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Planning for Accessibility: Implications for Regional and Local Planning, and Beyond

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Planning for Accessibility:

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by

Hao Ding

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ABSTRACT OF THE DISSERTATION

Planning for Accessibility:

Implications for Regional and Local Planning, and Beyond

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Doctor of Philosophy in Urban Planning

University of California, Los Angeles, 2024

Professor Anastasia Loukaitou-Sideris, Co-Chair

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The concept of accessibility has been heavily researched but slowly applied to practice. Numerous studies have shown that access to opportunities such as jobs, education, healthcare, and recreation affects people's socio-economic wellbeing, and that low income and minority populations often suffer from poor accessibility due to lack of transportation and land use investments in their neighborhoods, as well as a lack of private transportation resources, or cars. In recent years, the state and regional governments in California are increasingly emphasizing the importance of promoting accessibility, as the concept aligns well with the state's goal to reduce greenhouse gas

emissions by encouraging denser and mixed-use urban form and discouraging car use. However, progress has been rather slow at both the regional and local levels, due to technical challenges as well as political obstacles. Moreover, while regional and local planning can promote accessibility by shaping transportation and land use investments, they have limited capacity to address the lack of transportation resources among disadvantaged populations, which is a key reason for their poor accessibility. I explore these issues in this dissertation through three separate but related essays. Essay one focuses on the potential application of accessibility metrics in local development review processes. I compare accessibility with the conventional level of service metric and California's newly adopted vehicle miles traveled metric in evaluating transportation impacts of land use developments. I show that accessibility metrics offer a more complete and direct assessment of how land use developments affect people's access to opportunities by a variety of travel modes. Essay two focuses on the application of accessibility in regional planning processes. I investigate how California metropolitan planning organizations use accessibility metrics to plan for long-range transportation and land use investments and prioritize investment projects (mostly transportation) for short-term implementation. I find that California MPOs use accessibility metrics more in long-range planning than near-term project prioritization and use indirect measures of accessibility more than direct measures. I also discuss major obstacles that prevent MPOs from using accessibility metrics, and one key factor that facilitates adopting accessibility. Essay three extends beyond the transportation and land use system and focuses on financial barriers to transportation access. I examine how neighborhood-level variations in auto insurance premiums may influence household car ownership, and hence contribute to accessibility disparities among different income and racial groups. I find strong associations between higher premiums and lower car ownership, and significant differences in such associations among geographic

contexts, income levels, and to a limited extent, racial groups. These three essays address previously understudied topics in the literature and the findings have important implications for policy interventions to promote accessibility.

The dissertation of Hao Ding is approved.

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Table of Contents

List of Figures

List of Tables

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INTRODUCTION

For better than a century, US transportation planning has been largely guided by the concept of mobility, often defined as the ease of moving about (Hansen 1959; S. Handy 2005). But the principal goal of transportation system is not *the means* (moving people and goods), but rather *the ends* (accessing desired destinations and activities), of travel. Thus, many scholars have argued for a shift to an accessibility framework for transportation planning and defined the concept variably as the capacity to reach destinations, or the ease of or "potential for interaction" [of people and activities], which is a function of travel speed and proximity of destinations (Levine, Grengs, and Merlin 2019; Duranton and Guerra 2016; Handy 2005; 2020). Previous studies have demonstrated that accessibility to important resources and opportunities such as employment, goods and services, education, healthcare, and recreation affect people's socio-economic wellbeing, and that transportation plays an important role in improving accessibility (Handy 2020; Wachs and Kumagai 1973; Grengs 2015; Ong and Blumenberg 1998; Ong and Miller 2005; Blumenberg and Pierce 2014). Many scholars also see the concept of accessibility as a useful framework to integrate land use and transportation planning in practice because accessibility can be enhanced by improving mobility, or the ability to move about on transportation systems, and/or improving physical proximity or connectivity between different land uses and activities (Bertolini, le Clercq, and Kapoen 2005; Levine, Grengs, and Merlin 2019; Handy 2020).

Despite decades of advocacy by urban and transportation planning scholars to adopt accessibility in planning practice, regional and local governments have been slow in embracing this concept. Metropolitan Planning Organizations (MPOs) have increasingly incorporated in their regional plans the idea of accessibility, but in ways that are often ambiguously defined and poorly operationalized (Handy 2005; Proffitt et al. 2017). At the local level, practices like traffic impact analysis still focus primarily on mobility rather than accessibility (Combs, McDonald, and Leimenstoll 2020; Siddiq and Taylor 2021). The slow application of accessibility in planning practice may be explained by several factors, including data requirements, institutional resistance, complexity of accessibility measures, lack of standard and objective metrics, and lack of empirical evidence on the effects of accessibility on land value and agglomeration economies (Miller 2018; Siddiq and Taylor 2021).

Moreover, regional and local planning can certainly promote accessibility by shaping transportation systems and land use patterns, but such planning cannot directly address the lack of transportation resources, private vehicles in particular, among many low income and minority households. Yet, the lack of ownership or access to a car accounts for much of these households' poor accessibility, perhaps to a greater extent than their physical distance to jobs and other opportunities (Ong and Miller 2005; Blumenberg and Manville 2004; Taylor and Ong 1995; Shen 1998; 2001; Grengs 2010). The lack of car ownership or access, in turn, may be due to many factors, one of which is the cost of auto insurance, which unfairly burdens the low income and minority populations (Ong and Stoll 2007; Ong and Gonzalez 2019; Feltner and Heller 2015; Larson et al. 2017).

I explore these issues in this dissertation through three separate but related essays. Essay one focuses on the potential application of accessibility metric in local development review processes. In the US, land use development projects are required to evaluate their potential transportation impacts through traffic/transportation impact studies as part of the environmental review process. The conventional approach of such studies aims to reduce congestion and uses level of service (LOS) to measure the ease of vehicular flow on road networks and at intersections. This approach has long been criticized because the LOS metric tends to be biased towards suburban, lower density, car-oriented development patterns and against higher density, mixed-use, and infill development projects (Ding and Taylor 2021; Shoup 2003).

California recently moved to require transportation impact analysis mandated by California Environmental Quality Act (CEQA) to measure vehicle miles traveled (VMT) impacts instead. The VMT-based analysis aims to reduce vehicle travel and the associated emissions, and tends to favor higher density, mixed-use, and infill development projects (Lee and Handy 2018). However, neither LOS nor VMT directly assesses people's access to destinations and activities, which is what the transportation system ultimately aims to enable. LOS-based analysis focuses on improving auto mobility, which is only one component of accessibility; VMT-based analysis focuses on reducing vehicle travel – assuming any such reduction results from proximity of destinations – only partially and indirectly address accessibility. Using either LOS or VMT elevates reducing congestion or emissions to a higher priority of transportation policy than improving accessibility.

In this essay, I show the limitations of LOS and VMT and the merits of focusing on accessibility in evaluating transportation impacts of development projects by comparing the two metrics with a commonly used accessibility metric, and discuss their different implications for local land use development. I use a sample of 22 proposed development projects in the City of Los Angeles to show that VMT-based evaluation is less likely to find projects as having significant impacts than LOS-based evaluation. And more importantly, I show that both LOS-based and VMT-based evaluations can overlook accessibility gains from either improved mobility on transportation networks or higher proximity of destinations and activities, whereas accessibility metrics offer a more complete and direct assessment of how land use developments affect people's access to opportunities by a variety of travel modes.

Essay two focuses on the application of accessibility in regional planning processes. In the US, MPOs are the regional planning bodies responsible for transportation planning at the metropolitan scale. They typically plan for long-term transportation investment strategies in long-range transportation plans (RTPs) and prioritize investment projects for near-term implementation for transportation improvement programs (TIPs). For a long time, MPOs have focused on improving (auto) mobility (Handy 2005). But, as noted earlier, the principal goal of a transportation system is to enable access to destinations and activities. Many scholars have long argued that (regional) transportation planning needs to focus instead on improving accessibility (Handy 2005; Levine, Grengs, and Merlin 2019; Duranton and Guerra 2016; Handy 2020). And earlier studies have found that MPOs have started discussing accessibility and using accessibility metrics in their long-range transportation plans (RTPs), but often poorly define and operationalize accessibility (Handy 2005; Proffitt et al. 2019).

In California, MPOs, in addition to transportation planning, also engage in land use planning (though they still have more statutory authority over the former than the latter). California State Senate Bill 375 (SB375) requires California MPOs to prepare sustainable communities strategies (SCSs) to align transportation, housing, and land use strategies to reduce VMT and emissions. As noted earlier, accessibility can be improved by increasing mobility on transportation networks and/or bringing land uses in closer proximity. Thus, California MPOs, with the additional influence over land use strategies, may be in a better position than MPOs in other states to incorporate accessibility in regional planning.

In this essay, I evaluate how California MPOs use accessibility metrics in both the long-term transportation investment planning process and the near-term investment project prioritization process. I review seven MPOs' RTP-SCSs, TIPs, and other documents relevant to the processes through which projects are evaluated and selected for funding to examine how accessibility is used in these documents and processes. I also interview staff members of these MPOs to explore factors that facilitate and hinder the adoption of accessibility. I find that California MPOs use accessibility more in the long-range planning process than in the near-term project prioritization process because they have less control over project evaluation and selection processes. Also, California MPOs use indirect measures of accessibility (mostly VMT-related) more than direct measures, partly driven by the state-level policy priority of reducing VMT and emissions. Through interviews, I find that the biggest obstacles for adopting accessibility are the difficulty of interpreting and explaining complex and often abstract accessibility metrics to stakeholders and MPOs' limited control over project evaluation and selection. SB 375, on the other hand, has facilitated the adoption of accessibility metrics by allowing MPOs more influence over land use strategies.

Essay three extends the analysis of access beyond transportation and land use planning to focus on auto insurance premiums. Decades of mobility-focused transportation planning has created the auto-oriented urban form that dominates most US metropolitan areas., which gives cars a great advantage in providing access to destinations and activities. Much research has demonstrated the substantial accessibility gap between those having a car and those relying on public transit, and that low-income and minority travelers consistently have lower levels of accessibility, primarily due to less car ownership or access (Blumenberg and Manville 2004; Taylor and Ong 1995; Shen 1998; 2001; Grengs 2010). Thus, auto insurance premiums, as an important component of the cost of owning and operating a car, may influence households' car ownership, and hence travelers' accessibility to desired destinations and activities. Relatively few studies have examined the effect of auto insurance premiums on car ownership. Existing evidence suggests that auto insurance premiums vary unevenly across geographical contexts and racial groups, and that higher auto insurance premiums are correlated, at relatively high aggregate scales, with lower car ownership (Raphael and Rice 2002; P. M. Ong and Stoll 2007; P. M. Ong and Gonzalez 2019).

In this essay, I examine the association between auto insurance premiums and car ownership at a finer resolution, using data on average auto insurance premiums of census tracts and household car ownership in California. I also identify the mechanisms through which auto insurance may influence household decisions to purchase a vehicle by testing the differential effects of geographic context, income, and race on the association between auto insurance and car ownership. I find that higher tract-level auto insurance premiums are strongly associated with lower household car ownership. Also, significant differences exist among geographic context, income level, and to a limited extent, racial groups, in such associations.

These three essays each address a different aspect of planning for accessibility. Essay one highlights the benefits of applying accessibility metrics in development review processes at the local level. This is an important aspect of planning for accessibility because land use patterns, which affect proximity between destinations and activities, are very much shaped by local government decisions on individual land use developments. My findings show that accessibility-based evaluation can better inform local land use decisions and help shape land use patterns towards improving accessibility.

Essay two investigates the progress of addressing accessibility concerns at the regional level. This is another important aspect of planning for accessibility, because access to many important opportunities and activities, like jobs, needs to be considered at the regional scale, which means that transportation and land use investments should be coordinated at the regional level to better enhance access to such opportunities. My findings assess the status quo on California MPOs' use of accessibility in regional planning, highlight two major obstacles and one facilitating factor for adopting accessibility metrics. These findings can help inform future efforts to better shift regional planning to focus on improving accessibility.

While essays one and two focus on how local and regional governments shape transportation and land use systems, the interaction of which determines access potential, essay three focuses on how auto insurance influences car ownership, which is arguably the most important factor determining one's potential to realize such access potential, at least in the U.S. My findings highlight auto insurance's important role in affecting household car ownership, which implies that policy interventions aimed at improving accessibility for low-income and minority groups need to extend beyond transportation and land use to address auto insurance, a factor often considered external to the field of planning. Together, these three essays address the understudied topics in the field of urban and transportation planning regarding accessibility, and offer important evidence and lessons about how to better plan for accessibility.

ESSAY ONE: Measuring Accessibility at the Local Level: Comparing the Use of Level of Service, Vehicle Miles Traveled, and Accessibility Metrics in Evaluating Transportation Impacts of Land Use Projects

Abstract

Many scholars have advocated for a shift of focus from mobility to accessibility in transportation planning, but local governments have not embraced this idea in evaluating the transportation impacts of land use development projects. The conventional approach of such evaluations is based on level of service (LOS) which measures (auto) *mobility*, or the ease of motor vehicle flows, and aims to reduce congestion. California recently moved to measure vehicle miles traveled (VMT) effects instead in environmental reviews required by the California Environmental Quality Act (CEQA) in order to reduce vehicle travel and emissions. The VMT-based evaluation tends to favor development projects that bring destinations and activities in closer *proximity*, which can reduce the need for vehicle travel. Using either LOS or VMT to analyze transportation impacts of development projects elevates congestion or emission reduction to higher priorities than improving accessibility, which is the principal goal of transportation policy. In this study, I use a sample of 22 proposed development projects in the City of Los Angeles to show that both LOS and VMT can only partially and indirectly assess how land use developments affect residents' access to desired destinations and activities by assessing mobility changes or proximity changes. In contrast, accessibility metrics can account for both mobility and proximity, and hence can address both congestion and emissions concerns while prioritizing accessibility concerns.

Introduction

Many scholars have advocated for the application of the accessibility concept to transportation planning because it privileges the core function of the transportation system – to enable people to access destinations, rather than to simply promote mobility (Duranton and Guerra 2016; S. Handy 2005; Levine, Grengs, and Merlin 2019). Accessibility also offers an elegant framework to consider the transportation and land use systems holistically. Under this framework, access can be increased not only by improving mobility, or the ability to move about on transportation networks, but also by promoting higher density, mixed use, and infill development so that destinations become more proximate.

Despite its conceptual advantages over the conventional mobility framework, accessibility has not been well applied to transportation planning, at either the regional or local levels. At the local level, the conventional, and still most common, metric to study the transportation impacts of development projects is level of service (LOS), which measures the ease of vehicular flow on road networks and at intersections. Because a high LOS indicates free flowing traffic and a low LOS congested traffic, this metric tends to be biased towards suburban, lower density, car-oriented development patterns and against higher density, mixed use, and infill development (Ding and Taylor 2021). Recognizing the flaws of the LOS metric, California changed the metric for the transportation impact analysis required by California Environmental Quality Act (CEQA) to measure vehicle miles traveled (VMT) effects instead. Lee and Handy (2018) compared the VMT and LOS metrics and their implications on land use decisions, using three projects in Davis, California. They show that the adoption of a VMT metric can support the streamlining[1] of higher density, mixed use, and infill development projects in CEQA reviews because such projects tend

[1] Streamlining refers to projects being exempt from preparing an EIR for CEQA-mandated environmental review.

to reduce overall vehicle travel, and can avoid the need to build expensive, road capacity-increasing mitigation measures to improve travel speeds that an LOS-based analysis would tend to favor.

Both VMT and LOS are partial and indirect measures of accessibility. LOS is a measure of (auto) mobility, which is a component of accessibility. Improving LOS may improve accessibility, because making driving faster and more reliable can reduce the time needed to reach destinations or increase the number of opportunities accessible given the same amount of time. VMT is also a measure of (auto) mobility, but reflects a different, if not opposite, policy objective as compared to LOS. LOS is used to reduce vehicle delays, which indirectly increases vehicle travel; whereas VMT is used to reduce vehicle travel irrespective of delays. VMT does not directly measure travel speed or time, but it can serve as an indirect and partial measure of accessibility because a lower VMT could be due to reduced need for vehicle travel resulting from proximity of destinations, assuming that travelers can access needed destinations by means other than driving. In other words, accessibility may be improved if destinations are geographically closer, leading to shorter and fewer car trips as people substitute them with transit, biking, and walking trips. Thus, neither VMT nor LOS is a complete measure of accessibility.

Moreover, the policy objective for using either is not improving accessibility: LOS is used to reduce congestion, while VMT is used to reduce emissions (Lee and Handy 2018). Both congestion and emissions are legitimate problems in transportation, what economists term "negative externalities," but addressing them should not be the central goal of transportation planning and policy. If transportation policy's central goal is reducing congestion or reducing emission, they would each be maximized by eliminating vehicle travel entirely! Instead, the ultimate goal of the transportation systems is to enable access because, in most cases, people travel in order to get to destinations where they work, go to school, see a doctor, visit friends and families, etc. Focusing on improving LOS or reducing VMT when evaluating land use projects essentially elevates reducing congestion or reducing emission to a higher priority than improving access. In contrast, using accessibility as the metric to evaluate development projects places the focus on how these projects affect people's access to opportunities. And as I show in this paper, measuring accessibility can account for changes in both mobility on transportation networks (what LOS measures) and proximity of destinations (what VMT supposedly approximates).

In this paper, I compare LOS analysis, VMT analysis, and accessibility analysis, and their different implications for local land use decisions. I first review LOS and VMT analyses in the environmental impact reports (EIRs) of a sample of 22 development proposals in the City of Los Angeles. I then use data from these reports to conduct an accessibility analysis for three projects. I compare the results from the three different types of analysis and discuss their differences and what they imply. I contribute to the literature with four key findings. First, local congestion concerns could motivate local governments, like the City of Los Angeles, to continue requiring LOS analysis in addition to the CEQA-mandated VMT analysis in EIRs. Second, VMT-based evaluation is less likely to find projects as having significant impacts (that require mitigation), compared to LOS-based evaluation. Third, the LOS and VMT metrics can overlook accessibility gains from either mobility or proximity increases. Fourth, an accessibility metric offers a more complete and direct assessment of how land use developments affect people's access to opportunities by a variety of travel modes.

The next section reviews relevant literature on measuring transportation impacts of land use changes. I then describe my method and data. After that, I present and discuss my analysis results. Lastly, I conclude with a discussion on policy implications.

Literature Review – Measures of Transportation Impacts of Land Use Developments

Level of Service – The Conventional Measure

In local development approval processes, the transportation impact of a new development or land use change is typically studied through a traffic impact analysis (TIA). The conventional TIA evaluates how a proposed project or land use change may affect the circulation of motor vehicle traffic on nearby road segments and at nearby intersections, as measured by level of service (LOS), based on the ease of vehicular flow, on a scale from “A” (free flow) to “F” (forced flow). If the LOS analysis identifies significant local traffic impacts caused by the proposed project, the developer will typically be required to propose mitigation measures such as road and other transportation system improvements to maintain an acceptable LOS as part of the TIA. In addition to, or in lieu of, developer-financed traffic mitigations, the developer may also be asked to pay traffic impact fees or other fees to the local government to fund transportation improvements (Fulton 2018).

This conventional method has long been criticized because it relies on biased, inadequate, and theoretically flawed trip generation estimates, which collectively tend to be biased against denser and/or mixed-use developments. Shoup (2003; 2017) argued that trip generation rates (along with parking generation rates, compiled by the Institute of Transportation Engineers (ITE)) are inaccurate because they rely on small samples, and that are logically flawed because the these rates tend to be measured at peak volumes in suburban contexts with ample free parking and little or no accommodation for non-car travel. Thus, the conventional TIA tends to produce estimates biased in favor of driving, which leads to enhanced parking and street capacity to accommodate that driving, which then encourages driving in a self-fulfilling prophecy.

Such bias has been empirically proven by many studies (Clifton, Currans, and Muhs 2015; Currans et al. 2020; Ewing et al. 2011; 2017; Tian et al. 2015; 2020). The overwhelming weight of the empirical evidence suggests that ITE trip generation rates tend to overestimate vehicle trips in more urban contexts with higher densities, mix of land uses, and infrastructure for alternative travel modes such as public transit, biking, and walking. To address this bias, many researchers have suggested ways to improve trip generation analyses by estimating trip generation rates from characteristics of urban form at the neighborhood level and socio-demographics at the household level, based on theories of travel demand and travel behavior (Clifton et al. 2012; Clifton, Currans, and Muhs 2013; 2015; Currans 2017; Currans et al. 2020; Currans and Clifton 2015; Ewing et al. 2017; Howell et al. 2018; Tian, Park, and Ewing 2019; Tian et al. 2020). Partly in response to these criticisms, the ITE recommends users of its manuals to consider site contexts when applying trip generation rates and to adjust the rates to fit particular contexts, though they are largely silent on the form that such consideration should take. In practice, most local jurisdictions still rely on the conventional LOS-based TIA, and while some jurisdictions adopt improvements to this method by incorporating non-auto travel modes into the study, the mobility-based LOS framework remains largely intact (Combs, McDonald, and Leimenstoll 2020; Combs and McDonald 2021).

More importantly, even if the systematic overestimation of trip and parking generation rates is reduced, the problematic focus on LOS remains because trip generation analyses and LOS-based TIAs are centered on local area traffic flow and mobility. Without changing the focus from local vehicular mobility to local and regional accessibility, even the most accurate trip generation analysis is a self-referential mobility framework, where adding road capacity and parking to accommodate predicted vehicle trips all but ensures that those vehicle trips will indeed occur. In other words, if these more fundamental conceptual flaws are not addressed, adjusting trip generation rates in the conventional LOS-based TIA may reduce bias by adding complexity to a conceptually flawed system (Ding and Taylor 2021).

Vehicle Miles Travelled – A Better Measure

One alternative metric to LOS is vehicle miles travelled (VMT). California moved to change the basis of TIAs required in CEQA from LOS to VMT, which better captures the transportation impacts of a project or program in terms of emissions. Different from the LOS metric that has been used to ensure free flow of motor vehicle traffic, the VMT metric estimates the amount of travel generated by a new project and encourages developments and mitigations that reduce vehicle travel. Lee and Handy (2018) compared the predicted VMT impacts of three land use projects in Davis, California to LOS-based traffic impacts. They concluded that the switch to VMT could lead to lower development costs for transit-oriented, infill, and mixed-use developments, because of streamlined development review processes, and fewer required mitigation measures. Such developments are thought to reduce per resident vehicle travel overall, but would have large nearby LOS impacts because they tended to be located in more traffic congested areas. Volker, Lee, and Fitch (2019) took a historical counterfactual approach to examine what could have happened to development projects if the VMT metric were in place instead of LOS. They estimated the VMT impacts of 153 development projects in the City of Los Angeles that produced EIRs (meaning that they were determined to have a significant LOS impact) between 2001 and 2016, and found that 99 out of 153 projects could have been streamlined if evaluated based on the VMT metric and that projects containing residential units would more likely have been streamlined than non-residential projects. In other words, more development, housing in particular, could have been built under the VMT approach.

Thus, under the new VMT-based framework in CEQA, not only will projects estimated to generate less vehicle travel be less costly to build, but mitigation measures required under the VMT-based framework will emphasize travel by means other than driving and in-town locations near other destinations, both of which favor compact, mixed-use developments (Lee and Handy 2018). They conclude that the VMT metric should encourage more development, housing included, in already built-up areas where both traffic and housing costs tend to be highest.

