Procurement and Infrastructure Costs

Zachary Liscow, William Nober, Cailin Slattery

Yale, Columbia, UC Berkeley

July 2024

It is very expensive to build and maintain infrastructure in the U.S.

U.S. public sector spent $266B on highways in 2022

- This is primarily maintenance and rehabilitation

Costs of building a road mile increased 3x since 1960 (Brooks and Liscow 2023)

- Increase not explained by materials and labor costs

U.S. transit costs are remarkably high by international standards (Goldwyn et al 2023)

It is very expensive to build and maintain infrastructure in the U.S.

The Pew Charitable Trusts

State and Local Governments Face Persistent Infrastructure Investment Challenges

State and local governments across the United States spend roughly half a trillion dollars annually on transportation and water...

Feb 3, 2023

Vox

Why do roads, rail, and infrastructure cost so much to build in the US?

As Congress argues over the size of the infrastructure bill and how to pay for it, very little attention is being devoted to one of the most...

Jun 28, 2021

CNN

The cost to fix America's crumbling infrastructure? Nearly $2.6 trillion, engineers say

With the money from his $1.9 trillion coronavirus relief law starting to flow, President Joe Biden is turning his attention to his next...

Mar 30, 2021

New York Magazine

Why We Can't Figure Out Why Infrastructure Is So Expensive

The GAO set about to find out why American infrastructure is so expensive, and their failure points to a problem that is going to be...

Jul 24, 2019

U.S. infrastructure costs are high—how much does procurement matter?

Public procurement accounts for 25% of U.S. government expenditures

- Every infrastructure project involves a government procurement process

Design and implementation of procurement practices have implications for costs

- Various studies showing specific instances of design mattering for project costs in a specific state (De Silva et al. 2008, OK DOT; Barrus & Scott 2020, KY DOT; Bajari et al. 2014, Caltrans; Lewis & Bajari 2013, MN DOT)

U.S. infrastructure costs are high—how much does procurement matter?

Public procurement accounts for 25% of U.S. government expenditures

- Every infrastructure project involves a government procurement process

Design and implementation of procurement practices have implications for costs

- Various studies showing specific instances of design mattering for project costs in a specific state (De Silva et al. 2008, OK DOT; Barrus & Scott 2020, KY DOT; Bajari et al. 2014, Caltrans; Lewis & Bajari 2013, MN DOT)

Challenge: No comprehensive data on DOT procurement practices, or project costs, across states

Procurement and Infrastructure Costs

What we do:

- Conduct a 50-state survey of state DOT procurement practices
  - Survey both procurement officers and contractors in each state
- Collect *project-level* cost data for all 50 states
- Assemble administrative data on relevant industries

→ Correlate project-level cost data with procurement practices

- Use separate administrative data from California to quantify the role of engineers across steps of the procurement process

Procurement and Infrastructure Costs

What we do:

- Conduct a 50-state survey of state DOT procurement practices
  - Survey both procurement officers and contractors in each state
- Collect *project-level* cost data for all 50 states
- Assemble administrative data on relevant industries

→ Correlate project-level cost data with procurement practices

- Use separate administrative data from California to quantify the role of engineers across steps of the procurement process

Takeaways:

1. Capacity of state DOT drives project-level costs
   - Broad agreement that state capacity has declined; admin data confirms
2. Practices that increase competition associated with significantly lower costs
3. The identity of state DOT engineer explains a significant portion of cost per mile differences

Background and New Data on Highway Procurement and Costs

Data Pt. 1: Survey of State DOTs and Local Contractors

The survey questions address several potential cost drivers:

1. **Transparency**
2. **Competition**
3. **Quality control**
4. **Capacity of agency, contract credibility**
5. **Corruption**

+ Free-response questions

Data Pt. 1: Survey of State DOTs and Local Contractors

The survey questions address several potential cost drivers:

1. **Transparency**
2. **Competition**
3. **Quality control**
4. **Capacity of agency, contract credibility**
5. **Corruption**

+ Free-response questions

We distribute the survey via email

- $\sim$40 questions in total
- Questions framed around "case study" project
- Sent directly to procurement officers and contractors
  - E-mail addresses from state websites, trade associations
- Sample: 123 DOT employees in 50 states, 211 contractors in 47 states Map

