are understaffed than overstaffed—though, on average, they do not feel as strongly. They also feel less positive about employee quality—most think that employees are of neither high nor low quality. Therefore, most of the variation in quality that we will exploit will be coming from procurement officials, giving their perspective on the quality of their employees.

Figure 3: Broad agreement on DOT Quantity and Quality

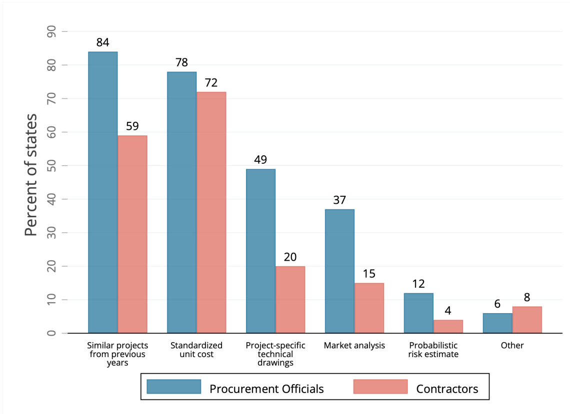


(a) Staffing Levels

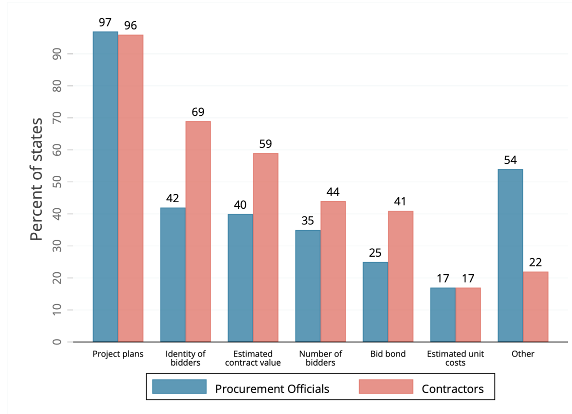
(b) Employee Quality

Notes: Author survey: survey question on x-axis and frequency of response on y-axis. Data aggregated to the state level. Survey available in Appendix F.

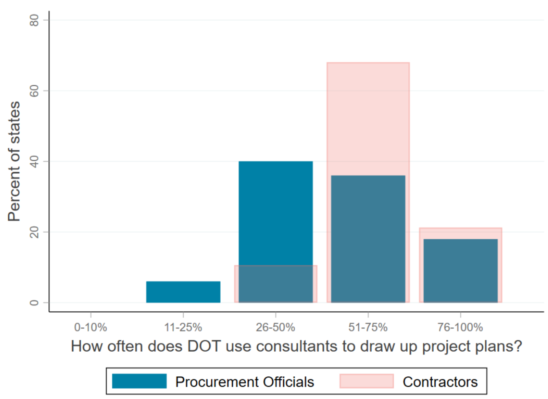
Figure 4: Variation Across States: Planning, Bid Letting, and Consultant Use



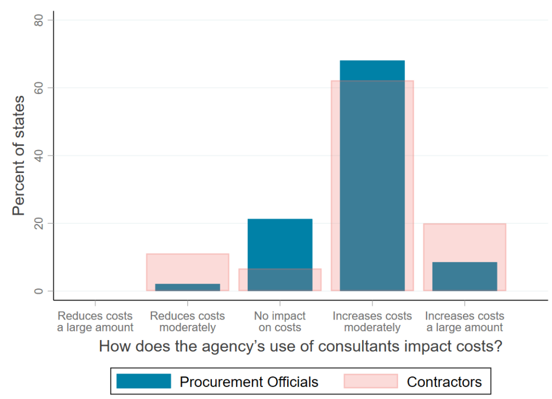
(a) Methods to Estimate Contract Costs



(b) Information Published Before Bids Are Due



(c) Variation in Consultant Use



(d) Consultants and Costs

Notes: Author survey. Panel (a) shows the methods the DOT uses to estimate the contract value and projected schedule, and panel (b) shows the information the DOT publishes before bids are due. Respondents are directed to select all answers that apply. Panel (c) and (d) show the percent of states with each response for two questions on consultant use. Data collected by authors, and aggregated to the state level. Survey available in Appendix F.

3.2 Variation between states

We also find significant variation across states in a few key topics. For example, states differ in both the methods they use to estimate the cost of the contract and the information they share with bidders. While the majority of states use similar projects from previous years, and standardized unit cost analysis to estimate contract costs, fewer take more advanced techniques, such as project-specific technical drawings, market analysis, and risk estimation (Figure 4(a)). Moreover, after developing the project plans and cost estimates, there is variation in how much information is shared with bidders (Figure 4(b)). Previous research has shown that while providing more information to bidders can reduce costs, by decreasing uncertainty and allowing them to make more accurate bids (De Silva et al., 2008), providing too much information on the competition (i.e. providing information on the number and identity of bidders) can increase costs, as contractors will be able to submit higher bids when they know there is less competition for the contract (Barrus and Scott, 2020).

Another interesting source of variation is the use of consultants. Figure 4(c) shows that there is considerable variation in how often the DOT uses consultants to draw up project plans, but Figure 4(d) suggests some consensus that using consultants increases costs at least moderately. This is likely tied to the fact that the state DOTs are understaffed. Even though using consultants may increase costs, each DOT may not have the capacity to do all of the required work in-house.[18]

We provide more details on variation across states by reporting the sample means and standard deviations of each survey response (Appendix F).

3.3 Cost drivers

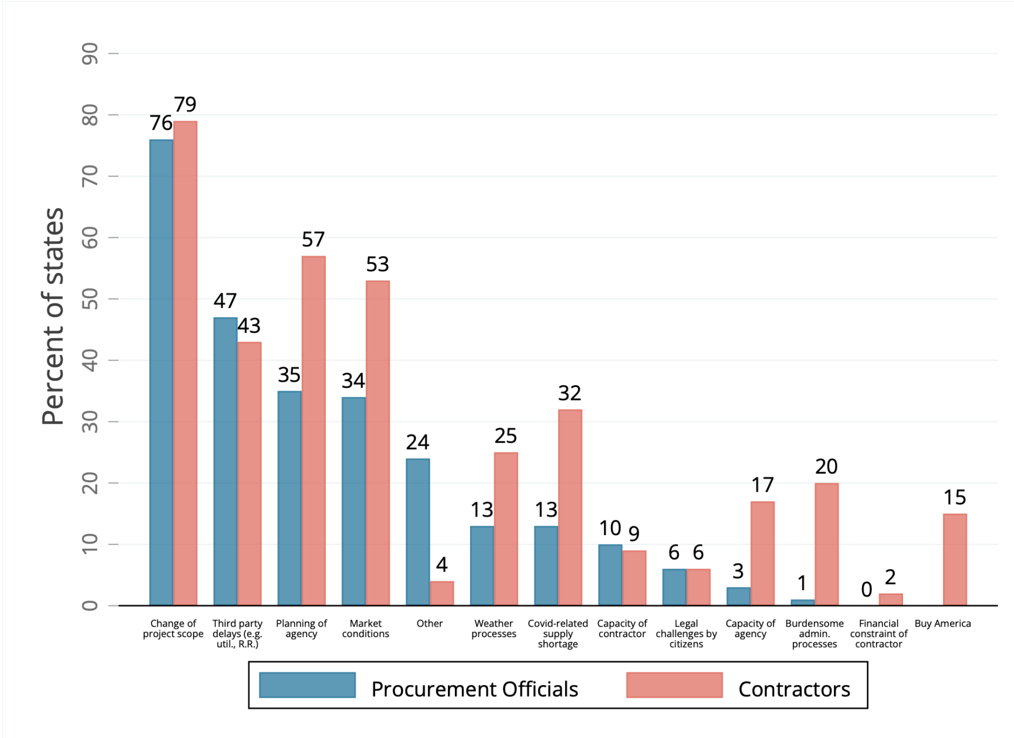
Figure 5 summarizes what procurement officials think drives costs. Respondents were free to choose as many items as they wanted. The most common cause of cost overruns cited by procurement officials was "change of project scope." This was also frequently mentioned in the free response. For example, one officer writes, "Bad or unclear specifications or contracts breed uncertainty, which contractors will factor into their prices as risk." Similarly, many officials specifically cite incomplete project plans as a source of costs, writing, "Vague or unclear contract plans and/or language," and, "Ambiguity in the specifications," when asked about what they think increases costs. The second most highly cited cost driver, from the perspective of the contractors, was "planning of the agency."

This narrative from the survey suggests that DOT capacity and costs are closely related. A lack of capacity at the DOT can hurt the quality of project plans, either from under-staffing in-house or from outsourcing to consultants with limited institutional knowledge and misaligned incentives. The lack of specificity in plans introduces risk to the contractor which increases contractor bids and opens up the DOT to a costly and time-consuming renegotiation process when the scope of project changes.

We use administrative data on public sector employment to investigate capacity issues in state DOTs. We see that state DOT employment has experienced a substantial decline in the last 20 years. Between 1997 and 2020 the number of people employed in state "Highways" (as defined by the Census Annual Survey of Public Sector Employment and Payroll) has shrunk by 40,000, a decrease of about 20%. Total state public sector employment rose over the same period, such that the "Highways" share of total state public employment shrunk from over 6% to about 4.5% (Figure 6(a)). The states that experienced the largest losses in employment are most likely to report being understaffed.

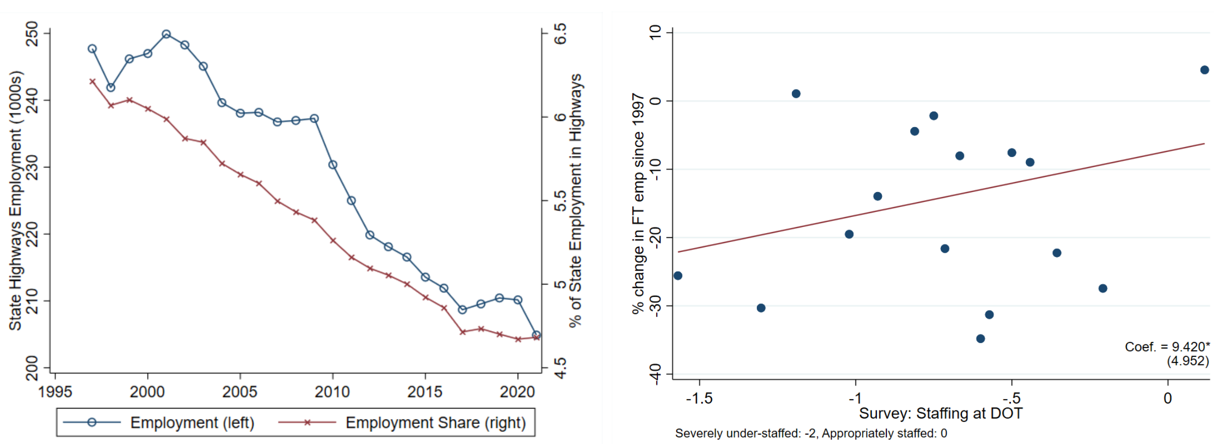
[18] In free responses, both contractors and procurement officials cite retirements and departures of high-quality state DOT employees as reasons for increased use of consultants.

Figure 5: Cost Drivers



Notes: Author survey. Respondents are asked "If a project has a cost overrun, what are usually the main reasons? Select all that apply." Data aggregated to the state level. Survey available in the Appendix. Only contractors were given the option to choose "Buy America."

Figure 6: State Highway Employment



(a) Time Series

(b) Survey

Notes: The panel on the left shows the total state employment in the "Highway" category, both in levels and as a share of public sector employment (US Census Bureau, 1997-2021). The panel on the right correlates the state specific "highway" employment change with state-level concerns about staffing, as measured by the author survey. The state-level "highway" employment change is measured from 1997 to 2021, but the figure looks similar using a shorter time span for the difference.

The second theme that arises from the survey responses is a lack of competition. Procurement officials often mention competition explicitly when asked to describe cost drivers in their states. Here is a sample from these responses:

- "A main aspect that increases construction costs in [state] is competition. The timing of project lettings, the number of projects advertised on lettings, and the availability/workloads of contractors all factor into the competition. Increasing the number of bidders reduces procurement costs."
- "Advertising period (Inadequate or too short of an advertising period, time of year chosen to advertise, other projects in the area that will be ongoing simultaneously)"
- "Competition: Costs tend to rise when the number of bidders falls (e.g., a single bidder can 'try to name their price). Number of bidders tends to fall as the market reaches capacity."
- "Contractor availability" [mentioned multiple times]
- "Limited funds cause limited projects cause limited contractors cause limited competition. Years of limited work has caused many contractors to get out of the business. Now we have very few contractors. Limited competition causes higher prices."

Despite the focus on competition and contractor availability in the free response, 70% of states *rarely* do bidder outreach (Appendix Figure C.2). This could be because the DOT has low capacity or willingness to do outreach, or because they know the market well and no other capable firms exist in the area.

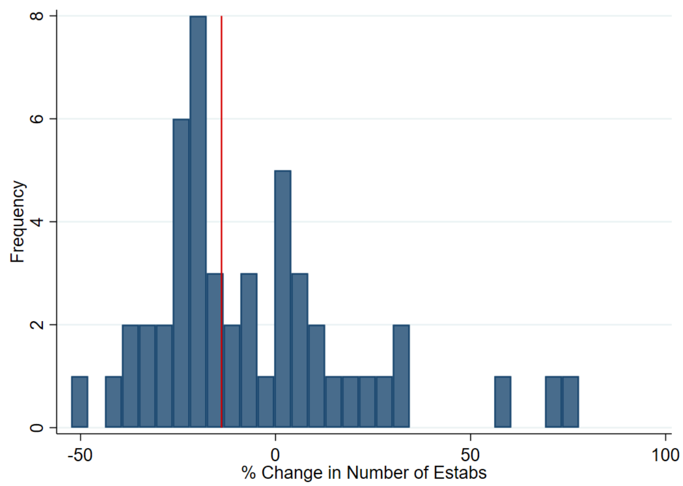
The survey responses of the contracts show how a lack of competition can have immediate implications for costs. Appendix Figure C.5(a) verifies that in states where competition is mentioned as a concern, contractors report expecting to face fewer competitors. Moreover, the fewer competitors a contractor expects to face, the higher the probability they know all of their competitors, and thus are likely have some information about competitor's capacity and costs (Appendix Figure C.5(b)). [19]

We use administrative data on industry structure to study the competitive landscape. We observe a change in the market structure in the highway construction industry over the last 10 years, with most states losing establishments. Almost 70% of states experienced a decrease in establishments in the Highway Construction industry over the period of 2007-2017 (Figure 7), with the median state experiencing a decrease of 13% in total industry establishments.[20]

[19]We note that contractors also mention competition as a cost driver, but they focus on competition in the downstream market for subcontractors. We discuss this further in Section 4.2.1.

[20]A 13% decrease translates to a loss of 17 establishments.