However, despite its many plausible virtues, the VMT metric does not measure accessibility; it, like LOS analyses, centers on mobility, but instead of seeking to improve vehicular mobility, the goal instead is to reduce it (Ding and Taylor, 2021).

Accessibility – The Ideal Measure

In contrast to LOS and VMT, accessibility is a more conceptually complete measure of transportation impacts of land use changes, as it accounts for both mobility, or ease of travel, and proximity among destinations (Handy and Niemeier 1997; Levine, Grengs, and Merlin 2019; Handy 2020). The key implication of this framework is that access depends on travel time rather than travel speed, thus can be improved not only by allowing freer and faster travel, but also by reducing the distance to opportunities. While a growing chorus of urban and transportation planning scholars have been advocating for the shift from mobility to accessibility for decades, given its conceptual completeness and theoretical elegance, accessibility has not yet been widely taken up in practice (Duranton and Guerra 2016; El-Geneidy and Levinson 2006; Geurs and Van Wee 2004; Hansen 1959; Handy 2005; 2020; Handy and Niemeier 1997; Levine, Grengs, and Merlin 2019; Levinson and King 2019; Wachs and Kumagai 1973). As noted above, at the local level, TIA practices still focus primarily on mobility, which is most often operationalized as LOS, though California’s recent shift to VMT is a notable exception (Combs, McDonald, and Leimenstoll 2020; Volker, Kaylor, and Lee 2019).

Many different accessibility metrics have been developed, and most metrics incorporate a land use component that measures proximity among destinations and a transportation component that measures mobility, or the ease of moving about, on transportation networks (Handy and Niemeier 1997). More complicated metrics also account for individual characteristics and temporal constraints: individual characteristics describe individuals’ different needs and opportunities depending on socio-economic backgrounds, and their different abilities depending on physical conditions and availability of travel modes; temporal constraints can limit availability of opportunities at different times, or alter the time it takes for individuals to participate in certain activities (Geurs and van Wee 2004).

The simplest type of accessibility metrics are cumulative opportunities measures, which count the number of opportunities reached within a given travel time or distance. These types of metrics weigh all potential destinations within the cutoff time or distance equally, thus do not differentiate between opportunities that are closer to the origin and those farther away (Handy and Niemeier 1997; Geurs and van Wee 2004; El-Geneidy and Levinson 2006). Gravity-based measures improve upon cumulative opportunities measures by weighing opportunities, usually the quantity of an activity such as jobs, by impedance, generally as a function of travel time or travel cost, such that farther jobs carry less weight. But the difficulty lies in developing an impedance factor and appropriate weights for different destinations, and combining different travel modes into one metric (ibid.). Both cumulative opportunities and gravity-based measures focus on accessibility potential at the place level, thus do not account for individual characteristics or temporal constraints.

Utility-based measures, in contrast, account for individual characteristics by including the relative attractiveness of destinations and individualized measures of travel impedance, and the tastes and preferences of individuals. Accessibility can be calculated as logsums that measure the expected maximum net utility from a choice of a destination or travel mode among all choices, which represent utility gains or losses due to that choice (Siddiq and Taylor 2021; Miller 2018). Utility-based measures can also be estimated to capture temporal constraints if such information is available at the person level. Constraints-based measures also can account for temporal constraints by using the concept of space-time geography. However, the key challenge to accounting for temporal constraints is that it is very difficult to obtain detailed information about travelers' activity schedules (El-Geneidy and Levinson 2006; Siddiq and Taylor 2021).

Cumulative opportunities and gravity measures are perhaps the two most commonly used accessibility measures, because they are easier to compute and interpret, but they have also been criticized for not fully accounting for spatial and temporal constraints faced by individuals. But more conceptually complete measures like constraints-based measures and utility-based measures are also more complex, require more data, and are thus more difficult to apply in practice and explain to non-experts. Therefore, developing accessibility measures faces a fundamental tradeoff between conceptual completeness and ease of application (Siddiq and Taylor 2021). Factors like the complexity of accessibility measures, data requirements, and the lack of standard and objective metrics have been underscored as major obstacles to the application of accessibility in practice, besides factors related to institutional resistance (Miller 2018; Siddiq and Taylor 2021). Nevertheless, many scholars have acknowledged that widespread use of place-based cumulative opportunities measures and gravity-based measures, albeit imperfect, could fulfill many core policy tasks of urban and transportation planning (Boisjoly and El-Geneidy 2017; Curl, Nelson, and Anable 2011; Grengs et al. 2010; Handy 2020). Indeed, placed-based gravity measures of accessibility are a function of proximity between land uses and travel cost (often measured in terms of time), which are the two targets that urban and transportation planners can change.

Under the accessibility framework, instead of assessing the transportation impacts of a proposed development based solely or largely on the number of auto trips it may generate and attract, as LOS-based TIAs do, an accessibility-based development impact analysis would focus instead on how a new grocery store or apartment building would affect overall access to destinations in a given community. Such a shift would more fully address the bias against denser, mixed-use, and infill developments inherent in LOS-based TIA (Ding and Taylor 2021). There are promising new innovations in the development and use of access measurement tools, which are beginning to be adopted by some planning jurisdictions, though more of these innovations to date have focused on regional accessibility measurement and only a few on project evaluation (Siddiq and Taylor 2021).

Method and Data

My main research questions are: 1) what are the projected impacts of projects based on each of the three types of metrics, and how do they differ? 2) what do the projected impacts from each metric suggest? 3) can an accessibility metric that is relatively easy to compute and interpret offer a more complete and direct assessment of the transportation impacts of land use developments than either long-established LOS or newer VMT measures?

To answer these questions, I use a sample of 22 projects to illustrate the differences between the three metrics. They are proposed development projects in the City of Los Angeles that have published environmental impact reports (EIRs) that contain VMT analysis (see Table 1-1). The time frame of this sample is from 2016, when the California Governor's Office of Planning and

Research first published the technical advisory on the VMT metric, to August 2023 when this sample was selected. Choosing the City of Los Angeles is based on two considerations: 1) it is a large enough city to have project proposals that are of different contexts and types; and 2) focusing on a single city can help control for regulatory differences across municipalities that may affect the development review processes. Most projects in my sample are mixed-use development with some combination of residential, office, commercial (usually retail and/or restaurants), and hotel in urban high-density neighborhoods. The three proposals in suburban neighborhoods are rather unique: District NoHo, a transit-oriented development project adjacent to a major transit center; Harvard-Westlake River Park, a publicly available sports facility of an educational institution; and Paseo Marina, a mixed-use project near a marina.

Table 1-1. Sample of project proposals

Project Name	**Project Type**	**Urban Context | Community Plan Areas**
8th, Grand and Hope	Residential – Commercial	Urban | Central City
Angel's Landing	Residential – Hotel – Commercial	Urban | Central City
The Morrison	Hotel – Residential – Commercial	Urban | Central City
1111 Sunset	Residential – Office – Commercial – Optional Hotel	Urban | Central City North
2143 Violet Street	Residential – Office – Commercial	Urban | Central City North
2159 Bay Street	Office – Commercial	Urban | Central City North
4th and Hewitt	Office – Commercial	Urban | Central City North
670 Mesquit	Office – Hotel – Residential – Commercial	Urban | Central City North
676 Mateo Street	Residential – Commercial	Urban | Central City North
Violet Street Creative Office Campus	Office – Commercial	Urban | Central City North
1000 Seward	Office – Commercial	Urban | Hollywood
1360 N. Vine Street	Residential – Office – Commercial	Urban | Hollywood
5420 Sunset	Residential – Commercial	Urban | Hollywood
Artisan Hollywood	Residential – Commercial	Urban | Hollywood
Hollywood Center	Residential – Commercial	Urban | Hollywood
Sunset + Wilcox	Office – Commercial	Urban | Hollywood
3rd and Fairfax Mixed Use	Residential – Commercial	Urban | Wilshire

656 South San Vicente Medical Office	Medical Office – Commercial	Urban | Wilshire
Our Lady of Mt. Lebanon	Church – Residential	Urban | Wilshire
District NoHo	Residential – Commercial – Office	Suburban | North Hollywood - Valley Village
Harvard-Westlake River Park	Educational (Publicly Accessible Athletic and Recreational Facility)	Suburban | Sherman Oaks - Studio City - Toluca Lake - Cahuenga Pass
Paseo Marina	Residential – Commercial – Optional Office	Suburban | Palms - Mar Vista - Del Rey

I first review these projects' EIRs and compare the VMT and LOS analyses results. While environmental impact reviews for these projects all use the VMT metric to assess transportation impacts as required by CEQA, they also include LOS analysis to assess impacts on site access and circulation as required by the city. In other words, VMT has been an additional metric rather than a replacement of the traditional LOS metric in the City of Los Angeles. I then use three example projects, 2143 Violet Street, District NoHo, and Paseo Marina, to illustrate how they can be evaluated using an accessibility metric. I describe the three types of analysis below.

VMT Analysis

The VMT analysis uses the VMT calculator provided by the Los Angeles Department of Transportation (LADOT) and Department of City Planning (LADCP) to estimate project-specific daily household VMT per capita and daily work VMT per employee. The VMT calculator accounts for a variety of socio-demographic and built environment factors, as well as adjustments for mixed-use projects and transportation demand management (TDM) measures (LADOT and LADCP 2020). Thresholds for significant VMT impacts are specific to each of the City's seven Area Planning Commissions[2] – defined as 15% below, or 85% of an area's existing average daily

[2] The seven areas are Central, East LA, West LA, South LA, Harbor, North Valley, and South Valley.

household VMT per capita and average daily work VMT per employee (LADOT 2022). Retail uses are analyzed separately: if retail space of the project is under 50,000 square feet in floor area, it is considered local-serving and hence exempted from the VMT analysis; otherwise, it is considered regional-serving and its VMT impacts need to be assessed either qualitatively using a market study or quantitatively using the City's travel demand forecasting model (LADOT 2022).

Projects that are estimated to generate household or work VMT higher than the area-specific thresholds or result in a net increase in regional retail VMT are deemed to have significant project-level VMT impacts and are required to implement TDM measures to mitigate such impacts, mostly by limiting parking supply and raising parking costs, while promoting alternative transportation options and improving their quality (see Table 1-2). These TDM measures are incorporated in the VMT calculator, so project sponsors can estimate the VMT impacts of their projects with mitigation measures – indeed, many projects actually include some TDM measures in their proposal to reduce their VMT estimates.

Table 1-2. TDM measures to mitigate significant project VMT impacts (source: LADOT Transportation Assessment Guidelines)

Category	Measure

Parking	• Reduce parking supply
	• Unbundle parking
	  ○ unbundle parking cost from property cost
	• Parking cash-out
	  ○ offer employees cash in lieu of free/subsidized parking
	• Price workplace parking

Transit	• Reduce transit headways ○ more frequent service • Implement neighborhood shuttle • Transit subsidies

Education & Encouragement	• Voluntary travel behavior change program
	  ○ mass communication campaigns that actively engage individuals
	• Promotions and marketing (of alternative transportation options)
	  ○ passive educational tools like posters and information displays

Commute Trip Reductions	• Required commute trip reduction program
	  ○ often a combination of the other measures in this category
	• Alternative work schedules and telecommute program
	  ○ e.g. staggered start times, flexible schedules
	• Employer-sponsored vanpool or shuttle
	• Rideshare program

Shared Mobility	• Car share • Bike share • Other shared mobility devices • School carpool program
Bicycle Infrastructure	• On-street bicycle facility • Outdoor bike parking • Secure bike parking and showers
Neighborhood Enhancement	• Traffic calming improvements ○ e.g. enhanced crossings, raised crosswalks, speed humps • Pedestrian network improvements

LOS Analysis

The LOS analysis follows methodologies from the latest edition of the Transportation Research Board Highway Capacity Manual to evaluate intersection LOS. Study locations are determined in consultation with LADOT and, at a minimum, include 1) all primary driveways (main points of access), 2) intersections in the immediate surroundings of the project, 3) adjacent unsignalized intersections or those that are integral to the project's site access and circulation plan, and 4) nearby signalized intersections where the project is projected to add 100 or more net new peak hour trips. Traffic counts are either obtained from the LADOT database or – if recent data is not available in the database – collected by a qualified firm; vehicle trips generated by the project can either be estimated using the City's VMT calculator or referencing the latest edition of the Institute of Transportation Engineer Trip Generation Manual (LADOT 2022). Intersection LOS is measured as either volume-to-capacity ratio or delay in seconds and each studied intersection is assigned a LOS grade for the baseline year (the year of the study) and the future year (the year when the project will be fully built out). Future year estimates also consider planned transportation investments and land use projects in the surrounding area.

Unlike in the past, the LOS analysis no longer concludes if the project causes significant LOS impacts. Nevertheless, LADOT still recommends a set of "corrective actions" to address site access and circulation constraints (see Table 1-3). To facilitate the comparison of the LOS and VMT analyses results, I use significance thresholds described in LADOT's 2014 Traffic Study Policies and Procedures (LADOT 2014)[3] to determine whether each project would result in significant LOS impacts if they were to be evaluated before 2016.

Table 1-3. Recommended measures to address site access and circulation constraints (source: LADOT Transportation Assessment Guidelines)

1. TDM measures that reduce trips (including the ones in Table 1-2)
2. Measures internal to the project site • Installation of a traffic signal or stop signs or electronic warning devices at site access points • Redesign and/or relocation of project access points • Redesign of the internal access and circulation system • Installation of stop-signs and pavement markings internal to the site • Restrict or prohibit turns at site access points • Repurpose existing curb space to better accommodate passenger loading
3. Measures external to the project site • New traffic signal installation, left-turn signal phasing, or other vehicle flow enhancements (e.g., ATSAC system upgrades) at nearby intersections • Intersection reconfiguration that reduces gridlock and unsafe conflict points • Provide continuous paved sidewalks, walkways or shared use paths to off-site pedestrians and bicyclists to adjacent or nearby transit facilities • Fair share contribution to planned LADOT capital project that accomplishes one or more of the above

[3] This document contains thresholds for determining LOS grades (A to F) based on current and predicted absolute measures of LOS (volume-to-capacity ratios or delays in second); and for determining significant LOS impacts based on predicted changes in LOS.

Accessibility Analysis

As mentioned above, I focus on three projects – 2143 Violet Street, District NoHo, and Paseo Marina – for the accessibility analysis. They each represent a different context to offer insight on how the three metrics compare and contrast (more details below). I use *Conveyal Analysis (*for convenience, referred to as *Conveyal* below*)* for the accessibility analysis. *Conveyal* can be used to calculate accessibility via multiple travel modes for different land use and transportation scenarios. The main input data is a transportation network bundle for the study area using Open Street Map data and General Transit Feed Specification (GTFS) data[4], and a destination opportunity map layer using job data from the 2021 LODES (*Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics)* dataset (from the U.S. census).

I draw data from the projects' EIRs to edit the transportation and land use data to account for the changes expected from these projects. More specifically, I use land use assumptions from the VMT calculator to create a separate map layer of destination opportunities with new jobs hosted in these projects in addition to existing jobs in the LODES data; I use the LOS results to adjust the average vehicular speed (of cars and buses) on street segments near the projects; I also adjust walking and biking conditions of street segments if the project includes off-site pedestrian and bicycle improvements. Then, for each project, I calculate job accessibility, by different travel modes from locations at or near the project site, for the no-project and with-project scenarios to show accessibility changes resulting from the proposed development.

The output from *Conveyal* includes isochrones representing the areas that can be reached from the origin for the no-project and with-project scenarios and counts (weighted) of jobs that fall into

[4] Street network data is downloaded from Open Street Map; GTFS feeds are obtained from LA Metro, LADOT, Culver City Bus, and Big Blue Bus websites.

these areas. These isochrones represent the changes in how far one can travel by a specific mode due to changes in transportation networks. I then overlay these isochrones onto the two opportunities layers – one with existing jobs and the other with existing plus added jobs – to capture changes in opportunities that can be reached due to land use changes. I need to do the analysis in these two steps because *Conveyal* currently only offers a function to create scenarios by editing transportation changes but not land use changes.

This essentially means that I get four estimates for job accessibility at each location by a specific travel mode: 1) a baseline estimate for the no-project scenario, 2) an intermediate estimate of job accessibility due to transportation changes only, 3) another intermediate estimate of job accessibility due to land use changes only, and 4) a final estimate of job accessibility resulting from the combined effects of transportation and land use changes. While not being able to edit land use changes for scenarios might be a limitation of the tool's application in practice, it allows me to tease out the mobility effect – changes in accessibility due to changes in travel speed or time (difference between estimates 2 and 1), and the proximity effect – changes in accessibility due to changes in the number of destinations (difference between estimates 3 and 1).

For each project, I use these estimates to show the overall changes in job accessibility and the mobility and proximity effects at a set of locations via multiple modes. I calculate gravity-based accessibility by applying a built-in exponential decay function in *Conveyal* (for methodology, see Conway, Byrd, and van der Linden 2017). For each project, I calculate job accessibility by 15-minute driving, 50-minute transit, 10-minute walking, and 15-minute biking at the project site and nearby intersections that have significant LOS impacts. For transit trips, I assume travelers walk to and from transit stops or stations, which counts towards the 50 minutes. These travel time cutoff values are the median trip durations for the four travel modes in the Los Angeles – Long Beach –

Anaheim Metropolitan Statistical Area, based on the 2017 National Household Travel Survey California add-on data.

I only measure access to jobs, mostly due to data limitations. As described above, the VMT calculator only estimates household and work VMT, so I can only obtain an estimate on new jobs hosted by each project, but not other non-work opportunities. Moreover, these estimates do not consider each new job's occupation or industry. Thus, I only compare one metric – accessibility to all jobs – before and after a project. While this certainly is a limitation of my analysis, it should not seriously undermine the validity of my results for two reasons. First, job accessibility has often been used as a proxy for access to all kinds of opportunities, because other land uses like shops, schools, hospitals all generate jobs. Second, the purpose of my analysis is to test the relative changes in accessibility levels due to a development project, rather than to accurately measure the absolute levels of accessibility, so the internal consistency of the measurement matters more.

Another limitation is that I can only calculate accessibility from individual addresses rather than an aggregate measure of accessibility for the local neighborhood surrounding the proposed project, because *Conveyal* currently only offers a single-point analysis function for local-scale analysis. But I still try to capture, to some extent, how a new project may affect the accessibility of existing residents, because they are usually concerned about potential traffic impacts of new developments. So, in addition to calculating accessibility from the project site – where the most accessibility gains are – I also calculate accessibility from residential locations near intersections that would have significant LOS impacts, or traffic delays. The rationale is that any access gains due to new jobs in close proximity can be negated by slower travel speed or longer travel time to reach these new jobs, the degree of which is the highest for those living next to the intersections with the greatest traffic delays. In other words, these locations are likely to have the least accessibility gains within the surrounding neighborhood of a new project.

An overall limitation of my study is its narrow geographic focus. This is inevitably a California-focused study because California is the first and to date only state that has mandated the VMT metric for development reviews. However, the findings from this study may be useful for cities in other US states because local municipalities are already finding the LOS metric problematic or insufficient and hence have adopted modifications to it (Combs, McDonald, and Leimenstoll 2020). Moreover, VMT and accessibility are not new concepts to planning professionals around the nation, who have discussed and incorporated VMT and accessibility metrics into planning practices to some degree – Metropolitan Planning Organizations in many states have regional plans that discuss accessibility and use VMT metrics as performance measures (Proffitt et al. 2019; more detail also discussed in essay two on California MPOs' use of accessibility metrics).

Results

LOS vs. VMT Analysis Results

As noted above, the switch from LOS to VMT as the metric for transportation impacts under CEQA does not mean the conventional LOS metric has been completely abandoned. Cities can still require project proposals to include LOS analysis to address congestion concerns, as the City of Los Angeles does. So instead of including only LOS analysis required by the State prior to the CEQA change, project EIRs now include a VMT analysis, which tend to favor projects that generate less vehicle travel to reduce the environmental impacts of transportation, and an LOS analysis, which aims to maintain an acceptable level of vehicular mobility. But, again, neither directly assesses accessibility to opportunities.

The current version of the LOS analysis required by the City of Los Angeles, however, is somewhat different from more traditional versions, and reflects a reduced emphasis on vehicular mobility to some extent. While the methodology of the analysis remains mostly unchanged (as described above), the criterion for determining significant impacts has changed. Prior to the CEQA change, an intersection was determined to have a significant impact if 1) the intersection had an LOS grade of C or lower, and 2) the increase in volume to capacity ratio or vehicular delay exceeded some threshold specific to the given grade. After the CEQA change, the term “significant impact” is now reserved only for the VMT analysis, while the LOS analysis focuses on identifying to find intersections that would have “unacceptable or extended queuing”, which is determined if 1) the intersection has an LOS grade of D or lower, and 2) the increase in queuing exceeds some threshold specific to the given grade (LADOT 2014; 2022). Just like project proposals/EIRs were required to address significant LOS impacts before 2016, they are now required to address unacceptable or extended queuing through a set of recommended “corrective actions” (see Table 1-3 above). The key difference here is that this new set of recommended measures no longer includes street widening, which was recommended, among other measures, in the old guidelines (ibid).

Table 1-4. VMT and LOS analysis results for all projects

Project Name	**VMT Estimates**			**Significant VMT Impact**	**Significant LOS Impact (signalized intersections)**
	Household	**Work**	**Commercial**		
8th, Grand and Hope	3.4 (6.0)	-	Local serving	No	2 out of 4
Angel's Landing	3.9 (6.0)	7.3 (7.6)	Local serving	No	7 out of 10
The Morrison	3.5 (6.0)	6.6 (7.6)	Local serving	No	1 out of 4
1111 Sunset – no hotel option	4.9 (7.2)	8.3 (12.7)	Local serving	No	6 out of 13

1111 Sunset – with hotel option	4.8 (7.2)	8.4 (12.7)	-	No ^	6 out of 13
2143 Violet Street	9.3 (6.0)	9.1 (7.6)	Local serving	Yes	2 out of 3
2159 Bay Street	-	7.5 (7.6)	-	No ^	1 out of 2
4th and Hewitt	-	7.2 (7.6)	-	No	8 out of 22
670 Mesquit	4.0 (6.0)	6.6 (7.6)	Net increase	Yes	17 out of 22
676 Mateo Street – no office option	5.0 (6.0)	7.4 (7.6)	-	No ^	None
676 Mateo Street – with office option	5.0 (6.0)	7.6 (7.6)	-	No ^	None
Violet Street Creative Office Campus	-	6.7 (7.6)	Local serving	No	3 out of 5
1000 Seward	-	7.5 (7.6)	Local serving	No ^	None
1360 N. Vine Street – residential option	5.6 (6.0)	-	Net decrease	No	2 out of 3
1360 N. Vine Street – office option	3.0 (6.0)	5.2 (7.6)	Local serving	No	3 out of 3
5420 Sunset	4.6 (6.0)	-	Net decrease	No	4 out of 18
Artisan Hollywood	3.9 (6.0)	-	Local serving	No	1 out of 2
Hollywood Center – no hotel option	4.8 (6.0)	-	-	No ^	5 out of 9
Hollywood Center – with hotel option	4.7 (6.0)	4.8 (7.6)	Local serving	No ^	5 out of 9
Sunset + Wilcox	-	6.1 (7.6)	Local serving	No	1 out of 9
3rd and Fairfax Mixed Use	5.9 (6.0)	-	Net decrease	No ^	None
656 South San Vicente Medical Office	-	7.5 (7.6)	Local serving	No ^	2 out of 7
Our Lady of Mt. Lebanon	5.8 (6.0)	2.8 (7.6)	-	No ^	None
District NoHo	5.3 (9.4)	10.4 (11.6)	-	No	13 out of 23
Paseo Marina – option A	6.9 (7.4)	-	Local serving	No	1 out of 7
Paseo Marina – option B	5.4 (7.4)	11.6 (11.1)	-	Yes ^	1 out of 7

Harvard-Westlake River Park	Net decrease	No	2 out of 5

Notes: 1) Household and work VMT estimates are daily per capita measures, and significant thresholds are in parentheses; 2) VMT for commercial uses is assessed differently, which does not yield estimates; 3) "^" indicates that the project's impact is determined based on VMT estimates that already account for TDM measures; 4) VMT impact for Harvard-Westlake River Park is not assessed using the VMT calculator because it does not contain residential, office, or commercial uses; 5) LOS impacts are determined using LADOT 2014 Traffic Policies and Procedures, and are only assessed for signalized intersections, per LADOT guidelines.

