Project Proposal for NBER Transportation in the 21st Century

Summary Statement:
This research will explain where private infrastructure providers choose to build freight infrastructure. The model of infrastructure provision can inform immediate policy priorities such as DOT's ongoing projects to expand truck parking, as well as the DOT's transition planning for freight decarbonization. For example, the model could suggest new rules for targeting public parking grants or other public infrastructure, inform the design of subsidy programs for private truck stop operators, or identify potential policy collaborations with local governments to remove regulatory barriers for private operators. The model could also suggest guidelines for balancing public refuelling infrastructure versus subsidies for private providers on the transition to freight decarbonization.

Research Question:
The modern industrial and consumer economy relies on the movement of goods. An efficient freight transportation network depends not only on direct inputs such as roads and trucks, but also complementary inputs such as real estate, refueling facilities, and parking infrastructure. Under-provision of these inputs – resulting in capacity constraints, suboptimal routes, and delays – may create costs that spread through the transportation network and affect all parts of the economy.

In this project, we study the provision of complementary infrastructure for freight transportation, focusing on the example of truck parking. Trucking freight relies on the availability of parking spaces for mid-day and end-of-day rest breaks, as mandated by labor and safety regulations, and time spent searching for parking directly leads to underutilization of trucking capital[1]. Parking spaces are provided by a mix of public and private sector entities, and conversations with individuals in the trucking industry have suggested that existing infrastructure is already underprovided and has contributed to higher transportation costs.

Studying the provision of freight infrastructure matters not only for policy decisions about parking (e.g., the administration of INFRA grants for new parking spaces and other components of the Bipartisan Infrastructure Law / IIJA), but also for near-term decisions that will affect the climate transition in subsequent decades. Currently responsible for 25% of U.S. transportation sector emissions of greenhouse gases[2], truck freight is widely considered a "hard-to-decarbonize" sector due to the need for high density energy sources to move heavy loads over long distances. Current R&D efforts are pursuing multiple pathways, including battery electric trucks paired with very fast charging capabilities; hydrogen fuel, either direct combustion or in fuel cells; and hydrogen-derived fuels such as ammonia and methanol. All of these technological solutions will require large-scale development of new truck refueling infrastructure. By studying the provision of existing infrastructure such as parking, we will be able to analyze forward-looking policy counterfactuals across a range of technological scenarios[3].

[1] Drivers in one survey "'gave up' an average of 56 minutes of available drive time per day parking early rather than risking not being able to find parking down the road" (American Transportation Research Institute 2016)
[2] In 2020, domestic U.S. trucking freight generated an estimated 420 million metric tons of CO2 equivalent, compared to 1,632 million metric tons from all transportation (Bureau of Transportation Statistics 2020)
[3] "Truck parking and truck charging are entirely interconnected. If there are not enough parking spaces, there will not be enough charging spaces." (Short et al. 2022). More optimistically, Hurtado-Beltran et al. (2021) and Burke (2022) suggest complementarities between existing truck parking and zero-emissions truck refueling.

The project will seek to answer several questions about infrastructure provision:

1. How do drivers value route efficiency relative to access to complementary infrastructure such as parking, and what are the implications for optimal allocation of resources for infrastructure?
2. Given private entry incentives of infrastructure providers, which policy regimes most closely approximate the optimal infrastructure network?
3. Given the behavior of drivers and infrastructure providers, how can policymakers efficiently support infrastructure for alternative fuel trucks, recognizing uncertainty about the development of various decarbonization pathways?

Our analysis will focus on three economic forces which are fundamental to addressing these research questions: strategic complementarities in infrastructure provision, market power among private infrastructure providers, and regulatory barriers (including local zoning). When strategic complementarities are present, infrastructure providers see limited returns to entry unless enough providers enter to provide a sufficient level of provider density. As a result, equilibria may exist with both high and low levels of infrastructure provision. Large providers with market power may open fewer locations for fear of competing with their existing locations. Regulatory barriers, such as lack of industrial zones or explicit bans on freight truck parking, restrict the set of available locations and raise entry costs. These forces have been cited as causes for the existing undersupply of truck parking, and as a result are relevant to any future refueling infrastructure.

