# State Capacity and Infrastructure Costs

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# How much is a good bureaucrat worth?

To deliver public goods the government needs enough capacity to operate effectively

This capacity includes the bureaucrats who implement policy, deliver goods, services

- Rising fiscal pressures limit state govts' ability to recruit and retain skilled employees
- Recent efforts to increase govt efficiency focused on reducing size of the federal workforce

Public procurement accounts for 25% of all government expenditures in the US

- Few government employees manage a tremendous amount of money

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How important is bureaucrat skill, experience? What are the implications for costs?

# State Capacity, Engineers, and Infrastructure Costs

We study these questions in the case of infrastructure provision in the US

- A setting where public concern is growing over both cost and quality More

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- Many channels for capacity to affect costs, both at agency and engineer level

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We will study "state capacity" broadly defined:

- The practices the agency (DOT) uses to plan, procure, manage projects, and
- The quantity and quality of the personnel (engineers)

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

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BUSINESS

ONLY IN NEWSDAY

## Shortage of engineers on Long Island delays projects, increases costs, leaders say

September 8, 2025 5:00 am

# What we do: 2 complementary sources of evidence

1. Descriptive findings on capacity and costs across states
    - Collect *project-level* cost data for all 50 states
    - Conduct a 50-state “management practices” style survey of state DOT practices (Bloom and Van Reenen, 2007; Bosio et al., 2022)

2. In-depth analysis on impact of DOT personnel in California
    - Universe of highway projects linked to personnel records
    - Measure engineer-level quality and district-level retirement shock

# Preview of Results

1. National state-by-state survey of experts and cost data
   - New, comparable cross-state measurement of highway construction costs!
   - Broad agreement that DOT staffing has declined; admin data confirms
   - Low capacity practices (consultants, poor planning) correlated with higher costs

2. Large impacts of personnel on construction costs in California
   - Higher quality engineers deliver projects at lower cost
     - Moving from 25th to 75th pctle of quality $\rightarrow$ 14% $\downarrow$ costs ($>$3x avg salary)
     - Employee quality most important in low-competition markets
   - Retirement shocks slow project timelines, increase costs
     - Experienced workers more than pay for themselves 6:1

$\Rightarrow$ DOT should be willing to offer private sector wage to retain experienced engineers

Contribution and Literature

# Background and New Data
# on Infrastructure Delivery and Costs

# Highway construction and procurement in the U.S.

U.S. government spent $266B on highways in 2022 ($27B on transit)

Government itself does not build infrastructure; it procures it

- Complicated public good provision problem
- Government engineers need to design, contract, and supervise construction

| planning | → | bid letting | → | evaluate bids | → | construction |
|---|---|---|---|---|---|---|
| *plan the project* | | *open the bidding* | | *award the project* | | *firm completes work* |
| draw up plans | | publish plans, docs | | firms submit unit bids | | DOT inspects/oversees |
| estimate project cost | | advertise project | | lowest bidder wins | | negotiate change orders |

Example Project | Example Change Orders

# Two data collection efforts

1. We collect data from each of the 50 states on *project-level* costs
   - Data on realized costs collected via public records requests
     - Additional variables collected from bid lettings, project plans, google maps
   - Focus on resurfacing projects for descriptive exercise
     - We create like-for-like measure of cost per mile—our focus is total cost, not overrun

2. We conduct a survey of state DOTs and local contractors
   - We adapt World Bank "Doing Business" Procurement Survey to U.S. context
   - Survey design benefits from a rich empirical and theoretical IO literature (e.g. Krasnokutskaya and Seim, 2011; Balat, 2012; Bajari et al., 2014)
   - Questions framed around "case study" resurfacing project
     - Modal project done by state DOTs More
   - Sample: 123 DOT employees in 50 states, 211 contractors in 47 states Map

# Survey respondents emphasize two main concerns

1. DOT capacity More
   - Understaffing is big concern (88% of DOT officials and 59% of contractors)
     - Confirmed in admin data (Census Annual Survey of Public Emp.) More
   - Reliance on consultants increases costs (64% of officials, 78% of contractors)
   - Changes in project scope #1 reason for cost overrun.

2. Competition among contractors More
   - Competition is most cited cost driver in free-response, though DOTs rarely do outreach to increase bidder pool (less than 20% of projects More)
   - Only 6% of states say that there are often firms bidding they don't know/expect.

**Take to cost data:** Lower capacity practices correlate with higher costs More

- Consultants, administrative burden, change orders correlate with higher cost per mile
- Practices that increase competition (i.e. outreach) correlate with lower cost per mile

# Evidence from California: Government Engineers

# Investigate role of capacity as a cost driver in California

Focus on employee quality and retirements; frequent concern in survey, e.g.:

*"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"*

*"Competent but increasingly short staffed and less experienced employees with a high turnover"*

*"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."*

*"The DOT workforce is getting younger and less experienced all of the time. This impacts work through delay in decision making and poor decision making."*

*"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."*

# Caltrans employs 7,000 engineers across 12 districts

Administrative data: Highway construction projects (bridge, road, maintenance), including cost, project description, and identity of key personnel

- Engineer FE explain 7% of variation in costs, but many engineers have few projects
- We match each engineer to salary and benefit data from "Transparent California."

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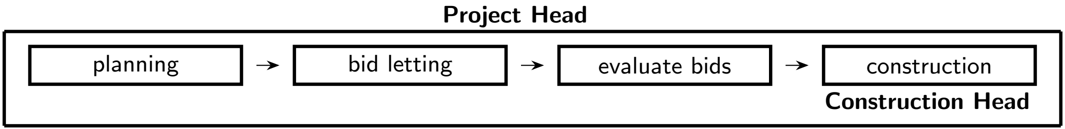
*What do Caltrans engineers do?*




Multiple engineers and other personnel are involved in delivery of a Caltrans project.

1. **Project Head** is in charge of entire project—can affect costs in multiple stages
2. **Construction Head** affects costs by working to control overruns and delays

# *Evidence from California*: Quality and Costs

# How to measure engineer quality?

We use residualized compensation as our measure of engineer quality

Caltrans engineer compensation follows rigid pay schedule:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3135 | TRANSPORTATION ENGINEER (CIVIL) | | | | | | | |
| | A | \$6,299.00 - \$7,510.00 | 01 19 21 | 289 | 1 | 12 | 2 | R09 |
| | B | \$7,212.00 - \$9,025.00 | 01 19 21 | 289 | 1 | 12 | 2 | R09 |
| | C | \$8,637.00 - \$10,807.00 | 01 19 21 | 289 | 1 | 12 | 2 | R09 |
| | D | \$9,429.00 - \$11,798.00 | 01 19 21 | 289 | 1 | 12 | 2 | R09 |

We regress job title and year dummies on compensation (salary+benefits)

- This explains over 80% of variation in data Results
- We attribute residual to engineer "quality" Distribution
  - Employees receive raises by moving within and across pay ranges with experience, performance, and investment in quality
  - Our quality measure correlates with noisy measure of years of experience Sanity Check

# Quality and costs: Empirical approach

Each project, $i$, is indexed by:

- County, $c$, highway route, $r$, district, $d$, year $t$, job title of Construction Head, $j$
- Project characteristics, $X_i$: mileage, project type, project type × mileage

Outcomes, $Y$, include log(cost per mile), cost overrun, and duration:

$$
\begin{aligned}
Y_{ijrcdt} = & \beta_1 \text{ Quality CH}_i + \beta_2 \text{ Quality PH}_i + \beta_3 \text{ Quality CH}_i \times \text{Quality PH}_i \\
& + X_i + \nu_r + \phi_c + \gamma_d + \phi_t + \alpha_j + \epsilon_{ijrcdt}.
\end{aligned}
$$

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**Engineer Assignment:**

- If lower quality engineers are assigned to more complicated projects then negative relationship between quality and cost due to assignment, not quality
- Institutional details suggest the opposite More

# Engineer quality and project-level costs

| | log(Cost per Mile) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Quality of: | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Construction Head | -0.05 | | | 0.03 | | | -0.01 | | |
| | (0.05) | | | (0.04) | | | (0.04) | | |
| Project Chars | | | | × | × | × | × | × | × |
| County, Route FE | | | | | | | × | × | × |
| Adj. R-squared | 0.03 | 0.04 | 0.04 | 0.44 | 0.45 | 0.45 | 0.46 | 0.46 | 0.46 |
| Observations | 1,733 | 1,733 | 1,733 | 1,733 | 1,733 | 1,733 | 1,687 | 1,687 | 1,687 |

District and Year FE included in all specifications. Robust to wild bootstrap cluster at District level.

