Effects of Pavement Maintenance on Traffic Outcomes: Evidence from California

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1 Introduction

Highway safety represents a major concern to multiple governmental bodies, and substantial resources go into ensuring its provision. While a sizeable body of research investigates highway safety, this literature contains many gaps. One specific aspect of highway safety neglected in the literature thus far is the impact of road quality or smoothness on safety. Obviously, not all roads or streets are of equal quality, and road quality can be improved by spending money on road maintenance or repaving. Road repair often constitutes the largest item in a department of transportation's budget. For example, in 2018-19, California Department of Transportation ("Caltrans") increased their budget for road maintenance from $421 million to $576 million, and their budget for road rehabilitation from $424 million to $994 million. What makes California particularly interesting, especially in terms of pavement quality, is the statewide variation in climate and state's expansive highway system. Different climate zones will age pavements differently depending on humidity, precipitation, and temperature.

An obvious question that stems from this is how does pavement quality impact highway safety, if at all? Moreover, if a significant impact exists, what is an appropriate economic policy response? It might be the case that smoother surfaces decrease crash rates. However, continual maintenance might be too costly for the rate of road deterioration. Maintenance could even lead to dangerous situations for both workers and commuters in work zones. In addition, rougher roads might cause slower travel, leading to longer response times for emergency and commercial vehicles, generating deadweight loss.

Investigating the relationship between road quality and traffic safety poses many econometric difficulties. Specifically, pavement deteriorates for a variety of reasons, and the factors associated with road deterioration might also cause changes in highway safety. For example, highways that experience high traffic volume will deteriorate quicker than highways with low traffic volume, but might also be associated with higher crash rates. Likewise, highways

that experience icy weather conditions will deteriorate quicker but also present worse safety outcomes.

Investigating the relationship between road quality and traffic safety represents an important empirical contribution to the literature on the economics of transportation. In a seminal paper in this literature, Newbery (1988) investigated the economics of road damage. The "Fundamental Theorem" in this paper finds that, assuming no damaging effects of weather on roads, equal road age distribution, and constant traffic flow, the marginal social cost of road use exactly equals the average resurfacing cost. This theorem also shows that the road damage externality, which arises because a vehicle that damages pavement through driving increases the operating costs of all subsequent vehicles using the road, is zero under these conditions. If road quality affects traffic safety, and deteriorating roads feature more accidents, then the conditions under which this theorem holds may be violated.

Road quality represents a choice variable for government transportation agencies (Small and Winston, 1988). Some previous empirical research addresses the issue of optimal road durability. This literature generally omits any external costs of road deterioration associated with traffic safety and accidents. This proposed research would also help to inform government policy on road quality.

This project will empirically analyze the relationship between road roughness and traffic safety using spatially and temporally disaggregated road data from California. Substantial data have been collected, and provided by Caltrans, including data on traffic conditions, pavement quality, construction projects, weather information, and highway vehicle crashes and other incidents. However, some additional data and institutional knowledge from Caltrans are still required.

Funding would be helpful in order to most effectively work with Caltrans. All of the data collected thus far is due to the generosity of Caltrans. If we had funding, we would be able to travel to meet with Caltrans employees, which would allow us to work with them more efficiently. Further, travel for academic conferences to share findings and get feedback would also be invaluable. Finally, since the data sets we are working with are very large, collection, storage, and computation costs all become relevant.

2 Empirical Setting

California represents an interesting setting to study the effects of pavement quality on highway safety. According to the Federal Highway Association, California has almost 400,000 road miles in total, behind only Texas (680,000 miles) and ahead of Illinois (300,000 miles). Further, California is the most populous state by about 10 million people. California, unlike Texas and Illinois, contains a variety of climate types which might age pavement differently. In other words, California has an environment conducive to studying highways on a large scale, as well as exploring the impacts of outside forces on said highway network.

Data used come from multiple sources. Caltrans periodically releases results from the Automated Pavement Condition Survey ("APCS"). The APCS takes measurements to detail the quality of road segments at tenth of a mile intervals. Some of the data collected include the international roughness index ("IRI") and different types of cracking, or pothole, measurements for aslphault and concrete. Caltrans uses IRI data, and some other measures,

to generate Priority Matrices ("ROBYG") that identify road segments by color; these colors indicate how deteriorated segments are. Data from the APCS were collected by contacting Caltrans directly. The APCS data spans California's highway system and contains three waves: first in 2011-12, again in 2015-16, and also in 2018.

While each survey is extremely detailed, an ideal dataset would track each segment in a more granular temporal fashion. Therefore, the pavement quality must be interpolated between surveys. In order to do this, we turn to Caltrans's Pavement Management System ("PaveM"). PaveM takes data from the APCS, applies complex algorithms, and predicts how road segments will age (Wang and Pyle, 2019). Unfortunately, since PaveM's main function is to predict yearly deterioration for future maintenance, it cannot directly generate monthly estimates in its current form. Luckily, PaveM's predictions for 2015-16 and 2018 are available from the University of California Pavement Research Center. This facilitates two key portions of this research project. First, PaveM's algorithm can be approximated using variables such as weather, traffic volume, and current construction projects in a regression framework. Moreover, since 2018 data are both predicted by PaveM as well as assessed by the APCS, it becomes possible to augment PaveM assessments. We are currently in contact with employees at Caltrans about this.

Additional data comes from the Caltrans Performance Measurement System ("PeMS"), the California Highway Patrol ("CHP"), the National Oceanic and Atmospheric Administration ("NOAA"), and the Automated Surface Observing System ("ASOS") in California. PeMS provides extremely detailed, hourly information about traffic volume, incidents, and lane closures for the entire sample period. The CHP provides detailed information on each crash that occurred in the sample period. Finally, NOAA and ASOS provide hourly weather information for the sample period.

3 Empirical Strategy

Since Caltrans uses PaveM and their priority matrix to make construction decisions, the formula can be leveraged for plausibly exogenous variation in the probability of road construction or repair. In other words, while roads just above and just below the cutoff for a certain color label might be very similar, the slightly rougher road has a discontinuously higher probability of repair. One of the road segments will be exogenously treated and exhibits a higher pavement quality, while the other road segment would remain at a lower quality. This would allow for the estimation of a causal effect of pavement quality on traffic outcomes. It would also be possible to evaluate the effects of road construction itself on traffic outcomes via a regression discontinuity or a differences-in-differences framework.

Relevant traffic-related outcome variables include crash rates, crash severity, response times by emergency services, congestion, pollution, and so on. Variables reflecting these outcomes exist in data already collected from various sources.

The results of this study would be important to the transportation industry due to the size of their budgets and the vast implications on drivers and the local economy. Specifically, this work would yield an improved model of deterioration over PaveM, which is cutting edge for California, and then quantify the social costs of pavement maintenance, specifically in terms of safety.

Existing Literature and Contribution

Mamlouk et al. (2018) represents the most closely related paper to our planned research agenda beyond deterioration modeling. Data from Arizona, North Carolina, and Maryland were collected to examine the effect of pavement quality conditions (IRI and rut depth) on accident rates. The main goal of this paper was to determine the IRI and rut depth thresholds that correlate to increased accident rates. This paper finds that there was not a substantial increase in the accident rate until the IRI reached a level of 210 inches/mile or a critical rut depth of 0.4. Beyond these calculated correlations, this paper does not estimate any potential causal relationships between road quality and accidents. We hope to fill this void in the literature with our research.

Wang and Pyle (2019) provide insight into the current pavement deterioration predictions PaveM makes for Caltrans. Although the exact algorithm used by PaveM is not (and has not been) disclosed, the authors state that the data are divided into bins based on observable characteristics, and then deterioration is regressed on age alone within each bin. Though imperfect, Wang and Pyle (2019) provides an established starting point to improve upon current prediction mechanisms to accurately inform government policy on a non-negligible size of the transportation spending budget in California.

Theofilatos and Yannis (2014) reviews the literature assessing the impact of traffic and weather characteristics on road safety. Despite mixed evidence across the literature, in terms of traffic conditions, most studies find a non-linear relationship between traffic flow and accident rates. Additionally, increased speed limits are also found to have a positive relationship with accident occurrence. Precipitation generally leads to increased accident frequency but does not seem to affect accident severity. The authors also include some suggestions for future research including further usage of micro-level weather and traffic data. We plan to utilize these type of data in our research.

The nonprofit organization TRIP, which researches surface transportation issues, released a report in 2018 focused only on roads in California. In this report, the organization reviews the state's roads and bridges and evaluates congestion, safety, and pavement condition. TRIP estimates that California's road quality costs drivers over $22 billion dollars in total, or $843 per driver, each year in additional vehicle operating costs via the Highway Development and Management Model. Again, this constitutes a road damage externality. Further, TRIP reports that 68% of major roads and highways are of poor or mediocre condition. This deterioration is generated by traffic, moisture and climate, but also inadequate maintenance. TRIP suggests that continual preservation and resurfacing will extend pavement life, and costs significantly less than occasional complete reconstruction. TRIP also estimates the economic costs of traffic fatalities where roadway features were a contributing factor, which are 1/3 of all fatalities, at almost $10 billion. Clearly, road conditions have large effects on California drivers. Finally, TRIP examines congestion in terms of time and cost. They find that this number is approximately $29 billion for California residents.

While Caltrans would be interested in reducing these costs, there are clear tradeoffs for lowering any given one. For example, suppose Caltrans aimed to minimize additional vehicle operation costs by keeping roads as smooth as possible, which of course would cost an exceptional amount of money. To address this problem, traffic must be diverted, thus increasing congestion costs. Second, introducing work zones might increase the propensity

of a crash, thus increasing the associated expected costs. Essentially, it is critical that California, or any state, strike an appropriate balance between road deterioration and road maintenance. This proposed work will quantify the links between pavement conditions and traffic outcomes. Importantly, this work will be among the first to do so in the economics literature.

4 Composition of Research Team

Brad R. Humphreys is Professor of Economics at West Virginia University. He is the 2017 Benedum Distinguished Scholar in Social and Behavioral Sciences at WVU. His research focuses on urban economics, including economic aspects of traffic congestion. Margaret Bock is a Ph.D candidate in the Department of Economics at West Virginia University. Her research interests include urban, regional and public economics. Alex Cardazzi is a Ph.D. student in the Department of Economics at West Virginia University. His research interests are in urban economics and sports economics. All three are eligible to be paid as NBER employees.

5 Conflict of Interest Statement

There is no conflict of interest. We do not work for anything related to the transportation industry. This will be important early work in the careers of Margaret and Alex as they begin their job searches in the coming years. Margaret's dissertation focuses on the economic and social impacts caused by roads and highways by overcoming previous endogeniety issues throughout the transportation literature. Alex is also planning on a transportation economics themed dissertation as well. Having early exposure to such rigorous research, especially if backed by the NBER, would be invaluable experience in the short, and long, run.

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