My review of the 22 projects' EIRs find that most (18 out of 22) projects would have had significant LOS impacts if they were to be assessed using the 2014 LADOT guidelines, whereas only three projects are predicted to have significant VMT impact based on the current guidelines (see Table 1-4). Many of these projects' VMT estimates are well below the significant thresholds while some projects' estimates are close to thresholds. This latter group of projects often already includes TDM measures as part of their proposals, which helps bring the VMT estimates down. For instance, 2159 Bay Street, an office project (217,189 sq. ft. of office space plus 5,000 sq. ft. of retail and restaurant space), was initially estimated to generate 9.1 daily work VMT per employee; after accounting for TDM measures, which included parking cash-out, ride-share programs, car- and bike-share spaces, bicycle and pedestrian amenities, and promotions and marketing (see Table 1-2 for details), the estimate was down to 7.5 daily work trips per employee, just below the 7.6 threshold. Another example is 3rd and Fairfax Mixed Use, a primarily residential project (331 multi-family units) with some ground floor retail use (83,994 sq. ft.): the initial estimate was 7.1 daily household VMT per capita; after accounting for TDM measures, which included unbundled parking, bicycle parking spaces, and promotions and marketing, the estimate became 5.9, just below the 6.0 threshold.

Three projects were estimated to have significant VMT impact: 2143 Violet Street, 670 Mesquit, and Paseo Marina. The Violet Street project is a mixed-use project including residential (347 live-work units), office (187,374 sq. ft.), and commercial (21,858 sq. ft.) uses. It is estimated to generate 9.3 daily household VMT per capita and 9.1 daily work VMT per employee, both of which exceed the significance thresholds. These estimates do not account for any TDM measures. The project EIR does not include a TDM plan, but identifies several potential TDM measures to reduce these household and work VMT, which include bicycle and pedestrian amenities, unbundled parking, commute trip reduction program, promotions and marketing. While it is unclear how much these measures can reduce the VMT estimates, the developer is likely to include as many TDM measures as possible to bring the estimates down to just below the significance thresholds, like the ones discussed above.

The 670 Mesquit project is a different case because its household and work VMT estimates are below significance thresholds, but its commercial VMT – associated with a food hall, a grocery store, general retail (136,152 sq. ft.), restaurants (89,577 sq. ft.), studio/event/gallery/museum space (93,617 sq. ft.), and a gym (62,148 sq. ft.) – is considered regional-serving and would result in a net increase of 32,000 daily miles in VMT (equivalent to 0.03% increase from the no-project scenario). The project's EIR discusses some potential mitigation measures, emphasizing that those related to bicycle, pedestrian, and transit amenities are expected to effectively reduce commercial VMT, while also further reducing household and work VMT.

Paseo Marina is proposed with two options: option A is a primarily residential development (658 multi-family units) with some local-serving retail and restaurant space (27,300 sq. ft.); option B includes fewer residential units (425 multi-family units), but more retail and restaurant (40,000 sq. ft.) and additional office space (90,000 sq. ft.). Option A is estimated to generate less than significant VMT impact, while option B is estimated to generate 14.5 daily work VMT per employee without TDM measures. After accounting for proposed TDM measures, which include transit subsidies, promotion and marketing, alternate work schedules and telework programs, bicycle infrastructures (parking/shower), pedestrian network improvements, the estimate is down to 11.6, which is still higher than the significant threshold of 11.1. To address this unmitigated impact, the developer proposes to contribute $18,578 annually to Metro's U-Pass (college student transit pass) program.

I draw three main findings from the comparison between the VMT and LOS analysis results of these 22 projects. First, projects tend to perform better, or have less than significant impact, when evaluated under the VMT metric. Half (11 out of 22) of these projects would have significant LOS impact but less than significant VMT impact even without accounting for TDM measures. An additional four projects would have significant LOS and VMT impacts, but are able to reduce the VMT estimates below the significant threshold by including TDM measures as part of the project proposal. On the other hand, the four projects that have less than significant LOS impact also have less than significant VMT impact, but only after accounting for additional TDM measures. This leads to the second finding: developers are likely motivated to include TDM measures in project proposals to achieve less than significant VMT impacts, which may speed up the development review process. Out of the 22 projects, 9 projects include TDM measures as part of the project proposal to lower their VMT estimates. And the inclusion of TDM measures in the VMT calculator has likely made it easier for developers to do so.

Third, fewer projects are required to implement mitigation measures when they are evaluated using the VMT metric, as compared to being evaluated using the LOS metric prior to the CEQA change. Moreover, the mitigation measures differ in their focus under the two metrics, which has very different implications for local transportation and land use systems. As noted earlier, the key difference is that mitigation measures for LOS impacts prior to the CEQA change aimed to reduce congestion by discouraging vehicle travel on the one hand using measures similar to the TDM measures for VMT impacts, while also accommodating more vehicle travel on the other hand by expanding road capacities through measures like street widening. The different focuses of the mitigation measures reflect the increasing importance of emissions reduction relative to congestion reduction in state-level transportation policy. Note that local governments can still require projects to be evaluated using the LOS metric in addition to the CEQA-mandated VMT evaluation, as the City of Los Angeles does. However, as discussed earlier, the current version of LOS evaluation required by the City of Los Angeles has a lower standard for acceptable vehicular flows and does not recommend capacity-increasing mitigation measures such as street widening. Nonetheless, the persistence of the LOS metric reflects the enduring importance of congestion as the main transportation problem for local governments.

Accessibility Analysis Results

I illustrate the accessibility impacts of three projects: 2143 Violet Street, Paseo Marina (option B), and District NoHo (see Figure 1-1 for their locations). As briefly mentioned earlier, they are different in land use composition, urban context, and LOS and VMT impacts. All three projects would have significant LOS impact, while 2143 Violet Street and Paseo Marina (option B) are estimated to have significant VMT impact, District NoHo is estimated to have less than significant VMT impact. District NoHo is different in two other important aspects. First, District NoHo includes off-site pedestrian and bicycle infrastructure improvements in its proposal. I can use this information to adjust walking and biking conditions in *Conveyal* to estimate the mobility effect for walking and biking. Second, the LOS analysis for District NoHo predicts not only significant delays at some intersections, but also improvements at a few intersections, which means there can be accessibility gains from faster vehicular speed.

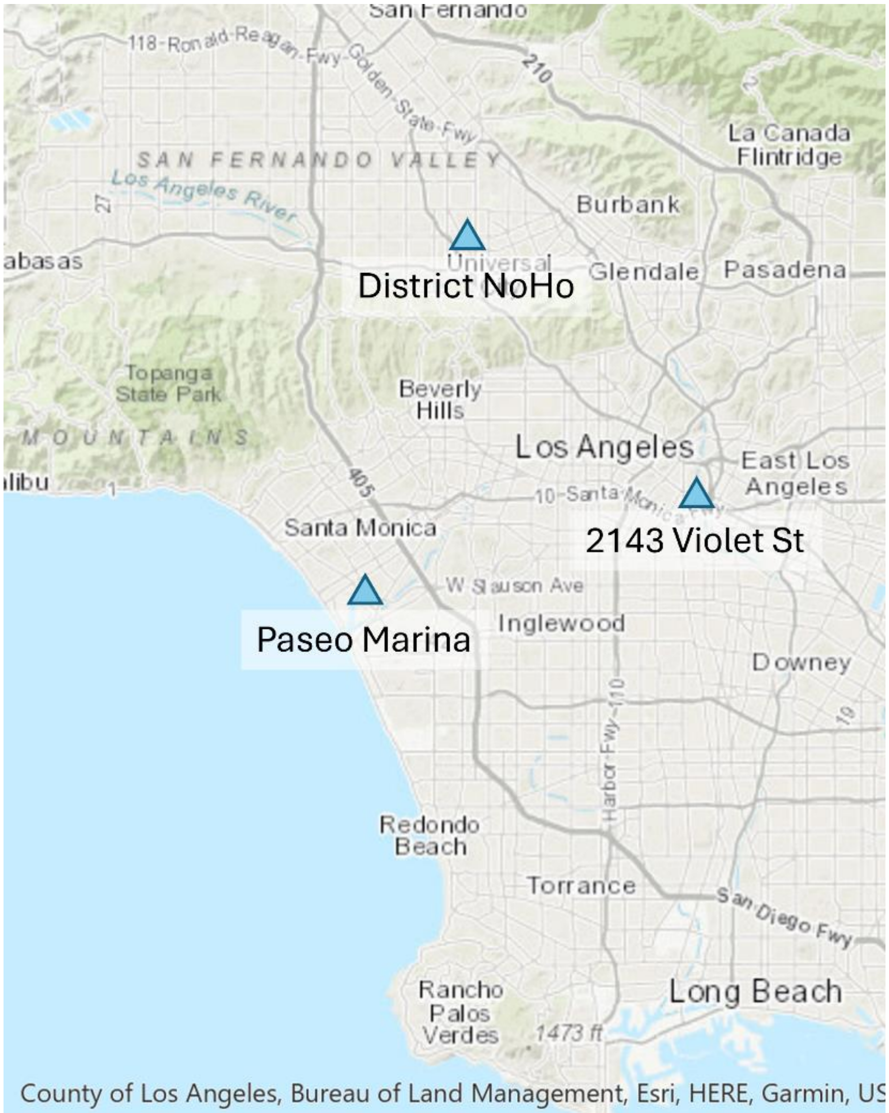

Figure 1-1. Locations of evaluated projects

Table 1-5. Accessibility analysis results

Locations	Mode (travel time cutoff)	Baseline accessibility (no. of jobs)	Mobility effect		Proximity effect		Overall access impact	
			Absolute change (no. of jobs)	Percent change	Absolute change (no. of jobs)	Percent change	Absolute change (no. of jobs)	Percent change
2143 Violet Street								
Project site	Driving (15 mins)	1,665,463	-51,550	-3%	1,817	0%	-49,806	-3%
	Transit (50 mins)	1,319,882	-63,364	-5%	1,995	0%	-61,421	-5%
	Walking (10 mins)	27,691	0	0%	332	1%	332	1%
	Biking (15 mins)	336,972	0	0%	702	0%	702	0%
Intersection #1 (Santa Fe & Violet)	Driving (15 mins)	1,681,335	-69,793	-4%	1,838	0%	-68,028	-4%
	Transit (50 mins)	1,323,039	-44,067	-3%	2,004	0%	-42,097	-3%
	Walking (10 mins)	29,047	0	0%	356	1%	356	1%
	Biking (15 mins)	341,657	0	0%	715	0%	715	0%
Intersection #2 (Santa Fe & 7th)	Driving (15 mins)	1,707,716	-77,820	-5%	1,850	0%	-76,052	-4%
	Transit (50 mins)	1,326,010	-27,743	-2%	1,984	0%	-25,786	-2%
	Walking (10 mins)	32,403	0	0%	286	1%	286	1%
	Biking (15 mins)	348,097	0	0%	679	0%	679	0%
Intersection #3 (Mateo & 7th)	Driving (15 mins)	1,699,521	-62,278	-4%	1,832	0%	-60,500	-4%
	Transit (50 mins)	1,319,684	6,541	0%	1,955	0%	8,516	1%
	Walking (10 mins)	36,515	0	0%	248	1%	248	1%
	Biking (15 mins)	356,850	0	0%	662	0%	662	0%
Paseo Marina								
Project site	Driving (15 mins)	1,234,947	-3,899	0%	1,354	0%	-2,545	0%
	Transit (50 mins)	779,417	-125	0%	1,260	0%	1,130	0%
	Walking (10 mins)	10,495	0	0%	368	4%	368	4%
	Biking (15 mins)	182,491	0	0%	471	0%	471	0%
Intersection #1 (Villa Velletri)	Driving (15 mins)	1,289,689	-4,159	0%	1,400	0%	-2,761	0%
	Transit (50 mins)	779,403	1,675	0%	1,260	0%	2,927	0%
	Walking (10 mins)	10,329	0	0%	347	3%	347	3%
	Biking (15 mins)	187,966	0	0%	467	0%	467	0%

Intersection #2 (Glencoe & Mindanao)	Driving (15 mins)	1,243,824	-246	0%	1,343	0%	1,096	0%
	Transit (50 mins)	755,881	-315	0%	1,220	0%	894	0%
	Walking (10 mins)	9,393	0	0%	277	3%	277	3%
	Biking (15 mins)	189,647	0	0%	449	0%	449	0%
District NoHo								
Project site	Driving (15 mins)	1,250,012	383,636	31%	2,701	0%	386,561	31%
	Transit (50 mins)	1,338,184	-1,762	0%	2,832	0%	1,072	0%
	Walking (10 mins)	9,380	220	2%	1,895	20%	2,125	23%
	Biking (15 mins)	205,340	325	0%	2,381	1%	2,708	1%
Intersection #1 (Burbank & Tujunga & Lankershim)	Driving (15 mins)	1,214,955	371,509	31%	2,470	0%	374,226	31%
	Transit (50 mins)	1,219,492	774	0%	2,572	0%	3,353	0%
	Walking (10 mins)	7,663	100	1%	1,158	15%	1,277	17%
	Biking (15 mins)	192,528	249	0%	2,112	1%	2,362	1%
Intersection #2 (Burbank & Vineland)	Driving (15 mins)	1,300,745	400,249	31%	2,517	0%	403,002	31%
	Transit (50 mins)	1,171,074	-7,290	-1%	2,460	0%	-4,843	0%
	Walking (10 mins)	9,878	36	0%	891	9%	932	9%
	Biking (15 mins)	209,686	39	0%	1,996	1%	2,034	1%
Intersection #3 (Chandler & Vineland)	Driving (15 mins)	1,307,103	388,275	30%	2,665	0%	391,139	30%
	Transit (50 mins)	1,246,683	-2,965	0%	2,676	0%	-290	0%
	Walking (10 mins)	10,365	57	1%	1,443	14%	1,501	14%
	Biking (15 mins)	214,349	108	0%	2,240	1%	2,349	1%
Intersection #4 (Magnolia & Lankershim - Vineland)	Driving (15 mins)	1,311,161	350,065	27%	2,617	0%	352,849	27%
	Transit (50 mins)	1,212,999	-750	0%	2,641	0%	1,891	0%
	Walking (10 mins)	10,061	48	0%	1,372	14%	1,419	14%
	Biking (15 mins)	211,780	97	0%	2,193	1%	2,290	1%
Intersection #5 (Tujunga & Magnolia)	Driving (15 mins)	1,345,996	352,125	26%	2,650	0%	354,973	26%
	Transit (50 mins)	1,198,984	-1,102	0%	2,626	0%	1,524	0%
	Walking (10 mins)	8,559	60	1%	1,325	15%	1,385	16%
	Biking (15 mins)	202,394	33	0%	2,172	1%	2,205	1%
Intersection #6 (Magnolia & SR170)	Driving (15 mins)	1,417,681	277,466	20%	2,550	0%	280,200	20%
	Transit (50 mins)	1,146,305	-4,352	0%	2,509	0%	-1,844	0%

	Walking (10 mins)	7,188	73	1%	1,049	15%	1,122	16%
	Biking (15 mins)	194,098	10	0%	2,076	1%	2,085	1%
Intersection #7 (Burbank & SR170 & Colfax)	Driving (15 mins)	1,300,721	356,737	27%	2,426	0%	359,394	28%
	Transit (50 mins)	1,101,539	3,381	0%	2,330	0%	5,716	1%
	Walking (10 mins)	6,791	52	1%	702	10%	765	11%
	Biking (15 mins)	184,734	63	0%	1,880	1%	1,944	1%
Intersection #8 (Tujunga & Riverside & Camarillo)	Driving (15 mins)	1,362,582	389,072	29%	2,376	0%	391,779	29%
	Transit (50 mins)	1,035,284	3,586	0%	2,218	0%	5,804	1%
	Walking (10 mins)	7,579	30	0%	681	9%	710	9%
	Biking (15 mins)	200,348	15	0%	1,869	1%	1,885	1%
Intersection #9 (Lankershim & Vineland & Camarillo)	Driving (15 mins)	1,406,591	352,489	25%	2,476	0%	355,189	25%
	Transit (50 mins)	1,155,093	-5,593	0%	2,444	0%	-3,170	0%
	Walking (10 mins)	11,194	22	0%	795	7%	818	7%
	Biking (15 mins)	221,096	55	0%	1,938	1%	1,993	1%
Intersection #10 (Lankershim & Moorpark)	Driving (15 mins)	1,496,221	321,956	22%	2,296	0%	324,559	22%
	Transit (50 mins)	1,202,960	-2,893	0%	2,356	0%	-581	0%
	Walking (10 mins)	13,848	11	0%	387	3%	398	3%
	Biking (15 mins)	230,330	43	0%	1,650	1%	1,693	1%

Table 1-5 shows the accessibility analysis results for all three projects. Intersections are numbered based on their distance away from the project site – larger number indicates that the intersection is farther away from the project site. Baseline accessibility measures the current level of job accessibility. As previously described, I use a gravity-based measure, so the values indicate the total numbers of jobs, weighted based on distance from origin, that can be reached by each mode in the given travel time. Mobility effect measures the change in job accessibility due to changes in traffic conditions, proximity effect measures the change due to new jobs added by the proposed project, and overall access impact measures the overall change in job accessibility due to the combined effects of mobility and proximity effects. Below I describe each project in a bit more detail and discuss their accessibility analysis results.

2143 Violet Street

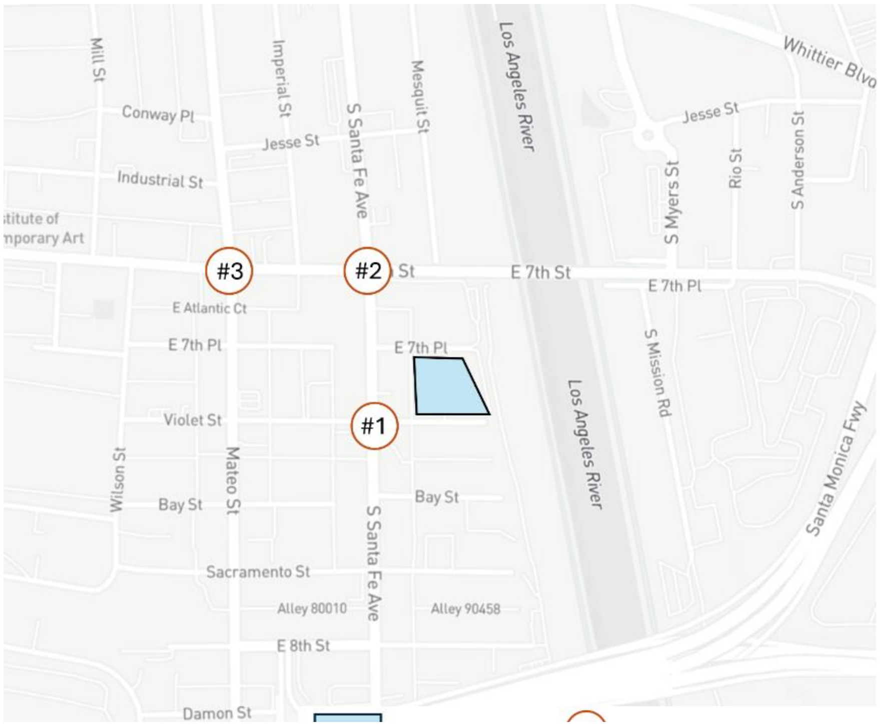

Figure 1-2. Map of 2143 Violet Street and surrounding

2143 Violet Street, as described earlier, is a mixed-use high-rise development in Downtown Los Angeles. Access to and from the site is limited because it is located at the end of a cul-de-sac with Los Angeles River on the east side (see Figure 1-2). Metro local bus routes 60 and 62 run on nearby streets: East 7th Street and South Santa Fe Avenue, but the site is not directly served by any transit routes. The site has good access to freeways, being located near the intersection of I-10, I-5, US-101, and CA-60. The LOS analysis shows that three nearby intersections would experience significant delays due to the project (#1 is unsignalized, #2 and #3 are signalized); the VMT analysis assumes that the project will add 837 new jobs.

Results in Table 1-5 show that the project would result in small (3-4%) decreases in accessibility by car, which can be mostly attributed to the mobility effect. These decreases are small because delays at local intersections account for a small percentage of the overall travel time of a 15-minute drive. But the absolute accessibility decreases due to mobility effect are much larger than the increases due to proximity effect, because the added new jobs are a very small share of all jobs that can be reached in 15 minutes by driving.

Similarly, changes in accessibility by transit are also mostly due to the mobility effect. Decreases are bigger at the project site (5%) and the closest intersection (3%), where traffic conditions worsen the most, but the effect is smaller at the two farther intersections (2% decrease at #2, and 1% increase at #3). On the one hand, traffic delays are smaller at these two intersections; on the other hand, residents near these intersections (on 7th Street) can more easily walk to alternative routes on 6th Street to avoid congestion.

There are very small (0-1%) increases for accessibility by walking and biking at all locations. These increases are fully attributed to the proximity effect, because I assume that delays in vehicular flow do not meaningfully affect walking and biking speeds.

Paseo Marina

Figure 1-3. Map of Paseo Marina and surrounding

Paseo Marina, as briefly described above, is a mixed-use development in the Del Ray neighborhood in Los Angeles' Westside. Accessibility from this location – about 1.5 miles away from the oceanfront – is restricted on the west by the ocean (see Figure 1-1). The project site is directly served by Culver City Bus 7 on Glencoe Avenue and Maxella Avenue, and Santa Monica Big Blue Bus 16 on Glencoe Avenue. Metro local bus 108 and LADOT Commuter Express 437 run on nearby Mindanao Way, Big Blue Bus 3 (local and rapid[5]) run on nearby Lincoln Boulevard. The site is also located near the entrance to the CA-90 freeway (see Figure 1-3). I analyze the

[5] Big Blue Bus 3 runs on two kinds of services: local service makes more stops and has a slower average speed; rapid service makes fewer stops and has a faster average speed.

impact of option B of the project because this option is estimated to have significant VMT impact (even after accounting for TDM measures). The LOS analysis predicts that two nearby intersections will experience significant delays due to the project (#1 is unsignalized and #2 is signalized); the VMT analysis assumes that the project will add 480 new jobs.