Figure 7: Changes in Highway Construction Establishments: 2007-2017



Notes: The figure shows the change in the number of highway construction establishments in each state, with the vertical line displaying the value of the median state. Data on establishment counts are from US Census Bureau (2007,2012,2017), and we subset to the "Highway, Bridge, and Street Construction" industry (NAICS 2373).

In order to verify that we capture the main cost drivers in the choices we offered respondents, we also perform a textual analysis of responses to the free response question, "What do you think are the main aspects of the procurement and administrative process of highway construction that increase construction costs?" Many respondents mention capacity-related or competition-related cost drivers. Appendix Figure C.6 displays a word cloud of the most frequent bigrams, with relative font size representing relative frequency. "Bid document," "poor plan," "plan spec," "change order," and "plan error" suggest inadequate bidding plans, a potential result of limited DOT capacity. "DBE goal," "numb bidder" (number of bidders), and "DBE requirement" suggest limited competition, both in the bidding stage and in competition for subcontracting.

In summary, the survey respondents are highly concerned with two inputs to the procurement process: DOT capacity and competition between contractors. We see these two themes highlighted in many different survey responses, and we use external data to verify that both DOT capacity, as measured by employment, and competition, as measure by construction establishments, have declined in the recent past. In the next section we will link these two concerns, and other procurement practices that we record with the survey, to realized infrastructure costs.

4 Correlations: Procurement and Realized Costs

This section shows the correlation between our measures of costs and potential cost drivers. We first correlate our project-level cost data with project characteristics, and cost drivers at the state and local level (i.e. wages and climate). We will use this set of observables as controls when we correlate costs with procurement practices. Then we move to the correlation between costs and the survey responses.

4.1 Observables and Costs

Table 1 shows the relationship between project-level resurfacing costs and established cost drivers, which include project level details, local characteristics, and weather.[21,22] The standard errors are clustered at the state level, and we have 5 projects per state, as discussed in Section 2.2.

The project-level details include a dummy for whether the project involves non-standard work in addition to the resurfacing (we call this "Complex"), the size of the project ("Lane-Miles"), and a dummy for whether the project is on a state highway, as opposed to a US highway ("State-Highway"). Column (1) shows that as expected, the complex projects are more expensive. There are also fixed costs of resurfacing: longer projects cost less per lane-mile, which is consistent with discussions we have had with highway engineers.

In Column (2) we add local characteristics that can affect resurfacing costs. This includes labor inputs, as measured by local wages in the "Highway, Bridge, and Street Construction" industry.[23] We find that wages are positively correlated with costs, as expected. Our other local variable is population density in the county of the project. Population density is also positively correlated with costs. This could be due to both road use, which affects the amount of work needed to be done for the resurfacing job, and the additional costs of traffic stoppage and diversion during the project completion.

In Column (3) we add variables that capture the climate of the state. States with more snow and longer winters tend to have higher costs, due to the shorter window that contractors have to complete the jobs, the toll the salt takes on the roads, and the damage to pavement from repeated freezing and thawing. The state-level weather characteristics have the expected signs, where costs are higher in states with more snow and lower in warmer states.[24]

In Column (4), we add state-level measurements of road roughness. FHWA mandates that states collect these data annually; it measures the total vertical deviation from smoothness in an average

[21] External data sources are described in Appendix D.

[22] We talked on background to helpful DOT engineers to verify the established cost drivers.

[23] This industry classification (NAICS 2373) includes new work, reconstruction, rehabilitation and repairs, so it is not exclusively resurfacing industry wages, but would encompass the wages paid for the projects in our database. We measure wages at the MSA or county level (using the smallest aggregation that is available).

[24] We do not have a direct measure of snowfall but proxy this with the average precipitation in the state multiplied by the inverse of the winter high temperature.

Table 1: Project Costs and Observable Cost Drivers

	Project Cost per Mile (log($M))					
	(1)	(2)	(3)	(4)	(5)	(6)
Project Details:						
Complex Dummy	1.027***	0.948***	0.932***	0.818***	0.880***	-0.082
	(0.270)	(0.259)	(0.281)	(0.282)	(0.266)	(0.095)
Lane-Miles	-0.023***	-0.023***	-0.024***	-0.023***	-0.024***	-0.005
	(0.006)	(0.006)	(0.004)	(0.004)	(0.004)	(0.007)
State Highway Dummy	-0.234*	-0.273*	-0.067	-0.046	-0.083	0.104
	(0.133)	(0.140)	(0.127)	(0.122)	(0.129)	(0.144)
Engineer's Estimate (log(Cost/Mile))						0.838***
						(0.158)
Local Characteristics:						
Log(Population Density)		0.026	0.067+	0.052	0.056	0.026
		(0.044)	(0.040)	(0.041)	(0.041)	(0.030)
Log(Wages in Highway Construction)		0.218	0.344*	0.064	0.214	-0.423+
		(0.171)	(0.196)	(0.176)	(0.207)	(0.253)
State Characteristics:						
Precipitation Days (Average)			-0.033***	-0.032***	-0.032***	-0.009
			(0.007)	(0.006)	(0.008)	(0.006)
Winter Low (Average)			0.055***	0.041***	0.052***	0.009
			(0.011)	(0.010)	(0.012)	(0.011)
Snow Proxy			0.021+	0.019	0.033**	0.008
			(0.014)	(0.015)	(0.016)	(0.009)
Summer High (Average)			-0.057***	-0.039*	-0.066***	-0.011
			(0.021)	(0.021)	(0.021)	(0.023)
Roughness Index				0.017***		
				(0.005)		
Potential Cost Drivers:						
DOT Employment/Population (1,000)					-0.263+	0.022
					(0.165)	(0.113)
Number of Bidders					-0.011	-0.083**
					(0.044)	(0.035)
Observations	250	250	250	250	250	94
R-squared	0.18	0.19	0.35	0.39	0.37	0.68

Notes: This table presents a simple regression of resurfacing costs on potential cost drivers. The project-level costs and characteristics (including number of bidders) are collected by the authors, and the data on other observables is described in detail in Appendix D. Standard errors are clustered at the state level. "Lane-Miles" is the size of the project (lanes × length of highway), "Complex" is a dummy to denote that the project involves work beyond a standard resurfacing job, and "State Highway" is a dummy to denote it is a state highway resurfacing project, as opposed to an interstate. "Roughness Index" is the average of a state-level roughness measure from the years 2014, 2018, and 2019. This comes from Highway Statistics (Federal Highway Administration, 2014,2018,2019). A larger value of "Roughness Index" corresponds to rougher roads. Column (6) adds the "Engineer's Estimate" i.e. the projected cost per mile (only available for 19 states). This estimate controls for all of the observables (i.e. project details, weather, local characteristics), rendering those correlations insignificant and allowing us to focus on the role of the number of bidders. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, +$p < 0.15$.

Table 2: Descriptive Statistics

	Count	Mean	Std. Dev.	Min.	Max.
Project Cost per Mile (log($M))	250	-1.48	0.96	-4.87	1.65
Project Details:					
Complex Dummy	250	0.06	0.24	0.00	1.00
Lane-Miles	250	15.17	13.26	1.00	87.64
State Highway Dummy	250	0.66	0.47	0.00	1.00
Engineer's Estimate (log(Cost/Mile))	94	-1.43	0.75	-3.13	0.29
Local Characteristics:					
Log(Population Density)	250	3.30	1.85	-2.25	8.88
Log(Wages in Highway Construction)	250	4.36	0.38	3.55	5.51
State Characteristics:					
Precipitation Days (Average)	250	38.67	14.44	9.96	70.00
Winter Low (Average)	250	23.50	11.91	1.10	68.00
Snow Proxy	250	2.60	4.72	0.36	34.54
Summer High (Average)	250	83.61	6.07	60.20	94.20
Roughness Index	250	96.60	14.81	72.46	141.45
Potential Cost Drivers:					
DOT Employment/Population (1,000)	250	0.92	0.63	0.23	3.25
Number of Bidders	250	3.36	1.49	1.00	9.00

Notes: This table presents summary statistics of the variables used in Table 1. The project-level costs and characteristics (including number of bidders) are collected by the authors, and the data on other observables is described in detail in Appendix D. "Lane-Miles" is the size of the project (lanes × length of highway), "Complex" is a dummy to denote that the project involves work beyond a standard resurfacing job, and "State Highway" is a dummy to denote it is a state highway resurfacing project, as opposed to an interstate. "Roughness Index" is the average of a state-level roughness measure from the years 2014, 2018, and 2019. This comes from Highway Statistics (Federal Highway Administration, 2014,2018,2019). A larger value of "Roughness Index" corresponds to rougher roads. The "Engineer's Estimate" is the projected cost per mile (only available for 19 states).

kilometer.[25] We add this index to capture the fact that rougher, more damaged roads require more intense resurfacing work, which is likely to be more expensive.[26] Indeed, we see that states with rougher roads have higher costs, and that roughness captures some of the correlation in Column 3 between weather and costs. Our data shows a stronger relationship between roughness and costs than FHWA spending data, as seen in the scatter plots in Appendix Figure B.7.

Finally, in Column (5) we introduce two variables that capture some of the most cited cost drivers from the survey: DOT capacity and competition. For DOT capacity we take the number of full-time employees in state highways (from the Annual Survey of Public Sector Employment and Payroll) and divide it by the state population. For competition we use the number of bidders, which is a project-level variable that we collected directly from the state. As hypothesized, states with higher capacity have lower project costs. The relationship between competition and costs is much weaker. We further investigate this by controlling for the "Engineer's Estimate" in Column (6), which we view as over-controlling for costs, but allowing us to get closer to a measure of cost overruns. This is the DOT's best estimate of how much the project will cost, which is why all the other observables we use to explain costs are no longer statistically significant—these are taken into account in the estimate. Once we control for the "Engineer's Estimate", and therefore also the unobservables that affect bidder participation, we see a strong negative correlation between the number of bidders and costs, as expected.[27] One additional bidder is associated with 8% lower costs per mile, or a savings of $30,000 per lane-mile.

4.2 Procurement Practices and Costs

After accounting for state and project observable characteristics, substantial variation in project-level costs remains across states (Appendix Figure B.5). We now look to see how much of this remaining variation is explained by the differences in procurement practices across states that our survey uncovers.

We take the survey responses and correlate them with the project-level cost data. The dependent variable is log cost per mile, as in Table 1. We also control for all of the project, local, and weather

[25] This is the International Roughness Index, and we use the average of the roughness measure from 2014, 2018, and 2019. Currier et al. (2023) point out significant issues with FHWA's roughness measurements for minor arterial roads, and highlight its lack of availability for local roads. The roads in our sample tend to be major arterial roads, which should suffer from less roughness measurement error.

[26] Pavement with extensive damage must undergo a "mill-and-fill," in which several inches of asphalt are removed and replaced. Pavement in better condition can receive a cheaper treatment such as a chip seal, in which a new, smooth layer of asphalt is applied to the top of an existing layer and topped with crushed rock.

[27] Unfortunately we only have data on the engineer's estimate for 19 states, which is why we do not use it more broadly across our analysis.

observables that we included in Column (3) of Table 1, and cluster standard errors at the state level. The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions. In total, we estimate 79 correlations of survey responses with realized project costs.

Both procurement practices and costs vary widely across states, as highlighted in Section 4. But most state-level procurement practices do not correlate with realized costs. However, the correlations that emerge are consistent with the two themes that predominated in the descriptive statistics: 1) limited state DOT capacity and 2) limited competition.

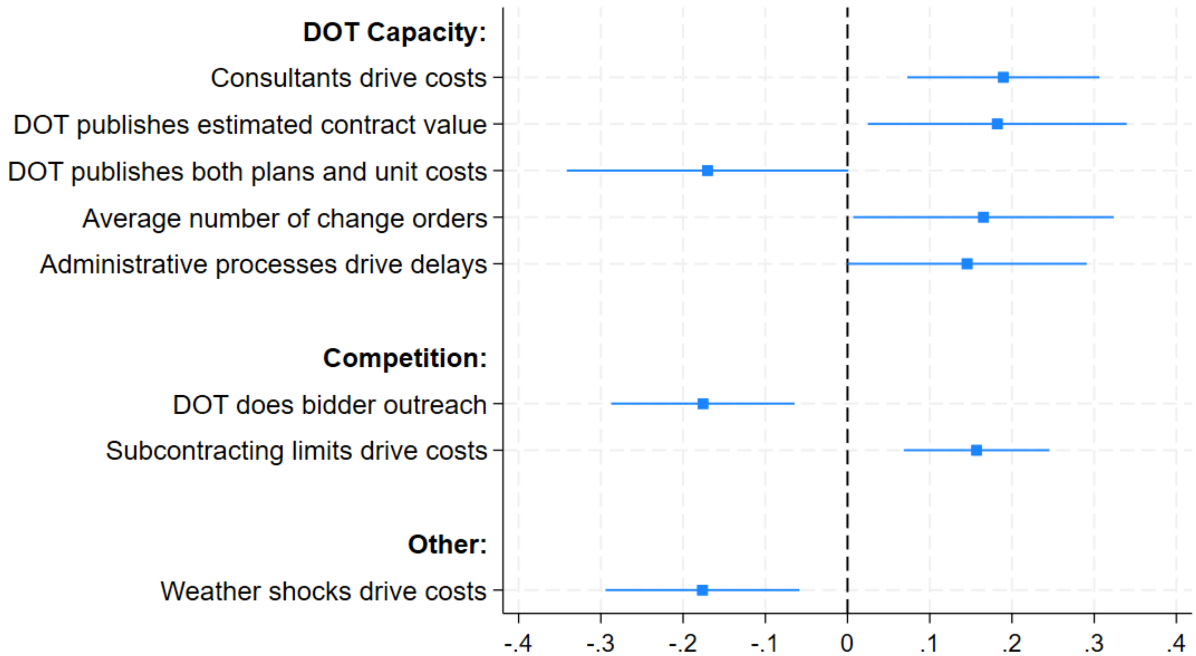
Figure 8 shows correlations between procurement practices and realized costs that are statistically significant at the 10% level after adjusting for multiple hypothesis testing using the Romano-Wolf multiple hypothesis correction.[28] The figure presents the significant results by hypothesis and lists them by the absolute value of the magnitude. Results for all survey responses can be found in Appendix E, including the (often much smaller) unadjusted p-values.

We turn first to the results concerning DOT capacity. As we discussed earlier, we view consultant use by state DOTs is an indicator of limited resources at the DOT. If the state DOT is understaffed and lacks the personnel necessary to complete a project, then it is likely to outsource work to consultants. In fact, we find that states where respondents cite consultants as a cost driver have significantly higher costs. This is especially striking, given that we are only measuring the cost of the project that is paid to the contractor, not any internal staffing costs for the DOT. Therefore, the increase in costs due to the consultant is not because the consultants bill at a high hourly rate (which can also be true). There are a few mechanisms that can lead contractors to increase costs ex-post. The most frequently cited by industry professionals is a lack of institutional knowledge, which can lead to both mistakes in the project plans and delays when communicating with contractors.