Data Pt. 2: Project-Level Cost Data

Federal Highway Administration (FHWA) provides spending data at state level

- States have discretion over categorization of projects, accounting standards
- No reporting of size and scope of work (need denominator)

Data Pt. 2: Project-Level Cost Data

Federal Highway Administration (FHWA) provides spending data at state level

- States have discretion over categorization of projects, accounting standards
- No reporting of size and scope of work (need denominator)

We collect data from each of the 50 states on *project-level* costs

- Create a subsample of 5 projects in each state meeting standard criteria
  - Resurfacing project between 1 and 20 miles
  - Total cost, lane-mileage, # bidders, project description, estimate, location
- Data on costs collected via public records requests, additional variables collected from bid lettings, project plans, google maps

Data Pt. 3: Admin. data on the highway construction industry

- Public sector that manages projects
  - Source: Annual Survey of Public Employment and Payroll (Census)
  - State "Highways" category (separate category for "Transit")
  - Employment, Payroll

- Private sector that completes projects
  - Source: Economic Census for Construction (every 5 years)
  - NAICS 2373: "Highway, Street, and Bridge Construction"
  - Employment, Establishments, Revenue, Payroll

- Private sector firms registered in Disadvantaged Business Enterprise (DBE) directories
  - State and Federal government have requirements for DBE share of work completed
  - DBE "market" data collected from state registries, using NAICS and address of firm

Results

Summary of survey results, admin data

We document variation in costs and procurement practices across states

In general, survey respondents are concerned with 2 inputs to the procurement process:

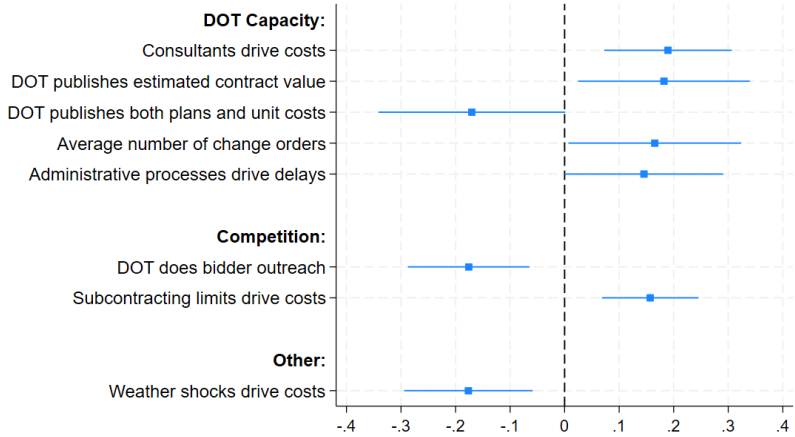
1. DOT capacity: Understaffing Consultant use
2. Competition between contractors: Predictable bidders Minimal state DOT outreach

We see these two themes highlighted in many different survey responses

- Admin data verifies both DOT employment and the number of construction firms has fallen in the last 10-20 years

Next, we will correlate the survey responses with our cost data

Significant correlations are consistent with stated cost drivers



- Also find evidence for the two cost drivers highlighted in survey:
  - One SD increase in DOT employment per capita is associated with 16% lower costs
  - One additional bidder is associated with 8% lower costs

The Role of the DOT Engineer

How much do DOT employees matter?

Descriptive analysis suggests significant role for state DOT investment in high-quality engineers in lowering project costs.

- → Given detailed project-level data on engineer assignments and costs, can we confirm this?
- → Further, where in the procurement and construction process does engineer investment matter most?

How much do DOT employees matter?

Descriptive analysis suggests significant role for state DOT investment in high-quality engineers in lowering project costs.

→ Given detailed project-level data on engineer assignments and costs, can we confirm this?

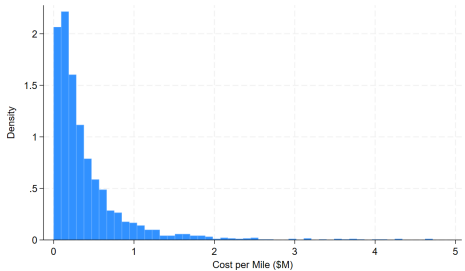
→ Further, where in the procurement and construction process does engineer investment matter most?