Results from the accessibility analysis show that the project will result in little to no percentage change in accessibility by car and transit at the studied locations (see Table 1-5). But accessibility by transit increases in absolute terms, albeit by very small amounts, at all locations, which is mostly attributed to the proximity effect. The same is true for accessibility by car at intersection #2. The mobility effect is small because the predicted traffic delays, while significant based on 2014 LADOT thresholds, are not substantive.

Accessibility by walking increases by 4% at the project site and 3% at the two intersections. As expected, the effect becomes smaller as the analyzed location gets farther away from the project, where all the new jobs are located. Absolute increases in accessibility by biking are bigger than by walking, but these increases are very small in percentage terms because these new jobs account for a much smaller share of all jobs that can be reached with the cutoff time for biking as compared to walking, given the relatively low-density suburban context of this project.

District NoHo

District NoHo is a transit-oriented mixed-use development in the North Hollywood neighborhood in Los Angeles's San Fernando Valley. Accessibility from this site is limited by mountains to the south and the east (see Figure 1-1). This project will be built on several parcels adjacent to the North Hollywood Transit Center. Metro B Line, a subway connecting North Hollywood and Downtown Los Angeles, and G Line, a busway that runs through San Fernando Valley, as well as ten local bus routes operated by LA Metro and LADOT connect at the transit center. In addition to good transit access, the project also has good freeway access, being located very close to the CA-170 freeway.

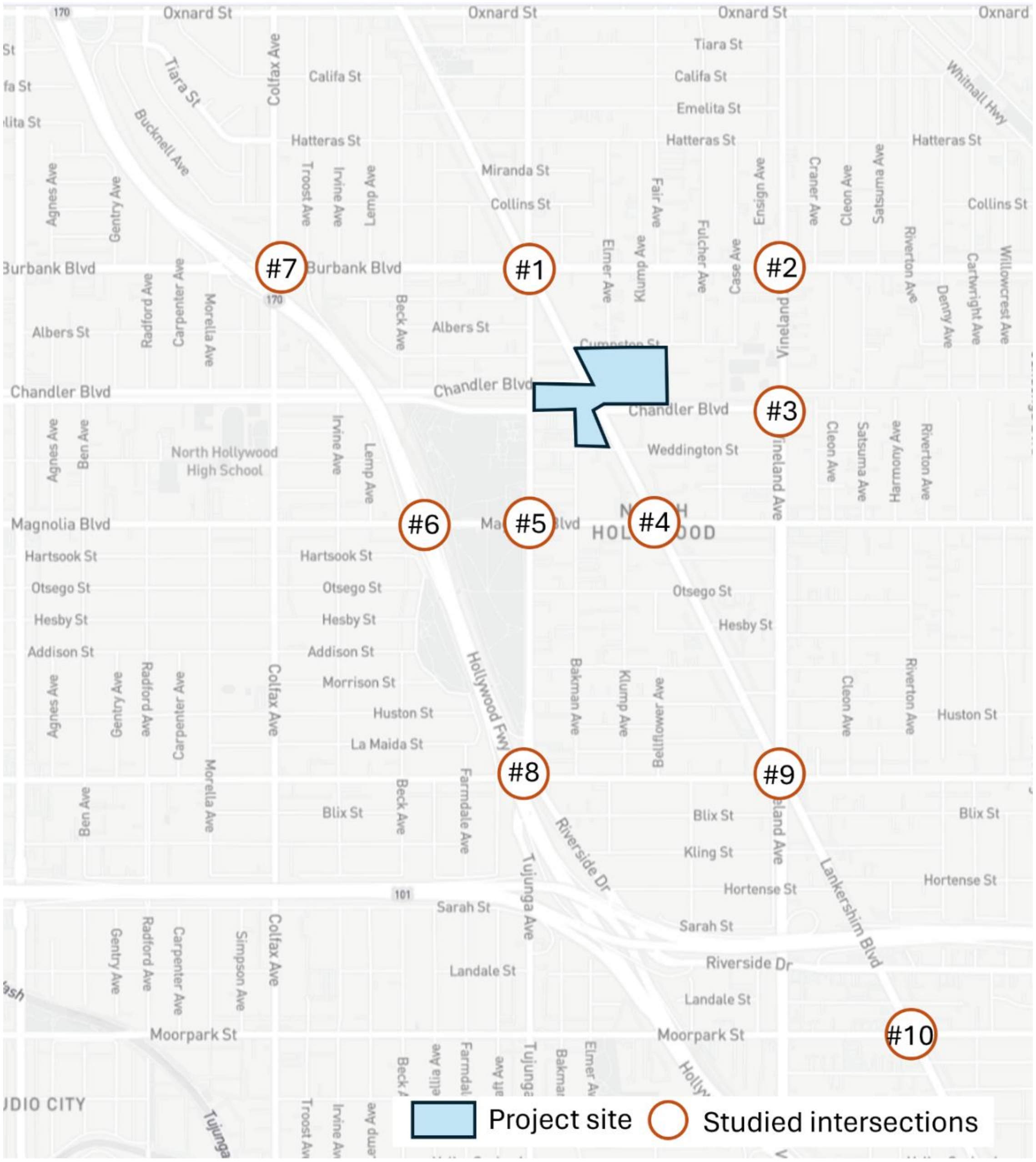

Figure 1-4. Map of District NoHo and surrounding

The project would add a mix of residential (1,527 housing units), commercial (105,125 sq. ft. of retail/restaurant uses), and office (580,374 sq. ft.) space to the site. In addition, the project proposal includes transit facility improvements and off-site pedestrian and bicycle amenities. The LOS analysis predicts significant delays at 13 signalized intersections. I omit three in this analysis because they are either adjacent to the project site or very close to other intersections already included (see Figure 1-4 for locations of project site and studied intersections). Several intersections close to the project site and along Chandler Boulevard are also predicted to have improved traffic conditions, and I adjust the vehicular speed for cars and buses accordingly. Pedestrian and bicycle improvements would be implemented along segments of Chandler Boulevard and Fair Avenue adjacent to the project site (and the transit center), and I adjust walking and biking conditions accordingly. The VMT analysis assumes that the project will add 2,545 jobs.

Results from the accessibility analysis show that accessibility by car would increase substantially (20-31%), largely due to mobility effect (see Table 1-5). This reflects the accessibility gains from faster vehicle speeds on street segments adjacent to the project site, particularly along Chandler Boulevard, which likely makes it quicker and easier to access the CA-170 freeway. These accessibility gains outweigh the decreases due to slower vehicle speed on other local streets. This result does not necessarily imply that reducing congestion yields enormous accessibility gains and should be prioritized. But it probably means that focused congestion reduction efforts targeted at bottlenecks may be more cost-effective than if implemented indiscriminately.

Accessibility by transit, however, does not change much. This is mostly because transit speed is assumed to decrease in general, as only a few bus routes run on the street segments that are predicted to have increased vehicle speed. And even for these few routes, these segments with increased speed account for a much shorter distance than those with decreased speed combined.

At a few intersections (#1, #7, and #8), there are small increases in accessibility due to mobility effect. This is likely due to increased walkability rather than increased vehicle speed.

Accessibility by walking, in contrast, increases considerably (3-23%), though not as much as by car. This increase is primarily due to the proximity effect. And as expected, this effect is bigger (16-23%) at the project site and several intersections that are closest to the project site (#1, #3, #4, #5, and #6). But there are small increases (1-2%) due to mobility effect at the project site and several intersections (#1, #3, #5, #6, and #7). This can be attributed to improved walkability resulting from pedestrian amenities including several new crosswalks at intersections adjacent to the project site and transit center.

Accessibility by biking also increases but only by 1% at all studied locations. While there are increases due to both mobility (in very small amounts) and proximity effects, proximity effect is far bigger than mobility effect for biking. This is expected because proposed bicycle amenities, including adding bike lanes and crossings along a few street segments, are not likely to improve biking speed significantly, though the experience of cyclists might be meaningfully improved.

In Table 1-6, I summarize the results from LOS, VMT, and accessibility analyses for the three projects. The 2143 Violet Street project is predicted to cause significant traffic delays, generate significant household and work VMT, and decrease accessibility by car and transit while increasing accessibility by walking and biking. The Paseo Marina project is predicted to cause significant traffic delays, generate significant work VMT, and cause little change to accessibility by car and transit while increasing accessibility by walking and biking. The District NoHo project is predicted to cause significant traffic delays, generate less than significant VMT, and increase accessibility by car, walking and biking while causing little change to accessibility by transit.

Table 1-6. Summary of LOS, VMT, and accessibility results for 2143 Violet Street, Paseo Marina, and District NoHo

Project	LOS Results	VMT Results	Accessibility Results
2143 Violet Street *Residential – office – commercial mixed-use development in downtown Los Angeles*	**Significant** delays at 2 out of 3 signalized intersections	• **Significant** VMT impact • Household and work VMT estimates exceed thresholds • VMT estimates do not account for TDM measures	• Accessibility by car decreases by 3-4%, mostly due to mobility effect from vehicle delays • Accessibility by transit decreases by 2-5% at most locations, mostly due to mobility effect from vehicle delays, but increases by 1% at one location, due to small increases from mobility and proximity effects • Accessibility by walking increases by 1%, due to proximity effect • Accessibility by biking increases by less than 1%, due to small proximity effect
Paseo Marina (option B) *Residential – commercial – office mixed-use development in suburban Los Angeles*	**Significant** delays at 1 out of 7 signalized intersections	• **Significant** VMT impact • Work VMT estimate exceeds threshold • VMT estimates account for TDM measures	• Accessibility by car and transit changes by less than 1%, due to relatively small mobility effect from vehicle delays • Accessibility by walking increases by 3-4%, due to proximity effect • Accessibility by biking increases by less than 1%, due to small proximity effect
District NoHo *Residential – commercial – office mixed-use transit-oriented development in suburban Los Angeles*	**Significant** delays at 13 out of 23 signalized intersections	• **Less than significant** VMT impact • VMT estimates do not account for TDM measures	• Accessibility by car increases by 20-31%, mostly due to mobility effect from improved LOS at key intersections near the project site • Accessibility by transit changes by less than 1% at most locations, with 1% increases at a few locations due to increased walkability • Accessibility by walking increases by 3-23%, mostly due to proximity effect, with small increases due to mobility effect at a few locations due to increased walkability • Accessibility by biking increases by 1%, mostly due to proximity effect

Implications of Accessibility Analysis Results

The accessibility analysis results suggest that whether mobility effect contributes more or less than proximity effect to changes in accessibility depends on the travel mode. For accessibility by car, mobility effect usually has a predominant role; for transit, both mobility and proximity effects can be the dominating factor at times; but for walking and biking, proximity effect is the dominant factor. While these results might appear self-evident, I highlight some nuance below.

The predominant role of mobility effect for accessibility by car does not mean that proximity effect is irrelevant for cars. The results discussed are calculated for the median (duration) trip for each mode, and the median car trip usually travels longer distances and reaches many more destinations than median trips by other modes, which makes the new opportunities nearby appear marginal in relative terms. This means that the results will differ if the calculation uses a different travel time cutoff, and proximity effect will become more important for a 10-minute or a 5-minute drive than for the median car trip. After all, proximity effect works by bringing destinations closer together, which is also partly why it is the dominant factor for walking and biking.

However, the small role of mobility effect for walking and biking should not discourage pedestrian and bicycle infrastructure improvements. One the one hand, results for District NoHo show that pedestrian and bicycle amenities that make walking and biking easier and faster can increase accessibility. The relatively small magnitude of such an effect is due to the limited scale of such improvements. On the other hand, even if mobility effect has a smaller role than proximity effect in calculating accessibility, that accessibility is only a measure of *potential* access. Whether people choose to realize that potential access, by actually choosing to walk and bike to destinations will depend a lot on the quality of pedestrian and bicycle infrastructure.

The accessibility results also suggest that focusing on congestion reduction, as the conventional LOS-based approach does, may not impact overall accessibility too much. As the results show, reduced vehicle speed on local streets and at local intersections (resulting in significant LOS impact) has a limited impact on accessibility by car, and focused congestion reduction at strategic locations or bottlenecks can more than compensate for the decrease in accessibility due to slower traffic on other streets (see Table 1-6). Moreover, there are significant accessibility gains for non-car travel modes due to proximity of destinations, even if traffic slows down on local streets. While my results are based on simulations, prior research using travel survey and traffic count data also show that people in more central, built-up areas make many trips and engage in many activities despite lots of congestion because they can walk or make shorter trips to nearby destinations (Mondschein and Taylor 2017).

Moreover, these results also suggest that focusing only on reducing vehicle travel and emission, as the VMT-based approach does, may overlook potential accessibility gains from mobility effect, such as in the case of District NoHo (see Table 1-6). This is because under this approach, reduction in vehicle travel is the priority, and any such reduction is assumed to be due to proximity of destinations. In other words, this shows that the VMT metric is indeed an indirect and partial measure of accessibility.

Conclusion

This study addresses an understudied area in the accessibility literature: the use of accessibility metrics in local planning. By evaluating the different outcomes of a sample of varied projects in Los Angeles using LOS, VMT, and accessibility metrics, I demonstrate the different implications for land use developments under each metric. The majority of the projects in my sample are high density mixed-use development in urban contexts, which the conventional LOS-based traffic impact studies tend to bias against. I find that these projects are less likely to be found to have significant impacts and be required to implement mitigation measures, when evaluated using the VMT metric as compared to using the LOS metric. This may mean that these projects would be required to pay higher impact fees and/or implement more mitigation measures to be approved prior to the CEQA change to VMT, which likely will raise development costs and/or reduce the scale of development. More importantly, these mitigation measures – aimed to improve LOS – would likely include capacity increasing measures like street widening, which further helps perpetuate driving. Mitigation measures for VMT impacts, in contrast, mainly focus on discouraging driving and promoting transit, walking, and biking.

While shifting from LOS to VMT may well be an encouraging move to reduce the focus on congestion reduction and help promote more compact development patterns and lower vehicle emissions, I show that both the LOS and VMT metrics can overlook accessibility gains from either mobility or proximity increases. As noted at the beginning, neither LOS nor VMT is conceptually linked to the goal of promoting accessibility, because using these metrics places congestion reduction (in the case of LOS) and emission reduction (in the case of VMT) as the top priority for project evaluation. Additionally, VMT has not replaced LOS in practice, even in California. Local governments, like the City of Los Angeles, continue to require LOS analysis in addition to the CEQA-mandated VMT analysis to address local congestion concerns. So instead of a shift from congestion reduction to emission reduction, what has happened is emission reduction being elevated to the top priority while congestion reduction persists as an important goal. Access, which is primarily why people travel, remains in the back seat.

However, my analysis shows that an accessibility metric can account for both mobility changes and proximity changes. More specifically, it can highlight the limited effect of local congestion on overall accessibility, thus may help ease residents' concerns (or at least planners') over traffic congestion. Residents often worry about new developments increasing local congestion, but they might worry less if planners can use accessibility analysis (similar to mine) to show that delays at several local intersections tend not to substantially increase their commutes, and they would be able to easily walk, bike, or take transit to get to new restaurants or grocery stores at the a new development. It can also highlight potential accessibility gains from targeted congestion reduction efforts that a VMT analysis would likely overlook. More importantly, an accessibility analysis can more directly assess changes across different modes, which can help focus potential mitigation measures on non-car travel modes such as transit, walking, and biking. Thus, focusing on accessibility in assessing the transportation impacts of land use developments can help achieve the same policy goals of vehicle travel and emission reduction that underlie the VMT metric. And with readily available tools like *Conveyal Analysis,* it is becoming easier to implement accessibility analysis at the local level.

ESSAY TWO: Regional Planning for Accessibility in California: How MPOs Are Using Accessibility Metrics

Abstract

The concept of accessibility has been heavily researched but slowly applied to practice in transportation planning, due to technical challenges and political obstacles. In this study I conduct archival research of key planning documents to investigate whether and how seven metropolitan planning organizations (MPOs) in California use accessibility concepts and metrics in regional planning that informs both long-range investment and strategies planning and short-term project selection and programming. This is complemented by interviews with MPO staff to explore obstacles in adopting accessibility metrics and factors that have facilitated such efforts. The focus on California is intentional because of its unique legislation (Senate Bill 375) that mandates integrated land use and transportation planning at the regional level to reduce vehicle travel and greenhouse gas emissions. In theory, SB 375 should give California MPOs more leverage in shaping land use patterns, which is one of the two main components that determine physical accessibility – the other being the transportation system. The analysis showed that accessibility metrics are used more in long-range planning than in short-term programming, and that many metrics used are indirect and partial measures of accessibility. The biggest implementation obstacles cited by interviewees are the difficulty of explaining accessibility to stakeholders and MPOs' limited agency in project selection and programming. I also find that California's SB 375 legislation has allowed MPOs to have a greater influence in local land use planning and has facilitated the adoption of accessibility metrics. I conclude with three recommendations to facilitate future efforts to use accessibility metrics in regional planning, including building

organizational capacity, supporting regional planning with legislation, and coordinating project selection and programming processes.

Introduction

In the U.S., metropolitan planning organizations (MPOs), the regional planning bodies responsible for transportation planning at the metropolitan scale, have long focused on improving the mobility of people and goods (Handy 2005). But the principal goal of a transportation system is not *the means* (moving people and goods), but rather *the ends* (accessing desired destinations and activities) of travel. Thus, many scholars have argued for a shift from a mobility to an accessibility framework for transportation planning (Handy 2005; Levine, Grengs, and Merlin 2019; Duranton and Guerra 2016; Handy 2020). They typically define the concept variably as the capacity to reach destinations, or the ease of or potential for interaction of people and opportunities, which is a function of travel speed and proximity of destinations. Proffitt et al. studied 42 long-range regional transportation plans (RTP) across the U.S. and found that while most plans were beginning to discuss accessibility, the concept was vaguely defined and poorly operationalized (Proffitt et al. 2019). Other than the RTPs studied by Proffitt et al., MPOs also create transportation improvement programs (TIP), which is a list of projects to be implemented in the near term, at least partially funded with federal dollars.

In California, MPOs, in addition to transportation planning, also engage in land use planning. As required by California State Senate Bill 375 (SB 375), California MPOs prepare sustainable communities strategies (SCS) to align transportation, housing, and land use decisions to reduce vehicle miles traveled (VMT) in order to achieve the state's greenhouse gas (GHG) emission reduction targets[6]. It has been argued that MPOs in the US, being sandwiched between state government and local governments, have limited authority, and hence local planning does not always conform to regional plans (Sciara and Handy 2017; Sciara 2017). But, at least in California, state legislation like SB 375 has given increased responsibility to MPOs to plan for transportation and land use developments and help meet the state's climate and equity goals.

The concept of accessibility shows great promise to help MPOs better shape transportation and land use patterns and perhaps exert greater influence over local land use decisions. On the one hand, accessibility offers a framework for MPOs to envision transportation and land use systems more holistically since access can be improved by both better mobility on transportation networks and proximity among land uses (Levine, Grengs, and Merlin 2019; Handy 2020). On the other hand, if accessibility can be used as an evaluation measure to determine what projects to be included in the TIPs, funding administered by MPOs can be directed more towards projects that create access benefits rather than simply improve flows of traffic, thus helping to create more compact development patterns. Accordingly, this essay investigates how MPOs in California incorporate the concept and metrics of accessibility into regional planning through archival study of key regional planning documents including RTPs, SCS, and TIPs, as well as interviews of MPO staff.

[6] California State Senate Bill 375, or the Sustainable Communities and Climate Protection Act of 2008, is a California state law targeting greenhouse gas emissions from passenger vehicles. Under this law, the California Air Resources Board will set emission reduction targets for each metropolitan region, and each MPO is mandated to produce a Sustainable Communities Strategy to demonstrate how the region will meet the emission reduction targets through coordinated transportation, housing, and land use strategies.

Literature Review – Adopting Accessibility in Regional Planning

Regional Planning for Accessibility

In the US, MPOs are charged with the undertaking of regional transportation planning in order to ensure effective expenditure of federal transportation dollars. MPOs are mandated to prepare an RTP that lays out strategies and actions that will guide transportation system investment and development over a 20- to 30-year time frame. The RTP should include a list of transportation investments (projects, programs, etc.) expected to be implemented over this time period. MPOs are also mandated to prepare a TIP that includes all federal-funded and regionally significant transportation investment projects that are prioritized over a four-year period. In California, MPOs are also required to prepare the SCS – regional land use plans that promote sustainable and smart growth to reduce auto-dependance, vehicle miles travelled (VMT), and greenhouse gas emissions (Sciara and Handy 2017; Sciara 2017).

Previous studies have found an increasing trend among MPOs adopting the concept of accessibility in their RTPs. Handy analyzed the RTPs of four northern California MPOs to evaluate whether and to what degree each plan was oriented towards mobility vis-à-vis accessibility by examining the plan's goals, objectives, performance measures, and what kinds of investments it prioritized (Handy 2005). A key finding is that a concern for accessibility was evident in all four plans, but mostly as an additional aim rather than as a replacement for mobility planning, which remained the core concern. Proffitt et al. analyzed the RTPs among a national sample of 42 MPOs and found that while most RTPs included accessibility-related goals, the concept was generally poorly defined and operationalized (Proffitt et al. 2019). Notably, only about half of the RTPs set goals for or select projects in terms of accessibility, and only 20 percent of the RTPs use metrics to directly measure accessibility. Overall, they found that mobility, or congestion relief, remained the top priority for most MPOs. They also found that MPOs serving large and wealthier regions were most likely to produce accessibility-oriented RTPs, which they suggested was because of greater planning capacity.

While these two studies rightfully focused on the most important regional planning document, the RTP, they did not address an important part of the regional planning process, which is the TIP, which can reveal the MPOs' priorities in the short term. These two studies also did not address land use planning, which forms a key component of the accessibility framework. To be fair, Handy and Proffitt et al. could not have addressed this component, as the former was conducted before the passage of SB 375 in California, which asked MPOs to produce regional land use plans, or the SCSs; the latter was a national study and most MPOs (except one, which was in Fresno, CA) in the study sample did not have any appreciable responsibility over land use planning. This study is an attempt to address these two missed components of regional planning.

Challenges Faced by MPOs

With regard to the application of accessibility to regional planning, MPOs may face two kinds of challenges. One kind is associated with the difficulty of operationalizing the concept of accessibility; the other is associated with the limited power and authority of an MPO given its position in the government structure in the US.

<u>Operationalizing Accessibility</u>

Many different accessibility metrics have been developed, and most metrics incorporate a land use component that measures the proximity between destinations and a transportation component that measures the mobility on transportation networks (Handy and Niemeier 1997). For example, gravity-based measures of accessibility count the number of destinations that can be reached within a given travel time (which depends on how close destinations are and how fast one can travel), and weigh these destinations by an impedance factor (typically a function of travel time or cost). More complicated metrics also account for individual characteristics including people's different needs and opportunities as well as abilities and capabilities, and temporal constraints that may limit availability of opportunities (Geurs and Van Wee 2004). The most commonly used metrics, like cumulative opportunities and gravity measures are easier to compute and interpret, but they cannot fully account for spatial and temporal constraints faced by individuals. More conceptually complete measures include constraints-based measures that account for personal and temporal constraints that limit individuals' accessibility, and utility-based measures that value accessible opportunities based on their utility. But these measures are also more complex, require more data, and are thus more difficult to apply in practice. Therefore, developing accessibility measures faces a fundamental tradeoff between conceptual completeness and ease of application (Siddiq and Taylor 2021).