For this question, survey respondents were asked, "How does the agency's use of consultants impact costs?" Respondents could choose from five different answers, ranging from "Reduces costs a large amount" to "Increases costs a large amount." Interestingly, this correlation displays the largest magnitude of our statistically significant results, indicating that consultants could be one of the key mechanisms through which weak state DOT capacity could increase costs. A one standard deviation

[28] The Romano-Wolf multiple hypothesis correction is typically used when testing a large number of statistical hypotheses. As we test more hypotheses, the probability of falsely rejecting a true null hypothesis increases. The Romano-Wolf multiple hypothesis correction addresses this problem by controlling for the "familywise error rate", which is the "probability of rejecting at least one true null hypothesis among the family of hypotheses under test" (Clarke et al., 2020). We consider all of our survey results listed in Appendix E to be in the same "family of hypotheses". For more information on the Romano-Wolf correction, see Romano and Wolf (2005a,b), Romano and Wolf (2016), Clarke et al. (2020).

Figure 8: Survey Correlates: Significant Results



Notes: This figure shows the correlation coefficients between the survey responses and the project cost that are significant at the 10% level, or close to significant at the 10% level, after adjusting for multiple hypothesis testing using the Romano-Wolf multiple hypothesis correction (Clarke et al., 2020; Romano and Wolf, 2005a,b, 2016). The dependent variable is log cost per lane-mile. Regressions include controls for project, local, and weather observables (per Column (3) of Table 1), and cluster standard errors at the state level. The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. The bars represent the 90% confidence interval, which is determined using Romano-Wolf adjusted p-values. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions.

increase in reported consultant costs is associated with a 19% increase in cost per lane-mile. At the mean, this corresponds to a $70,000 increase in cost per lane-mile.

The next two correlations highlight the information that the DOT provides to bidders. Here, we find that when the DOT publishes the estimated contract value, costs are higher. There may be two reasons for this. First, it is possible that the state systematically overestimates costs and anchors bidders to an inflated price. Second, publishing the total estimated cost provides some information to the bidders, but is not informative as providing estimates at the unit level (i.e. providing estimates for each item that the contractor will bid on). To probe this further, we create a measure of "Best Practices", which sums the selection of 'Project Plans' and 'Estimated Standard Unit Costs', and subtracts the selections of the less informative 'Estimated contract value' as well as information that would allow contractors to learn more about potential competition and make less competitive bids when needed ('Number of bidders', 'Identity of bidders', and 'Bid Bond'). This measure of "Best Practices", which is labeled "DOT publishes both plans and unit costs" in Figure 8, is negatively correlated with costs: a one standard deviation increase in the "Best Practices" score is associated with a 17% decrease in cost per lane-mile.

Next, we see that change orders have a positive correlation with costs—the more change orders that are expected, the higher the costs. Frequent change orders could directly lead to higher costs through delays and costly renegotiation; they could also be a downstream symptom of poor administrative capacity at a state DOT—many contractors reference poor-quality project plans made by third-party consultants. One additional change order is associated with a $25,000 increase in cost per lane-mile, at the mean.

Lastly, related to the capacity hypothesis, we find that states that are more likely to flag "burdensome administrative processes" as a source of project delays have higher realized costs. It seems likely that slow administrative processes could be a result of limited DOT capacity. If a state DOT is understaffed, each staffer will have a large workload, likely leading to delays as the staffers work through administrative hurdles. A one standard deviation increase in the proportion of people that cite administrative processes as a source of delays is associated with a 14% increase in cost per lane-mile.

Most of our significant results related to DOT capacity speak to potential symptoms of understaffing. It is worth noting that we have suggestive evidence on a different axis of DOT capacity—quality of DOT employees. In the survey, we ask, "How would you rate the quality of the employees at the state department of transportation?" A higher DOT quality is associated with lower costs, though this correlation is not statistically significant at the 10% level after adjusting for multiple hypothesis testing[29] The magnitude is striking– a state with a neutral rating has 28.6% higher costs than one that rates the DOT employees as "moderately high quality", all else equal. This corresponds to a $105,000 increase in cost per lane-mile.

The next two significant correlations concern competition. First, states that do outreach to increase the bidder pool have significantly lower costs, highlighting both the importance of competition and the role the DOT can play to increase it.[30] A one standard deviation (12 percentage point) increase in bidder outreach is correlated with a 17.6% decrease in costs. At the mean, this translates to a decrease in costs of $65,000 per lane-mile and $1 million at the project level.

There is also a relationship between subcontracting restrictions and realized costs. Many contractors do not have the capacity to do 100% of the work of resurfacing a highway in-house, so they

[29] The unadjusted p-value on the employee quality rating is 0.09 while the Romano-Wolf p-value is 0.21; see Appendix E).

[30] This has also been found to be important to procurement in the Government Performance Lab's work in St. Paul, Minnesota (Government Performance Lab, 2016; Liebman and Azemati, 2016).

subcontract parts of the project.[31] State governments can restrict the share of a contract's dollar value that prime contractors (those that bid on the project) are allowed to subcontract, and states can vary in how simple it is to add subcontractors to a project.[32] A one standard deviation increase in citing issues with subcontracting limits is associated with a 15.7% increase in costs. This is a large effect; in a state where every respondent selects "Limits on share of project that can be subcontracted" as a cost driver realized costs are 62% higher than in a state where none of the respondents select subcontracting limits, all else equal.[33]

The final statistically significant correlation regards weather. Selecting "Weather Shocks" as a source of cost overruns is *negatively* correlated with costs. The specific question is, "If a project has a cost overrun, what are usually the main reasons?", so it may be that in states where the main reason for cost overrun is weather, things are operating well.

Appendix Tables E.1-E.4 presents the results of all of the correlations with cost, which includes the beta estimates, unadjusted p-values, and the Romano-Wolf p-values. We note that not every capacity or competition survey question has a significant correlation with costs—but it is striking that none of the other original hypotheses exhibit any correlation. In Section 2.1.3 we introduced 5 broad hypotheses related to procurement costs: transparency, competition, quality, capacity, and corruption. We find no relationship between realized costs and questions on transparency, quality, or corruption.

On corruption, we asked questions related to general corruption, bidder collusion, unethical contractor behavior, or improper state employee behavior. Very few respondents cited concerns with corruption, and these concerns did not correlate with realized costs (Appendix Table E.4). However, we had fewer respondents for these questions and were concerned that this could be driving the null results. We were also concerned that perceptions of corruption among survey respondents might differ substantially from relative levels of corruption in reality. Thus, we also tested for corruption using an external measure—a state-level corruption index from Boylan and Long (2003), constructed using surveys of State House reporters. Similar to our survey questions, the Boylan and Long index showed no correlation with project costs.

In Appendix Table E.2 we see that the average length of time between procurement steps at the

[31] For example, a contractor may be able to produce asphalt in-house, but may have to hire another firm to put down concrete for a curb cut. In most states the bidding contractor does not need to submit the list of subcontractors at the time of bidding, but they do need to estimate the costs of the subcontracted work.

[32] All projects that receive federal funding have an upper bound for subcontracting of 70% of contract value

[33] Generally, subcontracting limits may be either lower or upper bounds—in the case of DBE regulations, there is sometimes a lower bound on how much of a contract's value must be let out to a DBE-qualified subcontractor. The relationship between subcontracting limits and costs does not seem to come from DBE-related lower bounds: states that cite DBE requirements as a cost driver do not seem to have higher realized costs.

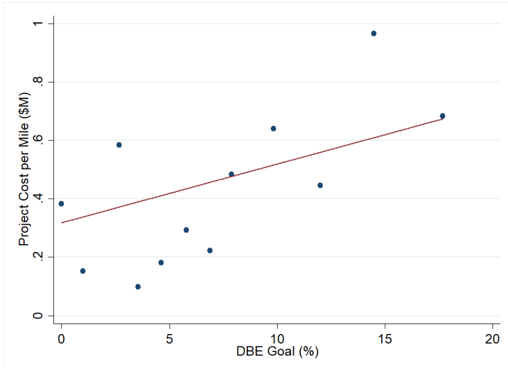
state level do not correlate with realized costs, which goes against common wisdom on the cost of delays. However, we note that costs and project duration exhibit a tight positive relationship. We have project duration for projects in 33 states. Appendix Figure C.8 shows the relationship between cost per mile and days per mile: a standard deviation increase in duration (50 days per mile) correlates with 43% higher costs per mile. This is consistent with the discussion of the role of delays in Section A.4 (though, of course, more complicated projects might both take longer and be more expensive). For this reason, we also correlate the project duration variable with the survey responses in Appendix C.2. Here, we find many similarities to the cost correlations, and a few additional variables, such as the timing questions, that correlate highly with delays.

4.2.1 Competition: The Market for Subcontractors

In this section we further investigate the role of subcontractors. Procurement officials and contractors in over 80% of states mentioned the Disadvantaged Business Enterprise (DBE) program as a cost driver (Appendix Figure C.4). However, we do not find any correlation between this response and realized costs. This may be due to lack of variation, as it is a federal program. This may also be due to the politicization of the program; some contractors and officials view it unfavorably as an affirmative action initiative. However, since we do see a correlation between subcontracting limits and costs, we use the DBE program as a case study to further probe the role of competition in the subcontracting market. If states do not have a thick market of DBE qualified firms, any DBE requirements may directly affect costs through limiting competition at the subcontractor level.

Here, we collect two variables to measure the market for Disadvantaged Business Enterprise (DBE) firms. First, at the project level, we assemble the project-specific “DBE goal.” This is the percentage of work that the DOT would like to be subcontracted to a DBE, which the state DOT can vary by project in order to meet overall state-wide goals. Second, we create a measure of the thickness of the DBE market by calculating the number of registered DBE firms over the number of construction establishments in the state. Figure 9 shows that projects with higher DBE goals cost more–a 10 percentage point increase in the DBE goal is associated with 25% higher costs per mile. However, in states with a thicker DBE market costs are lower. Of course, these results are just correlations, and projects with high DBE goals could differ from other in a host of ways that also increase costs. It may also be that states that are not able to encourage entry of DBE firms are high cost in other ways.

Figure 9: Costs and the Disadvantaged Business Enterprise (DBE) Program



	Project Cost per Mile (log($M))		
	(1)	(2)	(3)
Project DBE Goal (%)	0.022+		0.025+
	(0.015)		(0.015)
State DBE Share		-0.026	-0.220
		(0.315)	(0.297)
Observations	119	119	119
R-squared	0.49	0.48	0.49

Notes: The figure on the left shows a binned scatter plot of project-level costs and DBE goals. The DBE Goal % is a project-level variable that denotes the amount of the project that should be completed by a DBE. This is collected by the authors from bid lettings and is available for projects in 32 states. This table on the right presents a simple regression between resurfacing costs and the Disadvantaged Business Enterprise program. The regressions include all of the controls from Column (4) of Table 1 (project details, local characteristics, state weather, and potential cost drivers). Standard errors are clustered at the state level. The DBE Share is a state-level variable that measures the number of construction firms registered as a DBE, as a share of the total number of construction firms. This is collected by the authors by downloading DBE registries in each state that it is available (36 states).

5 The role of the DOT engineer

The evidence from our survey suggests two important inputs to the procurement process are driving up costs of infrastructure procurement in the U.S.: (1) the quality of the Department of Transportation (DOT) procuring the project, and (2) the lack of competition in the market for government construction contracts. Moreover, these two things are related—we see that higher quality DOTs are more likely to actively seek out bidders for their projects. Higher quality ratings are also associated with more realized bidders in the project data (Appendix Figure C.7).

In this section we investigate the role of capacity with detailed administrative data from the state of California's DOT, Caltrans. The goal of this analysis is to quantify the role of the *individual* DOT employees on the realized costs for standard DOT infrastructure projects. Our estimates will help inform potential policy solutions, by highlighting the role of workload, experience, and employee retention—issues that were highlighted in discussions with stakeholders.

This analysis contributes to an existing literature on the role of individuals and bureaucracies on procurement outcomes. Our analysis is most closely related to Best et al. (2023) and Decarolis et al. (2020). We depart from Best et al. (2023) by analyzing the role of the individual in the procurement of *services*, specifically road resurfacing. This is much more complex than the procurement of goods. For the procurement of goods, the role of a procurement official is primarily constrained to the bid letting and bid evaluation; there is no role for the individual to impact costs after the auction. In the case of highway resurfacing, DOT engineers can impact costs with their efforts throughout the pre-bidding, bidding and the post-auction phases. At the pre-bidding stage the DOT can affect realized costs by developing detailed project plans (decreasing risk to the contractor, thereby potentially decreasing the winning bid). A DOT engineer can also affect costs in the bidding stage with bidder outreach to increase participation (increasing competition, thereby potentially decreasing the winning bid). At the post-auction phase a DOT engineer can work to control (or not control) cost overruns and delays, which often prevent projects from being completed on time and at cost.

Decarolis et al. (2020) also studies the role of capacity in procuring more complex services, but at the agency level. Therefore, the analysis compares service contracts across agencies, using variation in bureaucratic capacity generated by bureaucrat deaths. Instead, our study focuses on the role of the individual, for a specific type of contract: road resurfacing. In a departure from both studies, our data and setting will allow us to separate the role of the bureaucrat in different parts of the procurement process: planning, bidding, and post-award performance.

With administrative data from Caltrans, we are able to observe the DOT engineer who manages the project, from inception to completion, as well as the DOT engineer who communicates with the contractor through the construction phase of the project. We also observe details about the project (length, type of work, location) and a variety of project outcomes (number of bidders, winning bid, realized cost, duration). We use a fixed effects analysis in order to understand how much of variation in realized costs can be explained by the individual engineer that is assigned to manage the project. Our preliminary analysis suggests a one standard deviation decrease in the engineer fixed effect decreases cost per mile by about 2.8%.

In ongoing work, we will be able to use this rich personnel data to decompose the role of the DOT engineer in the pre-bidding and bidding stages (i.e. the role of the project manager before construction begins), with the role of the engineer during the construction phase (i.e. the engineer on the ground managing the contractor). At this point, we present results about the construction engineers, and discuss some of the difficulties of comparing the two going forward.

5.1 Background and Data

In California, the DOT (Caltrans) employs over 7,000 engineers across 12 geographic districts and the state headquarters. Each district is responsible for overseeing transportation projects in its jurisdiction. At the staff level—the focus of our analysis—this involves a district manager who will assign a project manager to lead each project in that district's current portfolio.

The project manager is a senior engineer who is responsible for overseeing the life cycle of the project, from planning to completion. The project manager oversees pre-bidding, bidding, and construction phases of the projects. However, there are many other DOT engineers involved in the process. First, there is a design team that puts together the project plans, which the project manager will then approve and pass to the awards team. The awards office posts the bid-letting and collects bids, which the project manager, together with the construction team, will evaluate. Lastly, the construction team will oversee the work on the ground. Specifically, there will be a construction engineer who heads the construction team. This, similarly to the project manager, is a senior position. Next, there is the resident engineer, who actually communicates with the contractor. Lastly, there are inspection engineers. The construction phase is where the project manager has the least involvement—the construction team takes the lead. In our data we observe the identities of the project managers and the resident engineers.