- No relationship between Construction Head quality and costs

# Engineer quality and project-level costs

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| | (0.05) | | | (0.04) | | | (0.04) | | |
| Project Head | | -0.11** | | | -0.11*** | | | -0.11** | |
| | | (0.05) | | | (0.04) | | | (0.04) | |
| Project Chars | | | | × | × | × | × | × | × |
| County, Route FE | | | | | | | × | × | × |
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- No relationship between Construction Head quality and costs
- One SD ↑ in Project Head quality associated with 11% ↓ in cost/mile

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| Project Head | | -0.11** | -0.11** | | -0.11*** | -0.11*** | | -0.11** | -0.11** |
| | | (0.05) | (0.05) | | (0.04) | (0.04) | | (0.04) | (0.04) |
| Qual. CH × PH | | | -0.04 | | | -0.05* | | | -0.05+ |
| | | | (0.04) | | | (0.03) | | | (0.03) |
| Project Chars | | | | × | × | × | × | × | × |
| County, Route FE | | | | | | | × | × | × |
| Adj. R-squared | 0.03 | 0.04 | 0.04 | 0.44 | 0.45 | 0.45 | 0.46 | 0.46 | 0.46 |
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District and Year FE included in all specifications. Robust to wild bootstrap cluster at District level.

- No relationship between Construction Head quality and costs
- One SD ↑ in Project Head quality associated with 11% ↓ in cost/mile
- High quality Construction + Project Heads together *further* decreases costs

# Engineer quality and project-level costs

Construction Head only reduces total costs when paired with high-quality Project Head

- Constrained by decisions made in project planning and bid-letting phases
- When we look only at cost *overrun*, Construction Head quality lowers costs More

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- When we look only at cost *overrun*, Construction Head quality lowers costs More

Moving from $25^{th}$ to $75^{th}$ percentile of Project Head quality: 14% decrease in costs

- For the median project, this is $384,000 in cost savings

Survey responses provide useful context for interpreting quality results:

- Lack of experience, knowledge, can affect planning ("*they send the project out to bid even though its missing a lot of details*"), bid letting ("*unfamiliar with what the plans & specs require*"), and construction in the field ("*hesitant to make simple decisions*")
- High variance in quality ("*some are really good and some are pretty bad*"), which can even affect participation into projects (i.e., firms avoid working with certain engineers)

→ We find quality has a larger effect in markets with less competition More

# *Evidence from California*: Retirements and Costs

# Do retirements of DOT engineers affect procurement outcomes?

Variation in state capacity arising from engineer retirements

- Institutional knowledge departs district with retirement
- Possible workload effects

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Variation in state capacity arising from engineer retirements

- Institutional knowledge departs district with retirement
- Possible workload effects

We study retirement "shocks" at the district level:

$$Y_{d,t} = \beta_0 + \beta_1 \frac{\text{Retirements}}{\text{Engineer}}_{d,t} + \beta_2 \text{ \# of Projects} + \gamma_d + \phi_t + \epsilon_{d,t}$$

- $Y_{d,t}$: Outcome (total cost, cost overrun, duration) for district $d$ in year $t$
  - Outcomes for projects that *start* in $t$, i.e. awarded in year of shock Assumption
- $\frac{\text{Retirements}}{\text{Engineer}}_{d,t}$: Retirement shock (%) for district $d$ in year $t$ Distribution
- # of Projects: Number of projects that are awarded in year $t$ for district $d$
- District, Year FE

# Engineer retirements and district-level procurement outcomes

| | log(Total Cost ($)) | | Cost Overrun (%) | | Duration (Days) | |
|---|---|---|---|---|---|---|
| | Mean | Median | Mean | Median | Mean | Median |
| $\frac{\text{Retirements}}{\text{Engineers}}$ (%) | 0.043** | 0.023 | 0.380* | 0.351** | 11.735*** | 7.564+ |
| | (0.018) | (0.015) | (0.204) | (0.149) | (3.704) | (4.367) |
| R-squared | 0.73 | 0.71 | 0.60 | 0.61 | 0.70 | 0.66 |
| Observations | 228 | 228 | 228 | 228 | 228 | 228 |
| Dep. Var. Mean | 13.90 | 13.75 | 6.80 | 4.90 | 365.53 | 285.54 |

District and Year FE included in all specifications. Robust to wild bootstrap cluster at District level.

One percentage point ↑ in retirements for engineers is associated with:

- 4.3% increase in mean costs Reconciling with quality result Increase in cost 6x the benefit
- 0.38 percentage point increase in mean overrun (5.6%)
- 11.7 day increase in mean duration (3.2%)

# Back of the Envelope: How much is a good bureaucrat worth?

Results suggest high value of quality, high cost to losing experience to retirement

- DOT should like to retain high-quality employees and prevent early retirements
- Pension data suggest many engineers retire soon after pension threshold (50yo)
    - Partly the result of wage compression in public sector (Katz and Krueger, 1991)

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How much would government be WTP to retain experienced, high-quality engineers?

- Level effect: 1 sd in quality reduces costs by \$480k/mile, \$1.44M/ project
- Project heads work on 0.52 projects per year, at median (0.65 at mean)
  $\rightarrow$ 1 sd in quality worth \$749,000 in cost savings, per engineer-year
  (\$475,000 under assumption of 1 project per 3 years)
- Average Project Head makes \$154k in salary and benefits; $99^{th}$ pctle make \$196-216k
  - In comparison, senior engineer make \$210-\$380k in the private sector (Glassdoor)

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*Offering private sector wage to retain experienced employees would* **reduce** *total costs*

# Discussion: Public Sector Capacity

Rising fiscal pressures have limited govt ability to recruit and retain skilled employees

- Especially at state level, given balanced budget requirements
- Recent attempts to increase government efficiency have focused on reducing the size of federal bureaucracy—encouraging early retirements—in the name of cost saving.

Overregulation may be a reason experience is so valuable in this setting
(Klein and Thompson, 2025; Bosio et al., 2022)

- New employees unfamiliar with many rules, requirements, and specifications
- Admin burden, proxied by length of required bid documents, correlated with higher costs

Expensive government provision can get even more expensive if governments lack the capacity to plan, contract, and supervise well

# Bonus Slides

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

U.S. government 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 about 3x OECD average (Goldwyn et al., 2023)

Growing concern that the quality of infrastructure is declining across the United States (American Society of Civil Engineers, 2021)

> *"1 in 5 miles of highways and major roads, and 45,000 bridges, are in poor condition."*
>
> – 2021 Bipartisan Infrastructure Bill

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Jul 24, 2019

# Congress request for GAO Back

> Not later than 9 months after the enactment of this act, the GAO shall report to the House and Senate Committees on Appropriations regarding the construction costs of transit capital projects in the United States in comparison to other developed G-20 nations, such as South Korea, Japan, Spain, France, Italy and Germany. The GAO shall examine potential cost drivers, including: contracting and procurement, project and station design, routing, regulatory barriers, interagency cooperation and legal systems, but not those which are required by Federal law.

Sixteen months later, the GAO has produced its report, and it doesn't actually perform the cost comparisons as instructed.