Factors like the complexity of accessibility measures, data requirements, and the lack of standard and objective metrics have been underscored as major obstacles to the application of accessibility in practice, in addition to factors related to institutional resistance (Miller 2018; Siddiq and Taylor 2021; Karner et al. 2022). Nevertheless, many scholars have acknowledged that widespread use of place-based cumulative opportunities and gravity-based measures, albeit imperfect, could fulfill many core policy tasks of urban and transportation planning (Handy 2020; Boisjoly and El-Geneidy 2017; Curl, Nelson, and Anable 2011; Grengs et al. 2010). Indeed, placed-based gravity measures of accessibility are a function of proximity among land uses and travel cost (often measured in terms of time), which are the two targets that urban and transportation planners can change. Also, there are readily available datasets, software, and tools that MPOs and other planning organizations can utilize to calculate accessibility measures (Karner et al. 2022).

MPO’s Limited Authority

Sciara reviewed the development of regional planning in the US, and identified six key challenges faced by MPOs today (Sciara 2017). First, most MPOs actually play a limited role in project selection and programming even though they are responsible for producing the TIP, because MPOs direct only the expenditure of federal transportation funds and have little authority over how state and local transportation funds are used. State departments of transportation and local municipalities often have considerable say over the shape, location, and implementation of regional projects (Sciara and Handy 2017). Second, MPOs usually have little or no authority over land use decisions, which typically rest almost entirely with local jurisdictions. Even in California, where SB 375 requires MPOs to produce regional land use plans focused on sustainability and smart growth in the form of the SCS, MPOs are not given authority over local land use and hence have limited control of the implementation of SCS (Sciara 2020). Third, most MPOs, unlike state and local governments, cannot impose taxes or fees to fund transportation investments, which undermines their ability to fund and deliver region-serving investments. Fourth, MPOs have varied organizational capacities, and many lack sufficient expertise and funding, which can limit the MPOs’ ability to conduct effective regional planning (US Government Accountability Office 2009). Fifth, public transit agencies often have only marginal participation in MPO decision making as they typically have either no seat or only non-voting seat on MPO boards (Hoover, McDowell, and Sciara 2004). Lastly, the composition of MPO boards, usually one voting seat for one local government, tends to over-represent many smaller suburban municipalities and under-represent more populous urban and central city communities, the latter of which are more likely to be lower income and/or communities of color (Goldman and Deakin 2000).

Many of the six challenges listed here can hinder the application of accessibility to regional planning. For instance, the problem of organizational capacity, compounded by the complexity of the concept of accessibility and the difficulty of its operationalization, can severely limit the MPOs' ability to effectively use accessibility metrics in regional planning (Karner et al. 2022). Also, MPOs' limited control over funding for regional projects and over local land use decisions can significantly undermine their capacity to promote sustainable land use patterns aimed at enhancing accessibility by improving proximity of destinations. Moreover, the inherent biases toward small local (majority suburban) governments in MPOs' board representation can also undermine the use of accessibility in regional planning because accessibility is inherently a regional concept which may appear anti-local. For example, a high-density mixed-use development may generate accessibility benefits that extend beyond the boundaries of a local city, but the increased traffic generated by that development is mostly likely to be noticed by the surrounding community. These are untested hypotheses that this study investigates.

Research Design

This paper seeks to answer three major research questions. First, how do California MPOs use accessibility in regional planning? More specifically, do MPOs incorporate accessibility in their RTPs and SCSs? For MPOs that do so, how is accessibility defined and operationalized? How much emphasis is placed on accessibility as compared to mobility? Is accessibility used to select projects for funding and programming (TIPs)? For MPOs that do so, how is accessibility measured and evaluated? How much weight is given to accessibility in decision-making? Second, what are the obstacles that MPOs face in applying accessibility to regional planning? And lastly, for MPOs that use accessibility more, what are the facilitating factors?

To answer these research questions, I first reviewed seven California MPOs' most recent RTP-SCSs[7] and TIPs and other associated documents to find evidence of the use of accessibility in both planning and programming. For conceptual completeness, I adopt the definition of accessibility by Ding and Taylor (2021) – *the ability of people, households, firms, or institutions to avail themselves of goods, services, activities, and opportunities* – and include virtual access and goods movement in addition to physical access and people movement in my review of MPO plans. This content analysis focused on four main questions: 1) how accessibility is defined; 2) whether and how much accessibility concerns are reflected in the goals and objectives of the plans; 3) whether and how much accessibility concerns are considered in project selection and programming processes; 4) whether and how much accessibility metrics are used in performance evaluation of the regional system and specific projects. I then interviewed staff from these MPOs who are involved in the development of regional plans and/or project selection and programming to mostly ask about the factors that facilitate the application of accessibility as well as obstacles that limit the use of accessibility.

[7] In practice, MPOs make RTP and SCS into one document as the comprehensive regional plan.

Figure 2-1. California MPOs (source: California Air Resource Board https://ww2.arb.ca.gov/our-work/programs/sustainable-communities-program/regional-plans-evaluations)

Table 2-1. Characteristics of California MPOs (MPOs in italics are included in this study)

MPO	Major city	Population (2020 Census)	Contains multiple county-level RTPAs/CTCs	LOST
Big Four				
Southern California Association of Governments	Los Angeles	18,823,705	X	
Metropolitan Transportation Commission /Association of Bay Area Governments	San Francisco	7,765,693	X	
San Diego Association of Governments	San Diego	3,298,495		X
Sacramento Area Council of Governments	Sacramento	2,537,783	X	
Central Valley				
Fresno Council of Governments	Fresno	1,009,236		X
Kern Council of Governments	Bakersfield	909,217		
San Joaquin Council of Governments	Stockton	779,233		X
Stanislaus Council of Governments	Modesto	552,857		X
Tulare County Association of Governments	Visalia	473,113		X
Merced County Association of Governments	Merced	280,652		X
Madera County Transportation Commission	Madera	156,249		X
Kings County Association of Governments	Lemoore	152,490		
Central Coast				
Association of Monterey Bay Area of Governments	Marina	773,843	X	
Santa Barbara County Association of Governments	Santa Barbara	448,018		X
San Luis Obispo Council of Governments	San Luis Obispo	282,633		
Northern California-Sierra				
Butte County Association of Governments	Chico	211,642		
Shasta Regional Transportation Authority	Redding	182,155		
Tahoe Metropolitan Planning Organization	Stateline	55,771		

Notes: RTPA – Regional Transportation Planning Agency; CTC – County Transportation Commission; LOST – Local Option Sales Tax; data sources: US Department of Transportation MPO database https://www.planning.dot.gov/mpo/ and Sciara 2020.

The sample of MPOs includes the Association of Monterey Bay Area Governments (AMBAG), Fresno Council of Governments for Fresno County (Fresno COG), Metropolitan Transportation Commission for the San Francisco Bay Area (MTC), Sacramento Area Council of Governments (SACOG), San Diego Association of Governments for San Diego County (SANDAG), Southern California Association of Governments for the six-county Southern California region (SCAG), and San Joaquin Council of Governments for San Joaquin County (SJCOG) (See Figure 2-1 for locations, and Table 2-1 for details of California MPOs). I intentionally focus on California MPOs because, as explained above, they have land use planning duties on top of the federally mandated transportation planning functions, and thus are better positioned to utilize accessibility metrics to coordinate transportation and land use investments to address the climate, transportation, and equity goals of the state.

The sample represents different sizes and levels of organizational capacity, and different regions. SCAG, MTC, SANDAG, and SACOG, or the so-called Big Four MPOs are the largest and most urban MPOs serving the Los Angeles, San Francisco, San Diego, and Sacramento regions. Among them, MTC and SCAG are the two largest MPOs and govern the two largest metro areas of the state, and they have greater organizational capacity in terms of expertise and resources than smaller MPOs like AMBAG and SJCOG. SANDAG, Fresno COG, and SJCOG are single-county MPOs that administer county sales tax revenues (local option sales tax, or LOST), presumably giving them more power in shaping transportation and land use investments than other multi-county MPOs that do not have control over such funds. SCAG, MTC, SACOG, and AMBAG all contain multiple county-level transportation planning agencies, and delegate some transportation planning duties to county-level agencies. MTC and SACOG are also the only two MPOs that have developed project-level evaluation tools for project selection and programming, though their tools differ considerably. Lastly, MPOs that govern large, urbanized areas like MTC and SCAG may have different investment priorities from MPOs that govern more rural areas like SJCOG in the Central Valley and AMBAG along the Central Coast. All these differences may affect how the MPOs use accessibility in their planning and programming tasks.

Findings

MPO's Use of Accessibility in Regional Planning

Defining Accessibility

While all of the RTP-SCSs reviewed use the term "accessibility" in many places throughout the document, only three plans define it. SANDAG's plan defines accessibility as "the ability of people to use the transportation system to travel to a destination," which emphasizes on mobility (SANDAG 2021). In its plan's technical appendix, SACOG defines its accessibility metric as a cumulative opportunities measure: "the number of activities a person can reach within a given travel time and mode," and notes that it can be increased in two ways – "improving travel speeds" and "putting more activities closer to homes" (SACOG 2019). SCAG offers a more conceptually complete discussion of accessibility: "accessibility is evaluated by the spatial distribution of potential destinations, the ease of reaching each destination by various transportation modes and the magnitude, quality and character of the activities at the destination sites" (SCAG 2020).

Earlier study by Proffitt et. al. found that MPOs tended to conflate the terms "accessibility" and "mobility" as they used the term "accessibility" exclusively in the phrase "mobility and accessibility" (Proffitt et al. 2019). My review found that while MPOs do not conflate the two terms, they have used accessibility to mean different things. For example, MTC used the term to mean access to opportunities whereas SANDAG used it the mean access to the transportation system in most cases. The latter is certainly an important concern for MPOs, but it represents a focus on providing mobility rather than providing access through coordinated transportation and land use planning.

Addressing Accessibility in Goals and Strategies

All seven plans discuss accessibility in their goals or vision statements, and contain strategies that will likely result in improved access to destinations and opportunities, but they differ in the extent to which land use strategies are pursued to improve access by bringing destinations closer together. Only SCAG, MTC, and SANDAG highlight physical accessibility to opportunities in their goals or visions, but SANDAG focuses almost exclusively on the role of mobility services, as stated in the plan: "our region's future prosperity will depend on mobility – the ability of people to travel quickly and easily from communities where they live to centers of innovation where they work" (SANDAG 2021). SCAG and MTC, along with SACOG (which doesn't highlight accessibility in their goals/visions), each proposes land use strategies to promote more compact and denser development patterns in coordination with mobility investments to increase access to destinations. Another group of MPOs, including AMBAG, Fresno COG, and SJCOG, also discuss similar land use strategies like promoting compact, walkable, and infill developments. But they put more emphasis on their role in reducing auto travel by promoting travel through transit, biking, and walking, rather than providing better access to destinations, although these strategies will likely have that effect.

A common trend observed across all seven MPOs is a shift away from auto mobility to focus more on providing multi-modal mobility. Most plans propose travel demand management (TDM) measures as well as investments in public transit and active transportation infrastructure to reduce auto travel and increase travel via other modes. Some MPOs, such as SCAG, SACOG, Fresno

COG, also emphasize the potential of compact and mixed-use development patterns to reduce motor vehicle travel. Moreover, all MPOs emphasize the need to increase transportation investments, mostly in transit, in disadvantaged communities to improve their mobility.

While these strategies may well increase multi-modal accessibility, which will benefit individuals with limited car access, such investments do not necessarily indicate that MPOs are placing accessibility at the core of their planning efforts. Rather, they appear largely driven by VMT and GHG emission reduction targets mandated by SB 375, as the plans often highlight expected effects on vehicle travel and emissions. A related trend is that while all plans contain strategies or policies to manage congestion, they all try to avoid expanding roadway capacities (except in rural areas), and instead focus on TDM and transportation system management (TSM) measures. Several MPOs in larger metro regions like SCAG, MTC, SANDAG, and SACOG also propose plans to implement road pricing to manage congestion.

As required by SB 375, the seven California MPOs produced SCSs as part of their RTPs to discuss how land use strategies and transportation investments can be coordinated to reduce VMT and GHG emissions. All MPOs, except SJCOG, discuss strategies to promote compact, higher density, mixed use, and infill developments to reduce auto travel; all MPOs, except Fresno COG, discuss strategies to promote growth near transit, especially along high-quality and frequency lines, to promote more travel via transit; all MPOs discuss strategies to invest in active transportation, mostly in the form of complete streets improvements, to encourage travel by non-motorized modes; some MPOS, including SCAG, MTC, SACOG, and SANDAG, also discuss strategies to promote jobs-housing balance to reduce commute VMT.

As noted earlier, the main objective of an SCS is to demonstrate that the region can achieve its VMT and GHG reduction targets, not to improve accessibility. But the above strategies aim to reduce vehicle travel by bringing destinations closer together and improving non-car travel modes, thereby promoting more compact and mixed-use development patterns integrated with a multi-modal transportation system. This will allow people to drive less but still reach their destinations just as, if not more, easily. As such, these strategies, if successfully implemented, will increase people's accessibility, especially via non-car modes, regardless of the objective.

Access can also be achieved without travel, as in cases of virtual access and having goods delivered. With regard to virtual access, most MPOs promote telecommuting, mostly as a TDM measure to manage congestion and reduce commute VMT; some MPOs, including SCAG, MTC, Fresno COG, and SJCOG, also propose greater investments in internet/broadband access to improve virtual access to jobs, education, and ecommerce – SCAG also highlights the particular benefits of virtual access for rural communities. As for goods movement, most MPOs focus on strategies to maintain and improve roads and highways to facilitate goods movement, especially in agricultural regions, whereas SCAG's plan acknowledges the need to better understand the impact of ecommerce on industrial land uses and truck industry to explore land use strategies that support goods movement needs.

Project Evaluation, Selection, and Prioritization

The project list in RTP-SCS contains project investments, mostly in transportation, which will be implemented in the next 30 years, reflecting the region's long range investment strategies. The same trend noted above – the shift away from auto-mobility and toward multi-modal mobility – is again reflected in these projects. Increasing road capacity for cars no longer appears to be a priority for most MPOs, as road widening projects usually only add managed lanes in the form of HOV lanes or toll lanes and/or transit and active transportation infrastructure; some MPO plans, including those at SCAG, SACOG, and AMBAG, emphasize that road projects are meant to improve access by addressing choke points and bottlenecks and gaps in the road network rather than to facilitate faster traffic flow; a few MPOs like SACOG and SJCOG also highlight the role of road investments to provide better access to areas currently underserved by the road network such as rural areas and infill areas; SANDAG is the only MPO in the sample that discusses the benefits of road projects in terms of increased traffic flow and mobility rather than access.

As for transit and active transportation investments, while they are largely described as efforts to reduce auto-dependence and VMT, some MPO plans discuss the need for these projects to connect households to destinations, which would provide better access. SCAG and SANDAG, for example, highlight the need for individual transit projects to link households to major activity centers, while AMBAG and SJCOG describe their transit investments as collectively improving intra-region and inter-region connectivity. A few MPOs like AMBAG and SJCOG also discuss the need for bike and pedestrian projects to connect households to local destinations such as transit stations, retail, and schools.

A varied level of emphasis on accessibility across MPOs is also reflected in the degree to which accessibility concerns and metrics are incorporated into the project evaluation and prioritization processes. While many MPOs address accessibility concerns, either directly or indirectly, in evaluating at least some projects, only MTC and SACOG use accessibility metrics to quantitively assess access impacts of individual projects. MTC uses the most sophisticated accessibility metric among the seven MPOs: potential access benefits of an individual project are quantified using a logsum measure of total consumer surplus resulting from the project, which is aggregated from individual-level changes in consumer surplus in terms of choices available. These quantified access benefits feed into a benefit-cost assessment as well as an equity assessment that looks at the distribution of access benefits across income groups. In contrast, rather than quantifying the potential access benefits of a project, SACOG measures existing accessibility levels of the project's proposed site using metrics of access to neighborhood service, jobs, and schools, which are used to determine investment needs; the potential access benefits of the project are assessed qualitatively.

Among the other MPOs, SCAG and AMBAG delegate most project evaluation to county transportation commissions (CTC) that usually have different evaluation criteria from one another across the MPO region. Nonetheless, the CTCs in these two MPOs and the other MPOs address accessibility concerns in project evaluations, albeit to a limited extent, often indirectly and qualitatively. Some common considerations include assessing a project's connectivity to certain destinations and/or the transit system, potential to promote non-auto travel, and effects on VMT reduction, the latter two of which may be deemed as outcomes of more compact and hence accessible land use patterns. These impacts are usually only qualitatively assessed through binary questions in scoring rubrics used during evaluations.

Accessibility Metrics as Performance Measures

Table 2-2. Accessibility metrics used by MPOs as performance measures

Direct Measures	**Indirect Measures**
• Measures of access to destinations ○ Share of employment/shopping destinations/park acreage reachable within 30 minutes by car or 45 minutes by transit during PM peak periods (SCAG) ○ Share of jobs reachable within a 20-minute walk/bike ride, a 30-minute drive, and a 45-minute transit trip (MTC) ○ Jobs within 30-minute drive or transit trip from homes in environmental justice (EJ) areas (SACOG)	• Measures of travel (mostly vehicular) ○ VMT per capita (SCAG, SACOG, SJCOG) ○ Vehicle hours traveled per capita (SCAG) ○ Average VMT per worker to jobs centers (SACOG) ○ Household generated VMT per capita (SACOG) ○ Commercial VMT per capita (SACOG) ○ Total miles driven (Fresno COG) • Measures of travel distance

• Measures of population catchment
  ○ Share of regional population that can reach retail and parks in less than 15 minutes by walking/biking/transit, healthcare services in less than 30 minutes by transit, and job centers and higher education in less than 30 or 45 minutes by transit (SANDAG)
  ○ Population within 30 minutes of healthcare and parks (AMBAG)
• Measures of jobs-housing balance
  ○ Jobs-housing ratio among various income levels and counties (SCAG)
  ○ Shares of regional household growth and employment growth in high quality transit areas (SCAG)
  ○ New homes and jobs in high-frequency transit areas (SACOG)
• Measures of access to transit/active transportation infrastructure
  ○ Population near bike facilities and high-quality transit (AMBAG)
  ○ Share of low-income and minority populations located within 0.5 mile of a transit stop (AMBAG)
  ○ Shares of households and jobs within 0.5 mile of high frequency transit (MTC)
  ○ Shares of households in EJ and non-EJ communities with access to high-quality transit (SJCOG)
	○ share of trips less than 3 miles (SCAG)
	○ share of peak period work trips within 45 minutes (SCAG)
	○ share of work trips within 30 minutes (AMBAG)
	○ work trip length distribution (SCAG)
	○ average distance travelled (SCAG)
	○ travel distance savings (SCAG)
	• Measures of travel time
	  ○ Average commute (SCAG, AMBAG)
	  ○ Travel time savings (SCAG)
	  ○ Average peak hour travel time (MTC, Fresno COG)
	  ○ Average travel time to various destinations (SACOG)
	  ○ Average travel time to jobs (SANDAG)
	  ○ Average travel time for EJ TAZs (Fresno COG)
	  ○ Share of workers commuting 60+ minutes one-way (SJCOG)
	• Measures of travel mode
	  ○ Share of commute/non-commute/all trips by different modes (SCAG, MTC, SACOG, SJCOG)
	  ○ Transit ridership (SJCOG)
	  ○ Transit use for work trips (SCAG)

While MPOs may or may not perform project-level evaluations, they all are required to evaluate the collective effect of all investments included in the project list using a set of performance measures, which often include direct and indirect measures of accessibility (See Table 2-2). Some direct measures (like access to destinations and population catchment metrics) gauge changes in the ease of reaching destinations due to changes in proximity of land uses and/or mobility on the transportation system. Other direct measures (like jobs-housing balance and access to transit and active transportation infrastructure) capture only the proximity component. Most MPOs, except Fresno COG, use at least one of these direct measures of access. While these metrics measure access to a variety of destinations, access to jobs appears to be the most commonly used metric.

All MPOs use many measures of vehicle travel, travel time and distance, and mode share, primarily to assess reductions in VMT and hence GHG emissions. These metrics may indirectly reflect improvements in multi-modal accessibility, which can lead to less travel, especially by car. On top of demonstrating the potential effects of the planned investments on access to opportunities and VMT and GHG reductions, these metrics are also used by many MPOs to assess the distribution of access benefits by comparing the accessibility levels of environmental justice (EJ) communities[8] or low-income and minority communities to those of the rest of the region or to the regional average.

Obstacles and Facilitating Factors for Adopting Accessibility

While the document content analysis presented here shows that MPOs vary in their use of accessibility concepts and metrics in regional planning, interviews with staff members from each of the MPOs reveal several key obstacles that limit MPOs' use of access metrics for regional planning, as well as a few factors that have facilitated the adoption of such metrics.

<u>Data and Modelling Limitations</u>

As noted earlier in the literature review, the data requirement for calculating accessibility metrics increases as the metrics become more conceptually complete and hence more sophisticated. A key

[8] According to SACOG's RTP/SCS, environmental justice (EJ) communities are areas that have concentrated low income, minority, or high pollution burden populations, or other disadvantaged populations such as single-parent households, less educated, linguistic-isolated, disabled, those burdened by excessive housing costs, or seniors over 75 years old (SACOG 2019).

challenge identified by MPO staff interviewed who have used access metrics in project evaluation is data and modelling limitations. For example, interviewees from both SACOG and MTC – the two MPOs that use access metrics to assess individual project impacts – contended that limited forecasting capacity is a weakness in their project impact analyses. One interviewee from MTC noted that there is no good way to forecast future land use patterns, especially for non-work destinations, which prevents them from assessing non-work accessibility. An interviewee from SACOG also noted that their model is not good at calculating accessibility via non-motorized modes. Interviewees from these two MPOs also commented that the access metrics used in region-level performance analysis tend to be coarser in resolution and hence face fewer data and modelling limitations. But, for MPOs that are just beginning to use access metrics, just "determining which specific metric could provide the best information on how our investments and strategies are performing toward achieving our objectives and serve as a reliable data source that can be repeated over time for comparison" can be very challenging, as one interviewee from SCAG noted (personal communication).

Explaining the Complex and Abstract Metrics

Related to the challenge of data and modelling limitations in computing more sophisticated access metrics is the complexity of such metrics, which makes them difficult to explain to stakeholders who are not familiar with the concept. For example, an interviewee from MTC noted that while they have technical staff and in-house capacity to compute the logsum metric, they find it very difficult to explain what the metric really measures to planning staff from local agencies. To address this, they would convert the logsum measure to dollar values that they would then feed into a cost-benefit analysis, which could produce more interpretable results for elected officials and the general public. Just as developing access metrics faces a tradeoff between conceptual completeness and ease of application (Siddiq and Taylor 2021), MPOs – when choosing which metric to use – also face a tradeoff between conceptual completeness, or accuracy and precision, and ease of communication. And according to many interviewees, this remains arguably the biggest challenge in using accessibility metrics.