From Caltrans (California's DOT), we have the following data:

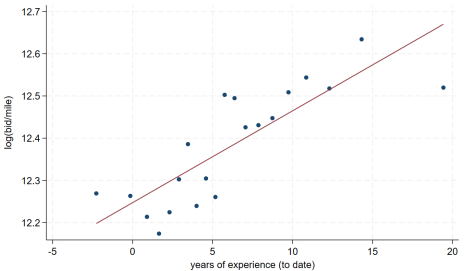
1. **Construction data**, 2000-2018: 11,000 projects with descriptions, basic payment info, *resident engineer* identities. Over 1,240 unique engineers. Over 2,000 resurfacing projects—$44 billion of spending
2. **Project delivery data**, 2012-2023: 8,000 projects info by project phase. Contains name of the *project manager*, the engineer who manages the bidding process.
3. **Bidding data**, 2018-2023: 2,000 projects with info on all bidders, not just winners

Caltrans Engineer Analysis

Figure: Caltrans Projects: Costs and Engineer Assignment



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



(b) Engineer Assignment

- Significant variation in resurfacing cost per mile to explain
- Conversations with Caltrans officials: Engineers assignment is nonrandom
  - A function of engineer experience, project complexity, location, type

Caltrans Engineer Analysis

Given many projects for an individual engineer, we can estimate the following model:

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

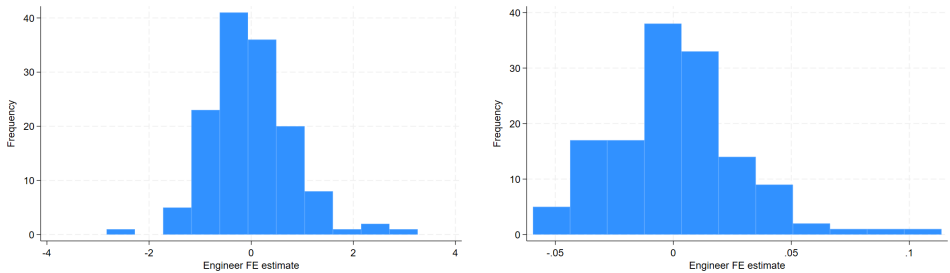
Which residualizes cost per mile for a resurfacing project p by route r, county c, year t, and engineer t

Outcome of interest: standard deviation of η_i, the engineer fixed effect.

- Given small sample of projects per engineer we shrink the fixed effects using Armstrong, et al. 2022

Caltrans Engineer Analysis: Results

Figure: Engineer Fixed Effects Results



(a) Raw Fixed Effects

(b) Empirical Bayes Fixed Effects

- Replacing a construction engineer at the 95th percentile of the cost distribution with a median engineer reduces costs by 5.2% ($24,000) per mile at the mean.

→ $220,000 per project (average project is 9 miles long)

→ Savings of $13 million per year

Conclusion and Next Steps

Conclusions and Next Steps

What is driving high infrastructure costs in the U.S.?

- We bring new data to tackle the question
- Document variation in procurement practices and costs among states
- Find evidence that individual engineer identities explain a portion of cost levels

We find compelling evidence for two cost drivers:

(1) Limited capacity of the DOT procuring the project
   - DOT employment per capita, consultant use, engineer quality (from California data)

(2) Lack of competition in the market for government construction contracts
   - Number of bidders, lack of outreach, limits on subcontracting

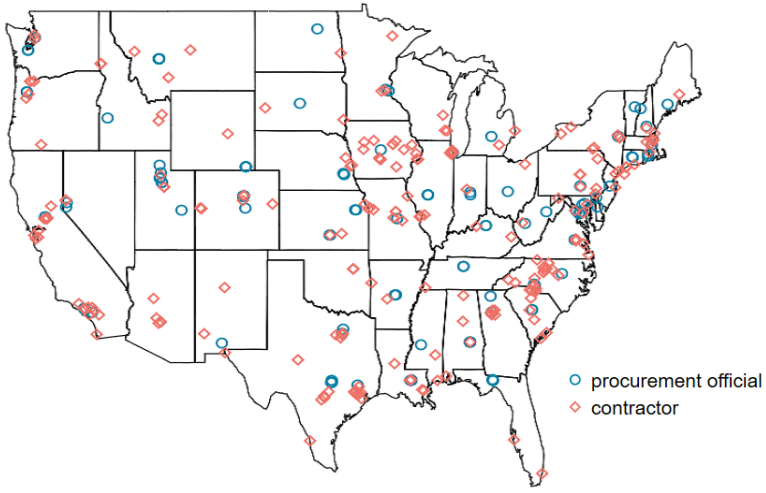
Going forward: Refine engineer FE model to further quantify the role of capacity

- Isolate the role of capacity at different stages of process (bidding vs. construction)

Bonus Slides

Geographic Distribution of Survey Responses

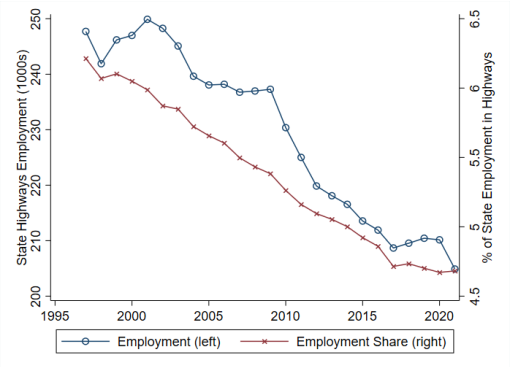
Back



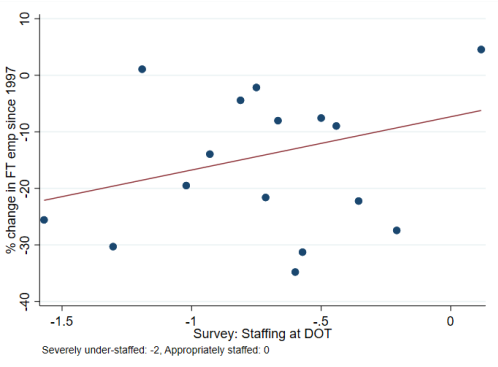
Decrease in DOT Capacity Confirmed in Admin Data

Back

- 20% drop in state highway employment from 1997-2021 (Census, ASPEP)
- Changes in employment, at the state-level, correlate with staffing concerns



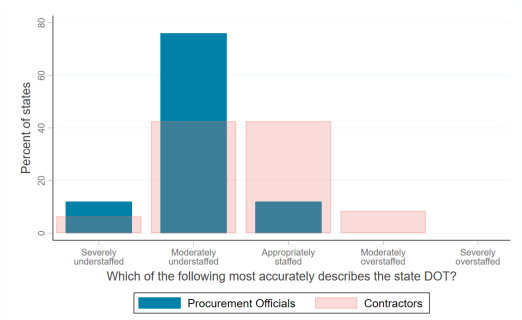
(a) State Highway employment over time



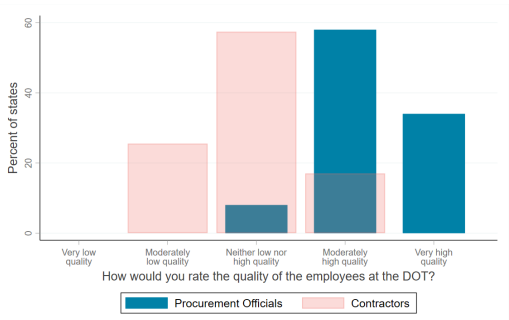
(b) Survey: Concern about staffing at DOT

3. Consensus: Procurement officials agree they are understaffed Back

Free responses on employee quantity, quality More



(c) Staffing Levels



(d) Employee Quality

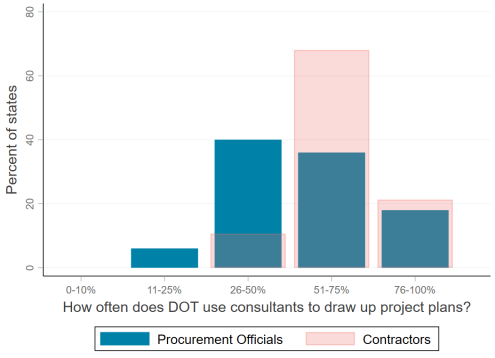
Decrease in DOT capacity confirmed in admin data More

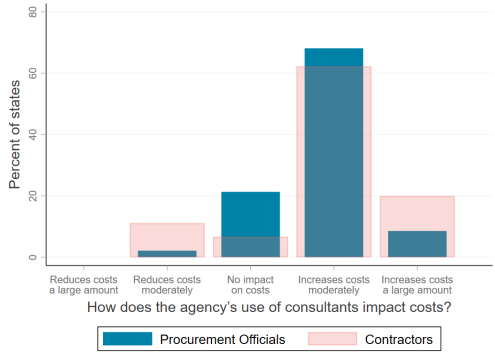
- 20% drop in state highway employment from 1997-2021

4. Variation: Use of consultants across states

Back

Capacity constrained DOTs can outsource work to consultants





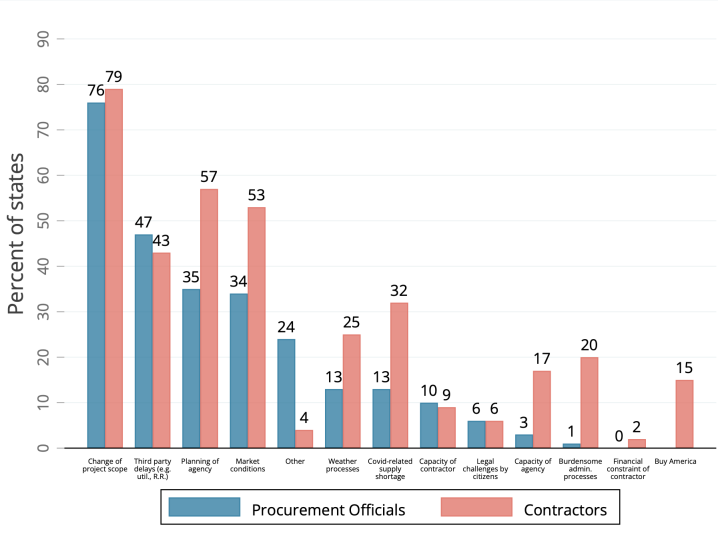
Agreement that consultant use increases costs—also a theme in the free response.

> *[Consultants] "lead to confusing and incorrect drawings which leads to delayed bids and change orders."* More

5. Top reported cost driver is change of project scope

Back

Question: If a project has a cost overrun, what are usually the main reasons?



6. Consensus: Lack of competition is a problem Back

Both procurement officials and contractors emphasize competition as a cost driver in free response More

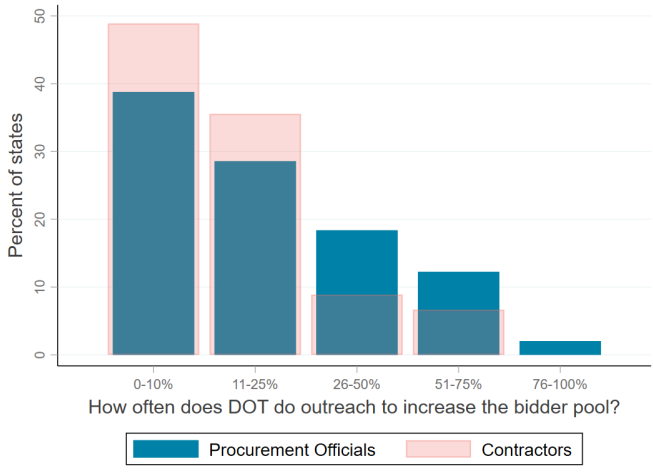
Which of the following best describes your experience regarding other companies' bids?	
I can usually predict exactly which firms will bid on a project.	25.2%
I know all the firms that are capable of bidding, but not which ones will actually bid.	22.4%
I know many of the firms that might bid, but sometimes there are surprise bidders.	46.7%
There are often firms bidding that I do not know/expect.	5.7%

- On average, contractors predict 3.8 bidders (projects in cost data have 3.3)
  - 33% of projects have $\leq$2 bidders
  - The fewer the bidders, the more likely contractor knows all competitors More
- Admin data shows an increase in concentration
  - 70% of states experienced a decrease in establishments in Hwy Construction More

7. Further, states do minimal outreach to increase # of bidders

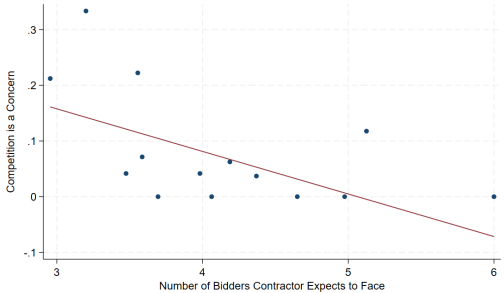
Back

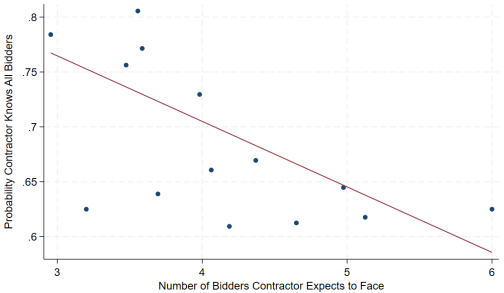
On average, less than 20% of projects involve outreach



Contractor Survey Responses on Competitors

Back

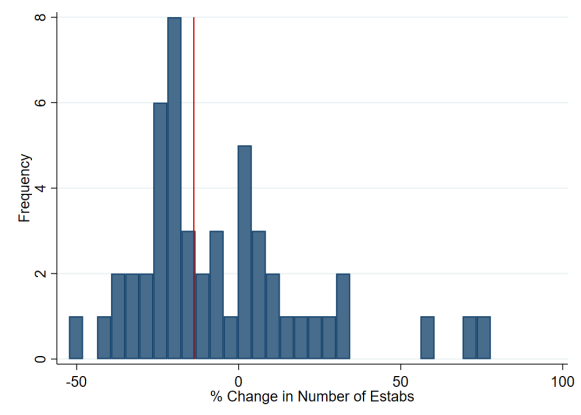




Trends in the Highway Construction Industry

Back

Changes in Highway Construction Establishments: 2007-2017



Text responses on consultants Back

Procurement officials:

- "One issue is that consultants can only design with 100% confidence of no failure. They must err on side of caution for every design"
- "Anecdotally, industry would claim that it takes longer to get important decisions made when consultants are inspecting vs. DOT staff"
- "A consultant inspector costs the department more than an equivalent in-house inspector"

Contractors

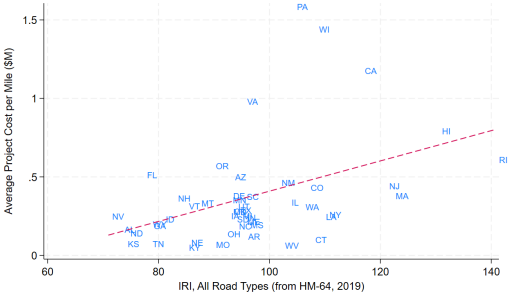
- "3rd party consultants are highly compensated based on a cost + factor, they don't have enough skin in the game during construction"
- "The third party companies aren't trained and usually don't have a clue. They just show up and ask you if everything is correct and [what] your quantities are so they can match your numbers so they can go back to the truck and watch YouTube"

	Project Cost per Mile (log($M))					
	(1)	(2)	(3)	(4)	(5)	(6)
Project Details:						
Complex Dummy	1.027***	0.948***	0.932***	0.880***	0.848***	-0.082
	(0.270)	(0.259)	(0.281)	(0.266)	(0.226)	(0.095)
Lane-Miles	-0.023***	-0.023***	-0.024***	-0.024***	-0.022***	-0.005
	(0.006)	(0.006)	(0.004)	(0.004)	(0.003)	(0.007)
State Highway Dummy	-0.234*	-0.273*	-0.067	-0.083	-0.113	0.104
	(0.133)	(0.140)	(0.127)	(0.129)	(0.123)	(0.144)
Engineer's Estimate (log(Cost/Mile))						0.838***
						(0.158)
Local Characteristics:						
Log (Population Density)		0.026	0.067+	0.056	0.062+	0.026
		(0.044)	(0.040)	(0.041)	(0.040)	(0.030)
Log(Wages in Highway Construction)		0.218	0.344*	0.214	0.178	-0.423+
		(0.171)	(0.196)	(0.207)	(0.210)	(0.253)
State Weather:						
Precipitation Days (Average)			-0.033***	-0.032***	-0.033***	-0.009
			(0.007)	(0.008)	(0.007)	(0.006)
Winter Low (Average)			0.055***	0.052***	0.052***	0.009
			(0.011)	(0.012)	(0.011)	(0.011)
Snow Proxy			0.021+	0.033**	0.037**	0.008
			(0.014)	(0.016)	(0.015)	(0.009)
Summer High (Average)			-0.057***	-0.066***	-0.065***	-0.011
			(0.021)	(0.021)	(0.020)	(0.023)
Potential Cost Drivers:						
DOT Employment/Population (1,000)				-0.263+	-0.261+	0.022
				(0.165)	(0.158)	(0.113)
Number of Bidders				-0.011	-0.020	-0.083**
				(0.044)	(0.036)	(0.035)
Observations	250	250	250	250	247	94
R-squared	0.18	0.19	0.35	0.37	0.38	0.68

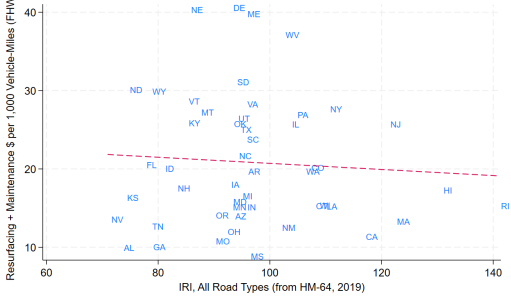
Back

Costs and Road Roughness

Back



(a) Our Cost per Mile

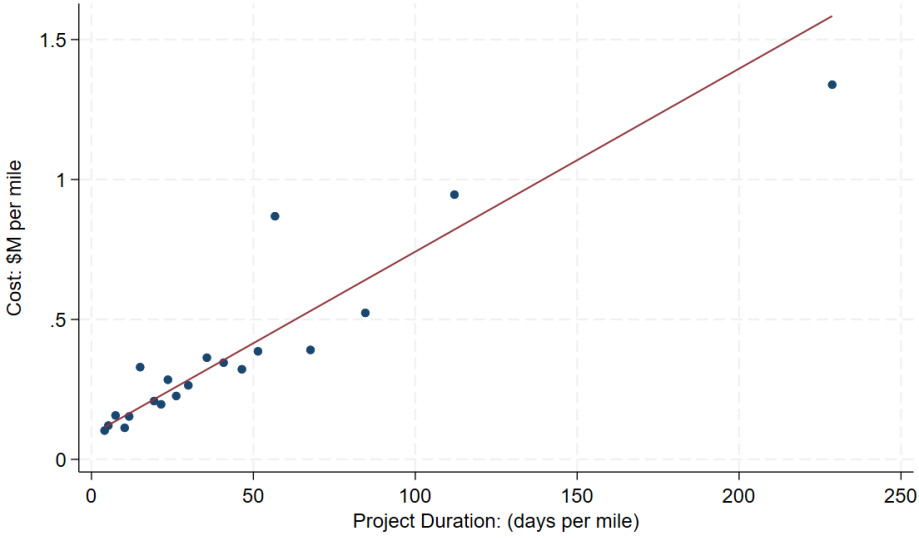


(b) FHWA $ per Vehicle-Mile

Project cost and duration are tightly correlated

Back

One SD increase in duration (50 days per mile) correlates with 43% higher costs per mile



Text responses on employee quality

Back (Descriptives) Back (Results)

Procurement officials:

- "We have a lot of talented individuals who are in the later stages of their career. Our issue in [state] is attracting new talent, the current candidate pool is very weak"
- "Open vacancies, and experienced staff either retiring or moving on, makes it difficult to train new hires with no experience or just out of college. It takes time to get them on board to produce contract plans and getting them up to speed on our standards. We also have hurdles with offering enough compensation to compete with private engineering firms."

Contractors

- "Those who can't, teach. Those who can't teach, work for []DOT"
- "Older employees tend to listen to contractors on how a project could be constructed. Newer employees tend to do things 'by-the-book' as they are usually unfamiliar with what the plans & specs require"

Text Responses on Competition

Back

- "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."

Contractors attribute lack of competition at subcontractor level to DBE

"It is hard to overstate the expense that the DBE, MBE, WBE program adds to the costs." Back