"The complexity of rail-transit construction projects and data limitations, among other things, limits the ability to compare the costs of these projects, according to the stakeholders we interviewed," the GAO explained. They noted a number of very real problems that make useful international comparisons difficult. For example: Projects are built in different contexts, requiring different construction methods; sometimes they require the purchase of expensive land and sometimes they do not; different authorities report costs by different methods, and there are some cost categories (such as financing costs) that are counted in some reports but not in others.

# Contribution and Literature Back

We quantify the value of high-quality bureaucrats

- Contribute to a growing literature measuring effectiveness of public-sector managers and agency-level management practices (e.g., Muñoz and Otero, 2025; Fenizia, 2022; Rasul and Rogger, 2017), and more specifically on state capacity and procurement (Bandiera et al., 2009, 2021; Best et al., 2023; Decarolis et al., 2020)
- Most govt managers produce outcomes that aren't observable to researchers
  - Infrastructure provision allows us to link engineer to project costs
  - Engineer can affect costs via planning, contracting, managing project
  - Survey highlights *how* agencies and individuals can matter for state effectiveness

We provide an additional explanation for high cost of building infrastructure in US

- Citizen voice (Brooks and Liscow, 2023); Competition (Currier, 2025); Overregulation (Klein and Thompson, 2025; Liscow, 2025); Overbuilding (Goldwyn et al., 2023); Productivity (Goolsbee and Syverson, 2023); Usage (Turner et al., 2023)

# Example project Back

**Project:** "grading, bituminous mill, and overlay" for 12 miles of MN State Highway 28

**Winning Bid:** \$2.50M (lowest of 5 bidders)

**Realized Spending:** \$2.58M

- Differences in bid and cost can be result of changes in quantities, materials, scope

(a) Mill

(b) Overlay

(c) Finished Product

# Example project: Proposal

Back

**MINNESOTA DEPARTMENT OF TRANSPORTATION**

395 JOHN IRELAND BOULEVARD MS 650 ST. PAUL, MINNESOTA 55155-1800

*********************** P R O P O S A L ***********************

FOR HIGHWAY CONSTRUCTION AND MAINTENANCE PROJECTS WITH

BIDS RECEIVED UNTIL 9:30 O'CLOCK A.M. ON

**MARCH 23, 2018**

Proposal of ____

Central Specialties, Inc.
6325 County Road 87 SW
Alexandria, MN 56308
(320) 762-7289

TO FURNISH AND DELIVER ALL MATERIALS AND TO PERFORM ALL WORK IN ACCORDANCE WITH THE CONTRACT, THE PLANS AND THE APPROVED DEPARTMENT OF TRANSPORTATION "STANDARD SPECIFICATIONS FOR CONSTRUCTION, **2018 EDITION" (USING ENGLISH UNITS)**, ON FILE IN THE OFFICE OF THE COMMISSIONER OF TRANSPORTATION EXCEPT AS STATED OTHERWISE IN THE SPECIAL PROVISIONS, WHICH ARE PART OF THIS PROPOSAL, FOR:

**PRIME SP:** 0606-11 **CONTRACT ID:** 180056

**STATE PROJECT NO.:** 0606-11 (TH 28=028), 7503-39 (TH 28=028)

**FHWA PROJECT NO.:** STPF 0618 (175)

**LOCATION:** In Big Stone and Stevens Counties on TH 28 from TH 75 to 510 Feet E of 610th Avenue

**TYPE OF WORK:** Grading, Bituminous Mill and Overlay

**LENGTH:** 12.280 Miles

**STARTING DATE:** May 07, 2018

**COMPLETION DATE:** 25 WD

# Example project: Plans

Back

# MINNESOTA DEPARTMENT OF TRANSPORTATION

CONSTRUCTION PLAN FOR GRADING, BITUMINOUS MILL & OVERLAY

LOCATED ON TH 28 FROM TH 75 TO 510' E. OF 610TH AVE.

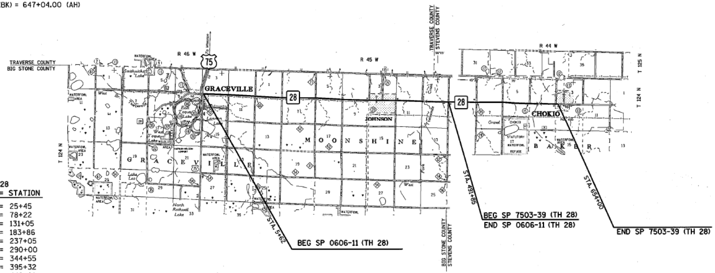
STATE PROJ. NO. 0606-11 (TH 28)
GROSS LENGTH 48622.80 FEET 9.209 MILES
BRIDGES-LENGTH FEET MILES
EXCEPTIONS-LENGTH FEET MILES
NET LENGTH 48622.80 FEET 9.209 MILES
REF. POINT 22+00.600 TO REF. POINT 31+00.833

STATE PROJ. NO. 7503-39 (TH 28)
GROSS LENGTH 16215.63 FEET 3.071 MILES
BRIDGES-LENGTH FEET MILES
EXCEPTIONS-LENGTH FEET MILES
NET LENGTH 16215.63 FEET 3.071 MILES
REF. POINT 31+00.833 TO REF. POINT 34+00.900

PLOTTED/REVISED: 10-JAN-2018

**TH 28 EQUATIONS**

55+33.37 (BK) = 55+29.24 (AH)
109+31.13 (BK) = 109+32.60 (AH)
117+34.97 (BK) = 117+36.77 (AH)
159+89.73 (BK) = 159+90.12 (AH)
198+82.31 (BK) = 198+83.29 (AH)
228+13.33 (BK) = 228+12.10 (AH)
252+51.49 (BK) = 252+53.08 (AH)
279+23.86 (BK) = 279+22.14 (AH)
307+71.59 (BK) = 307+72.00 (AH)
332+71.71 (BK) = 332+70.83 (AH)
384+63.87 (BK) = 384+64.75 (AH)
403+16.36 (BK) = 403+16.26 (AH)
438+44.08 (BK) = 438+42.86 (AH)
458+59.14 (BK) = 458+60.63 (AH)
489+61.42 (BK) = 489+61.89 (AH)
509+37.30 (BK) = 509+36.27 (AH)
538+28.73 (BK) = 538+29.83 (AH)
566+46.72 (BK) = 566+46.86 (AH)
594+24.99 (BK) = 594+25.40 (AH)
647+05.25 (BK) = 647+04.00 (AH)




TH 28

| REF. POST | = | STATION |
|---|---|---|
| 23+00.000 | = | 25+45 |
| 24+00.000 | = | 78+22 |
| 25+00.000 | = | 131+05 |
| 26+00.000 | = | 183+86 |
| 27+00.000 | = | 237+05 |
| 28+00.000 | = | 290+00 |
| 29+00.000 | = | 344+55 |
| 30+00.000 | = | 395+32 |
| 31+00.000 | = | 448+01 |
| 32+00.000 | = | 500+78 |
| 33+00.000 | = | 553+98 |
| 34+00.000 | = | 606+77 |
| 35+00.000 | = | 659+30 |

SCALES

PLAN — 50 FEET
INDEX MAP — 1 MILE
GENERAL LAYOUT — 500 FEET

PLAN REVISIONS

| DATE | SHEET NO. | APPROVER |
|---|---|---|

FILENAME: Projects\D4_DLK\028\0606\0l\Design\PlanSheets\4d0606ll_tshdgn

DESIGN DESIGNATION

Design ESALS 2016 = 1,225,000
ADT (Current Year) 2016 = 1250 Design Speed 70 MPH
ADT (Future Year) 2036 = 1585 Based on STOPPING Sight Distance
DHV (Design Hr. Vol.) = 190 Height of eye 3.75' Height of object 0.5'

PROJECT LOCATION

FOR PLANS AND UTILITIES SYMBOLS SEE TECHNICAL MANUAL

| STATE PROJ. NO. | CHARGE IDENTIFIER |
|---|---|
| 0606-11 | |
| 7503-39 | |

GOVERNING SPECIFICATIONS

THE 2018 EDITION OF THE MINNESOTA DEPARTMENT OF TRANSPORTATION "STANDARD SPECIFICATIONS FOR CONSTRUCTION" SHALL GOVERN.

INDEX



THIS PLAN CONTAINS 47 SHEETS

I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

PRINT NAME: BRIDGET MILLER LICENSE # 43947
DATE: 1-10-18 SIGNATURE: Bridget Miller
DESIGN SQUAD Ben. Greisen

RECOMMENDED FOR APPROVAL Shiloh Wahl 1-10 2018
FOR DISTRICT TRANSPORTATION ENGINEER

RECOMMENDED FOR APPROVAL 1-10 2018
DISTRICT MATERIALS ENGINEER

RECOMMENDED FOR APPROVAL 1-10 2018
FOR DISTRICT WATER RESOURCES/HYDRAULICS ENGINEER

RECOMMENDED FOR APPROVAL 1-10 2018
DISTRICT TRAFFIC ENGINEER

RECOMMENDED FOR APPROVAL 1/29 2018
STATE PRE-LETTING ENGINEER

OFFICE OF LAND MANAGEMENT APPROVAL 1/29 2018
DIRECTOR, LAND MANAGEMENT

APPROVED 1/29 2018
STATE DESIGN ENGINEER

I HEREBY CERTIFY THAT THE FINAL FIELD REVISIONS, IF ANY, WERE PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

PRINT NAME: LICENSE #
DATE: SIGNATURE:

# Example project: Bidding

Back

Minnesota Department of Transportation

**Contract Schedule** Page 1 of 5

**Contract ID:** 180056 **Project(s):** 120094, 127789

**Apparent Low Bidder:** 0000207897 Central Specialties, Inc.

**SECTION 0001** **SP 0606-11** **$2,503,227.55**

**Alt Set ID:** **Alt Mbr ID:**

| Proposal Line Number | Item ID / Description | Approximate Quantity and Units | Unit Price Dollars | Unit Price Cents | Bid Amount Dollars | Bid Amount Cents |
|---|---|---|---|---|---|---|
| 0035 | 2104502/00130<br>REMOVE PIPE APRON | 42.000<br>EACH | 150 | | 6,300.00 | |
| 0040 | 2104503/00195<br>SAWING CONCRETE PAVEMENT (FULL DEPTH) | 264.000<br>L F | 4 | | 1,056.00 | |
| 0045 | 2104503/00205<br>SAWING BITUMINOUS PAVEMENT (FULL DEPTH) | 411.000<br>L F | 1.50 | | 616.50 | |
| 0050 | 2104503/00255<br>REMOVE PIPE CULVERTS | 934.000<br>L F | 14 | | 13,076.00 | |
| 0055 | 2104504/00070<br>REMOVE PAVEMENT | 2,212.000<br>S Y | 20 | | 44,240.00 | |
| 0060 | 2104504/00120<br>REMOVE BITUMINOUS PAVEMENT | 1,050.000<br>S Y | 10 | | 10,500.00 | |
| 0065 | 2105603/00060<br>DITCH CLEANING | 1,351.000<br>L F | 10 | | 13,510.00 | |

# Example Change Orders Back

https://dot.ca.gov/programs/construction/change-order-information

**Change Orders** are ex post changes to the original contract between the bidder (contractor) and the DOT.

- "Differing Site Conditions"
  - Contractor encountered subsurface rock when excavating a structure: $12,000
- "Change in Materials"
  - Pre-specified material not functioning well, contractor had to redo work with new material: $404,250
- "Compensation for Critical Delay"
  - Work stoppage to move waterline, cost for time delay, moving equipment, idle equipment: $12,203
- Other common reasons: "Increase in Bid Item Quantities," "Item Adjustment," "Item Increase/Decrease and Extra Work, "Value Engineering Change Proposal"

# Observables explain almost 40% of cost variation Back

| | Project-Level Log(Cost/Mile) | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| *Project Details:* | | | |
| Complex Dummy | 0.932*** | 0.818*** | |
| | (0.281) | (0.282) | |
| Mileage | -0.024*** | -0.023*** | -0.067*** |
| | (0.004) | (0.004) | (0.011) |
| *Local Characteristics:* | | | |
| Log(Population Density) | 0.067+ | 0.052 | 0.067 |
| | (0.040) | (0.041) | (0.049) |
| Log(Wages in Hwy Construction) | 0.344* | 0.064 | 0.174 |
| | (0.196) | (0.176) | (0.268) |
| *State Characteristics:* | | | |
| Snow Proxy | 0.021+ | 0.019 | 0.022+ |
| | (0.014) | (0.015) | (0.014) |
| Summer High | -0.057*** | -0.039* | -0.035* |
| | (0.021) | (0.021) | (0.019) |
| Roughness Index | | 0.017*** | 0.013** |
| | | (0.005) | (0.006) |
| Observations | 250 | 250 | 2,210 |
| R-squared | 0.35 | 0.39 | 0.31 |

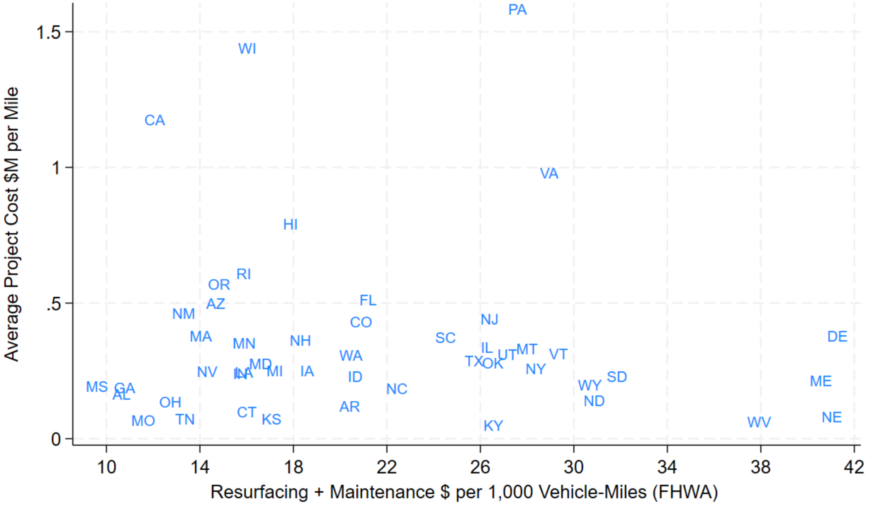
# Our data outperforms the highway administration data

Back

| | Project-Level Log(Cost/Mile) | | | State-Level | |
|---|---|---|---|---|---|
| | | | | Our Data | FHWA |
| | (1) | (2) | (3) | (4) | (5) |
| *Project Details:* | | | | | |
| Complex Dummy | 0.932*** | 0.818*** | | | |
| | (0.281) | (0.282) | | | |
| Mileage | -0.024*** | -0.023*** | -0.067*** | | |
| | (0.004) | (0.004) | (0.011) | | |
| *Local Characteristics:* | | | | | |
| Log(Population Density) | 0.067+ | 0.052 | 0.067 | | |
| | (0.040) | (0.041) | (0.049) | | |
| Log(Wages in Hwy Construction) | 0.344* | 0.064 | 0.174 | | |
| | (0.196) | (0.176) | (0.268) | | |
| *State Characteristics:* | | | | | |
| Snow Proxy | 0.021+ | 0.019 | 0.022+ | 0.204* | -0.014 |
| | (0.014) | (0.015) | (0.014) | (0.107) | (0.080) |
| Summer High | -0.057*** | -0.039* | -0.035* | -0.047** | -0.015 |
| | (0.021) | (0.021) | (0.019) | (0.022) | (0.015) |
| Roughness Index | | 0.017*** | 0.013** | 0.024*** | -0.001 |
| | | (0.005) | (0.006) | (0.005) | (0.004) |
| Observations | 250 | 250 | 2,210 | 49 | 49 |
| R-squared | 0.35 | 0.39 | 0.31 | 0.39 | 0.11 |