Another aspect of the access metrics – especially more complex ones like a logsum metric – that can make them difficult to explain is their inherent abstractness. One interviewee from SACOG commented on the use of metrics like VMT and reduced travel time as proxies for accessibility: "these metrics continue to hold a lot of power, and distract people from wanting to adopt accessibility more, but they hold power because they are way more intuitive" (personal communication). Interviewees from most MPOs all noted that it can be hard for members of the general public to relate to metrics that count the number of opportunities reachable within a certain amount of time because they tend to mostly care about their destinations, such as their job, their go-to supermarket, etc. rather than the many different jobs and supermarkets that they *are able to* reach. Therefore, most travelers more readily grasp personally relatable metrics, like travel time change. A comment by one interviewee from SCAG corroborates this point: "[the ideal metrics] are the ones that are more easily interpreted without having to go into excessive technical detail. Things like mode share and reduced travel times were well received by the public. So [the goal is] keeping things as intuitive as possible" (personal communication).

Limited Agency in Project Selection

Many interviewees commented that their organizations have been addressing accessibility concerns in developing their regional plans and using access metrics as performance measures to assess the collective impacts of the planned investments, but their limited role in selecting projects for funding programs often means that accessibility may receive a smaller emphasis when determining which project will be funded and implemented in the short term. For example, interviewees from SJCOG and MTC all pointed out that the different funding programs all have their own evaluation criteria, which may or may not incorporate accessibility concerns. For MPOs like SCAG and AMBAG, each CTC is responsible for selecting projects, which means MPOs can have even smaller influence in the selection process. Many interviewees also commented that project selection is ultimately a very political process, in which technical analysis can play an important but also limited role. As one interviewee from MTC contended, "commissioners from different counties try to advocate for their own counties, so they might either find issues with the analysis or argue that there are many other benefits not captured in the metrics. Many arguments can be made against these metrics, so it is important to think about how to use the metrics to inform the conversation knowing the limitations of metrics in this political process" (personal communication).

Facilitating Factors for Adopting Accessibility

<u>The Opportunity to Influence Land Use Patterns due to SB 375</u>

The most frequently mentioned factor that has helped California MPOs adopt more accessibility metrics was SB 375, which gave MPOs greater influence over land use planning by local governments. To be clear, SB 375 does not grant MPOs any land use authority over local governments: the SCSs do not supersede city or county general plans or other land use planning policies. But MPOs collaborate with local governments to develop their SCSs. Also, SB 375 offers CEQA incentives to local land use development projects that are consistent with regional land use strategies described in SCSs.

An interviewee from MTC said that the SB 375 mandate to integrate land use and transportation planning at the regional scale may be the biggest factor in the adoption of accessibility metrics since their agency first started using such metrics many years ago: “once you recognize that land use and transportation are connected and you are trying to optimize for both, suddenly you are thinking, ‘Ah, yes, I want to make sure we are moving to get to places.’ And the solution is to either bring places closer to people or make it faster to get to places. Whereas in other regions [where land use and transportation planning are not integrated], this is almost actively discouraged by basically saying that the land use pattern is a given. Looking at access to destinations in that context is kind of like trying to swim with one hand tied behind your back because you are only able to make progress on one of the variables” (personal communication).

Interviewees from other MPOs were a bit more cautious and emphasized that MPOs do not have land use authority, but nonetheless most with whom I spoke acknowledged that SB 375 does allow them to have greater influence on local land use planning. For these MPOs, SB 375 is not necessarily a facilitating factor for adopting accessibility metrics but allows them to better promote compact and mixed-use development patterns and integrate transportation and land use systems, which could improve regional accessibility. For example, an interviewee from SANDAG commented that “we do not have land use authority, which still lies with local jurisdictions. We are putting forth a scenario that we think would be best for our region to put transportation and land use together, and then we try to incentivize local jurisdictions to update their general plans to align with the regional plan and to bring their local land use planning efforts more closely aligned to the regional transportation investments to start to get that synergy” (personal communication). Similarly, interviewees from SJCOG emphasized that “MPOs cannot be prescriptive about land use" but that it is a collaborative process through which "the work between the regional and local agencies surrounding land use is becoming more synchronized" (personal communication).

An explicit objective of SB 375 is to reduce VMT and greenhouse gas emission through integrated land use and transportation planning. On the one hand, the legislation has motivated MPOs to plan more explicitly to meet VMT reduction targets by promoting compact and mixed-use land use patterns integrated with a multi-modal transportation system that, according to the staff interviewed for this research, likely improves accessibility. On the other hand, SB 375 has elevated the various VMT and travel reduction metrics at California MPOs to be a higher, if not the top, priority. This may lead MPOs to overlook accessibility, which, as argued at the outset, should be the ultimate goal of any transportation system. Whether any of the outcomes (improving accessibility or reducing VMT and GHG) can be achieved, however, depends very much on local governments' adopting land use plans and policies that are consistent with regional strategies. Local governments may not do so, and when that happens, MPOs, having limited authority, may have to rely on the state government to intervene. An interviewee from SJCOG cited the state government's recent lawsuit against the City of Huntington Beach because the city has not planned for enough housing to meet the state-mandated and MPO-allocated housing targets.

Technical Support

Given the technical challenges of adopting accessibility metrics, MPO interviewees collectively noted the importance of technical support and capacity in both computing the metrics and also communicating them to stakeholders. For example, an interviewee from MTC commented that it is very crucial that their planning staff be well versed in accessibility concepts and that they have strong modelling tools to allow them to talk about the accessibility impacts of plans and projects to non-experts. Regarding the challenge of explaining accessibility to stakeholders, an interviewee from SACOG commented that some guidance in the form of a handbook that illustrates effective ways to explain the concept and associated metrics to elected officials and the general public would be very helpful.

Leadership Efforts

Somewhat related to the above point is the role of leadership support, as it is costly to develop the level of technical capacity to be able to conduct accessibility analysis, especially at the project level. An interviewee from MTC also acknowledged that they are "fortunate" to have "forwarding thinking" executive leadership and board that understand the value of this kind of data analysis and have continued to invest in it (personal communication). Similarly, an interviewee from SJCOG also commented that their board has been very eager to learn about the theoretical concepts underlying transportation planning, which makes it easier for staff to communicate with board members about the evolving transportation investment strategies.

Conclusion

In this study, I examined the use of accessibility concepts and metrics in regional planning efforts in California through archival research of key planning documents of seven California MPOs and interviews with their staff members. Consistent with existing research, I find that California MPOs have been using accessibility concepts and metrics more in regional planning processes, though they do not always define the term well. I also find that MPOs face a variety of obstacles in adopting accessibility. Moreover, I draw several new findings that both contribute to the literature and have policy implications.

First, within the regional planning processes, I find that the concept of accessibility plays a more important role in long-range regional plans than in the short-term project selection and programming processes. This is because MPOs tend to have less control over project selection and programming. Consequently, MPOs use accessibility metrics more as performance measures that assess the collective impacts of the long-term transportation investments and strategies and less as factors that feed into project evaluations that determine funding allocations.

Second, I closely examined all accessibility-related metrics used by California MPOs, and found that they use indirect and partial metrics of accessibility, mostly VMT and travel reduction related, more commonly than direct metrics. This is largely due to two factors: on the one hand, SB375 compels MPOs to reduce VMT and GHGs, which could lead to improved accessibility; on the other hand, MPOs face a tradeoff between conceptual completeness (including accuracy and precision), and ease of interpretation and communication, when choosing which metrics to use.

Third, while the interviews confirmed the many obstacles to adopting accessibility metrics in practice identified in the literature, interviewees cited two factors as the biggest obstacles. First is the difficulty of explaining accessibility metrics to stakeholders, which increases as the metrics get more conceptually complete because they also become more complex and abstract at the same time. This is different from computational obstacles, which are becoming less of a concern for many MPOs, especially those with stronger technical analysis capacity. Second is MPOs' limited agency in project selection and programming, which limits the degree to which they can address accessibility concerns in this process. This is because various federal and state funding programs have specific focus and objectives that may or may not promote accessibility. Multi-county MPOs can have even less say because county-level transportation planning agencies often select projects for funding.

Lastly, California's SB 375 played a critical role in motivating MPOs adopt more accessibility metrics, or at least allowing them to play a bigger role in shaping land use patterns, which helps promote more compact and mixed-use land use patterns integrated with a multi-modal transportation system. While the goal of such efforts is to meet VMT and GHG reduction targets, they, if successfully implemented, will likely result in accessibility improvements as well. But SB 375 does not grant MPOs land use authority over local governments. Thus, whether VMT and GHG will be reduced and accessibility will be increased depends very much on local governments acting to make sure their plans and policies are consistent with regional strategies. If local governments choose not to do so, MPOs have little means of enforcing their plans but to rely on the state government to step in.

My study focuses on California because SB 375 offers a case study of how state legislation that grants MPOs land use planning responsibility can influence how MPOs use accessibility. This certainly limits the generalizability of some of my findings. More specifically, my finding that the reviewed MPOs have used accessibility – especially VMT related – metrics more could be a California-specific trend, which is due, at least partly, to SB 375. Nonetheless, my findings about obstacles may be more relevant to non-California context. For example, there is no reason to believe that the complexity and abstractness of accessibility metrics only create challenges for California MPOs. Similarly, MPOs across the US tend to have limited control over project selection and local land use planning. That SB 375 allows California MPOs some more influence on land use planning and helps MPOs adopt more accessibility may offer some experience for other states.

From these findings, I offer three recommendations. First, efforts to support MPOs in adopting accessibility metrics should focus on developing both their computational capacity and the ability to effectively communicate these complex and abstract ideas to stakeholders. The recent National Cooperative Highway Research Program report by Karner et al (2022) is a very good attempt at providing guidance to planning organizations on how to calculate and communicate accessibility metrics. Technical, and perhaps non-technical staff too, may benefit from workshops that disseminate such knowledge and information or demonstrate how to use existing software and tools to calculate accessibility.

Second, MPOs need supportive legislation like California's SB 375 that allows them to integrate transportation and land use planning in order to promote accessibility. In fact, SB 375 aims to reduce VMT and GHG, and accessibility is just a likely by-product of the intended outcome. States that wish to promote accessibility planning at the regional level may pass more targeted legislation that focuses on accessibility and/or grant MPOs some concrete control over land use planning by various means.

Finally, MPOs could better coordinate the currently fragmented project selection and programming processes and prioritize the regional goals and objectives for transportation and land use investments. This can help ensure that local governments and agencies consistently implement regional strategies. This may go hand-in-hand with supportive legislation because MPOs may need more authority to assert their priorities among the mixture of federal, state, and local goals and objectives.

ESSAY THREE: The Cost of Insuring Access: How Auto Insurance Premiums Influence Household Car Ownership

Abstract

Cars offer a great advantage over public transit and other travel modes in enabling access to destinations and activities, especially in the auto-oriented urban form that dominates many US metropolitan areas. Research has demonstrated that low-income and minority travelers consistently have the least accessibility, primarily due to less car ownership or access. While many studies have examined the factors affecting car ownership, only a few studies have focused on auto insurance premiums, an important component of the cost of owning and operating a car. Existing evidence shows the uneven distribution of auto insurance premiums across geographic contexts and racial groups and has established the association between auto insurance and car ownership at aggregate scales. In this study, I use data on average auto insurance premiums of census tracts and household car ownership in California to show that higher tract-level premiums are strongly associated with lower household car ownership. I also show that there are significant differences among geographic contexts, income levels, and, to a limited degree, racial groups, in such associations. The findings imply that policy efforts to promote car ownership among low-income and minority households need to lower the cost of insurance by addressing insurance redlining, subsiding travelers who cannot afford auto insurance, and promoting affordable shared mobility programs.

Introduction

The auto-oriented urban form in most US cities underscores the great advantage of automobiles in ensuring access to destinations and opportunities. Much existing evidence has demonstrated the substantial accessibility gaps between those having a car and those relying on public transit, and that low-income communities and communities of color consistently have the least accessibility, primarily due to less car access (Blumenberg and Manville 2004; Shen 1998; 2001; Grengs 2010). Thus, it is important to study the causes of disparities in car ownership. In this paper, I examine how auto insurance premiums may influence car ownership and contribute to such disparities.

In the US, most states require drivers to have, at the minimum, some level of liability insurance to protect them from being found legally liable in case of accidents. Drivers can choose to get additional coverage to pay for damages caused by collisions, theft, vandalism, and disasters. Drivers without the required insurance can face expensive penalties including fines, vehicle impoundment, and suspension of driver's license and vehicle registration. The cost of auto insurance can be a significant part of the overall owning and operating costs. According to the US Department of Transportation Bureau of Transportation Statistics (2024), owning and operating a car cost $12,182 annually on average in 2023 in the US. Of that overall annual cost, auto insurance costs $1,765 (about 14% of overall cost), which is slightly smaller to financial payments and license and registration fees combined ($2,015, or 17% of overall cost), and a little less than half of fuel and maintenance costs combined ($3,864, or 32% of overall cost)[9]. States also have different minimum coverage requirements, and hence varied average insurance costs. For example, California has relatively lower minimum coverage requirements, and according to estimates by the US News and World Report, California's average annual premium is about 14% lower than the national average (Dilmore 2024).

[9] The calculation uses data from the American Automobile Association. Overall annual cost of owning and operating a car includes fixed costs of depreciation, finance, insurance, license, registration, and taxes, as well as variable costs of fuel and maintenance, repair, and tires.

Many studies have highlighted the effect of income and other individual factors on car ownership, but fewer studies have included the effect of auto insurance and financing. Raphael and Rice (2002) found that differences across states in average insurance costs have large and negative impacts on car ownership rates, but they did not examine differences among neighborhoods within a region; Ong and Stoll (2007) showed that auto insurance premiums were higher for drivers in minority communities than for similar drivers in white communities in the Los Angeles metro area, all else equal; Ong and Gonzales (2019) showed that the neighborhood level variations in auto insurance premiums and auto finance costs help explain the disparities across racial groups in car ownership in Los Angeles, which has significant implications on employment outcomes.

While the above studies have shown the uneven distribution of auto insurance premiums across geographical contexts and racial groups and established some correlation between auto insurance and car ownership at highly aggregate scales, I examine this association at a finer resolution in this study. I use data on average auto insurance premiums for California census tracts from the UCLA Center for Neighborhood Knowledge (CNK) Transportation Disparities database and household data on car ownership from the 2010-2012 California Household Travel Survey (CHTS) to test the associations between neighborhood-level auto insurance premiums and household car ownership in California. A main contribution of this study is that I identify the mechanisms through which auto insurance may influence household decisions to purchase a vehicle. I do this by testing the differential effects of geographic context, income, and race on the association between auto insurance and car ownership.

I first use the CNK data to illustrate the uneven distribution of auto insurance premiums in California across urban, suburban, and rural neighborhoods, across income levels, and racial groups. I then use regressions to test the associations between auto insurance premiums and three measures of household car ownership, controlling for a set of socio-economic and built environment characteristics. These regressions show that higher tract-level average auto insurance premiums are strongly associated with lower household car ownership, and the magnitude of this association is smaller, but not trivial, as compared to that between household income (arguably the strongest predictor of car ownership) and car ownership. Moreover, regression results also show significant differences among geographic contexts, income levels, and to a limited extent, racial groups, in such associations.

The next section reviews some relevant literature on cars and accessibility disparities, and the relationship between auto insurance premiums and car ownership. I then describe the data and method of this study. Next, I present and discuss descriptive and regression results. Lastly, I conclude with key takeaways and implications.

Literature Review

Cars and Accessibility Disparities

Car ownership or access makes a significant difference in access to opportunities in the US. Earlier studies about (job) access disparities, following Kain's (1968) spatial mismatch hypothesis, tended to focus on physical distances between low income and minority neighborhoods in inner cities and jobs in the suburbs. These studies showed that distance to jobs explains, at least partially, the adverse employment outcomes of minorities living in inner city neighborhoods (Gobillon, Selod, and Zenou 2007). Studies on welfare recipients also confirm the importance of proximity to jobs for better economic well-being (Blumenberg and Manville 2004; Ong and Blumenberg 1998).

However, Kain's original 1968 study and many studies that followed did not fully address transportation mode choice. In many cases, the barrier preventing the unemployed in inner cities from reaching jobs in the suburbs is less the geographic distance but rather the lack of fast and reliable personal transportation that comes from having access to a car (Taylor and Ong 1995; Grengs 2010). Many studies have then emphasized the importance of "modal mismatch", or "a drastic divergence in the relative advantage between those who have access to automobiles and those who do not" in explaining inner city minorities' poor access to jobs (Blumenberg and Manville 2004). Many studies of job accessibility of low wage workers and welfare recipients have shown that considerable disparity in job accessibility exists between car users and public transit users, and that car ownership is a more important factor than locational proximity in explaining job accessibility (Blumenberg and Ong 2001; Shen 1998; 2001; Kawabata 2003; 2009; Kawabata and Shen 2007).

Moreover, while modal mismatch may have a bigger role in explaining job access disparities in larger and less compact cities that are more auto-centric, and spatial mismatch applies better to more compact cities that suffer from the hollow-out effect (Blumenberg and Manville 2004), whereby jobs, but not low-income and minority residents, tend to relocate from the central city to the suburbs over time. Studies of cities like Boston and Detroit show that inner city residents may have "a locational advantage" over suburban residents with respect to average distances to opportunities, but these accessibility differentials among locations are smaller than the differentials across transportation modes (Shen 1998; 2001; Grengs 2010). Thus, Ong and Gonzalez (2019) describe the issue as "spatial-transportation mismatch," acknowledging the role of physical proximity yet emphasizing the role of transportation mode, which fits well with the idea that accessibility can be improved by improving proximity and mobility. While most studies have focused on job accessibility, Grengs (2015) showed that low access to automobiles also explains minorities' poor access to non-work destinations like shopping, education, recreation and healthcare.

One important nuance for the importance of car ownership or car access for job accessibility compares commute distance vs commute time. For instance, in the central city, even short distance commute trips can take a long time when traveling at slow speeds, especially for people who travel on public transportation (Blumenberg and Manville 2004). Consequently, low-wage job seekers, most of whom rely on public transit, can reach far fewer jobs than they could have if they travelled by car. Another argument for the importance of car access or ownership concerns women, whose travel behaviors (and presumably needs) vary systematically from men's, on average. Women are much more likely than men to assume the household's supporting role, even when they are also working (Taylor, Ralph, and Smart 2015). Therefore, they usually need to "make multiple household-supporting trips over and above the work commute", which becomes particularly relevant for single mothers who are solely responsible for their households (Blumenberg 2004; Blumenberg and Manville 2004). Such need for multiple trips may lead women to take jobs closer to home, resulting both in shorter average commute distances, but more importantly, women's disproportionate reliance on cars, which offer more flexible and quicker mobility, allowing women to complete more trips in less time than on public transit.

Many studies also show that car ownership or access does lead to better employment outcomes (Raphael and Rice 2002; Ong 2002; Ong and Miller 2005; Ong and Gonzalez 2019; Gurley and Bruce 2005; Baum 2009; Blumenberg and Pierce 2014). Having a car allows one to reach more jobs per unit of time, which yields "a better bargaining position", and consequently those with cars end up with both higher employment rates and higher wages as compared to those without cars (Gautier and Zenou 2010). Thus, scholars have argued for policy interventions to promote car ownership and access (P. Ong and Blumenberg 1998; Blumenberg and Ong 2001; Blumenberg and Manville 2004; Grengs 2010; King, Smart, and Manville 2022).

Car Insurance and Car Ownership

Many factors explain variations in car ownership, and many barriers exist for low income and minority populations to own or gain access to cars. Studies of car ownership in general have underscored the effects of various factors like income, fixed and variable car ownership and operation costs, car reliability, license holding, sociodemographic characteristics, and individual attitudes (de Jong et al. 2004). However, fewer studies have focused on the barriers that limit car ownership among low income and minority populations. Ong and Gonzalez (2019) highlighted three key mechanisms that contribute to the "ethnoracial" gap in car ownership: higher auto loan interest rates, higher auto insurance premiums, and higher traffic fines. These factors affect not only the ability to purchase and keep a private vehicle, but also the vintage of the vehicle, which is related to its reliability.

Auto insurance is part of the cost to maintain car ownership, and a few studies have found systematic disparities in auto insurance premiums across racial groups. In a study of the effect of car ownership on employment outcomes, Raphael and Rice (2002) used average auto insurance costs and gas taxes at state level to construct an instrumental variable for car ownership in an attempt to assess the effect of car ownership on employment outcomes. They showed that higher auto insurance costs across some states have large and negative effects on car ownership, and negative indirect impacts on employment. At a more micro level, Ong and Stoll (2007) collected auto insurance premium quotes for each zip code in Los Angeles for the same hypothetical driver. They found that, after accounting for accident rates, insurance charges, and traffic density, insurance premiums were still higher in low income and minority zip codes, which they interpreted as evidence of redlining.

Subsequent studies confirmed this with larger-scale data. A Consumer Federation of America study examined auto insurance premium data from the five largest auto insurers for a single good driver profile in most zip codes across the nation, and found that, on average, a good driver in a predominantly Black community would pay considerably more for state-mandated auto insurance coverage as compared to a similar driver in a predominantly White community (Feltner and Heller 2015). Another study, by ProPublica, compared aggregate risk data collected by auto insurance commissioners of California, Illinois, Missouri and Texas, with liability insurance premiums charged by the largest insurers in each of the four states (Angwin et al. 2017; Larson et al. 2017). This study found that some insurance companies charged higher premiums in predominantly minority zip codes on average than in similarly risky (based on traffic crashes) non-minority zip codes, and in some cases, as much as 30 percent more.

Lastly, Ong and Gonzalez (2019) used household and census tract level data in Los Angeles and showed that higher insurance premiums are associated with lower vehicles per person ratios, controlling for income potential (education and age) and other key demographic characteristics as well as transit access. They also showed that higher auto insurance premiums, together with subprime lending (a proxy for auto loan rates) and higher license suspension rates (a measure of policing), help explain the racial gaps in vehicle ownership between minority, Hispanic and Black in particular, and White neighborhoods.

The reviewed studies together suggest that higher auto insurance premiums are partly responsible for the low ownership and/or relative lack of access to private vehicles among low income and minority travelers, which in turn is an important reason for these travelers' lower average levels of access to jobs and other opportunities. While several key studies have demonstrated the systematic disparities in auto insurance premiums across racial groups, few studies have investigated how and to what extent such disparities affect household car ownership. Ong and Gonzales (2019) tested the association between auto insurance premiums and car ownership but focused on Los Angeles only, and did not examine differential effects that could affect this association. Accordingly, this paper addresses this gap by testing the associations between auto insurance premiums and household car ownership, as well as potential differential effects due to different geographical contexts, income levels, and races. I also compare the relative importance of auto insurance premiums to household income in affecting car ownership.

Data and Method

In this study, I address the following research questions: do neighborhood-level variations in auto insurance premiums explain disparities in household vehicle ownership? If so, a) what is the relative importance of auto insurance premiums in explaining disparities in car ownership as compared to other factors affecting car ownership, notably household income? b) does this effect play out differently in low income and/or minority neighborhoods? and c) does the effect vary in different geographic contexts – urban vs. suburban vs rural?

My primary hypothesis is that auto insurance premiums, as a component of car ownership costs, influence people's decisions to own vehicles. I expect that households facing higher auto insurance premiums will be less likely to own a vehicle, or less likely to own more vehicles if they already own at least one. I also expect the magnitude of this association to be large enough to warrant policy intervention, but likely smaller than the effect of income on car ownership. Secondarily, I hypothesize that the association between auto insurance premiums and car ownership will vary across different geographical contexts, or more specifically, urban, suburban, and rural neighborhoods, and across income levels as well as racial groups. I expect that such association will be more pronounced in urban areas because these neighborhoods tend to have relatively higher insurance premiums on average due to higher traffic density and crash rates, as well as better transit services – an alternative to private cars – as compared to suburban and rural areas. I also expect that such an association will be stronger for low income and minority households, who may be more cost-sensitive to higher auto insurance premiums.

My primary data sources are the CNK's transportation disparities database and the 2010-2012 CHTS. The CNK's database contains tract-level information for nearly all census tracts in California on average auto insurance premiums. The CHTS is a large travel diary, carried out on behalf of the California Department of Transportation and designed to be representative of California households. It contains household-level data on car ownership. The CNK's data on auto insurance premiums comes from the years 2007 through 2011 and 2014, 2015, and 2016, which overlap with the CHTS data's time frame. Both data sets contain other relevant variables affecting car ownership (see Table 3-1 for all variables used in the analysis). I attach tract-level data to household-level data and test the association between tract-level average auto insurance premiums and household-level car ownership, controlling for a set of tract-level and household-level factors. I describe these variables and my models in more detail below.

Table 3-1. Variables used in the analysis

Variables	**Source**
Dependent variables	
Household (HH) owning at least one car (binary)	CHTS
Total number of cars owned by a HH	CHTS
Number of cars per HH member	CHTS
Independent variables	
Tract average auto insurance premium	CNK database
Interaction variables	
Geographic context of census tract	Voulgaris et al. (2017)

Income level of census tract	CNK database
Largest racial group in census tract	CNK database
Controls	
Tract subprime loan rates (proxy for lending barriers)	CNK database
Number of licensed drivers in HH	CHTS
HH size	CHTS
HH income	CHTS
HH racial composition (White, Asian, Black, Hispanic, Mixed/other)	CHTS
Employed ^	CHTS
Bachelor's degree or higher ^	CHTS
Less than high school ^	CHTS
Male ^	CHTS
Over 65 years old ^	CHTS
Foreign born ^	CHTS
Disabled ^	CHTS
Neighborhood typology	Voulgaris et al. (2017)
County fixed effects	CHTS
Notes: ^ these variables are computed as fractions of the household.	

Dependent Variables

Table 3-2. Descriptive statistics on household car ownership

	N	mean/%	median	s.d.	min & max
Share of HHs owning at least one car	42,421	94.2%			
Total number of cars owned by HH	39,964	2.0	2	0.91	1 & 8
Number of cars owned by HH member	39,964	0.88	1	0.45	0.125 & 8

Using the CHTS data, I measure car ownership at the household level with three variables: a binary variable indicating if the household owns at least one car, and for households that do so, a count variable for the total number of cars owned by the household and a ratio variable for the number of cars owned per household member (see Table 3-2 for descriptive statistics). In the sample, the vast majority (94.2%) of all households own at least one car, but there is considerable variation in how many cars these households own. On average, they own about two cars, and fewer than one car per household member. While the most car-rich household owns eight cars in total, a cardeficient household can own as few as 0.125 cars per household member. The different types of the three dependent variables call for different functional forms of the regression models: I fitted logit models for the binary variable, negative binomial models for the count variable, and ordinary least square models for the ratio variable.

Independent Variable

I measure auto insurance premiums at the census tract level using the auto insurance premiums indicator in CNK's data. For this indicator, California census tracts are divided into 10 percentile ranks based on their average auto insurance premiums, controlling for vehicle and coverage types (see Ong et al. 2022 for the detailed methodology). I attach these percentile ranks to each household in the CHTS. Thus, rather than each household's exact auto insurance premium, my independent variable measures the relative levels of average auto insurance premium of each household's census tract. There are about 2,500 (6%) to 9,200 (22%) households in each of these levels (see Figure 3-1 for the distribution). In addition, while the percentile rankings represent an ordinal scale, the differences in average auto insurance premiums between ranks are not equal. In fact, the increases in average premiums by jumping up a percentile rank range from less than 5% to almost 25% -- the biggest increase being the difference between the 80-90 percentile and 90-100 percentile ranks. If compared to the bottom 10 percent, the average premium of the 30-40 percentile is 20% higher, the 60-70 percentile 40%, the 80-90 percentile slightly less than 60%, and the top 10 percent almost 100% (or twice as high) (Ong et al. 2022).

One limitation of this data is that it measures tract average. So, readers should be mindful of ecological fallacy and not interpret any association between the auto insurance variable and car ownership as evidence for the influence of auto insurance premium paid by individual households on their car ownership decisions. Instead, with this data, I can only measure how tract-level variations in auto insurance premiums may affect household car ownership. That said, this is still a meaningful investigation because auto insurance companies do consider where people live when determining their premiums.

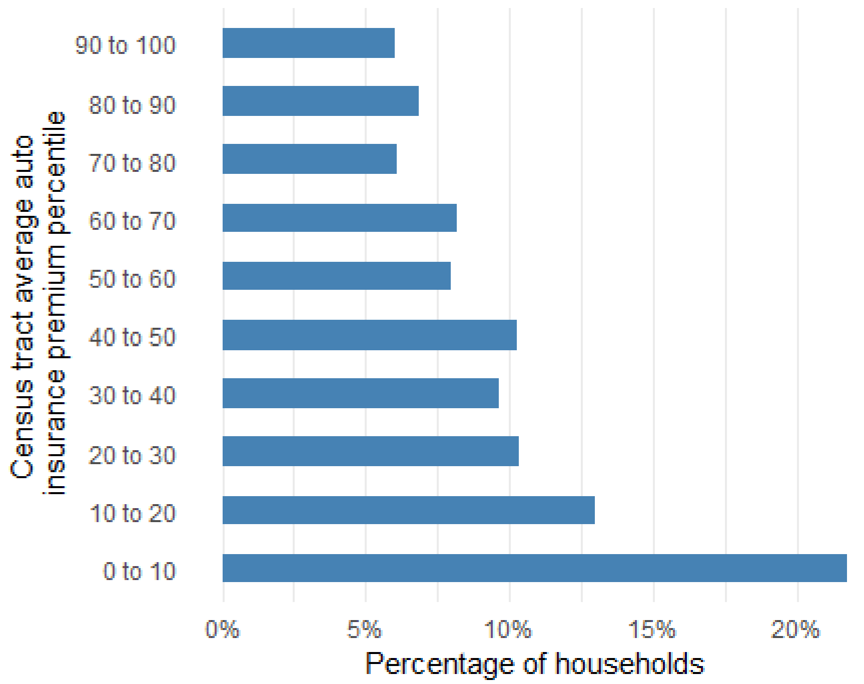

Figure 3-1. Distribution of California households across census tract average auto insurance premium percentile ranks

Control Variables

I control for lending barriers because access to auto loans can influence car ownership. I do this using the subprime mortgage rates indicator in the CNK data. Similar to the auto insurance premiums indicator, California census tracts are divided into 10 percentile ranks based on their proportions of mortgage loans with high interest rates. I attach these ranks to each household and, to simplify the models, convert the variable to numeric based on these ranks. Thus, readers should not interpret this variable's coefficients as measures of linear associations between subprime mortgage rates, as a proxy for auto lending barriers, and car ownership, but may interpret the coefficients' signs as the general direction of such associations.

I also control for a variety of socio-economic factors likely to influence vehicle ownership. Using the CHTS data, I control for the number of licensed drivers in a household, household size, household income, and household racial composition. I also control for other socio-economic factors including employment, education, age, gender, nativity, and disability. The latter set of factors are measured at the individual level in the CHTS, so I constructed household-level measures of these factors as fractions of a household (e.g. fraction of a household that is employed, etc.).

To control for built environment factors, I use neighborhood typologies developed by Voulgaris et al. (2017). Voulgaris et al. collected 2010 data on 20 different measures of census tract-level built environments, including measures of density, transit service, job access, and street layouts. They then used factor and cluster analysis to categorize census tracts into seven distinct neighborhood types. The CHTS has census tract identifiers for each household, which I used to merge the CHTS data with the neighborhood typology data, and the CNK data as well. I also include county fixed effects for all models. None of the independent and control variables are highly correlated with each other.

Interaction variables

My first set of regressions test the associations between auto insurance premiums and car ownership. I then add interaction terms of auto insurance premiums with geographic contexts to explore the differential effects among urban, suburban, and rural neighborhoods. I also allow auto insurance premiums to interact separately with the income level and the largest racial group of census tracts to test if there are any differential effects for low income and minority neighborhoods. For income levels, census tracts are categorized – based on their median household income as a percentage of area median household income – into lowest (0-60%), lower (60-80%), middle (80-140%), and high (over 140%) income levels (see Ong et al. 2022 for detailed methodology of this categorization).

Results

Descriptive results

I first use CNK's unique data on auto insurance premiums to paint a picture of their unequal distribution across geographical contexts, income levels, and racial groups. Figure 3-2 maps the average auto insurance premium of all California census tracts. It shows that urban census tracts tend to have higher average premiums than suburban and rural census tracts. It also shows that Los Angeles has the largest number of highest-average-premium census tracts among major metropolitan regions in California.

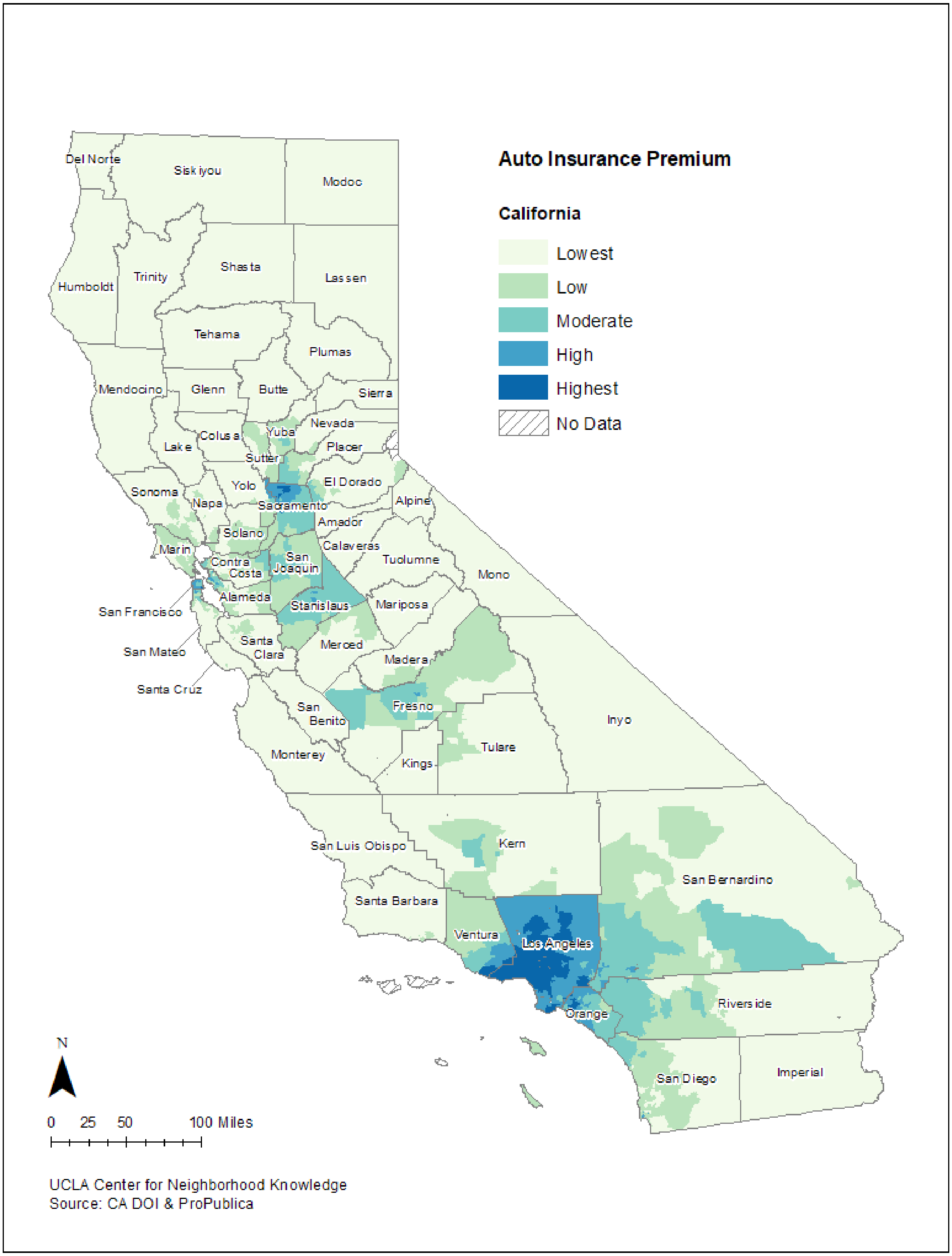

Figure 3-2. Map of census tract average auto insurance premiums (source: (Ong et al. 2022))

Figure 3-3 shows the distribution of California census tracts with respect to average auto insurance premiums for three different geographical contexts: urban, suburban, and rural. This chart illustrates a substantial difference between rural and non-rural census tracts: greater shares of urban and suburban tracts are among the top percentile ranks as compared to rural tracts, whereas a much greater share (more than 70%) of rural tracts are among the bottom three percentile ranks as compared to urban (less than 25%) and suburban (less than one-third) tracts. Differences also exist between urban and suburban tracts, but in smaller magnitudes. Thus, households in urban neighborhoods pay higher auto insurance premiums on average than their suburban counterparts, and together they pay higher premiums on average than rural households. A Chi-squared test found significant differences in auto insurance premiums across the three geographical contexts (Chi-squared = 1296, p = 0.00).

Figure 3-3. Distribution of auto insurance premiums by geographical contexts (data source: CNK)

Average auto insurance premiums are unevenly distributed across different income levels (see Figure 3-4). The chart illustrates a general trend: greater shares of the lowest (almost 50%) and lower income (over one-third) census tracts are in the top three percentile ranks as compared to middle- and high-income tracts (about 25%). And in particular, a much greater share of the lowest-income tracts (more than 20%) is among the top percentile rank, while a much smaller share of these tracts (about 5%) is among the bottom percentile rank. In other words, households in the lowest and lower income census tracts are more likely to pay higher auto insurance premiums on average as compared to their higher income counterparts. A Chi-squared test found statistically significant differences in auto insurance premiums across the four income levels (Chi-squared = 476, p = 0.00).

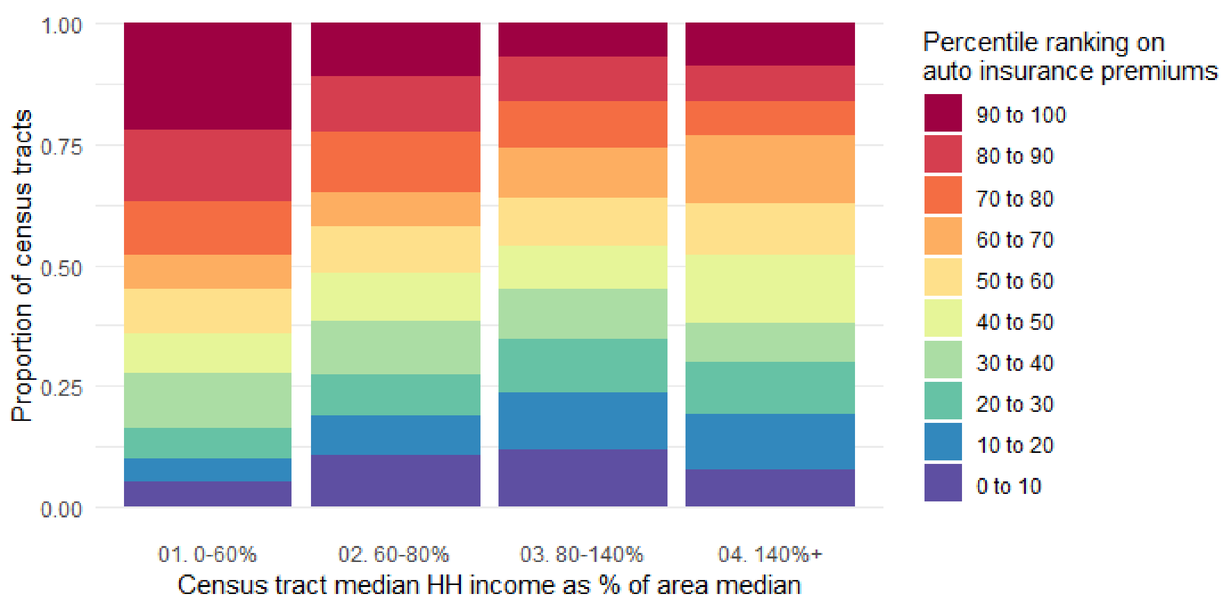

Figure 3-4. Distribution of auto insurance premiums by income (data source: CNK)

The distribution also varies by race (see Figure 3-5). For this chart, census tracts are categorized into four groups based on their largest, or dominant, racial group. The starkest contrast is the considerably higher proportions (almost 75%) of Black-dominant census tracts in the top 30 percentile as compared to the other three groups of tracts (about 40% for Asian-dominant tracts, 37% for Hispanic, and 20% for White). But the chart shows a general trend of higher proportions of minority-dominant census tracts in the top percentile ranks as compared to White-dominant tracts. A Chi-squared test found such differences to be statistically significant (Chi-squared = 921, p = 0.00). It is worth noting that minority-dominant tracts are not homogeneous: Black-dominant tracts have the highest shares of high auto insurance premiums and the lowest shares of low auto insurance premiums; Asian-dominant tracts have high shares of both high and low auto insurance premiums; Hispanic-dominant tracts are less concentrated at either end.

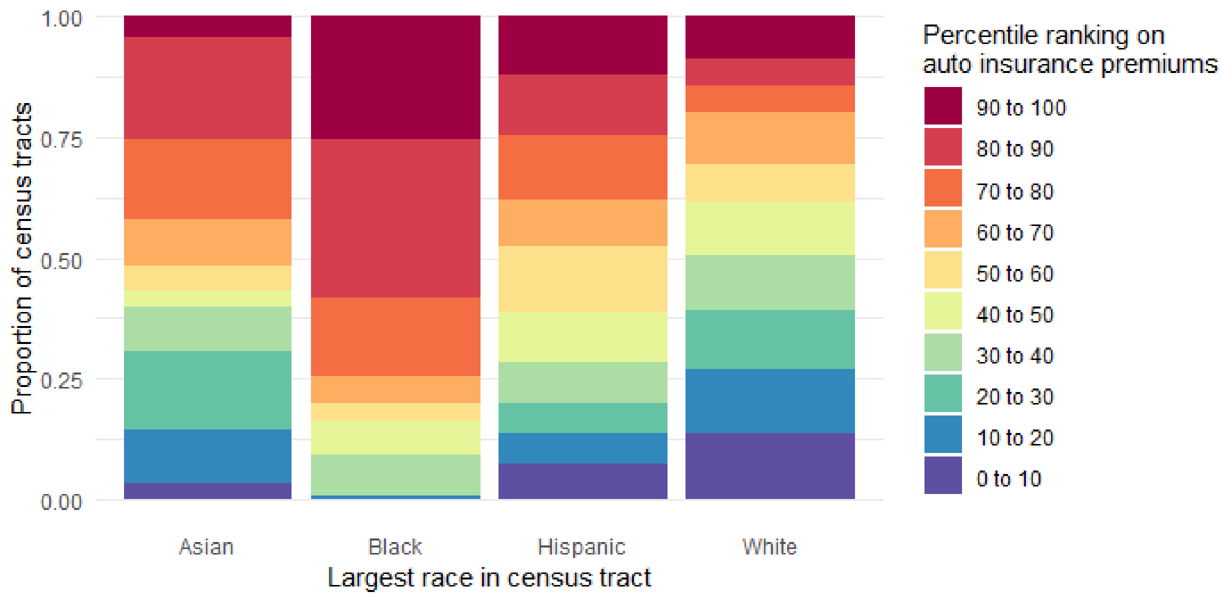

Figure 3-5. Distribution of auto insurance premiums by race (data source: CNK)

Overall, these charts and the Chi-squared tests show an uneven distribution of auto insurance premiums among California census tracts, and households in urban, low income, and minority neighborhoods tend to pay higher auto insurance premiums on average. How does this affect car ownership? Next, I estimate regression models to test the overall association between tract average auto insurance premiums and household car ownership. I also examine the specific differential effects that being located in urban, low income, and minority tracts might have on this association.

Regression results

The first set of regressions find that households in census tracts with higher average auto insurance premiums are less likely to own a car, and that those households that do own cars, tend to own fewer cars overall and per household member as compared to households in the 10 percent of census tracts with the lowest average auto insurance premiums (see Table 3-3). These differences become consistently statistically significant for the upper 60% of the census tracts. Recall that the average auto insurance premiums for these census tracts are between 20% to 100% higher than the bottom 10 percent tracts, which means that differences in auto insurance premiums likely only influence household decision about auto ownership once above certain thresholds. Auto insurance premiums, after all, are usually smaller than payments (down and monthly) for the vehicle, but they can become a material concern if they are high enough.

Table 3-3. Associations between auto insurance premium and household car ownership

	Owning at least one car in HH (Logit)		No. of cars owned by HH (Negative binomial)		Cars per HH member (OLS)
	Logit	Odds ratio	Coefficient	Marginal effect	
Auto insurance (tract average premium): 0-10 percentile	Omitted category				
Auto insurance: 10-20 percentile	-0.03 (0.18)	0.97	-0.01 (0.02)	-0.02	-0.00 (0.01)
Auto insurance: 20-30 percentile	-0.54 ** (0.19)	0.58	-0.01 (0.02)	-0.02	-0.01 (0.01)
Auto insurance: 30-40 percentile	-0.25 (0.19)	0.78	-0.03 (0.02)	-0.06	-0.01 (0.01)
Auto insurance: 40-50 percentile	-0.52 ** (0.20)	0.59	-0.04 ^ (0.02)	-0.08	-0.03 * (0.01)

Auto insurance: 50-60 percentile	-0.48 ** (0.22)	0.62	-0.06 * (0.03)	-0.13	-0.05 *** (0.01)
Auto insurance: 60-70 percentile	-0.82 *** (0.24)	0.44	-0.06 ^ (0.03)	-0.11	-0.04 ** (0.01)
Auto insurance: 70-80 percentile	-0.71 ** (0.26)	0.49	-0.07 * (0.03)	-0.14	-0.05 ** (0.02)
Auto insurance: 80-90 percentile	-0.63 * (0.28)	0.53	-0.08 ** (0.03)	-0.16	-0.05 ** (0.02)
Aito insurance: 90-100 percentile	-0.91 ** (0.28)	0.40	-0.10 ** (0.04)	-0.19	-0.07 *** (0.02)
Subprime loan (tract proportion)	0.01 (0.02)	1.0	0.01 ** (0.00)	0.01	0.01 *** (0.00)
No. of licensed drivers in HH	2.7 *** (0.07)	15.5	0.28 *** (0.01)	0.55	0.08 *** (0.00)
HH size	0.08 * (0.03)	1.1	0.01 * (0.01)	0.03	-0.19 *** (0.00)
HH income: 0-10k			Omitted category		
HH income: 10k-25k	0.54 *** (0.09)	1.7	0.02 (0.03)	0.04	-0.00 (0.01)
HH income: 25k-35k	1.2 *** (0.12)	3.4	0.10 ** (0.03)	0.16	0.01 (0.01)
HH income: 35k-50k	1.6 *** (0.13)	5.2	0.14 *** (0.03)	0.24	0.04 ** (0.01)
HH income: 50k-75k	2.0 *** (0.14)	7.7	0.22 *** (0.03)	0.39	0.09 *** (0.01)
HH income: 75k-100k	2.2 *** (0.18)	9.1	0.25 *** (0.03)	0.46	0.10 *** (0.01)
HH income: 100k-150k	1.8 *** (0.17)	5.8	0.29 *** (0.03)	0.53	0.12 *** (0.01)
HH income: 150k-200k	1.7 *** (0.25)	5.3	0.32 *** (0.03)	0.60	0.14 *** (0.01)
HH income: 200k-250k	1.7 *** (0.36)	5.3	0.35 *** (0.03)	0.67	0.17 *** (0.02)
HH income: 250k+	2.3 *** (0.47)	10.0	0.38 *** (0.03)	0.73	0.19 *** (0.02)
Socio-economic controls	Y		Y		Y
Neighborhood controls	Y		Y		Y
County fixed effects	Y		Y		Y
Constant	-3.1 *** (0.28)	0.05	-0.31 *** (0.05)		0.96 *** (0.02)

Observations	37,415	35,270	35,270

Notes: significance codes: ***p < 0.001, **p < 0.01, *p < 0.05, ^p < 0.1; standard errors in parentheses. Socio-economic controls: household income, race (White (omitted), Asian, Black, Hispanic, Mixed and other), male, 65 or older, foreign born, disabled, employed, bachelor's degree or higher, less than high school; neighborhood controls: neighborhood typologies (Voulgaris et al. 2017) of home locations; county fixed effects are counties of home location.

The magnitudes of the associations are not trivial. For example, households in the top 10 percent tracts – of which the average premium is almost twice as high as the bottom 10 percent – are 60% less likely to own a car. In other words, households in the bottom 10 percent census tracts are 2.5 times more likely to own a car than their counterparts in the top 10 percent tracts. This is larger than the effects of jumping up one income category, the biggest of which is between the top two income categories – 200k-250k and above 250k – an 89% increase in the likelihood of owning a car.

For households that already own at least one car, the marginal effect for those in the top 10 percent tracts is owning 0.19 fewer cars in the household as compared to those in the bottom 10 percent insurance premium tracts, which is again larger than the effects of jumping up one income category, which ranges from 0.04 to 0.15 more cars. Looking at cars per household member, the difference between the top 10 percent insurance premium tracts and the bottom 10 percent is 0.07 fewer cars per household member, which is larger than the differences between any two adjacent income categories, which ranges from 0.01 to 0.05 cars per household.

It is important to note that the associations between income and car ownership are likely overestimated. This is due to reverse causality or simultaneity bias: higher income households have more purchasing power to buy cars, but those with cars are more likely to get a job and earn more income (Ong and Gonzalez 2019). This means that the true effect of income on car ownership may be smaller than what these models show, which in turn means that the relative importance of auto insurance premiums as discussed above could be underestimated. The reverse causality between income and car ownership may raise concerns over endogeneity – estimates of the coefficients on auto insurance premiums may be biased if there is substantial correlation between income and premiums. A test of correlation between the auto insurance premiums variable and household income variable finds little to no correlation ($r = 0.00$, $p = 0.9$), thus there is no need to account for that in the models.

The directions of association for the control variables are mostly as expected, except for tract subprime loan rates (proportion of mortgage loans with high interest rates in census tracts). I had expected that higher subprime loan rates – as a proxy for auto lending barriers – would be associated with lower car ownership. But results of all three models indicate that higher loan rates are associated with higher car ownership, though the associations are only statistically significant for vehicle-owning households. This could reflect substitution effects: higher borrowing costs for home mortgages means less opportunity to purchase a home, which could lead households to shift their expenditure to other important household items, such as a car.

I then estimated a second set of models to explore the differential effects of geographical context on the association between auto insurance premiums and car ownership. I add an interaction term of auto insurance premiums and geographical contexts. To simplify the models and make the interaction effects more interpretable, I merged the categories of the auto insurance premiums variable and the neighborhood typologies variable and created two new variables with fewer categories; this allowed them to more manageably interact. The new auto insurance premiums variable has three categories: 0-10 percentile (lowest), 10-50 percentile (moderate), and 60-100 percentile (high) for auto insurance premiums, since most significant differences as discussed above are between the upper half of the percentile ranks and the bottom 10 percent. The seven neighborhood types are merged into three more general categories of urban, suburban, and rural.

Table 3-4. Differences between geographical contexts regarding the associations between auto insurance and car ownership

	Owning at least one car in HH (Logit)	No. of cars owned by HH (Negative binomial)	Cars per HH member (OLS)
Auto insurance (tract average premium): 0-10 percentile		Omitted category	
Auto insurance: 10-50 percentile	-0.2 (0.2)	-0.04 (0.03)	-0.02 (0.01)
Auto insurance: 60-100 percentile	-0.51 * (0.23)	-0.08 * (0.03)	-0.04 ** (0.02)
Urban		Omitted category	
Suburban	0.63 *** (0.18)	0.02 (0.02)	0.03 * (0.01)
Rural	1.1 *** (0.23)	0.07 * (0.03)	0.07 *** (0.01)
Auto insurance: 10-50 percentile * Suburban	-0.1 (0.21)	0.02 (0.03)	0.01 (0.01)
Auto insurance: 60-100 percentile * Suburban	0.17 (0.21)	0.05 (0.03)	0.01 (0.01)
Auto insurance: 10-50 percentile * Rural	0.0 (0.32)	0.04 (0.03)	0.04 ** (0.02)
Auto insurance: 60-100 percentile * Rural	-0.36 (0.55)	0.02 (0.05)	0.01 (0.03)
Subprime loan (tract proportion)	0.03 ^ (0.01)	0.01 ** (0.0)	0.01 *** (0.0)
No. of licensed drivers in HH	2.75 *** (0.07)	0.28 *** (0.01)	0.08 *** (0.00)
HH size	0.08 * (0.03)	0.01 * (0.01)	-0.19 *** (0.0)
Socio-economic controls	Y	Y	Y
Neighborhood controls	N	N	N
County fixed effects	Y	Y	Y
Constant	-2.97 *** (0.28)	-0.26 *** (0.05)	0.99 *** (0.02)
Observations	37,382	35,237	35,237

Notes: See Table 3-3 notes for significant codes and controls; Neighborhood controls excluded from these models to reduce multi-collinearity with geographical context variable (urban vs. suburban vs. rural).

The main finding from this set of interaction models is that there doesn't appear to be much difference between households in urban, suburban, and rural neighborhoods regarding how auto insurance premiums influence their decisions to own cars (see Table 3-4). For the most part, the differences in car ownership between households in tracts with high auto insurance premiums (60-100 percentile) and those in tracts with the lowest premiums (bottom 10 percent) are smaller for suburban and rural households as compared to their urban counterparts, but these differences are not statistically significant. The only significant difference is between rural households in census tracts with moderate premiums (10-50 percentile) and their urban counterparts.

I ran these models with two additional iterations – each time changing the reference category to suburban and rural respectively. I find that the associations between auto insurance premiums and (1) owning at least one car and (2) the total number of cars are only significant for urban households, while the association between premiums and cars owned per household member is significant for both urban and suburban households. None of the three associations is significant for rural households.

Two factors may explain why auto insurance premiums appear to have little influence over car ownership for rural and suburban households. First, rural and suburban households (the latter to a lesser degree) have little to no access to quality public transit services as an alternative to traveling by car, which may make their demand for private cars less elastic. This, in turn, means that their decision to own a car is less influenced by the cost of car ownership, including auto insurance. Second, most rural neighborhoods have low auto insurance premiums (almost 90% of rural tracts are in the lower 50 percentile in average auto insurance premium), which means that there is not much variation in premiums for rural households. While the variation is larger for suburban census tracts, suburban households tend to be wealthier on average, which could make them less sensitive to variations in premiums. But the significant association between premiums and cars owned per household for suburban households also suggests that, for car-owning households in the suburbs, higher auto insurance premiums might lead households to own fewer cars.

Table 3-5. Differences between income levels regarding the association between auto insurance premiums and car ownership

	Likelihood of owning at least one car	
	Logit	Odds ratio
Auto insurance (tract average premium): 0-10 percentile	Omitted category	
Auto insurance: 10-50 percentile	0.26 (0.29)	1.3
Auto insurance: 60-100 percentile	0.10 (0.30)	1.1
Lowest income census tract	Omitted category	
Lower income census tract	0.79 ** (0.28)	2.2
Middle income census tract	0.92 *** (0.26)	2.5
High income census tract	1.30 *** (0.37)	3.7
Auto insurance: 10-50 percentile * Lower income census tract	-0.68 * (0.31)	0.66 †
Auto insurance: 60-100 percentile * Lower income census tract	-0.63 * (0.30)	0.59 †
Auto insurance: 10-50 percentile * Middle income census tract	-0.48 ^ (0.29)	0.80 †
Auto insurance: 60-100 percentile * Middle income census tract	-0.49 ^ (0.29)	0.68 †
Auto insurance: 10-50 percentile * High income census tract	-0.83 * (0.42)	0.57 †
Auto insurance: 60-100 percentile * High income census tract	-0.74 ^ (0.41)	0.53 †
Subprime loan (tract proportion)	0.03 * (0.02)	1.03
No. of licensed drivers in HH	2.73 *** (0.07)	15.4
HH size	0.09 * (0.03)	1.1

SES controls	Y	
Neighborhood controls	Y	
County fixed effects	Y	
Constant	-2.7 *** (0.36)	0.02
Observations	11,063	

Notes: See Table 3-3 notes for significant codes and controls.
† Unlike the coefficients of interaction terms that represent differential effects (e.g. the differential in the association between auto insurance and owning a car between households in lower and higher income tracts), these odds ratios measure the combined effect (e.g. the likelihood of households in census tracts that are higher income and higher premium as compared to the reference group, i.e. households in tracts that are the lowest income and lowest premium).

I also test for any differential effects due to income by including an interaction term of auto insurance and income levels of census tracts. I find statistically significant interaction effects for the regression on owning at least one car, but not the other two dependent variables. Results in Table 3-5 show that, for households in the lowest income census tracts, higher auto insurance premiums are not consistently associated with lower likelihood of owning a car because the direction of the association is not clear, and the association is not statistically significant. Yet, the differences in the likelihood of owning a car associated with higher auto insurance premiums are statistically significantly larger for households in the lower-, middle-, and high-income census tracts as compared to those in the lowest-income tracts, and the combined effects indicate an overall negative association between auto insurance premiums and likelihood of owning a car.

Altogether, these results suggest that auto insurance premiums may have little to no influence over the decision to purchase a car for the poorest households, who might choose to not insure their cars if the premiums are too much of a burden to them. While it is illegal to drive uninsured in California and most other states, according to data from Insurance Research Council, 17% of motorists in California (higher than 14% for US overall) are uninsured in 2022 (Insurance

Information Institute, n.d.). Prior research about uninsured motorists suggest that they tend to be low income, minority, undocumented immigrant, younger, and less educated, and that the most common reason for not insuring their cars is the cost of insurance (Hunstad 1999; Kumazawa and Query 2023). In contrast, for the rest of the households, auto insurance premiums appear to factor into their decision about whether to purchase a car. Additional iterations of this model find that the differences between lower, middle-, and high-income categories are not statistically significant, which means that the main difference is between the lowest income category and the rest.

Tests of differential effects due to race do not yield significant results for the most part. The only significant result is the difference between Asian-dominant and White-dominant census tracts: the difference in the likelihood of owning a car associated with the difference between the highest and lowest insurance premiums is larger (more negative) for households in Asian-dominant tracts. This could mean that Asian households are more sensitive to very high insurance premiums than White households. However, there are no significant differential effects for other races or other ranks of auto insurance for any one of the dependent variables.

Conclusion

Owning or having access to a car is important in much of the US because cars have tremendous access advantage over any other modes of transportation in moving people to where they want to go given the predominately auto-oriented built environment. Existing evidence suggests that the lack of access to a car among low income and minority populations contributes significantly to their low levels of access to jobs and other non-work opportunities, which in turn negatively affects their employment outcome and overall wellbeing. There has been some evidence at relatively coarse resolutions that suggests that auto insurance premiums tend to be higher for low income and minority populations and that could contribute to their lower levels of car ownership.

I examined this question and drew two principal findings. First, using census tract auto insurance premiums data and household level car ownership data, I provide more evidence at a more disaggregate level and show that households living in neighborhoods with higher average premiums are less likely to own a car, and if they do own one, less likely to own additional cars. I also show that the magnitude of these associations is not trivial. Second, I provide insights on the mechanisms through which auto insurance premiums may influence household decisions to purchase a car. Specifically, I show that urban households may be more sensitive to higher auto insurance premiums than suburban and rural households. This may be due to the presence of travel alternatives, such as public transit, in urban areas, which may make urban travelers more elastic in their response to insurance premiums than suburban or rural travelers.

Further, the poorest households might be relatively less concerned about auto insurance premiums when deciding to buy a car compared to middle- and higher-income households because they may be more likely to risk driving without insurance. These results are robust to controls for socio-economic and built environment characteristics. Although I do not explicitly control for residential self-selection in my models, the existing literature suggests that controlling for self-selection would only modestly reduce the magnitude of my results, and might even increase them.

While I find that the poorest households might be insensitive to higher auto insurance premiums, it is likely because they choose to not insure their cars when premiums become too much of a burden. Thus, this finding does not necessarily invalidate the concern over auto insurance for low-income households. Rather, it amplifies the negative impacts of high premiums because they might lead to poor households driving uninsured and resulting in more citations and higher costs when crashes happen. Moreover, higher concentrations of uninsured motorists in poor neighborhoods and inner-cities may lead to higher insurance premiums, which may, in a vicious cycle, lead to more uninsured motorists.

That suburban households in my sample appear less sensitive to auto insurance premiums also does not mean that concerns over auto insurance are irrelevant in the suburbs. This finding might be due to the combined effects of higher incomes on average for suburban households and poorer transit services in suburban areas. But as poor households move out of the urban cores into suburban areas, where a substantial share of census tracts do have high average auto insurance premiums, they might be caught in a tougher situation in which higher premiums raise their costs of owning a car while a good alternative to driving is not available.

My results imply that efforts to promote car ownership among low income and minority households should seek innovative ways to address the cost of auto insurances. On one hand, for instances of insurance redlining (Ong and Stoll 2007), state governments need to pass legislations to forbid such discriminatory practices that unfairly raise low income and minority households' insurance costs. On the other hand, state and local governments may consider subsidy programs to help low income and minority households afford auto insurance and cars. These households are also more likely to drive uninsured, so with more affordable auto insurance, they can better protect their car access from crashes, thefts, and other accidents, rather than having to constantly worry about penalties. Moreover, with new forms of more affordable mobility like car share programs, low-income households that find insurance costs too high for them to own a car may instead choose to purchase car access one trip or several trips at a time. Governments need to support such programs' deployment and expansion in low income and minority neighborhoods to help deliver more affordable forms of car access.

While my study uses California data, my results and their policy implications may still be relevant beyond California. As noted in the introduction, auto insurance costs are a significant share of the overall cost of owning and operating a car, and California actually requires a relatively lower level of coverage compared to many other US states and hence has relatively lower premiums on average. This means that the association between auto insurance premiums and car ownership observed for California may be generalizable to other states, and may even be stronger in states that require more coverage.

CONCLUSION

Transportation planning in the US has long focused on improving (auto) mobility. But the principal goal of transportation policy is not *the* means (moving people and goods), but *the ends (accessing desired destinations and activities).* While scholars have argued for a shift of focus to improving accessibility, local and regional governments have not fully embraced this approach (Handy 2005; Levine, Grengs, and Merlin 2019; Proffitt et al. 2019; Combs, McDonald, and Leimenstoll 2020). Local governments, driven by residents' concern over traffic congestion, may be reluctant to move away from the conventional LOS-based transportation/traffic impact study in development review processes (Ding and Taylor 2021). California's newly-mandated VMT-based analysis aims to reduce vehicle travel and tends to favor land use developments that brings destinations in closer proximity (Lee and Handy 2018). But neither LOS nor VMT directly assesses how development projects may affect people's access to destinations and activities. With the development of analytical tools to calculate project-level accessibility (Siddiq and Taylor 2021), it is possible to demonstrate the merits of using accessibility metrics to evaluate impacts of land use developments.

Regional governments, on the other hand, have been more willing to adopt accessibility, but still face various technical and political obstacles (Handy 2005; Proffitt et al. 2019). SB 375 has given California MPOs greater influence over land use strategies, which may have put MPOs in California in a better position than MPOs in other states to adopt accessibility and plan for an integrated transportation and land use system. This presents a good opportunity to evaluate California MPOs' use of accessibility concept and metrics in regional planning processes. In the meantime, the auto-oriented urban form of many US metropolitan areas – the outcome of decades-long mobility-focused transportation and land use planning – has given cars a substantial advantage in enabling access to destinations and activities. Those who do not own or have access to a car and instead rely on public transit consistently have lower accessibility to jobs and other important opportunities (Taylor and Ong 1995; Shen 1998; 2001; Grengs 2010). While much research has examined factors affecting car ownership, fewer studies have studied the role of auto insurance premiums, an important component of the cost of owning and operating a car.

I address these literature gaps in this dissertation. In essay one, I compare LOS, VMT, and accessibility metrics in evaluating transportation impacts of land use development using a sample of 22 proposed projects in the City of Los Angeles. I summarize and compare LOS and VMT analysis results reported in the projects' EIRs, and use these analyses' data and assumptions to calculate potential job accessibility changes by different travel modes. I find that the VMT-based evaluation tends to favor higher density, mixed-use, and infill projects, and is less likely than the LOS-based evaluation to predict these development projects to have significant (negative) impacts. But both the LOS- and VMT-based evaluations can overlook accessibility gains from either increased mobility on transportation networks or closer proximity among land uses. In addition, I find that local governments, like the City of Los Angeles, continue to require LOS-based evaluation in addition to CEQA-mandated VMT-based evaluation. This means that while the changed focus to VMT elevates emission reduction to the top priority, congestion reduction persists as an important goal of local governments' transportation policy.

Thus, improving accessibility appears to be a lower priority for local governments. Yet, my analysis shows that gravity-based accessibility metrics can account for changes in both mobility on the transportation networks and proximity of destinations, thereby addressing congestion and emission concerns. One the one hand, the accessibility-based evaluation can demonstrate the limited effect of local congestion on overall accessibility, while highlighting potential accessibility gains from targeted congestion reduction efforts. This may help ease residents' and planners' concern over congestion and help focus limited resources on bottlenecks. On the other hand, the accessibility-based evaluation can more directly assess potential impacts on accessibility by various travel modes, and help focus mitigation efforts on transit, walking, and biking, which helps reducing VMT and vehicle emissions. Thus, local governments can still address congestion and emission concerns while prioritizing accessibility by focusing on accessibility impacts of development projects, which has become easier with developments in analytical tools.

In essay two, I evaluate how California MPOs use accessibility concepts and metrics in regional planning processes by reviewing key planning documents of seven MPOs and interviewing staff members from these MPOs. From the documents review, I find that California MPOs use accessibility more in the long-range regional plans than in the near-term project evaluation and prioritization processes, because MPOs tend to have less control over the latter. I also find that California MPOs have been using indirect measures of accessibility – mostly VMT-related – more than direct measures, mostly due to two factors. First, SB 375 compels MPOs to focus on reducing VMT and vehicle emissions; second, MPOs face a tradeoff between conceptual completeness of the metric and ease of interpretation and communication to stakeholders when choosing which metrics to use.

From interviews with MPO staff members, I find that computational obstacles are becoming less important as many California MPOs have developed or are developing their technical analytical capacity to calculate accessibility. But a big obstacle for adopting accessibility is what comes next: the difficulty of interpreting and explaining the complex and abstract accessibility metrics to stakeholders who are not familiar with the concept. Another big obstacle is MPOs' limited control over project evaluation and selection for funding programs, largely because various funding programs have specific goals and objectives that may or may not promote accessibility. In contrast, SB 375 has played a significant role in motivating MPOs to adopt more accessibility metrics as they plan for more compact and mixed-use land use patterns integrated with a multi-modal transportation system.

These findings imply that, to better promote accessibility in regional planning, MPOs need to develop both computational capacity and the ability to communicate complex and abstract metrics to stakeholders. Supportive legislation that gives MPOs more influence over land use strategies and local governments can also help MPOs prioritize accessibility over other goals. Finally, MPOs also need to better coordinate the currently fragmented project selection and programming processes to prioritize improving accessibility and other important regional goals.

In essay three, I look beyond the transportation and land use system which determines the potential for accessibility, and instead focus on cars, which is arguably the most important transportation resource to help realize that potential. I examine how auto insurance premiums – an important component of the cost of owning and operating a car – influence household car ownership. Using data on average auto insurance premiums of census tracts and household car ownership in California, I find that higher tract-level auto insurance premiums are strongly associated with lower household-level car ownership. I also show that urban households may be more sensitive to higher auto insurance premiums than suburban and rural households. This may be due to the presence of travel alternatives, such as public transit, in urban areas, which may make urban travelers more elastic in their response to insurance premiums than suburban or rural travelers.

Further, the poorest households might be relatively less concerned about auto insurance premiums when deciding to buy a car compared to middle- and higher-income households because they may be more likely to risk driving without insurance. This could amplify the negative impacts of high premiums on poor households because driving uninsured can result in more citations and higher costs when crashes happen. Moreover, higher concentrations of uninsured motorists in poor neighborhoods and inner-cities may lead to higher insurance premiums, which may, in a vicious cycle, lead to more uninsured motorists. These results imply that policy efforts to promote car ownership among low-income and minority households to improve their accessibility need to lower the cost of auto insurance by addressing "insurance redlining" (Ong and Stoll 2007) and subsidizing households that cannot afford auto insurance. Moreover, instead of focusing on car ownership, governments can also support various shared-mobility programs that can lower the cost of car access by allowing low-income and minority households to purchase car access one trip or several trips at a time.

Together, these three essays reveal the various challenges for regional and local governments to better plan transportation and land use systems to improve accessibility, and for low-income and minority households to materialize the access potential determined by the transportation and land use systems. These essays also highlight the opportunities to better apply the concept of accessibility in regional and local planning to promote compact and mixed-use land use patterns integrated with a multi-modal transportation system. Finally, these essays offer important policy implications for planning a multi-modal transportation system integrated with compact and mixed-use land use patterns where destinations and activities are closer together and can be reached by a variety of travel modes, as well as looking beyond the transportation and land use systems to promote car ownership and access for low-income and minority travelers to better enable them to access desired destinations and activities.

APPENDICES: Full Regression Tables for Essay Three

Table A-1. