Transportation Infrastructure in the US

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Introduction I

'*...we need major federal investments to rebuild our crumbling infrastructure and put millions of Americans back to work in decent paying jobs in both the public and private sectors.*'
2016 Democratic Party Platform.

'*We propose to remove from the Highway Trust Fund programs that should not be the business of the federal government.*'
2016 Republican Party Platform.

- The first statement requires that,
  - Infrastructure is crumbling
  - Infrastructure creates jobs
- The second statement implies that highways are a national public good and that transit is not.

Data/literature suggests; 'probably not', 'maybe a little', 'not really'.

Introduction II

- Big questions:
  - Is US infrastructure policy optimal?
  - Can we identify obvious deviations from optimality?
  - How can we fix them?

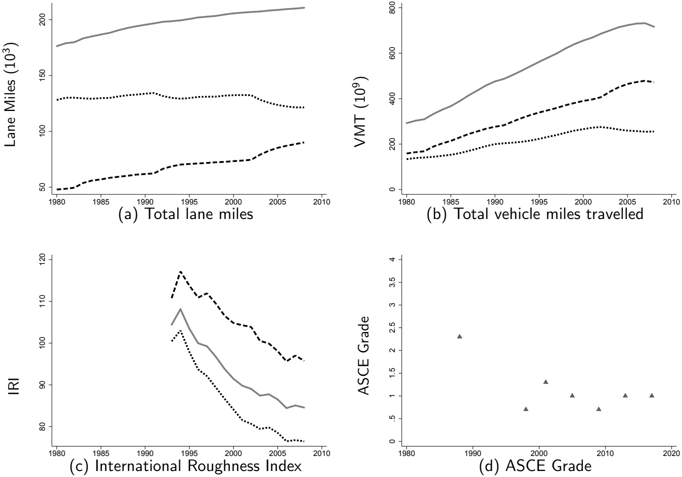
  This is too ambitious, but will guide our thinking about what we would like to know.
- Start a little smaller.
  - How much infrastructure do we have? (Roads, Bridges, Transit)
  - How much does it cost? (Roads, Bridges, Transit)
  - What can we say about the effects of marginal changes?
  - Does aggregate data suggest deviations from cost minimizing provision of trips?
- What additional facts/data would be most helpful in answering the big questions or our smaller questions?

Table: US roads and highways in 2008

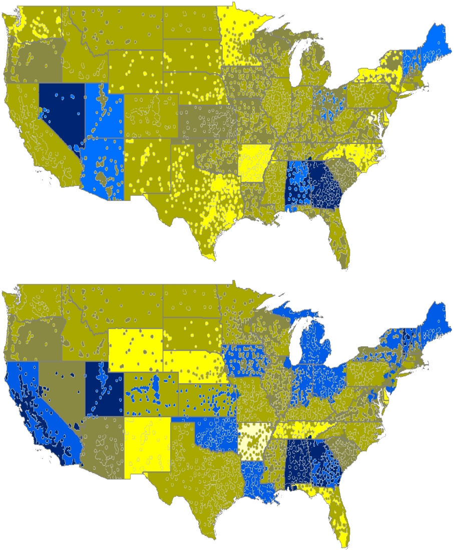
	Rural			Urban		
	Miles	Lane miles	VMT(10^9)	Miles	Lane miles	VMT(10^9)
Interstate	30,196	122,825	243	16,554	90,763	476
Federal Aid System	112,245	343,184	804	51,453	229,031	1,714
Total	2,977,222	6,091,943	990	1,065,556	2,392,026	1,983

- Main sources of administrative data about roads:
  - Highway Performance and Monitoring System (1980-2017). Representative sample of segment year data. Availability post 2008 is problematic. Mainly interstate.
  - PR511(1956-1993). Limited segment year level data. Availability is problematic?
  - Highway Statistics (1956-2017). State year data on expenditure and public finance. Project level data would be very helpful.
- Table above is taken from highway statistics in 2008, partly derived from HPMS.
  - The interstate accounts for about 1% of miles and 25% of travel.
  - Most existing research addresses highways. The data is better.
  - Note that the interstate is predominately urban. It serves much the same purpose as transit. Most federally financed roads are not the interstate.

Figure: Level and usage of the interstate 1980-2008



- Panels (a-c) are based on HPMS data (reproduced from MTU 2019). IRI is lane mile weighted. Dash is urban, dots is rural.
- Traffic per lane about doubles, lane miles up about 20%, VMT more than doubles, mean IRI improves from 'acceptable' to 'good'.
- Has the capital intensity of travel increased or decreased? Constructing theoretically coherent measures of interstate capital seems useful and non-trivial (MTU 2019).



Top: Spatial variation in IRI 1993-5. Bottom: Change in IRI 1993-2008. Only dark blue is ‘bad’. IRI was ‘acceptable’ or ‘good’ and improving almost everywhere. Alabama and Georgia are clear outliers.

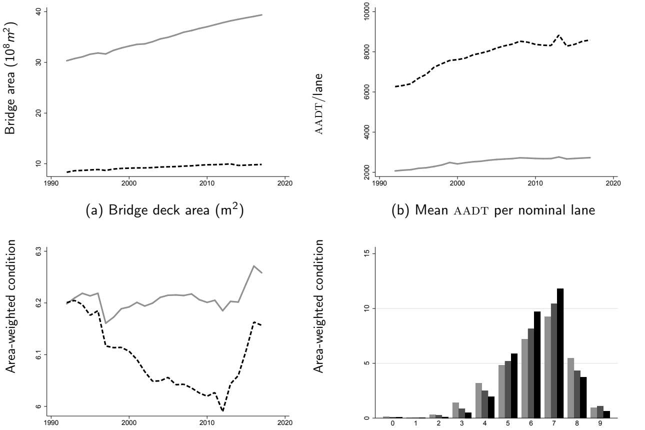
Bridges

- The National Bridge Inventory reports on every US bridge:

  > *A structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet ...*

- It is organized by bridge year and is similar to the HPMS.
- The only expenditure data is available at the state-year level from Highway Statistics.
- Bridge condition is tricky to measure.

Figure: Bridges: usage, stock, and condition



(a) Bridge deck area (m^2)

(b) Mean AADT per nominal lane

(c) Mean bridge condition index

(d) CDF index, 92 (light), 00 (medium),07 (dark)

- All panels are based on NBI data. Dashed line is interstate bridges, solid is universe. In panel (c), bridges are weighted by deck area. Bridge stock is growing at about the same rate as the interstate. Most new bridges are on the interstate. AADT has increased more slowly than for the interstate. Mean bridge condition is about constant, but variance is decreasing.

Table: Transit aggregate statistics by mode in 2017

	Bus	Light-Rail	Subway	Commuter-Rail	Van-Pool	Demand-Resp.
Riders(10^6)	4,679.4	554.7	3,808.9	497.8	35.24	157.4
Vehicles	68,972	2,553	11,671	7,121	15,174	57,487
Serv. Miles (10^6)	1,972.7	124.0	681.4	347.0	229.5	1,187.2
Pass. Miles (10^6)	16,843.3	2,690.3	17,555.5	12,250.7	1,254.6	934.4
Expenditure(10^6)	25,412.0	5,600.4	14,266.7	9,101.2	189.7	5,089.1
# transit dist.	1,530	67	18	42	167	2,298

- Transit data is available in the 'National Transit Data'. It is exhaustive and reports revenue, expenditure and physical capital by transit district year (1992-2017). It does not report on light rail/subway track, though this data seems to exist.
- Riders and service miles are in millions. Expenditure is in millions of dollars, and is all capital and maintenance. Transit districts are counted only if they have a positive number of vehicles.
- Buses and subways are the two most important modes by most measures. This is true even though buses are almost everywhere and subways are rare.