Policy makers face a menu of potential options to address these frictions: subsidies to within-fleet infrastructure ("make"), subsidies to third-party private infrastructure providers ("buy"), or public construction of new infrastructure ("provide"). For example, the DOT's investment in new truck parking spaces under the INFRA program at bottlenecks in Florida and Tennessee follow the "provide" paradigm. Alternatively, policymakers could instead focus on eliminating non-cost barriers, such as zoning. Our study will quantify the trade-offs between these policy options, which depend on the preferences of drivers and private infrastructure providers.

The same policy considerations will shape the geography of zero-emissions trucking. At one end of the distribution of trip length, the shortest distance trips can be fully implemented by fleets only using within-fleet refueling at home base, without needing any external infrastructure. At the other end, the longest distance trips rely heavily on refueling or recharging away from home base, necessitating a dense network of third-party infrastructure, either public or private. In the middle of the distribution, fleets may rely primarily on refueling at home base but still use external infrastructure to extend the driving range of their vehicles. The boundaries between these types of refueling needs depend on technology development and the availability of refueling infrastructure, both of which may be influenced by policy.

Early policy activity around decarbonizing freight trucking has focused on regional freight corridors, such as the proposed West Coast Clean Transit Corridor connecting California, Oregon, and Washington along Interstate 5. In this regional market, policymakers face trade-offs between subsidizing within-fleet refueling infrastructure, subsidizing third-party private infrastructure, or providing public infrastructure. Our model of driver preferences and entry incentives of infrastructure providers will enable us to assess the relative effectiveness of these approaches. Furthermore, recognizing that infrastructure investments made in the near term may create path dependency in future decarbonization efforts, we will also analyze which policy approaches are robust to a range of assumptions about future battery charging speeds, hydrogen availability, and other technological parameters which are still highly uncertain in the spirit of Stock and Stuart (2021).

Data and Methods:
Our analysis will consist of a model of the demand for infrastructure along routes, a model of the supply for complementary infrastructure, and a series of welfare assessments and policy counterfactuals.

Our infrastructure demand model will be a model of driver choice over routes which extends Allen & Arkolakis (2022) to account for network edge characteristics. Fixing a set of freight shipments with origins and destinations, each shipment's driver chooses a route (sequence of highway legs) to minimize total (subjective) travel costs. The utility cost of travelling along each leg depends on the availability of parking infrastructure, refueling (diesel, in our data) as well as other characteristics (distance, physical road quality). When infrastructure access, availability, and density along one leg of highway change, it affects the choices of drivers between many disparate origin-destination pairs. Though we estimate the demand model with current data, where virtually all trucks rely on diesel fuel, we can consider a variety of possible refueling technologies by decomposing travel costs into their economic fundamentals (driving range given driver preferences for rest and hours of service requirements).

Our infrastructure supply model will be a model of entry where infrastructure providers choose where to build. Given local costs (zoning, wages, etc.) and expected freight traffic, infrastructure providers enter to maximize profits. In this model, entry by two infrastructure providers on different highway segments may be strategic complements or substitutes. Entry by a provider on one segment increases "upstream" and "downstream" traffic (complements), while decreasing traffic on "parallel" segments (substitutes). The size of these effects is empirical and depends on how sensitive drivers are to infrastructure density/availability.

The proposed research will use several data sources, including aggregated freight traffic data along segments (Highway Performance Monitoring System / HPMS), freight truck shipments (DAT, Commodity Flow Survey), gas stations and other roadside businesses (Dun & Bradstreet), private/public parking locations and spots (Federal Highway Administration / Jason's Law Survey), and truck GPS pings (American Transportation Research Institute)[4].

We will estimate the truck driver preferences over highway legs using simulated method of moments. Our demand model predicts freight traffic flows along each highway leg, for a given vector of demand parameters and origin-destination shipping flows. We currently find the parameters that match predicted and empirical traffic flows from the HPMS. We will supplement the aggregate traffic-based estimation with driver stopping choices based on GPS ping data. This high-frequency micro data will enable us to more precisely identify driver preferences over route characteristics, including infrastructure availability. Having estimated a driver demand function, we will then estimate the cost parameters that explain the empirical pattern of infrastructure entry. We estimate supply under a range of assumptions about infrastructure provider market structure (e.g., competitive or oligopolistic).

Using our model, we can compute a variety of counterfactual policy analysis centered around (1) current parking needs, and (2) future decarbonization of freight trucking. For example, we will simulate how the DOT's ongoing investments in targeted truck parking capacity ("provide") may encourage or compete with additional entry by private truck stop operators ("buy"). We will also analyze how policy design

[4] DOT's expertise and resources could further enhance our data. We are especially interested in finer data on parking locations beyond the Jason's Law Survey, especially if that data included high-frequency utilization of parking spaces[4]. Additional sources of sensor/GPS data, including and beyond the ATRI's datasets, would also be helpful.

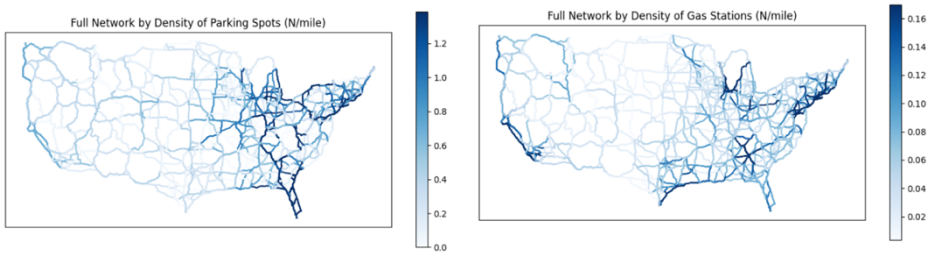
("make," "buy," or "provide") may affect the development of alternative refueling infrastructure in regional trucking markets. Additionally, we are interested in working with DOT staff as part of this process to define counterfactuals of greatest interest.

Proposed Use of Funds:
We propose to use the funds mainly to support a research assistant for the project; we would redirect the salary support component towards research assistant support, as our PI already has access to summer support. Other research costs include potential costs of acquiring additional truck GPS data and conference travel.

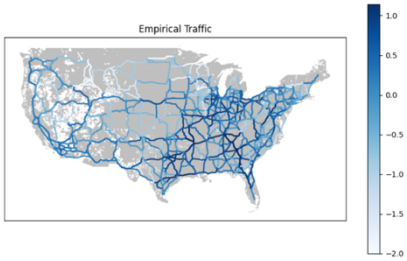
The research assistant will focus on geo-spatial data processing, including processing raw GPS ping data, reconstructing trips, route choices, and stop choices. As noted above, the high-frequency GPS data provides stronger identification of driver preferences over infrastructure locations and density. Incorporating this data also enables us to estimate driver preferences over wait times relative to route efficiency, which would allow counterfactual analyses about optimal resource allocation to incentivize new infrastructure. In a similar paper, Dorsey et al. (2022) use high-frequency travel data to study the allocation of resources for Level 2 versus Level 3 charging stations for passenger electric vehicles.

Additionally, the research assistant will process other geographic elements of costs to entry for infrastructure providers (local zoning and other regulatory restrictions, land prices). This component of the analysis will enable counterfactual analyses around non-market barriers to infrastructure provision and freight decarbonization.

Preliminary Results:
Preliminary results in the project, documented in Pinter and Yang (2022), have focused on documenting patterns in freight infrastructure provision across the U.S., as well as initial estimation of our demand model using aggregate traffic data. The following two figures show the density of two important types of freight infrastructure, parking spots and gas stations, across edges of the U.S. highway network.



Parking density is only weakly correlated (0.18) with freight traffic (as plotted in the figure below), and some U.S. states have systematically lower availability of parking spaces compared to the country as a whole.



Given these patterns, we estimate our demand model parameters using aggregate traffic data from the HPMS. Preliminary estimates for the role of roadside infrastructure in the utility cost of traversing different highway segments are presented in the table below. We find that truck drivers perceive highway legs which are longer distance and have lower gas station and parking density as more costly.

Parameter	Estimate (Util)	Estimate (Miles)
Distance (000s mi)	18.882	-
Gas Station Density (N per mile)	-0.6201	-32.84
Parking Spot Density (N per mile)	-0.0129	-0.6831
Population Density (N per mile)	0.0033	0.1747

Composition of Research Team:
The primary investigator for this project is Sarah Armitage (assistant professor at Boston University starting July 2023, currently postdoc at Environmental Defense Fund). The secondary investigator is Ron Yang (assistant professor at University of British Columbia starting July 2023, currently postdoc at Stanford University). Armitage will also work with a research assistant at Boston University.

Conflicts of Interest:
Armitage is currently a postdoc employed by the Environmental Defense Fund. This relationship will end on June 30, 2023. Yang has no conflicts of interest to declare.

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