The project manager is assigned to a project based on his or her experience, the location of the project, and the type. Conversations with DOT engineers suggest that district managers have discretion with this assignment process, but generally it is some combination of project complexity, location, and type. This is true for the assignment of the project manager and also the assignment of the engineers on the construction team. Figure 10(b) shows that this seems to be true in the data. Resident engineers with more experience are assigned to more complex projects, as measured by log(bid/mile).

Data We have three sets of administrative data at the project level.

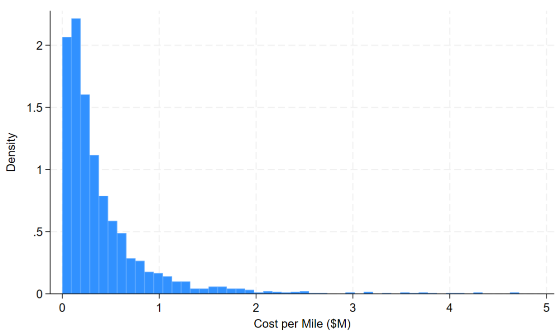
1. **Construction:** We have a short description of the project, the location (county), the mile markers (if relevant), the winning bid and the amount paid to the contractor, and the identity of the resident engineer, who is the engineer that manages the construction phase of the project. There are approximately 11,000 projects over 2000-2018, and 1,240 unique resident engineers. Over 2,000 of these projects are road resurfacing projects, which is the focus of our preliminary analysis—these projects represent over $44 billion in nominal spending by Caltrans. Figure 10(a) shows that there is significant variation in costs per mile in this sub sample of projects—a mile of road resurfacing in California costs $456,000 at the mean, with a standard deviation of $785,000.

2. **Project Delivery:** We have the allocated budgets and realized expenditures over each phase of the project (not only construction). We have the identity of the project manager, who is an engineer that oversees the life of the project. This data set also includes a description of the

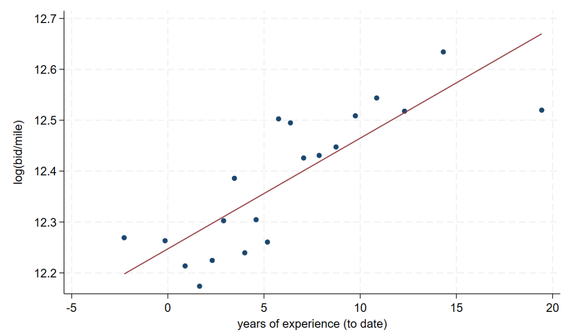
project, and information on timing of each phase. There are approximately 8,000 projects over 2012-2023, with 523 unique project managers.

3. **Bidding:** For a subset of construction projects we know not only the outcome of the auction, but information about participation. Specifically, we have the identity and bid for every firm that participated in the auction for 2,800 projects from 2018-2023.

Figure 10: Caltrans Projects: Costs and Engineer Assignment



(a) Project-Level Cost per Mile ($M)



(b) Engineer Assignment

Notes: The figure on the left shows the histogram of project-level resurfacing costs per lane-mile, for our subsample of 2,053 resurfacing projects in California. The figure restricts cost per mile to be under $5 million, for visibility. The figure on the right shows the relationship between engineer experience and the total winning bid per mile. The figure shows that more experienced engineers are assigned to "larger" projects, where large is measured by the winning bid. We use this as a proxy for project complexity—projects with higher bids per mile should be more difficult and complex to complete. The binned scatter plot is residualized, controlling for County, Year, and Route.

5.2 Analysis

The objective of our baseline analysis is to quantify how much of the observed variation in project level resurfacing costs can be attributed to the resident engineer in the construction phase. Given many projects for a given individual, we can track individual engineers across different projects over time. Then, we can estimate how much of the variation in project costs is attributed to the manager, after controlling for the location and timing of the project (because we focus only on resurfacing we do not control for project type, but will do that when we expand the scope of the analysis). This approach provides a lower bound for the impact of public sector engineers on realized infrastructure costs as long as more experienced and capable individuals are assigned to more complex projects—a pattern we suspect holds true from both conversations with Caltrans employees and patterns in the data (see Figure 10(b)).

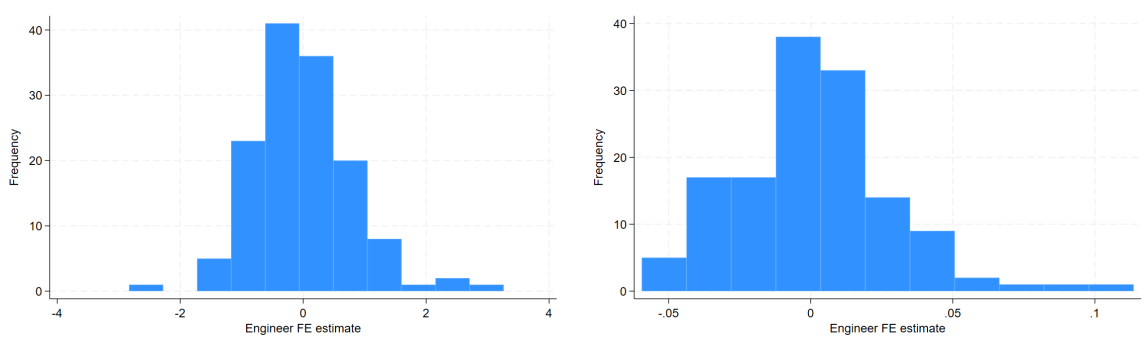
The estimating equation follows:

$$log(\text{cost per mile})_{prict} = \theta_r + \eta_i + \gamma_c + \psi_t + \epsilon_{prijt}. \quad (1)$$

Here, the cost of project p, on route r, for engineer i, in county c, and year t, is expressed as a function of road characteristics (route fixed effects, θ_r), location characteristics (county fixed effects, γ_c), engineer fixed effects (a dummy for each resident engineer, η_i), and year fixed effects, ψ_t. Here, the county fixed effects capture location observables that we know are important to resurfacing costs (Table 1), while the route fixed effects capture unobservables related to the actual road that is being resurfaced, i.e. whether it is a state highway or interstate.[34] Our current analysis sample consists of 1,144 projects affiliated with 139 unique resident engineers in the construction phase.

Our outcome of interest for this analysis is the standard deviation in engineer fixed effect estimates. Figure 11 shows the results, for the baseline fixed effects on the left, and after a Bayesian Shrinkage correction on the right using the method from Armstrong et al. (2022). The empirical Bayes procedure substantially decreases the standard deviation in the engineer fixed effects, due to the substantial amount of noise present when we estimate fixed effects for engineers, the majority of which are only observed in the data for 5-10 projects (the average number of resurfacing projects for an engineer in our sample is 8.3). If anything, these estimates likely understate the impact of the engineer on costs, given the selection of more experienced engineers into more complex projects.

Figure 11: Engineer Fixed Effects Results



(a) Raw Fixed Effects

(b) Empirical Bayes Fixed Effects

Notes: The figure on the left shows a histogram of estimated engineer fixed effects. The standard deviation of these estimates is 0.828. The figure on the right shows a histogram of estimated engineer fixed effects, after applying a Bayesian Shrinkage correction. The standard deviation of these estimates is 0.028. Fixed effects estimates are normalized to have a mean of 0. There are 1,144 project-level observations used in the regression, resulting in 138 fixed effects estimates. The outcome variable is log(cost per mile), winsorized at the 2nd and 98th percentiles of the sample. Covariates include County, Year, and Route fixed effects. Sample is restricted to engineers with at least 5 resurfacing projects. Some projects in our data have the start milepost or end milepost set to 0. We drop these observations from our sample because of concern that these are recorded inaccurately.

This preliminary analysis suggests that replacing a construction engineer at the 95th percentile of the cost distribution with a median engineer would reduce costs by 5.2%, or \$24,000 per mile at

[34] The results are similar when we do not include route fixed effects.

the mean. The average resurfacing project in the sample spans 9 miles, so this translates to $220,000 per project. Further, Caltrans completes 60 resurfacing projects per year, on average, so this effect scales to a savings of over $13 million per year.

Future Work We would like to compare the effect of resident engineers on the post-auction (construction) phase with project managers on the planning and bidding phases. This would allow us to provide some insight on where capacity is more important—developing plans and fostering competition for projects, or overseeing the project on the ground. However, since the project manager and resident engineer information come from two different data sets, this significantly reduces our sample size. Therefore, in order to do this analysis we will have to expand our project types beyond road resurfacing.

We also would like to consider other outcomes besides final cost per mile. First, we can separate the final cost into the cost from the winning bid, which is realized in the bidding stage, and the cost overrun that is realized after construction. As far as non-cost outcomes, we can measure the project duration and also the amount of competition (number of bidders). However, we do not have this data for the full sample.

6 Conclusion

US infrastructure construction costs are high by international standards and increasing. At the same time, costs vary greatly across states within the US. This paper is the first to use cross-state evidence to understand what role procurement practices play. To study this, we assemble and combine three novel datasets: (1) we conduct a survey of state procurement officials and contractors about state procurement practices and cost drivers, (2) we collect state-by-state a project-level data set of construction costs, and (3) we assemble administrative data on the construction industry that completes projects and the public sector industry that manages projects.

Two themes arise from our study of DOT highway procurement. First is the role of competition as a cost driver. This is evident from the survey and the administrative data—bidders know the identity and capacity of their competitors at the time of the bid-letting, DOTs do very little bidder outreach, and there are fewer construction firms in most states than there were 10 years ago. Further, the number of bidders, and the DOT propensity to do outreach, correlate with lower realized costs. The second theme is the role of DOT capacity as a cost driver. We find that DOTs that provide more details at the time of the bid-letting have lower costs, while states with more change orders, which are often the result of poor planning, have higher costs.

We further investigate the role of capacity with detailed data from the state of California. We find that the identity of the individual engineer that is assigned to manage a project on the ground (i.e. the engineer who communicates with the contractor and oversees the work after the bid letting) has a significant relationship with realized costs. In ongoing work we will compare the effect of the construction engineer in the post-auction phase with the project manager in the planning and bidding phase.

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Appendix

A Procurement Process and Hypotheses

In this section we provide more details on the state DOT procurement process. We proceed chronologically, and highlight which practices at each stage of the procurement process have the potential to affect final highway construction costs.

The hypotheses are mostly from the industrial organization literature, which includes many specific case studies from a handful of states. However, the survey will also allow us to highlight cost drivers that have not been studied much in existing literature. For example, we can ask about how often the state DOT employs consultants, which is often mentioned in conversations with practitioners as a potential costly practice (Levin and Tadelis, 2010).

Outside of the procurement process, we also ask about DOT capacity and quality, to speak to the ability of the state to run an efficient procurement system and oversee road maintenance and construction. On the contractor side, we ask about firm size and experience, as well as their knowledge of their competitors and their investments in cost reductions.

A.1 Pre-bidding

In the first stage, pre-bidding, the procuring entity (which is the state DOT here) assesses its procurement needs and budget. The DOT decides which projects to complete and the scope of each project (e.g., a project for 30 miles of road vs. three separate projects for 10 miles), and the state engineer estimates the cost of each project. State DOTs often plan highway construction projects 4 years or more in advance to conform with federal regulations.

Contractors' bids are higher when they are capacity constrained.

If there are only a few eligible contractors for a large complicated project, and these firms have capacity constraints, both the timing of projects and the size of the job have the potential to reduce the pool of potential bidders, reducing competition and driving up final procurement costs (Best et al., 2023; Jofre-Bonet and Pesendorfer, 2003).

For instance, timing procurement with aggregate demand shocks could take advantage of slack construction firm resources, although government stimulus may invert this effect. An examination of the 2009 ARRA stimulus package on highway construction found that the government paid prices that were 6.2% higher, due to the effect of stimulus projects on firms backlogs (Balat, 2012). Due to capacity constraints, the firm that has already committed to an ongoing project will have to pay overtime wages or rent additional workers; competitors may increase their bids if they know their rivals are constrained.

A.2 Bid Letting: Announcing the Project and Collecting Bids

In the second stage, bidding, the DOT determines the procurement method, the information made public for the project, and how the bids will be collected. The procurement method has a direct effect on costs, as different auction designs correspond to different optimal bidding strategies (Milgrom and Weber, 1982). However, given our focus on road resurfacing, there is no variation in the actual auction design; we know all states use low-bid (first price) auctions.[35] However, the states do have discretion on where they post the project, whether they advertise it, and what information they include.

Providing detailed and accurate information on project plans reduces final costs.

There is no federal mandate dictating how much information a state DOT needs to provide to bidders. However, there is evidence that providing more information to bidders on the specifics of the project and engineer's estimate can reduce costs (De Silva et al., 2008). In effect, providing more detailed plans to bidders reduces uncertainty on construction costs which will result in realized costs being closer to the winning bid. The accuracy of these plans is also important: conversations with practitioners indicate to us that incomplete or incorrect plans can delay project completion or lead to costly renegotiation.

Providing detailed information on competing bidders can increase costs.

It is also possible that more information can increase costs, when this information facilitates collusion. For example, in Kentucky, the DOT made the names of firms that purchased bid proposals public the Friday before bids were due. This allowed firms to know if anyone was eligible to bid against them before submitting their actual bid (Barrus and Scott, 2020). The authors suggest that "the threat of even a second potential bidder in an auction [would lower] the winning bid by over ten percent, and that reforming the two-step procurement process, with its opportunity for gaming bids, could reduce costs for highway construction in Kentucky.

Efforts to increase the bidder pool can decrease costs.

Advertising the project and doing outreach to potential bidders can have substantial effects on the

[35] This is typical for road resurfacing and building projects that use federal funds, which are the focus of our survey. More complicated projects might be evaluated on price and quality. There is evidence that evaluating bids on quality, not only price, provides incentives for faster delivery (Lewis and Bajari, 2011).

level of entry (Krasnokutskaya and Seim, 2011; Levin and Smith, 1994) and the ability of incumbent bidders to collude (Bajari and Ye, 2003; Clark et al., 2018; Porter and Zona, 1993). It is well-established in the auction literature that increasing competition can reduce costs, and efforts in St. Paul, Minnesota has shown bidder outreach can achieve this effect (Government Performance Lab, 2016; Liebman and Azemati, 2016).

The DOT's level of outreach is not specific to the auction design, so it is not the focus of much of the IO procurement auction literature. An important contribution of our survey approach is to collect data on these procurement practices which may not be codified in state regulations but have the potential to substantially affect costs.

A.3 Submitting Bids and Project Award

After the bids are collected, the bids are evaluated and the contract is awarded.

Strict criteria to evaluate bids have the potential to decrease costs.

The common legislative requirement is to award highway construction using a low-bid system. However, procurement officials are generally wary of extremely low bids. These could be the result of the bidders attempting to win the contract for a low price, expecting to renegotiate a higher price at a later date. These could also be the result of an inexperienced bidder, not realizing what actual costs will be: unrealistically low bids[s], while appearing to be a real bargain, may in fact result from the bidder, or lack of competence to successfully complete the given project, (National Academies of Sciences, Engineering, and Medicine, 2006). The procurement office can police "abnormally low bids by establishing a criterion to identify them, and then throwing out bids that are flagged as abnormally low or "mathematically unbalanced" (i.e., when a bid is unrealistic in its cost structure).

Strict criteria to evaluate bids have the potential to increase costs if overly burdensome.

During the bid screening process the procuring entity can exclude bids for other types of errors besides abnormally low bids. If the bidding process is too complicated it creates the possibility for bidders to make small technical mistakes that disqualify otherwise qualified bids (Best et al., 2023). Trivial reasons to exclude bids in the bid screening process will artificially reduce competition, and increase costs.

A.4 Construction: Execution of the Contract

Execution concerns everything that happens in the period between the commencement of work and when the project is completed. This includes delays, contract renegotiation, payment, and inspection of the final works.

Delays increase costs.

This is a well-known fact in the literature. Delays increase total project costs, and incur costs to commuters who would like to travel on the road that is being serviced. What are not as well established are the degree to which delays vary across states and the source of the delays. Our survey asks about the frequency of delays, the usual causes of delays, and about two specific processes that can cause delays: obtaining regulations and permits for work, and renegotiating the contract.[36] Recent work in the Kenyan setting show that more stringent certification and inspection requirements required by the World Bank led to substantial delays (Wolfram et al., 2023).

The renegotiation process causes realized costs to exceed winning bids.

Incomplete contracts can create a costly renegotiation process, which bidders might take advantage of when submitting bids in the bidding stage (Lewis and Bajari, 2014; Ryan, 2020). Completing any negotiation or change orders quickly will reduce delays, as discussed above. Beyond delays, the ability to renegotiate on costs can affect bidder strategy. Therefore, anything that the DOT does to constrain the renegotiation process can have an impact on costs.

B Cost Data

In this Appendix we review some additional descriptives on cost and compare our data with state-level aggregates provided by the Federal Highway Administration (FHWA).

B.1 Descriptives

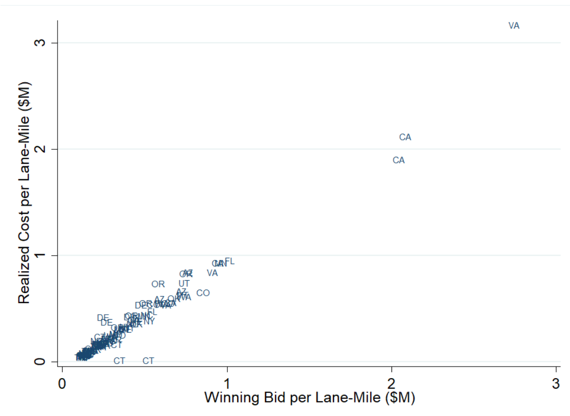
We request data on project-level costs directly from each state DOT. The states provide data in a variety of formats, and include different subsets of the variables that we request. For example, in some states we receive data on three cost variables: winning bid, realized cost, and amended contract cost. However, in some states we only receive one or two of the three. In the states that we only observe winning bid, for example, we want to be convinced that it is a good enough proxy for realized costs for the projects in our subsample.

Figure B.1 compares winning bids with realized costs, in the states where we have both (22 states). The panel on the left plots the two objects in the project-level data, and the panel on the right shows

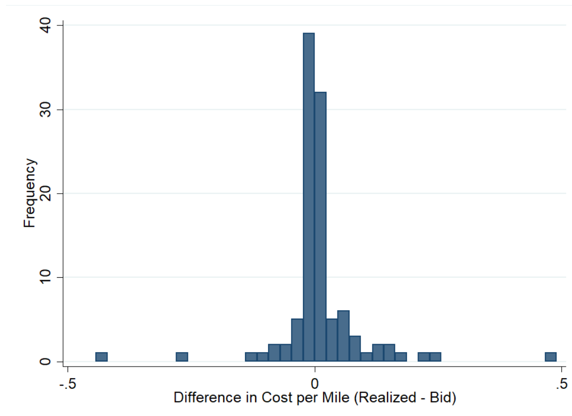
[36] After the passage of Resource Conservation and Recovery Act and subsequent regulation, Alabama DOT accepted bids for a project involving lead paint removal. One company that was aware of the regulations submitted a bid three times the size of a contractor that was unaware of the regulation changes (Tarrer and Boylan, 1995).

the differences, in a histogram. The two objects are highly correlated, with a correlation coefficient of 0.98.

Figure B.1: Bids vs Realized Costs



(a) Comparison of Cost per Mile

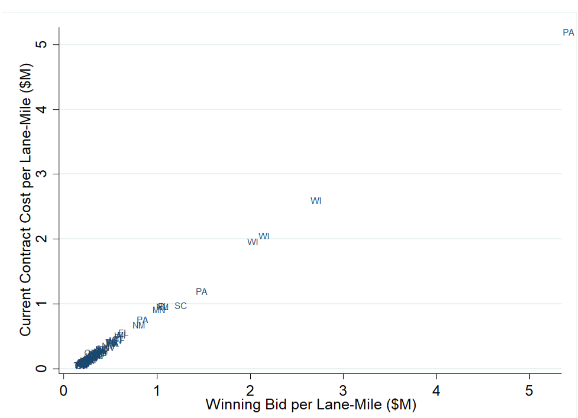


(b) Difference

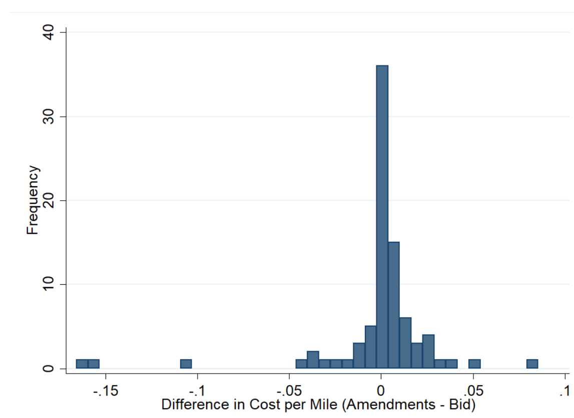
Notes: This figure compares winning bids with realized costs. The panel on the left plots the two objects in the project-level data, and the panel on the right shows the differences, in a histogram. The two objects are highly correlated, with a correlation coefficient of 0.9812.

Figure B.2 compares winning bids with "current contract" costs, in the states where we have both (17 states). Current contract costs are the winning bids plus or minus any contract amendments. Current contract costs are essentially realized costs, unless the project has not been completed. The two objects are highly correlated, with a correlation coefficient of 0.99.

Figure B.2: Bids vs Amended Contracts



(a) Comparison of Cost per Mile

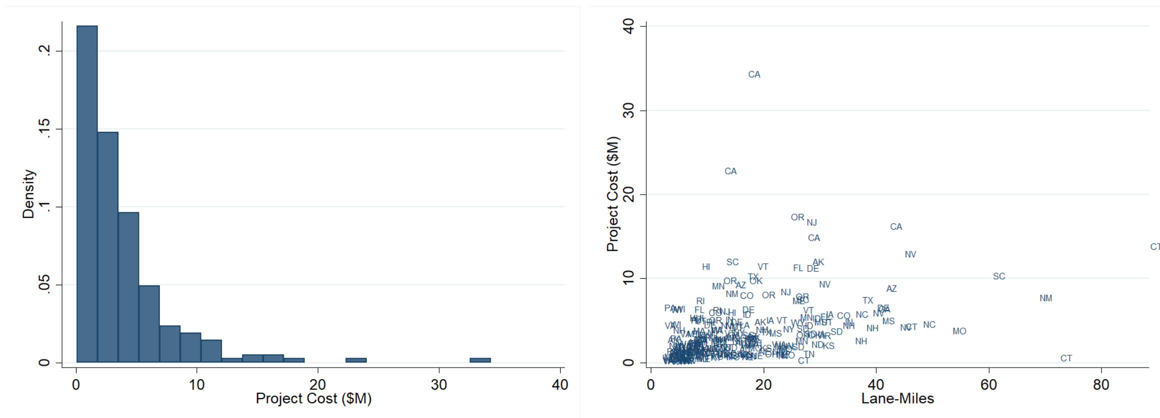


(b) Difference

Notes: This figure compares winning bids with "current contract" costs. Current contract costs are the winning bids plus or minus any contract amendments. The panel on the left plots the two objects in the project-level data, and the panel on the right shows the differences, in a histogram. The two objects are highly correlated, with a correlation coefficient of 0.999.

Our final sample uses the realized cost variable when available (23 states), then the current contract cost if available when realized cost is not (12 states), and the winning bid for the remainder (15 states). Figure B.3 shows the distribution of project costs across the sample and Figure B.4 shows the spending and length of the projects across space.

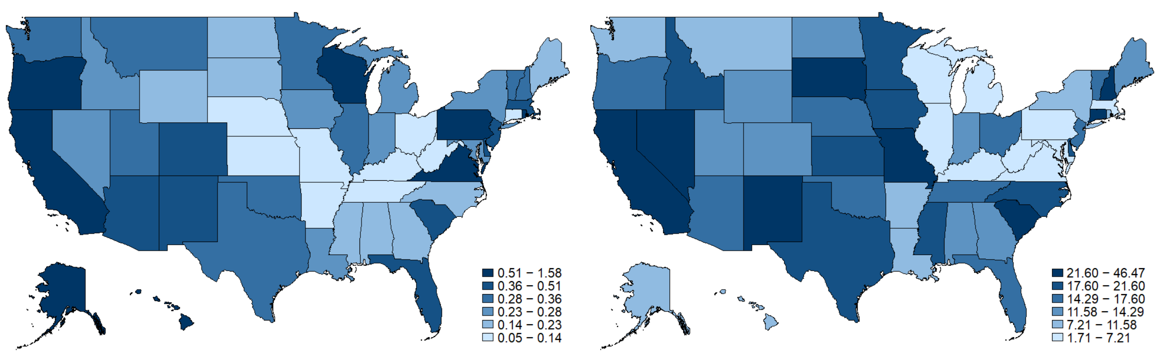
Figure B.3: Cost Data Sample: Totals



(a) Project-Level Total (b) Total vs Mileage

Notes: The histogram on the left shows the distribution of project-level costs in the data collected by the authors. The scatter plot on the right takes each project cost and plots it against total mileage of the project (in lane miles). The markers denote the state associated with the project One project that costs $62 million is not included, for visibility.

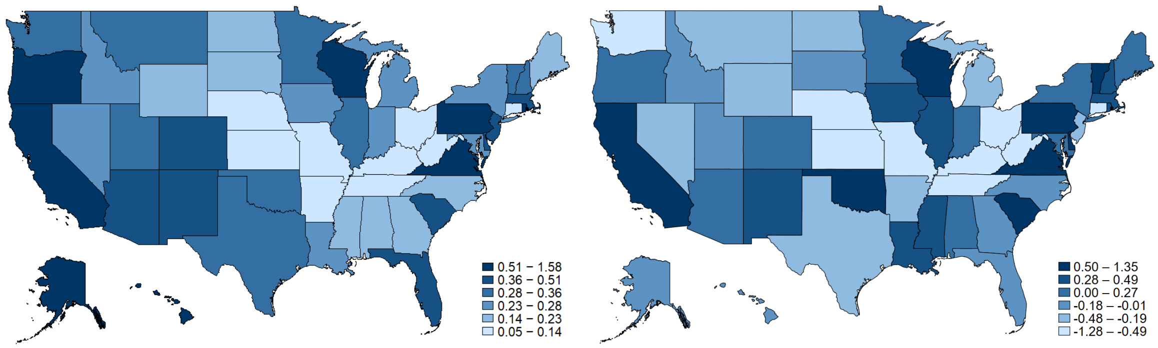
Figure B.4: Spending and Project Characteristics



(a) State-Level Spending (b) State-Level Mileage

Notes: The map on the left shows project costs per mile, and the right shows the mileage for these projects (reproduced from Figure 2 in the main text). The cost data collected by the authors is for resurfacing projects started in 2018 or 2019, with a length between 1 and 20 miles, on a non-interstate highway. There are 5 such projects per state, and the state average is used for this map. Interestingly, project length does seem to vary by state, with some states undertaking much longer projects, on average, than others.

Figure B.5: Average Project Cost by State



(a) State-Level Cost per Mile ($M) (b) State-Level Residualized Cost per Mile

Notes: The figure on the left takes the average of project costs at the state level (reproduced from Figure 2 in the main text). The figure on the right displays the state-level average of residualized costs. Residual costs are determined using a project-level regression of project costs per lane-mile on the observables included in Column (3) of Table 1. Data collected by the authors.

B.2 Comparison with the FHWA Data

We can compare our data with state-level cost data from the Federal Highway Administration (FHWA). The FHWA requires states to report spending on a variety of categories and types of roads via an annual survey. As such, these data are self-reported by the states. A potential concern is that states do not all report resurfacing spending, for example, in the same narrow category. A second concern is that we do not have a denominator of miles resurfaced, we only have total miles in the state. Therefore, it is hard to know if cost per mile is higher in one state because they did more projects than another state or because the projects are more expensive. However, this is the only comprehensive dataset on state-level costs and is often used in reports about spending across states (e.g. Reason Foundation, 2018).

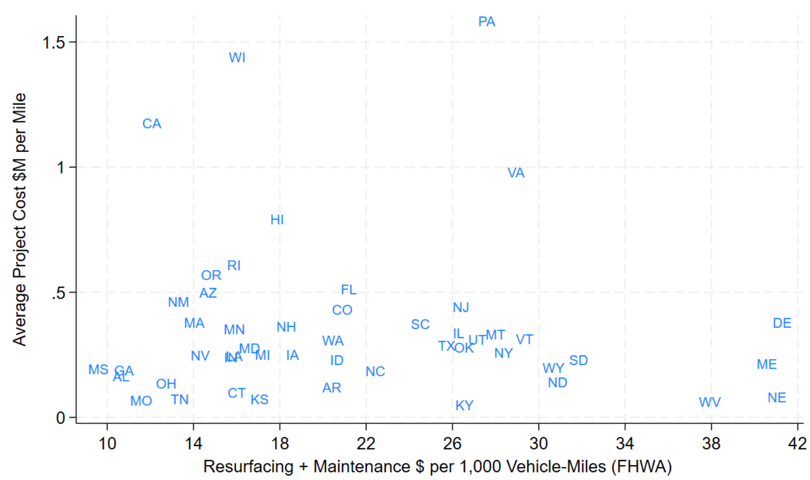
FHWA data includes spending by category, as we mentioned earlier. Therefore we need to select certain categories to compare with our sample of resurfacing projects. Due to potential reporting issues, we are fairly broad in the categories we include in the series we create. We define our series of interest as "Resurfacing + Maintenance cost per vehicle-mile." This includes all maintenance cost variables and certain capital overlay variables.[37] Vehicle-miles are the estimated number of miles traveled by vehicles on roads in that states. We use all road types in all definitions, but the series looks similar when we exclude local roads. These data are very similar to the series used by Mehrotra et al. (2021). For the FHWA data, we think spending per vehicle-mile is a better measure of cost efficiency, as it implicitly controls for the expected degradation due to heavy road use.

[37] The capital outlay variables are "Relocation", "Reconstruction: Added Capacity", "Reconstruction: No Added Capacity", "Major Widening", "Minor Widening", "Restoration & Rehabilitation", and "Resurfacing".

Figure B.6 shows the variation in spending across states for the two sources. There is a striking amount of variation in the FHWA data with Maine, Delaware, and Nebraska spending 4 times per vehicle mile than Mississippi, Georgia, and Alabama. Our series, although still exhibiting variation across states, does not exhibit as much heterogeneity. Importantly, there is very little correlation between the two series. Since we have directly collected resurfacing cost data from the states, this suggests the FHWA data is not a good proxy.

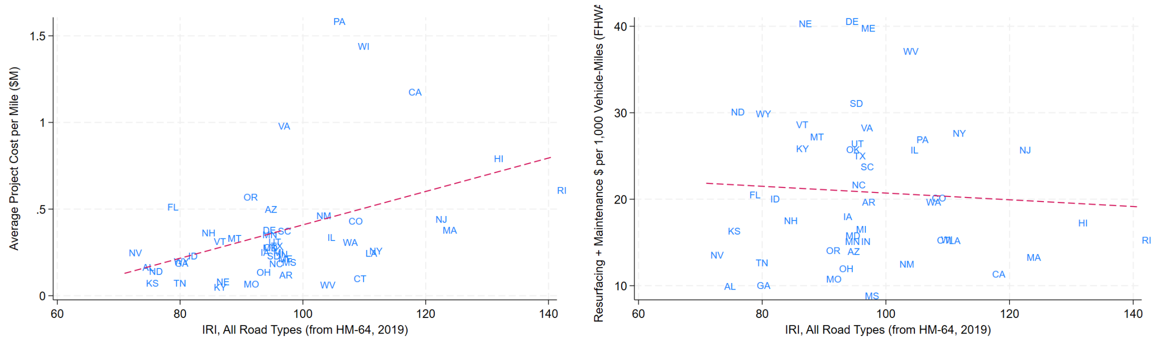
Moreover, it does not seem that costs are higher in areas where roads are rougher in the FHWA data, while our data show a stronger correlation between costs and road quality (Figure B.7). We would expect maintenance costs per lane mile to be higher on rougher, poorer-quality roads, so the lack of correlation with costs in the FHWA data is surprising.

Figure B.6: Comparison of Cost Data



Notes: This is a scatter plot with cost data collected by the authors on the y-axis and cost data collected by the FHWA on the x-axis. The cost data collected by the authors is for resurfacing projects started in 2018 or 2019, with a length between 1 and 20 miles, on a non-interstate highway. There are 5 such projects per state, and the state average is used for this plot. The FHWA cost data is spending on resurfacing and maintenance per vehicle mile.

Figure B.7: Costs and Road Roughness



(a) Cost per Mile and Roughness (b) FHWA $ per Vehicle-Mile and Roughness

Notes: The panel on the left shows a scatter plot of state-level resurfacing cost per mile and road roughness (IRI). The cost data collected by the authors is for resurfacing projects started in 2018 or 2019, with a length between 1 and 20 miles, on a non-interstate highway. There are 5 such projects per state, and the state average is used for this plot. The panel on the right shows the same using cost from Highway Statistics (FHWA). To create the cost series we include a subset of capital outlay costs (relocation, reconstruction, major widening, minor widening, restoration, rehabilitation, resurfacing) plus maintenance costs. We use the International Roughness Index (IRI) as the quality measure.

B.2.1 Comparison of FHWA and BidX Data

To further probe the reliability of the Highway Statistics spending data, we compare it to spending totals that we aggregated from BidX, a private-secotr service that many state DOTs contract for its construction bidding software. Data from BidX has also recently been used for research purposes (e.g. Bolotnyy and Vasserman, Forthcoming; Kroft et al., 2022). BidX posts winning bids for state DOT construction projects for 38 states. They post descriptions for each project, allowing us to select projects of a similar scope to those we look at in FHWA Highway Statistics.[38]

As a validation exercise, we compare cross-state spending differences in the BidX data with those from Highway Statistics. We first examine Georgia and South Carolina, a pair of states that are similar on observables but have divergent levels of spending per vehicle mile (VM) levels in the Highway Statistics data. In 2018 and 2019, spending per VM is higher in South Carolina in both data sources, but the difference is much larger in Highway Statistics than in BidX.

We repeat the exercise with Georgia and Alabama, two states with very similar spending per VM in Highway Statistics. In the averaged totals across 2014, 2018, and 2019, we find a 15 percent difference between the two states in BidX, whereas the averages in Highway Statistics are virtually identical.

Lastly, we compare New York and North Carolina, which both have high spending per VM in

[38]The following keywords are indicative of the projects we are looking for: “resurface”, “rehabilitation”, “widening”, in addition to “mill”, “surface”, “CMRB”. We focused on states that had the most detailed descriptions.

Highway Statistics, to Georgia and Alabama, which both have low spending levels. In 2019, the two datasets disagree: Highway Statistics has the spending per VM significantly higher in NY and NC, whereas BidX has spending per VM significantly higher in Alabama and Georgia. The last comparison also raised a red flag about the internal consistency of the BidX data, as NY has just over 1/3 of the spending per VM as Alabama, which is unlikely to reflect the full universe of spending.

We compare magnitudes of spending in addition to cross-state relative differences. To improve precision, we focus on two categories of spending: resurfacing, rehabilitation, and restoration (3R) and widening/reconstruction. These activities are accounted separately in Highway Statistics and are often grouped together in BidX projects. We choose Georgia for this exercise due to its detailed project descriptions on BidX. In this exercise, the BidX magnitudes are well below those we observe in Highway Statistics.

Overall, it appears that BidX does not typically include the universe of spending laid out in Highway Statistics, and that the degree of the coverage gap in BidX data varies widely by state.

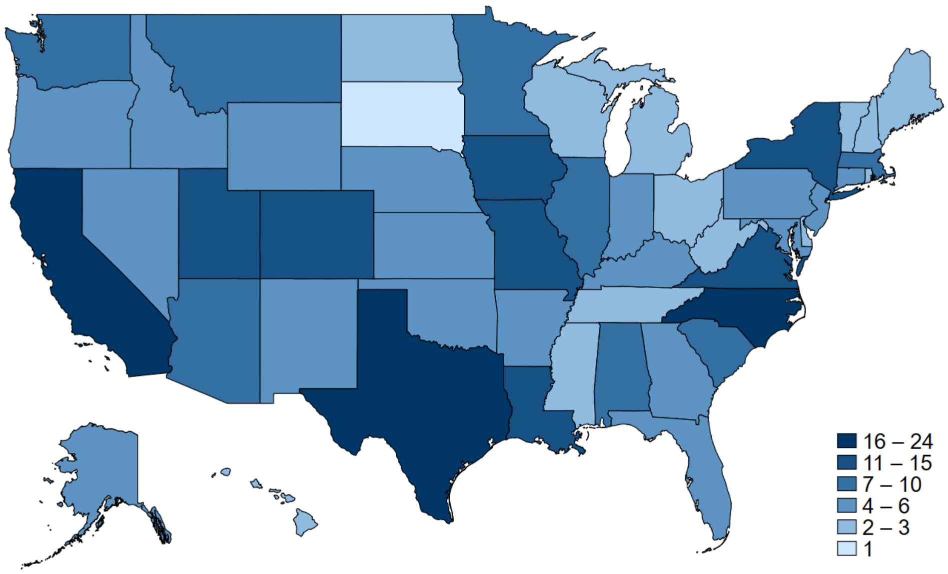
B.3 Example Resurfacing Project

As an example of the project-level data we have collected, consider the following project from Minnesota. The project was awarded on April 17, 2018, and consisted of "grading, bituminous mill, and overlay" per the project description. It covered 12.28 miles of Minnesota State Highway 28. The initial award amount was \$2.50 million and the final realized expenditures were \$2.58 million. It was completed on July 11, 2018, for a project duration of 85 days.

C Survey Descriptives and Data Cleaning

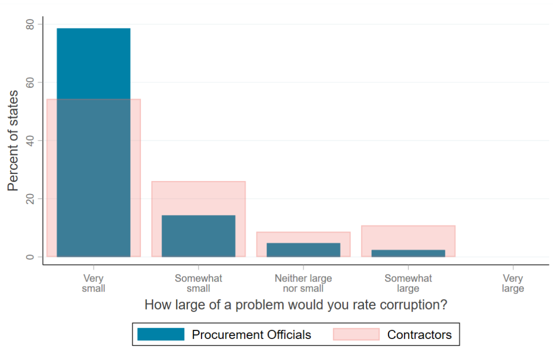
C.1 Basic Descriptives

Figure C.1: Survey Respondents by State

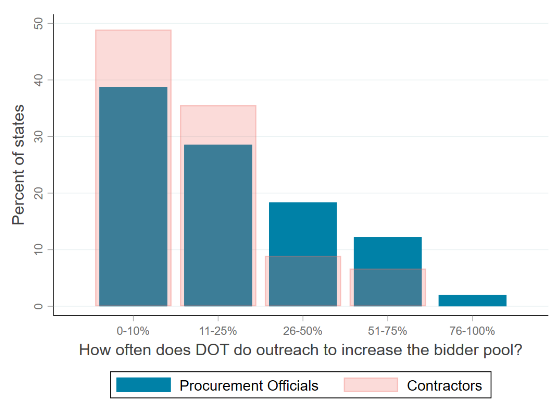


Notes: The map displays the total number of survey respondents by state. This includes both procurement officials and contractors. Contractors are classified according to their primary state.

Figure C.2: Survey Consensus



(a) Corruption

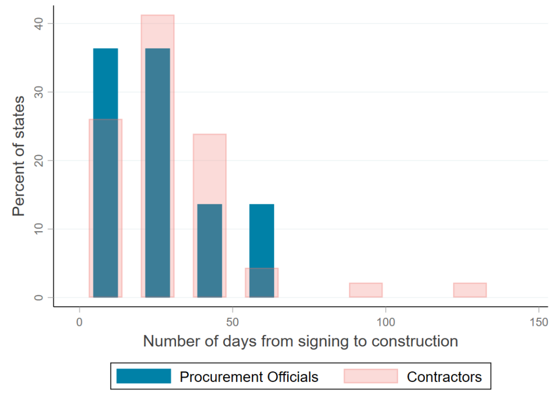


(b) Bidder Outreach

Notes: Author survey. Data aggregated to the state level. Survey available in Appendix F.

Figure C.3: Variation Across States

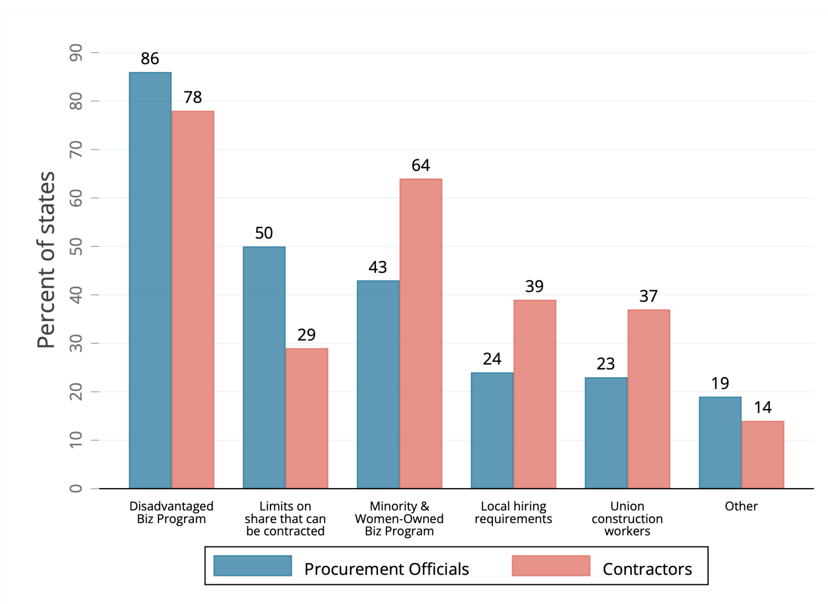
(a) Award to Signing



(b) Signing to Construction

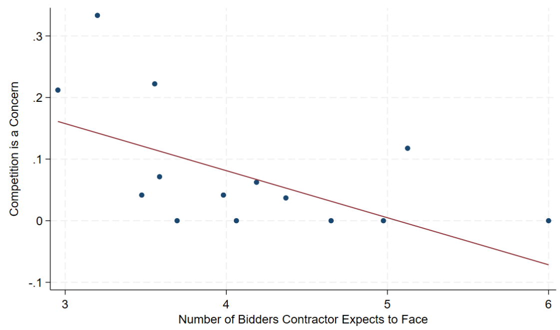
Notes: Author survey. Panels (a) and (b) ask the number of days from contract award to signing and contract signing to the start of construction. Data aggregated to the state level. Survey available in Appendix F.

Figure C.4: Labor Practices

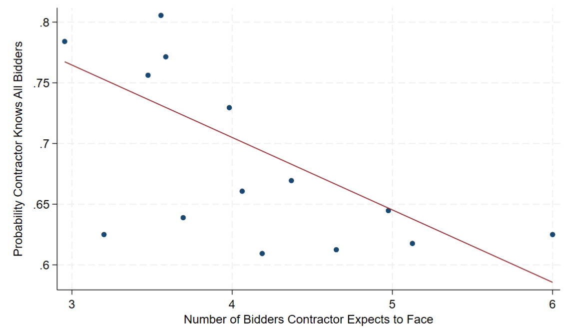


Notes: Author survey. Data aggregated to the state level. Survey available in Appendix F.

Figure C.5: Competition



(a) Stated Concerns and # of Bidders



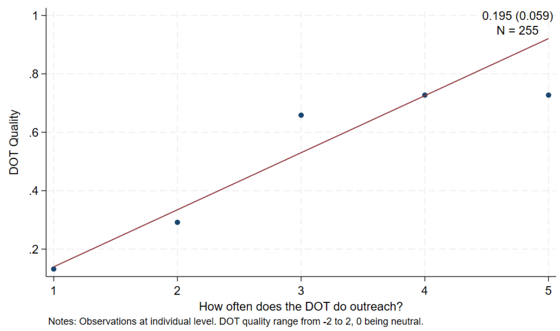
(b) Bidding Behavior

Notes: The panel on the left shows a binned scatter plot with the mention of competition as a concern on the y-axis and the number of bidders a contractor expects to face on the x-axis. This data is from the author survey, and responses are aggregated to the state level by taking the average. The panel on the right shows a binned scatter plot with the probability the contractor knows all of its competitors on the y-axis, and number of bidders on the x-axis.

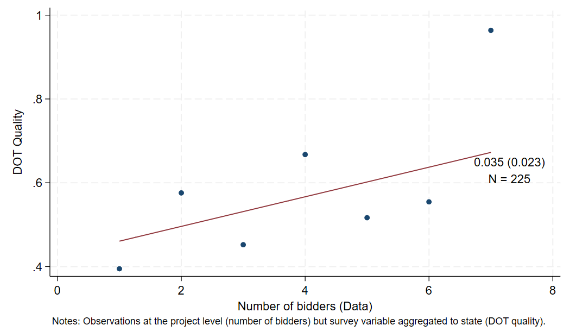
Figure C.6: Word Cloud from Free Response on Cost Drivers

Notes: The figure shows the frequency of bigrams in responses to a free response question on cost drivers of highway construction (Question 1 in Appendix F). A bigram is a pair of words used together. Responses are cleaned prior to determining the frequency of bigrams. This is done by removing “stop words” (words such as “the” or “are”), standardizing words, and removing words that are not informative. [Option 1: See Appendix X for more details on text cleaning] [Option 2: See Liscow and Pershing (2022) for more details on text cleaning–need to add cite to bib file]. Responses from both procurement officials and contractors are used.

Figure C.7: DOT Quality and Competition



(a) DOT Quality and Outreach

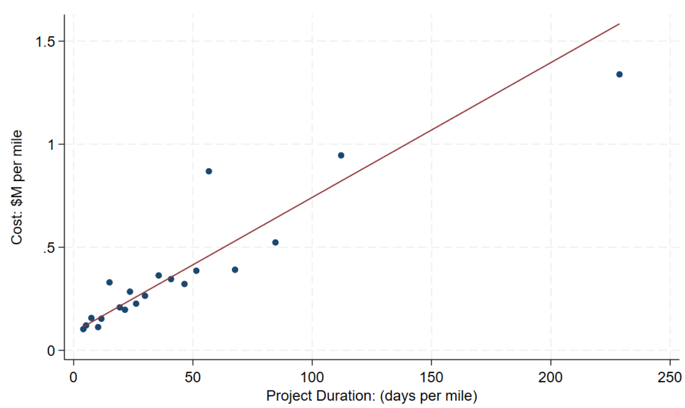


(b) DOT Quality and Number of Bidders

Notes: The panel on the left shows a binned scatter plot with the DOT quality on the y-axis and the frequency of DOT bidder outreach on the x-axis. This data is from the author survey, and responses are reported at the individual level. The panel on the right shows a binned scatter plot with the DOT quality on the y-axis, and number of bidders from the project-level cost data on the x-axis. Here, the data is aggregated to the state level.

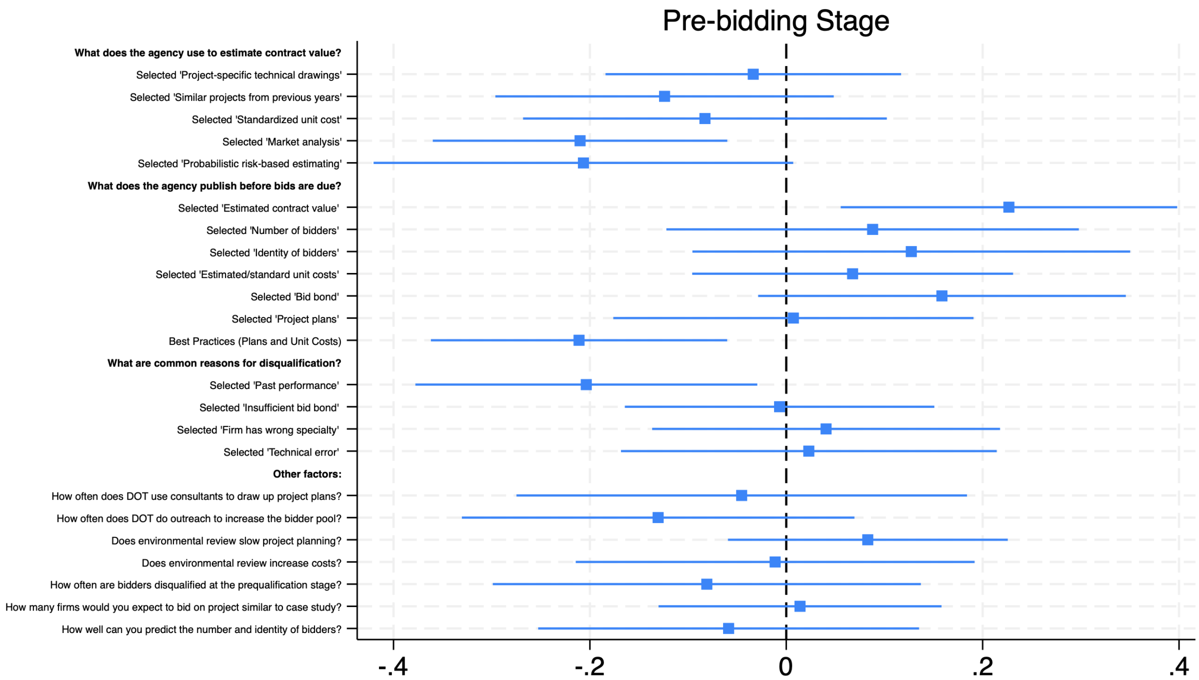
C.2 Procurement and Project Duration

Figure C.8: Costs and Project Duration



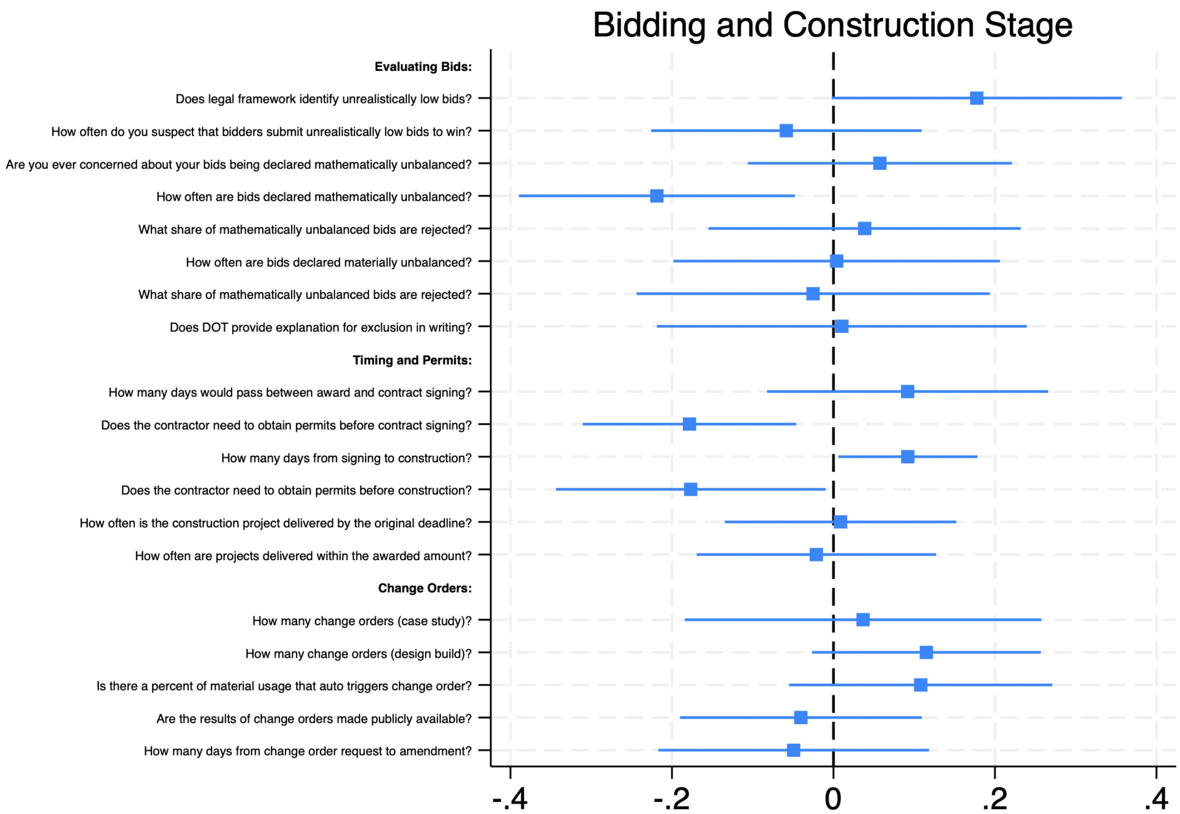
Notes: This is a binned scatter plot of project-level costs and duration. The y-axis shows the cost per lane-mile, in $M. The x-axis shows the duration per lane-mile, in days. The data was collected by the authors, as part of the project-level cost data. The project duration variable is only available for 33 states.

Figure C.9: Survey Correlates with Project Duration: Pre-Bidding



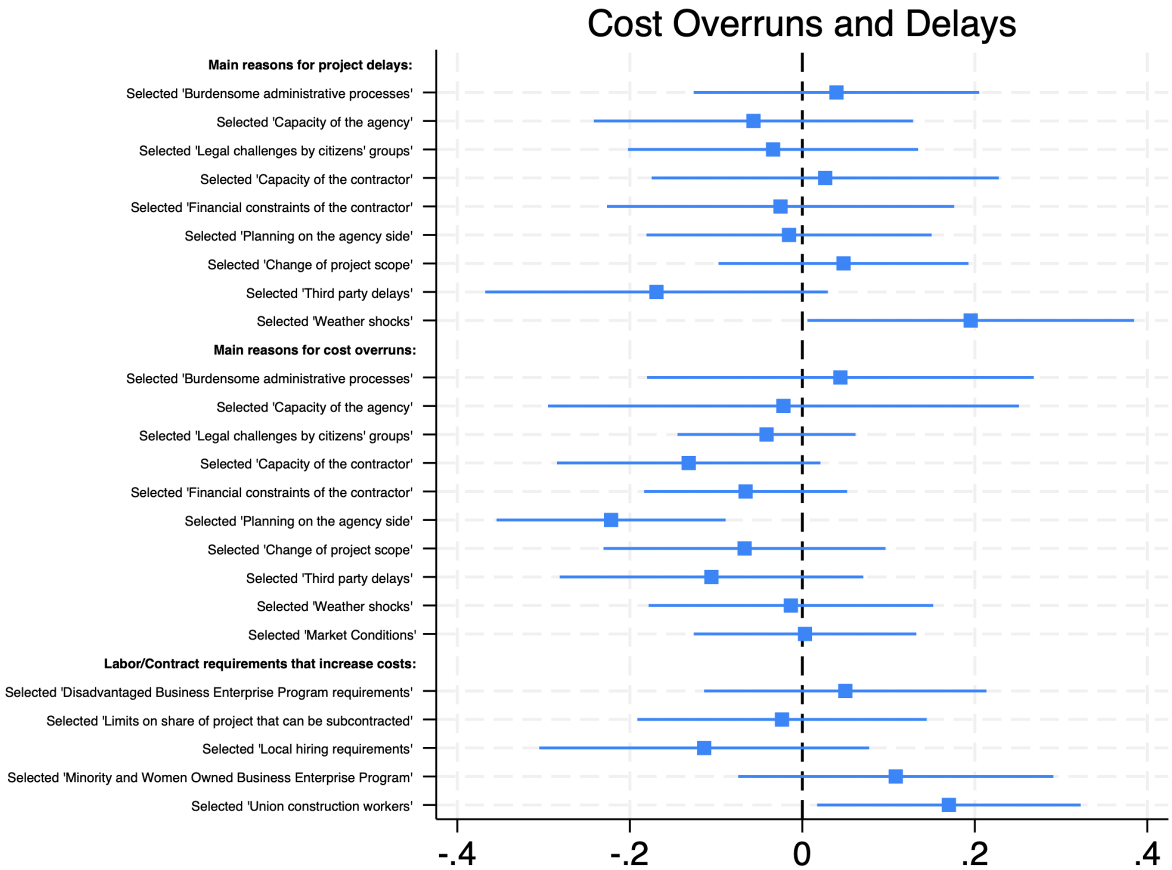
Notes: This figure shows the correlation coefficients between the survey responses and the project duration for the pre-bidding stage of the procurement process. The dependent variable is log days per lane-mile. Regressions include controls for project, local, and weather observables (per Column (3) of Table 1), and cluster standard errors at the state level. The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. The bars represent the 95% confidence interval. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions.

Figure C.10: Survey Correlates with Project Duration: Bidding and Construction



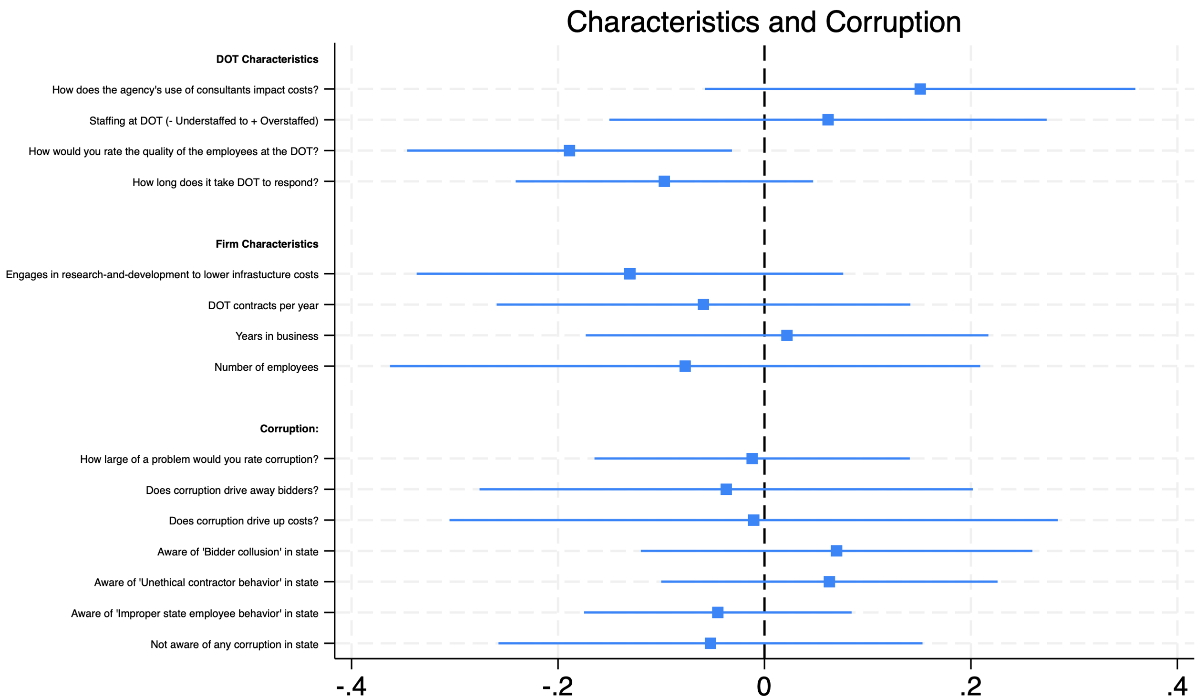
Notes: This figure shows the correlation coefficients between the survey responses and the project duration for the bidding and construction stages of the procurement process. The dependent variable is log days per lane-mile. Regressions include controls for project, local, and weather observables (per Column (3) of Table 1), and cluster standard errors at the state level. The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. The bars represent the 95% confidence interval. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions.

Figure C.11: Survey Correlates with Project Duration: Overruns and Delays



Notes: This figure shows the correlation coefficients between the survey responses and the project duration for the questions about cost overruns, delays, and labor costs. The dependent variable is log days per lane-mile. Regressions include controls for project, local, and weather observables (per Column (3) of Table 1), and cluster standard errors at the state level. The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. The bars represent the 95% confidence interval. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions.

Figure C.12: Survey Correlates with Project Duration: Other Factors



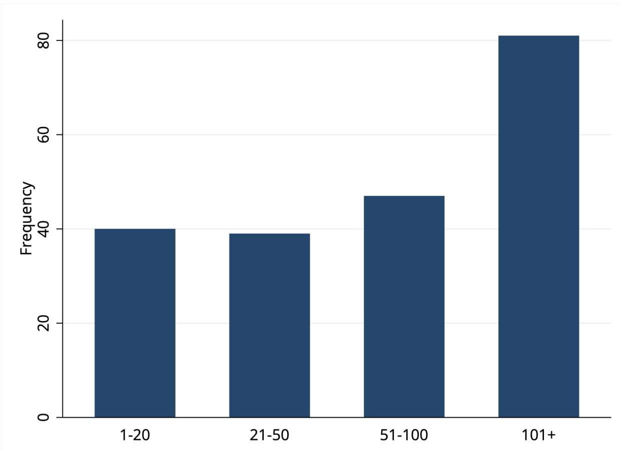
Notes: This figure shows the correlation coefficients between the survey responses and the project duration for the questions about DOT and Contractor characteristics and corruption. The dependent variable is log days per lane-mile. Regressions include controls for project, local, and weather observables (per Column (3) of Table 1), and cluster standard errors at the state level. The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. The bars represent the 95% confidence interval. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions.

C.3 Contractor Characteristics

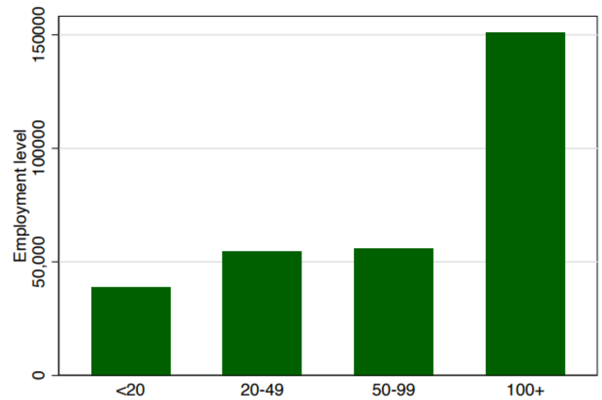
In the contractor survey we ask about the identity and characteristics of the firm: number of employees, number of years in business, and number of contracts with the state DOT. We note that the sample of contractors looks similar to the distribution of contracting firms in the U.S. by employment (Figure C.13).

We analyze whether firm characteristics correlate with certain responses to questions. A handful of interesting patterns emerge. First, respondents from larger and more experienced firms are less likely say that that corruption occurs or is a problem. These characteristics all correlate with lower values assigned to the question, “How large of a problem would you rate corruption;” the result is statistically significant for number of years in business and number of contracts. Second, respondents from larger (in terms of employees and contracts) and more experienced firms are also significantly more likely to select “planning on agency side” as a source of cost overrun. Third, respondents from firms with more years in business expect more firms to bid on projects, perhaps suggesting that the number of bidders has decreased throughout time. This is directly related to the procurement officials responses about the lack of competition.

Figure C.13: Size Distribution of Contracting Firms



(a) Our Survey



(b) 2021 QCEW

C.4 Data Cleaning

To address potential concerns on survey response quality, we perform additional cleaning of survey responses and repeat our main analysis (without Romano-Wolf multiple hypothesis correction). First, we drop individual respondents if they take less than 10 minutes to complete the survey. If respondents rush to finish the survey, they may not be thinking critically about our questions and provide inaccurate answers. Second, we drop individual respondents if they are a contractor and operate in more than five states. If contractors operate in more than five states, we are worried they could confuse procurement processes between states. This would lead to a situation in which a contractor provides information on procurement practices in State X, and we attribute those procurement practices to State Y. For our final response cleaning method, we drop individual respondents if they take less than 10 minutes to complete the survey or if they are a contractor and operate in more than five states. Results using these additional cleaning methods are not substantially different from our main results.

D Non-Procurement Observables

D.1 Weather

We collect data on several observable characteristics of states that may be linked to elevated road maintenance costs. The first set is environmental variables, which we download from the NOAA Centers for Environmental Information and average across the years 2000-2019: winter low temperatures, summer high temperatures, and precipitation levels. The first two variables are designed to capture the prevalence of extreme cold or heat, both of which of which cause asphalt deterioration. Precipitation also causes roads to deteriorate more quickly. The NOAA does not have state-level data for snowfall, so to proxy for snowfall levels, we multiply average precipitation by the inverse of average winter low temperature.

Table 1 shows that these observables explain little of the state-level variation in costs. When included as additional controls along with our survey data in the cost analysis, none reach statistical significance. When included along with our survey data in a Lasso regression, all coefficients on state observables shrink to zero. The only observable that shows evidence for explaining some cost variation is average winter low temperature, which has a significant negative bivariate correlation with spending. This is concerning, and motivation our data collection effort for project-level cost data.

D.2 Market Structure

We take data from the Economic Census for Construction in 2007, 2012, and 2017. This dataset provides state-level employment, payroll, revenues, and cost for all construction industries, including "Highway, Street, and Bridge Construction" (NAICS 23730). We use this data to create state-level variables on labor costs (construction worker payroll/employment), number of establishments, and establishment size (employees per establishment). Unfortunately, for the smallest states the number of establishments is censored so we lose two states when we include these controls in Table 1.

We also have data from publicly available DBE directories. This gives us the name, address, and NAICS industry code for every firm registered with the state DOT as a DBE. We match the zip codes to commuting zones in order to create a commuting zone measure.

D.3 Public Sector Employment

We have data from the Annual Survey of Public Employment and Payroll (ASPEP), which is produced by the Census Bureau. This includes statistics on the number of state and local government civilian employees and their payrolls in March. We take employment for the "Highways" category in each state as our proxy for DOT employment. Our measure of DOT capacity is the state "Highways" employment from ASPEP, over the employment in Highway Construction from the Census of Services.

E Full Results

Table E.1: Pre-bidding Stage

Variable	Beta Estimate	Unadjusted p-value	Romano-Wolf p-value
What does the agency use to estimate contract value?			
Selected 'Project-specific technical drawings'	0.08	0.29	0.89
Selected 'Similar projects from previous years'	-0.01	0.94	1.00
Selected 'Standardized unit cost'	-0.06	0.45	0.99
Selected 'Market analysis'	-0.03	0.61	1.00
Selected 'Probabilistic risk-based estimating'	-0.10	0.18	0.59
Selected 'Feasibility study'	0.03	0.83	1.00
What does the agency publish before bids are due?			
Selected 'Estimated contract value'	0.18	0.04	0.06
Selected 'Number of bidders'	0.11	0.20	0.67
Selected 'Identity of bidders'	0.10	0.14	0.41
Selected 'Estimated/standard unit costs'	0.05	0.52	1.00
Selected 'Bid bond'	0.04	0.67	1.00
Selected 'Project plans'	-0.06	0.23	0.75
Best Practices (Plans and Unit Costs)	-0.17	0.06	0.10
What are common reasons for disqualification?			
Selected 'Past performance'	0.04	0.68	1.00
Selected 'Insufficient bid bond'	0.05	0.59	1.00
Selected 'Firm has wrong specialty'	-0.01	0.85	1.00
Selected 'Technical error'	-0.07	0.44	0.99
Other factors:			
How often does DOT use consultants to draw up project plans?	0.08	0.28	0.88
How often does DOT do outreach to increase the bidder pool?	-0.18	0.02	0.01
Does environmental review slow project planning?†	-0.06	0.50	1.00
Does environmental review increase costs?†	-0.05	0.64	1.00
How often are bidders disqualified at the prequalification stage?†	-0.02	0.76	1.00
How many firms would you expect to bid on project similar to case study?$^{\wedge}$	0.17	0.10	0.26
How well can you predict the number and identity of bidders?$^{\wedge}$	-0.05	0.64	1.00

Notes: Beta Estimates are the correlation coefficients between the survey responses and the project cost for the pre-bidding stage of the procurement process. The dependent variable is log cost per lane-mile. Regressions include controls for project, local, and weather observables (per Column (3) of Table 1). The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions. Unadjusted p-values are computed using standard errors clustered at the state level. Romano-Wolf p-values are adjusted for multiple hypothesis testing, following Clarke et al. (2020). †question asked to procurement officials only. $^{\wedge}$question asked to contractors only.

Table E.2: Bidding and Construction Stage

Variable	Beta Estimate	Unadjusted p-value	Romano-Wolf p-value
Evaluating Bids:			
Does legal framework identify unrealistically low bids?†	0.10	0.26	0.84
How often do you suspect that bidders submit unrealistically low bids to win?†	-0.02	0.87	1.00
Are you ever concerned about your bids being declared mathematically unbalanced?$^{\wedge}$	-0.01	0.93	1.00
How often are bids declared mathematically unbalanced?†	-0.07	0.51	1.00
What share of mathematically unbalanced bids are rejected?†	0.10	0.33	0.94
How often are bids declared materially unbalanced?†	-0.12	0.15	0.48
What share of materially unbalanced bids are rejected?†	0.01	0.94	1.00
Does DOT provide explanation for exclusion in writing?	-0.02	0.84	1.00
Timing and Permits:			
How many days would pass between award and contract signing?	0.03	0.72	1.00
Does the contractor need to obtain permits before contract signing?	-0.05	0.41	0.99
How many days from signing to construction?	-0.01	0.93	1.00
Does the contractor need to obtain permits before construction?	0.05	0.59	1.00
How often is the construction project delivered by the original deadline?	-0.09	0.32	0.93
How often are projects delivered within the awarded amount?	-0.09	0.19	0.63
Change Orders:			
How many change orders (case study)?	0.17	0.05	0.09
How many change orders (design build)?	0.19	0.10	0.26
Is there a percent of material usage that auto triggers change order?†	0.11	0.29	0.89
Are the results of change orders made publicly available?	-0.03	0.70	1.00
How many days from change order request to amendment?	-0.13	0.16	0.49

Notes: Beta Estimates are the correlation coefficients between the survey responses and the project cost for the bidding and construction stages of the procurement process. The dependent variable is log cost per lane-mile. Regressions include controls for project, local, and weather observables (per Column (3) of Table 1). The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions. Unadjusted p-values are computed using standard errors clustered at the state level. Romano-Wolf p-values are adjusted for multiple hypothesis testing, following Clarke et al. (2020). †question asked to procurement officials only. $^{\wedge}$question asked to contractors only.

Table E.3: Cost Overruns and Delays

Variable	Beta Estimate	Unadjusted p-value	Romano-Wolf p-value
Main reasons for project delays:			
Administrative processes drive delays	0.15	0.06	0.10
Selected 'Capacity of the agency'	-0.05	0.45	0.99
Selected 'Legal challenges by citizens' groups'	0.05	0.51	1.00
Selected 'Capacity of the contractor'	-0.02	0.80	1.00
Selected 'Financial constraints of the contractor'	0.02	0.79	1.00
Selected 'Planning on the agency side'	-0.02	0.87	1.00
Selected 'Change of project scope'	0.07	0.28	0.88
Selected 'Third party delays'	-0.02	0.85	1.00
Selected 'Weather shocks'	-0.00	0.97	1.00
Main reasons for cost overruns:			
Selected 'Burdensome administrative processes'	-0.11	0.19	0.63
Selected 'Capacity of the agency'	-0.08	0.36	0.96
Selected 'Legal challenges by citizens' groups'	-0.06	0.32	0.94
Selected 'Capacity of the contractor'	-0.07	0.30	0.90
Selected 'Financial constraints of the contractor'	0.05	0.36	0.96
Selected 'Planning on the agency side'	-0.15	0.09	0.21
Selected 'Change of project scope'	-0.12	0.25	0.81
Selected 'Third party delays'	-0.08	0.33	0.94
Selected 'Weather shocks'	-0.18	0.02	0.02
Selected 'Market Conditions'	-0.03	0.67	1.00
Labor/Contract requirements that increase cost:			
Selected 'Disadvantaged Business Enterprise Program requirements'	-0.10	0.15	0.45
Subcontracting limits drive costs	0.16	0.01	0.00
Selected 'Local hiring requirements'	-0.02	0.88	1.00
Selected 'Minority and Women Owned Business Enterprise Program'	-0.00	0.96	1.00
Selected 'Union construction workers'	0.06	0.57	1.00

Notes: Beta Estimates are the correlation coefficients between the survey responses and the project cost for the questions about cost overruns, delays, and labor costs. The dependent variable is log cost per lane-mile. Regressions include controls for project, local, and weather observables (per Column (3) of Table 1). The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions. Unadjusted p-values are computed using standard errors clustered at the state level. Romano-Wolf p-values are adjusted for multiple hypothesis testing, following Clarke et al. (2020). †question asked to procurement officials only. ^question asked to contractors only.

Table E.4: Characteristics and Corruption

Variable	Beta Estimate	Unadjusted p-value	Romano-Wolf p-value
DOT Characteristics			
Consultants drive costs	0.19	0.02	0.01
Staffing at DOT (- Understaffed to + Overstaffed)	0.05	0.56	1.00
How would you rate the quality of the employees at the DOT?	-0.14	0.09	0.21
How long does it take DOT to respond?^	0.06	0.49	1.00
Firm Characteristics			
Engages in research-and-development to lower infrastructure costs^	-0.14	0.14	0.43
Corruption:			
How large of a problem would you rate corruption?	-0.02	0.74	1.00
Does corruption drive away bidders?	0.02	0.87	1.00
Does corruption drive up costs?	0.03	0.75	1.00
Aware of 'Bidder collusion' in state	-0.03	0.68	1.00
Aware of 'Unethical contractor behavior' in state	0.14	0.09	0.22
Aware of 'Improper state employee behavior' in state	-0.04	0.57	1.00
Not aware of any corruption in state	-0.15	0.11	0.30

Notes: Beta Estimates are the correlation coefficients between the survey responses and the project cost for the questions about DOT and Contractor characteristics and corruption. The dependent variable is log cost per lane-mile. Regressions include controls for project, local, and weather observables (per Column (3) of Table 1). The survey responses from the procurement officials and the contractors are aggregated to a state-level average, unless the question was only asked to one group. Each response variable is normalized to have a mean of zero and standard deviation of one, such that correlations are comparable across questions. Unadjusted p-values are computed using standard errors clustered at the state level. Romano-Wolf p-values are adjusted for multiple hypothesis testing, following Clarke et al. (2020). †question asked to procurement officials only. ^question asked to contractors only.

F Survey

The survey, with tabulated responses to each question, is attached following this page. It can also be found at `https://cailinslattery.com/s/Survey-with-Responses.pdf`.