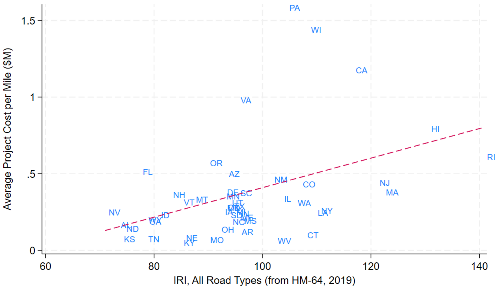
Raw Data

# Cost per mile vs. FHWA spend per vehicle-mile Back

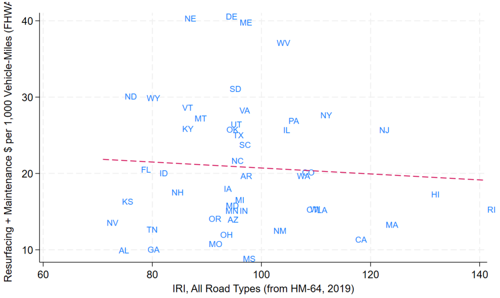


# Cost data and road roughness

Back



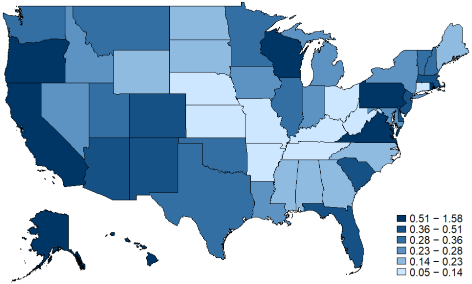

(a) Cost per mile and roughness



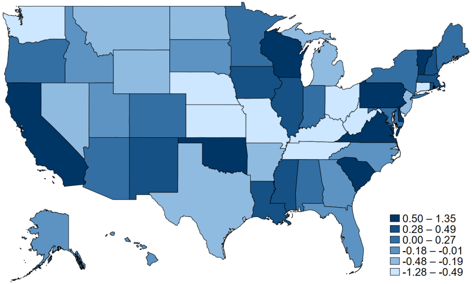

(b) FHWA $ per vehicle-mile and roughness

# Cost per mile, conditional on observables

Back




(a) State-level cost per mile ($M)




(b) State-level residual cost per mile

# 5 sets of hypotheses about cost drivers Back

We ask about a variety of features of the procurement and construction processes, all which have the potential to affect costs, in order to test hypotheses from the literature.

1. Transparency
   - Public availability of documents such as the engineer's estimate, number of registered bidders, and details of past contracts
2. Competition
   - Outreach, advertising of bid letting, and the number of bidders
3. Controls for quality
   - Bidder pre-qualification and bid screening
4. Capacity of agency
   - Renegotiation, changes in the project details, and timing of payments
5. Corruption

\+ Free-form questions about what proc. officials and contractors *think* drive costs

# Survey case study: Resurfacing of state highways Back

This is the modal project done by state DOTs

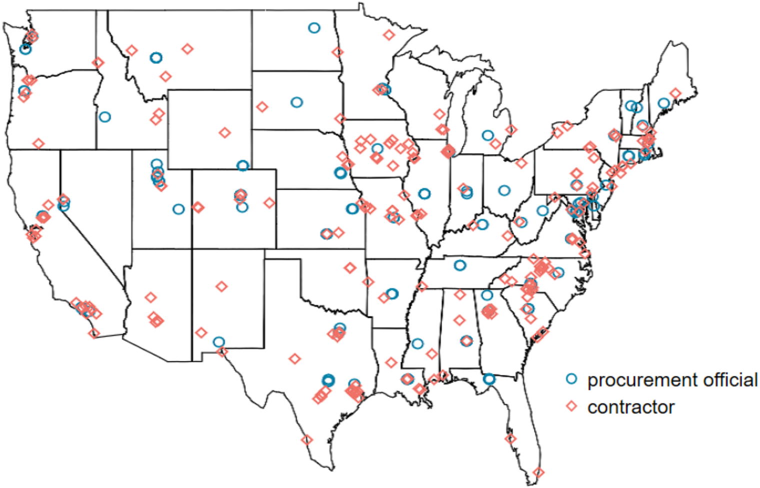
- 5 mile resurfacing of 2-lane highway
- Estimated contract value: \$1-5 million

Why focus on resurfacing?

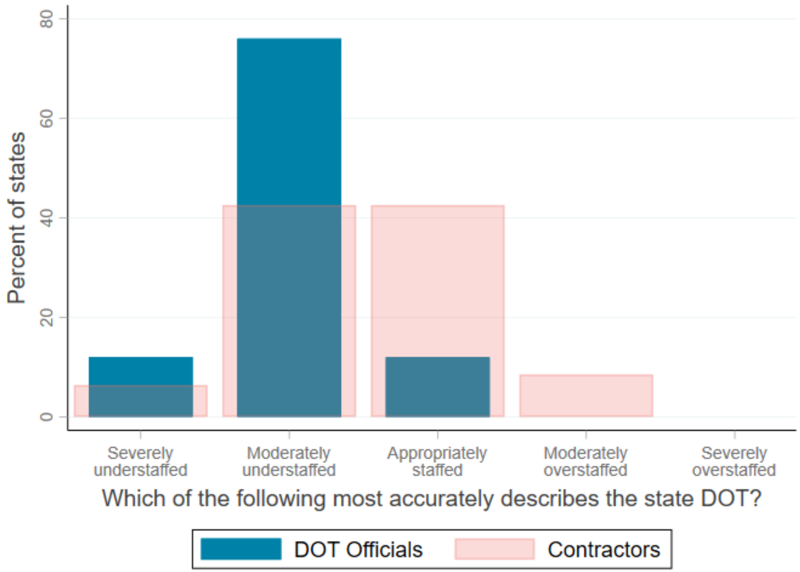
- Road building projects are more complicated, more discretion in procurement process (design-build contracts, consider quality as well as cost)
  - All states use unit bidding for resurfacing projects
- However, many states are not building new roads
  - Rehabilitation of roads [2004-2014]: 47 $\rightarrow$ 72 % of total capital outlays (FHWA 2019)

- Abstracts from issues of litigation, "citizen voice"
- External validity: Challenges for procurement of simple projects likely also evident, if not amplified, for complicated ones

# Geographic distribution of survey responses Back

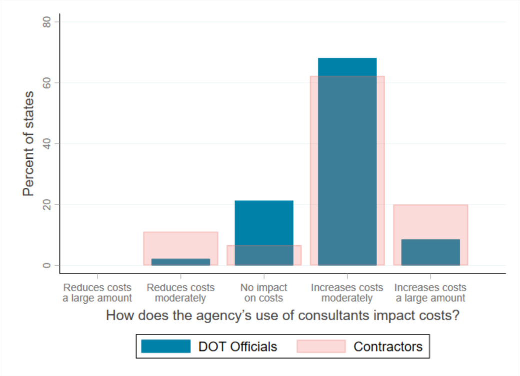


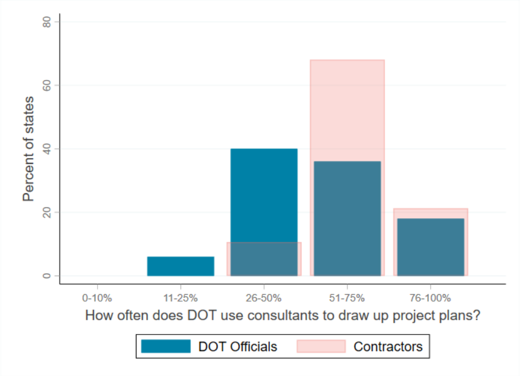
# Consensus: State DOTs are understaffed Back



# Consensus: Consultant use drives up costs Back

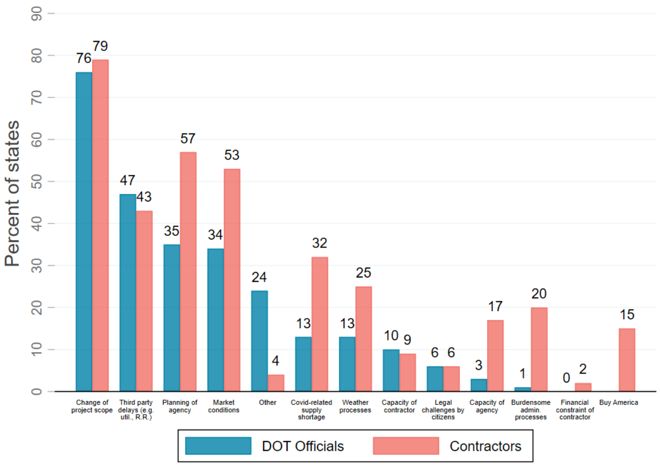
## Variation across states in consultant use, despite cost




- Capacity constrained DOTs outsource to consultants (GAO, 2008; TxDOT, 2010)

# Change of project scope is top reported reason for overruns Back




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

- Change of project scope a direct consequence of poor planning

# 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"

# Descriptives: Competition Back

- Competition is one of the top cited cost drivers ($\sim$20% of responses)
  - Both procurement officials and contractors emphasize competition as a cost driver in free response More
- 30% of projects in our dataset have $\leq$2 bidders
  - One additional bidder correlates with 8.3% lower costs per mile More (similar magnitude to Allende et al. (2024) on pharmaceuticals)
  - Only 6% of surveyed contractors report firms bidding they do not expect (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
- Further, states do minimal outreach to increase number of bidders More

# 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."

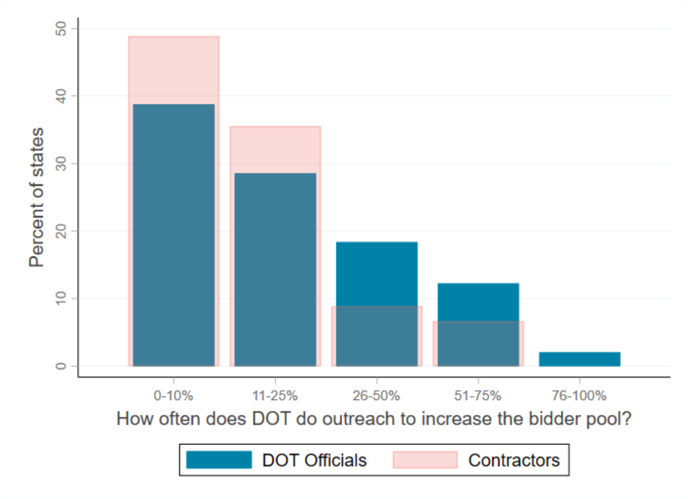
"Advertising period (Inadequate or too short of an advertising period, time of year chosen to advertise, other projects in the area that will be ongoing simultaneously)"

"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)

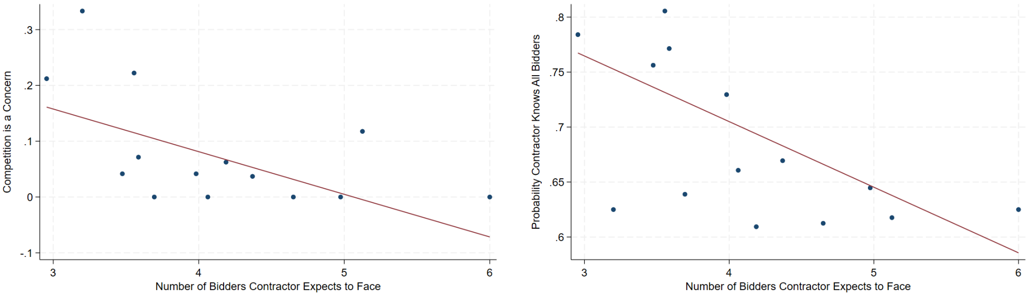
"Limited funds cause limited projects cause limited contractors cause limited competition. Years of limited work has caused many contractors to get out of the business. Now we have very few contractors. Limited competition causes higher prices."

# States do minimal outreach to increase # of bidders Back




On average, less than 20% of projects involve outreach

# Contractor survey responses on competitors Back



# Taking the cost data to the survey Back

We correlate costs with 79 survey responses:

- Control for observables ($\sim$40% of variation, observables + survey vars is 60%)
- Independently—given multiple hypothesis correction—few survey vars have a statistically significant correlation with costs Housekeeping

# Taking the cost data to the survey Back

We correlate costs with 79 survey responses:

- Control for observables ($\sim$40% of variation, observables + survey vars is 60%)
- Independently—given multiple hypothesis correction—few survey vars have a statistically significant correlation with costs Housekeeping

Significant correlations affirm two stated cost drivers, e.g.,

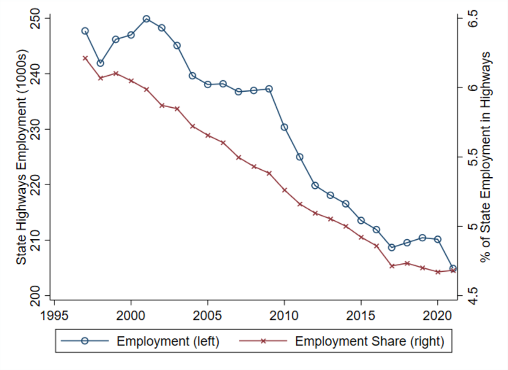
- Capacity: States with more change orders have higher costs
  - Change orders symptom of poor planning, given simple case study project
  - 1 SD increase in change orders $\rightarrow$ \$60,000 increase per lane-mile
- Competition: DOTs that do more bidder outreach have lower costs
  - 1 SD increase in bidder outreach correlates with 18% lower costs (\$1M/project)
- Other significant correlations on capacity (consultants, administrative processes) and competition (subcontracting limits) Results

# Costs, DOT Capacity, Admin Burden, and Competition

| | Log(Cost per Mile) | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Highway Employment per Capita (1,000) | -0.263+ | -0.245 | 0.022 |
| | (0.164) | (0.229) | (0.113) |
| Bid Document Page Length (per 10 pages) | | 0.025* | |
| | | (0.013) | |
| Number of Bidders | | | -0.083** |
| | | | (0.035) |
| Engineer's Estimate (log(Cost per Mile)) | | | 0.838*** |
| | | | (0.158) |
| Observations | 250 | 125 | 94 |
| R-squared | 0.37 | 0.50 | 0.68 |

Back

# *Decrease* in DOT staffing confirmed in administrative data ●Back

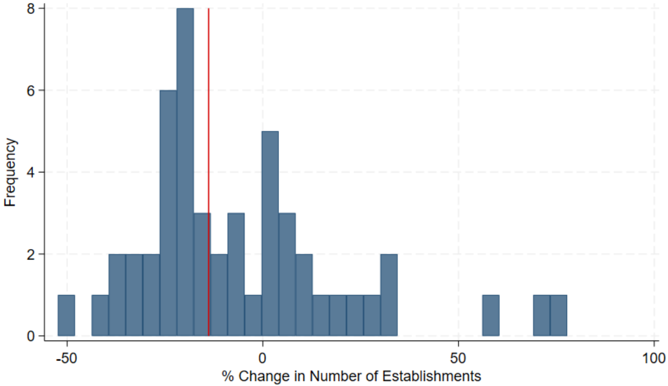



20% drop in state highway employment from 1997-2021 (U.S. Census Bureau, 1997-2021)

- Changes in employment, at the state-level, correlate with staffing concerns
- Increase in DOT employment per capita (1,000) correlates with 26% lower costs

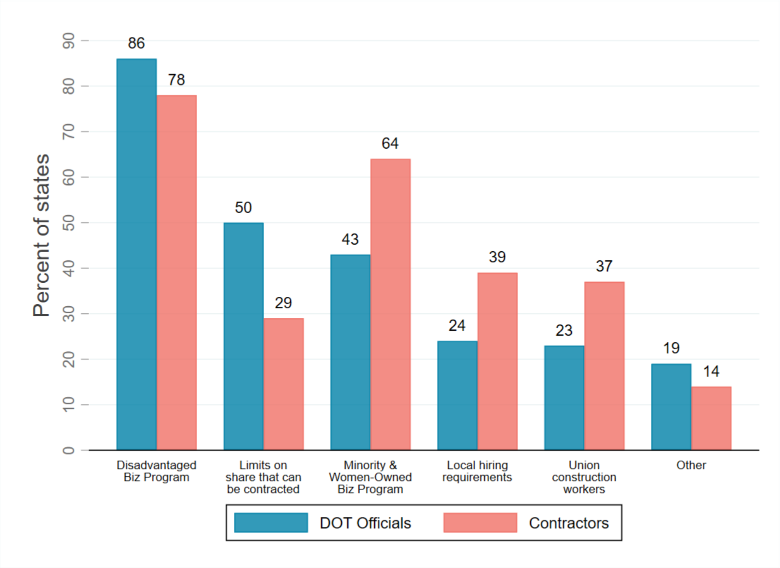
# Trends in the highway construction industry Back

Changes in highway construction establishments: 2007-2017



# 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



# Free response, categorized Back

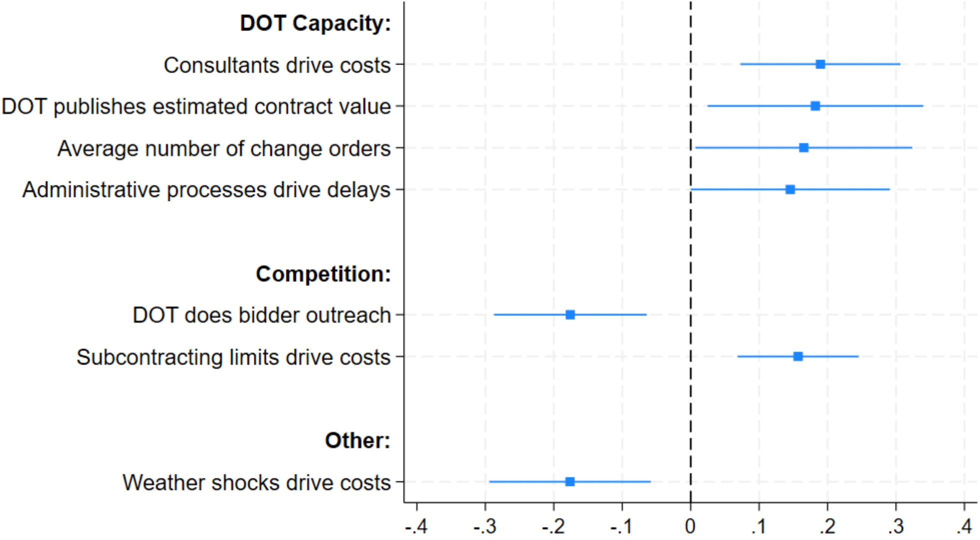
Question: What do you think are the main aspects of the procurement and administrative process...that increase construction costs?

| Category | N | % | List of Phrases |
|---|---|---|---|
| Competition | 434 | 18.66 | bid, available/availability (without material), dbe, competition, subcontract, limit contract, advertise, wbe |
| Materials and Labor | 417 | 17.93 | price, wage, material, labor, davis bacon, fuel, asphalt, cement, market condition, supply chain, equipment |
| Project Plans and Scope | 388 | 16.68 | plan, change, poor, detail, document, specification, scope, design, error, consult |
| Bureaucracy and Red Tape | 324 | 13.93 | paper, certify, red tape, overhead, bureaucrat, admin, require, federal, buy america |
| Risk and Complexity | 222 | 9.55 | risk, insurance, uncertainty, complex, night, traffic, utility(ies), right way |

# Correlations: Housekeeping Back

- We have 5 projects per state that match the resurfacing project in the case study
- We use the project details, local characteristics, and weather as controls
- We standardize the survey responses to mean 0, sd 1
- We cluster standard errors at the state level
- We apply Romano-Wolf multiple hypothesis correction

# Significant correlations are consistent with stated cost drivers Back

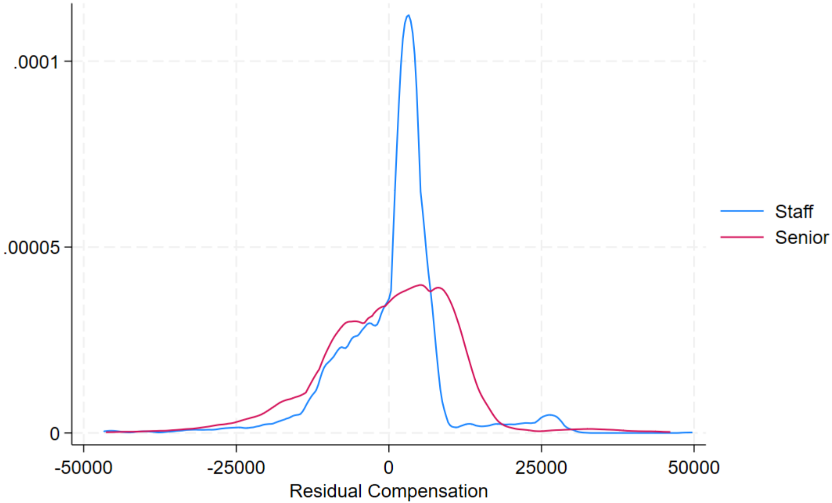


| | Compensation = Salary + Benefits ($2018) | | | |
|---|---|---|---|---|
| | Staff TE | All TE | All | All |
| Year (Base is 2011) | | | | |
| 2012 | 2,499.82*** | 2,382.23*** | 3,632.40*** | 2,580.73*** |
| | (793.16) | (638.47) | (919.91) | (644.24) |
| 2013 | -6,385.71 | -1,899.94 | 12,415.03 | 5,891.97 |
| | (7,179.47) | (7,592.93) | (15,257.86) | (8,027.01) |
| 2014 | -1,176.36 | 4,452.76 | 19,007.96 | 12,294.21+ |
| | (7,197.98) | (7,614.34) | (15,305.26) | (8,051.36) |
| 2015 | 4,237.74 | 10,212.08 | 23,325.04+ | 17,763.86** |
| | (7,185.79) | (7,613.35) | (15,309.99) | (8,061.53) |
| 2016 | 10,492.17+ | 16,795.75** | 30,033.03** | 24,444.04*** |
| | (7,182.41) | (7,618.18) | (15,309.14) | (8,055.13) |
| 2017 | 12,687.35* | 17,897.94** | 31,616.80** | 25,911.87*** |
| | (7,216.46) | (7,636.09) | (15,311.73) | (8,075.80) |
| 2018 | 13,880.50* | 19,664.93** | 33,192.08** | 27,402.97*** |
| | (7,258.78) | (7,653.44) | (15,322.67) | (8,085.23) |
| No Benefits Data | -43,269.02*** | -39,712.40*** | -26,767.96* | -31,622.35*** |
| | (7,138.76) | (7,582.43) | (15,242.48) | (8,044.53) |
| Job Title (Base is Staff Transport. Eng.) | | | | |
| Senior Transport. Engineer | | 20,134.16*** | | 20,164.47*** |
| | | (474.77) | | (477.27) |
| Supervising Transport. Engineer | | 34,045.00*** | | 34,180.08*** |
| | | (1,372.75) | | (1,376.58) |
| Staff Electrical Engineer | | | | 2,893.70*** |
| | | | | (836.12) |
| Senior Electrical Engineer | | | | 15,252.48*** |
| | | | | (3,215.34) |
| Senior Bridge Engineer | | | | 20,509.01*** |
| | | | | (2,120.90) |
| Senior Landscape Architect | | | | 19,320.24*** |
| | | | | (1,709.24) |
| Staff Planner/Surveyor | | | | -50,801.81*** |
| | | | | (4,669.85) |
| Senior Planner/Surveyor | | | | -21,619.24*** |
| | | | | (4,327.31) |
| R-squared | 0.78 | 0.83 | 0.65 | 0.82 |
| Observations | 1,959 | 2,801 | 3,080 | 3,080 |

Back

# Residual compensation

Back



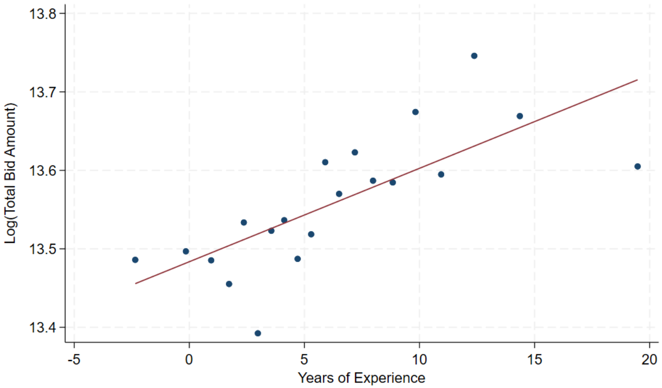
# Sanity check: Residual compensation and years of experience Back

| | Years of Experience | | | | |
|---|---|---|---|---|---|
| "Quality" Residual | 0.774*** | 0.856*** | 0.809*** | 0.615*** | 0.530*** |
| | (0.149) | (0.148) | (0.148) | (0.163) | (0.183) |
| R-squared | 0.06 | 0.10 | 0.11 | 0.16 | 0.19 |
| | Number of Projects | | | | |
| "Quality" Residual | 1.280*** | 1.428*** | 1.364*** | 1.212*** | 1.216*** |
| | (0.308) | (0.312) | (0.311) | (0.358) | (0.435) |
| R-squared | 0.03 | 0.10 | 0.11 | 0.14 | 0.17 |
| Fixed Effects | Job | Job, District | Job, District, Year | | |
| Project Cut-off | | | | 5 | 10 |
| Observations | 2,106 | 2,106 | 2,106 | 1,810 | 1,369 |

Our measure is positively correlated with years of experience and number of projects

- Source: historical construction dataset, which starts in 1970
- Many engineers observed very infrequently, so this is a noisy proxy

# Engineer assignment Back




- More experienced engineers are assigned to "larger" projects
- Conversations with Caltrans indicate assignment is at the discretion of district
  - *"Managers do not want to assign inexperienced PMs to complex projects."*
  - A function of project type, complexity, location (county, route)

# Engineer quality and project-level cost overruns Back

| | Cost Overrun (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Construction Head Quality | -0.32 | | -0.31 | -0.04 | | -0.01 | -0.87* | | -0.82* |
| | (0.38) | | (0.38) | (0.45) | | (0.46) | (0.46) | | (0.46) |
| Project Head Quality | | -0.27 | -0.26 | | -0.51 | -0.51 | | -0.77+ | -0.73+ |
| | | (0.43) | (0.43) | | (0.49) | (0.50) | | (0.48) | (0.48) |
| $\text{Quality}_{CH} \times \text{Quality}_{PH}$ | | | -0.08 | | | -0.13 | | | -0.11 |
| | | | (0.35) | | | (0.41) | | | (0.37) |
| Adj. R-squared | 0.03 | 0.03 | 0.03 | 0.05 | 0.05 | 0.05 | 0.10 | 0.10 | 0.10 |
| Observations | 1,685 | 1,685 | 1,685 | 1,469 | 1,469 | 1,469 | 1,429 | 1,429 | 1,429 |
| District, Year FE | × | × | × | × | × | × | × | × | × |
| Project Characteristics | | | | × | × | × | × | × | × |
| County, Route FE | | | | | | | × | × | × |

- Average overrun in sample is 7.7%; CH quality has a substantial effect on overrun (11.3%) but it translates to a small reduction in total costs (0.8%)

# Project Head may influence level of competition for project Back

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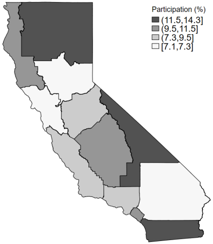
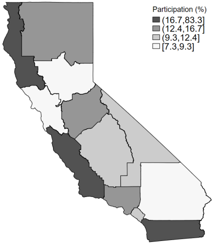
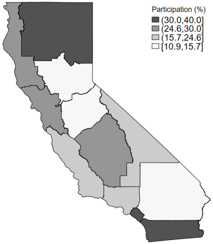
- Will study how quality effect varies with level of competition in a "market"
    - "Market" = District $\times$ Project Type (16 project types)
    - Measures: # of potential bidders, bidder participation (realized bidders/potential)
    - Only have data on bidders 2018-23, hence the "market" level measure




(a) Road Resurface




(b) Road Rehab




(c) Road Widen

# Heterogeneous effects of quality by market

| | log(Cost per Mile) | | | | |
|---|---|---|---|---|---|
| Project Head Quality | -0.11** | -0.05 | -0.11* | -0.05 | -0.11** |
| | (0.05) | (0.08) | (0.06) | (0.05) | (0.05) |
| $\times$ Potential Bidders $<$ Median | | -0.12 | | | |
| | | (0.10) | | | |
| $\times$ $\frac{\text{Potential Bidders}}{\text{District Size}}$ $<$ Median | | | -0.00 | | |
| | | | (0.10) | | |
| $\times$ Bidder Participation $<$ 10% | | | | -0.19* | |
| | | | | (0.11) | |
| $\times$ Emergency Project | | | | | -0.03 |
| | | | | | (0.20) |
| Project Chars, District, Year, County FE | $\times$ | $\times$ | $\times$ | $\times$ | $\times$ |
| Adj. R-squared | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 |
| Observations | 1,699 | 1,699 | 1,699 | 1,699 | 1,699 |

Only statistically significant difference is in low-participation markets

- Suggests Project Head may move needle on competition by increasing participation

# Assumption on retirement timing Back

Assumption: Retirements only affect outcomes through a loss of capacity (experience and manpower), not through other channels

- Retirement of civil servants largely driven by pension age thresholds (Asch et al., 2005; Giuffrida and Raiteri, 2023)
- Threat: Civil servants retire in order to avoid more complicated projects (or some district-specific shock causes both retirements and lengthier projects)
    - Timing: studying retirements in $t$ on project **awarded** in $t$
    - Results robust to controlling for mix of project type

# Reconciling the two sets of results Back

Individual engineer analysis: 1 SD $\uparrow$ in quality decreases project-level costs by 11%

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*Assumptions:*

1. Retiring engineer is replaced by engineer with 1 SD lower quality
   - Evidence: Engineer quality measure is about 1 SD higher in last year we observe than in first year, and we observe on average 5 years
2. Retiring engineers would have been assigned to largest projects
   - (Large as measured by winning bid.) Evidence: This is true in construction data

→ 1ppt retirement shock would increase total costs by 6.2% at the mean

- If we instead assume random assignment to project in top quartile of size → 2.8% increase in total cost

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Retirement results may also be driven by workload effects

# Back of the Envelope: Cost-Benefit [Back]

Suppose 1% of engineers in California retire.

Additional Costs:

- Assume 4.3% increase in costs uniformly across projects and districts

$\rightarrow$ Average district experiences increase of \$6.7 million

$\Rightarrow$ Aggregate to the state for increase in \$80.2 million

Additional Benefit:

- Benefit comes in the form of cost-savings
- Retirement shock of 1% = 60 engineers retire
- Assume these engineers are at the top of the pay distribution

$\rightarrow$ Save \$240,000 in salary and benefits per engineer

$\Rightarrow$ A total of \$14.4 million in cost savings
(which ignores pension obligations, cost of hiring new engineers)

*We estimate the benefit of experienced engineers is ∼6x the cost*