We see some interesting things in this table:

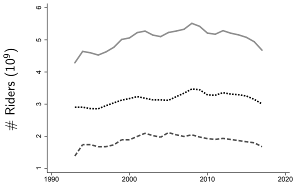
- The ratio of passenger miles to service miles gives us the number of passengers on a vehicle, on average. Buses $\approx$ 8.5, Subways $\approx$ 26, Demand response $\approx$ 0.8. A typical bus seats 65, A NY subway can carry about 2200. Load factors are tiny. Airlines do much better. Why does transit do so badly? How can transit do better?
- Demand response is also a big mode, by vehicles and expenditure.
- Passenger miles for bus and subway are on the order of 10b. Interstate VMT is almost two orders of magnitude greater in 2008.

Table: Buses and subways in six biggest transit districts, means over 2014-7

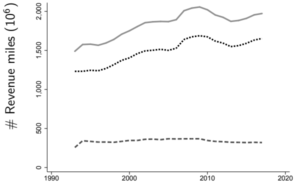
	All modes	Bus				Subway			
	% Riders	Riders	%	Exp.	% Tot. Exp.	Riders	%	Exp.	% Tot. Exp.
New York	40.3	722.9	15.4	2,765.7	10.9	2,699.5	70.9	7,098.4	49.8
Chicago	5.6	249.2	5.3	836.3	3.3	230.2	6.0	884.9	6.2
DC	4.1	123.1	2.6	715.0	2.8	227.1	6.0	1,390.9	9.7
Los Angeles	4.0	290.0	6.2	1,254.0	4.9	45.6	1.2	792.3	5.6
Boston	3.3	118.9	2.5	527.0	2.1	164.1	4.3	499.5	3.5
Philadelphia	3.1	169.4	3.6	697.7	2.7	93.9	2.5	308.4	2.2
Total	100.0	4,679.4	100.0	25,412.0	100.0	3,808.9	100.0	14,266.7	100.0

Notes: All counts of riders are given in millions per year. Expenditures are total capital and operating expenditures in millions of 2010 dollars. Second column gives total riders summed over all modes. The next four columns describe buses. The last four columns describe subways. Percentages describe the percentage of national totals in a city.

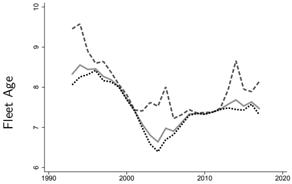
Figure: Level and usage of buses 1992-2017



(a)



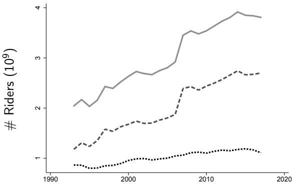
(b)



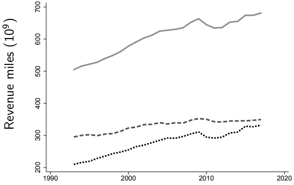
(c)

- All data from the National Transit Database. (a) Full count of bus riders (10^9). (b) Vehicle revenue miles (10^6). (c) Mean age of vehicle fleet. Dashed is 'big 6', dots is 'all others'.
- Ridership fluctuates within a range of about 20%, with a peak around the financial crisis.
- Vehicles and revenue miles are increasing monotonically.
- Mean age of a bus is constant or decreasing.

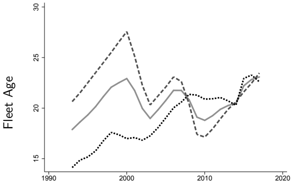
Figure: Level and usage of subways 1992-2017



(a)



(b)



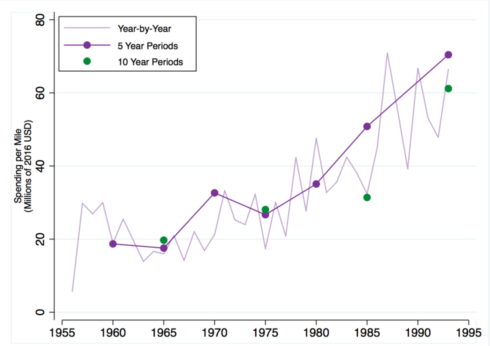
(c)

- All data from the National Transit Database. (a) Full count of subway riders (10^9). (b) Vehicle revenue miles (10^6). (c) Mean age of subway car fleet.
- Ridership doubled while service miles increased by about 40% and subway cars increased by about 20%. Subways are being used more intensively over time.
- Mean age of a subway car fluctuates around 21 years. Maintenance about offsets depreciation, but subway cars are pretty old.
- We can't monitor track condition, but NTA seems to have these data.
- The economist's traditional injunction to invest in buses rather than subways only makes sense if people will ride buses. The raw data don't look good for this.

Summary I

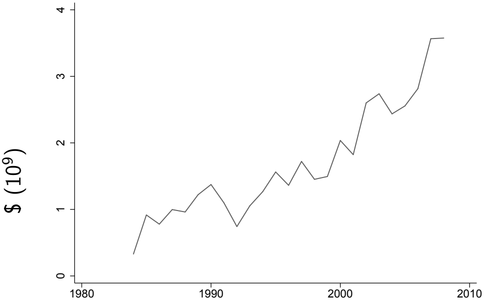
- For highways, bridges and subways:
  - Capital stock is increasing more slowly than population.
  - Use is increasing rapidly compared to population and capital stock.
  - Highway quality is improving. Bridge condition and subway car age are steady. If anything is crumbling, it is subways.
- For buses, the size of the fleet is increasing, its age is decreasing, ridership is falling.

Figure: Unit cost of the interstate



Mean expenditure per mile of new interstate highway between 1960 and 1995(Brooks and Liscow, 2019).

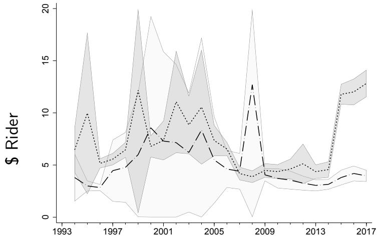
Figure: Bridge expenditure



(a)

- Total expenditure on bridges from highway statistics.
- In aggregate, expenditure about quadrupled while bridge condition stayed constant. This is consistent with the sorts of price increases we saw for highways.
- N.B. Bridge expenditure is counted as part of Interstate expenditure. It is about 20% of total.

Figure: Buses: Expenditure and unit cost



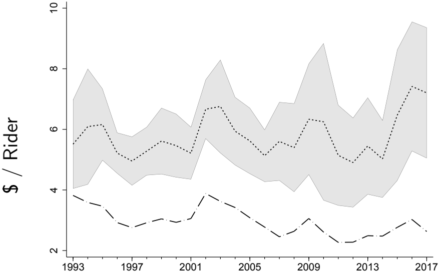
- (Right)Dash is 'big 6', dots is universe. Regression for cost per rider

$$\frac{\text{Tot. Exp}_{ist}}{\text{Riders}_{ist}} = \sum_{\tau=1992}^{2017} \beta_\tau \mathbf{1}_{ist}(\tau = t) + \epsilon_{ist}. \tag{1}$$

  i, s, t index transit districts, states, and years.
- Cost per rider does not show a strong trend. Noise probably reflects changes in accounting rules in NTD. Cost of a bus trip reaches about 10$ by 2017.

Subways

Unit cost



- Regression for cost per rider

$$\frac{\text{Tot. Exp}_{ist}}{\text{Riders}_{ist}} = \sum_{\tau=1992}^{2017} \beta_\tau \mathbf{1}_{ist}(\tau = t) + \epsilon_{ist}.$$

- Expenditure increases about in proportion to the increase in riders. Cost per rider does not show a trend and is constant at around 6$. Dash is NY, dots is universe.

Summary II

- Expenditure on the interstate, buses and subways is about 20b/year.
- Expenditures for all are rising pretty rapidly.
- Construction costs for roads is rising rapidly, probably bridges, too. Expenditure per rider is about constant for subways. Expenditure per rider for buses doesn't show a trend, but jumped to 10$/rider in 2015. We are probably accumulating 'highway capital' and depreciating 'subway capital'.

Effects of infrastructure

- Decentralization; Baum-Snow (2007), Baum-Snow (2019), Heblich, Redding and Sturm (2019).
- Urban growth; Duranton and Turner (2012), Gonzalez-Navarro and Turner (2018), Severen (2018), Tsivanidis (2019).
- Trade; Allen and Arkolakis (2014), Duranton, Morrow and Turner (2014).
- Macro; Leduc and Wilson (2013).

- Reduced form estimates typically find that
  - Transportation infrastructure reshapes cities, and likely regions. Mostly in way consistent with old urban models. (Highways and subways)
  - Effects on economic output or employment seem to be small compared to construction costs, and may be close to zero.(Highways and subways)

  but there is some disagreement between reduced form and structural estimates. It is hard to reconcile macro and micro estimates.

Optimality?

Table: Service and expenditure, Highways, Subways and Buses

	Interstate	Subway	Bus
Passenger miles(10^9)	719×1.25	16.8	21.0
Riders(10^9)	$719 \times 1.25/12$	3.8	4.7
Public Expenditure 2008(10^9)	22.0	12.3	21.3

- Can it possibly be optimal to spend as much public money on buses as on the interstate? The interstate serves an order of magnitude more miles/trips.
- Does the division of spending across buses and subways make sense?
- Note that 'current capital and maintenance expenditure' is clearly not what we want. We are adding to highway capital, probably adding to bus capital, and drawing down subway capital. It would be nice be able to do better on this.

A cost minimizing planner I

$$
\begin{aligned}
i &\sim \{\text{Highway, Bus, Subway}\} \\
K_i &\sim \text{Expenditure on infrastructure} \\
L_i &\sim \text{User inputs} \\
Q_i &\sim \text{Trips/Distance by mode } i \\
Z_i &\sim \text{`social value of trip by mode' } i
\end{aligned}
$$

Trips are produced according to

$$Q_i = F(K_i, L_i)$$

F homogenous degree ν_i.

A cost minimizing planner II

$$max_{K,L} V(\sum_i Z_i Q_i) + C$$

$$s.t.\ \textsc{Budget},\ F_i$$

$$\Longrightarrow \text{Cost minimizing production of } Q_i$$

$$\Longrightarrow Z_i v_i \text{AC}_i = Z_j v_j \text{AC}_j,\ \ i \neq j \in \{\text{Highway, Bus, Subway}\}.$$

$$\Longrightarrow Z_{Highway} 1.09 = Z_{Bus} 0.43 = Z_{Subway} 0.47$$

- If a cost minimizing planner to chooses current allocation, bus and subway miles must have about twice the weight as car miles. Is this really what we want?
- If a small agent chooses l_i taking L_i and K_i as given, rationalizing equilibrium average costs still requires people to value bus trips more highly than car trips. Why? Is this right?

$i \sim$ {Highway, Bus, Subway}, $K_i \sim$ Expenditure on infrastructure, $L_i \sim$ User inputs,

$Q_i \sim$ Trips/Distance by mode i, $Z_i \sim$ 'social value of trip by mode' i

Conclusions

- Policy:
  - Infrastructure is not crumbling. Infrastructure is probably not a big contributor to economic output (at the margin). Expansions are probably not good value for money, except, maybe in San Francisco and New York. Bridges, too?
  - Bus provision seems high, and service level and use are moving in opposite directions.
  - ... and of course, congestion pricing, tax trucks by axle weight.
- Data:
  - Fix the HPMS (easy)
  - Project level cost data.(medium)
  - Track/guiderail data.(medium)
  - Move to phone based data collection.(hard)
- Research
  - Still no consensus on the effect of highways on growth.
  - What is wrong with buses? How can we make transit work more like (pre-Covid) airlines?
  - Better estimates of costs and cost of capital.

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Baum-Snow, Nathaniel. 2007. Did highways cause suburbanization? *Quarterly Journal of Economics* 122(2): 775–805.

Baum-Snow, Nathaniel. 2019. Urban transport expansions and changes in the spatial structure of US cities: Implications for productivity and welfare. *Review of Economics and Statistics* forthcoming: 1–45.

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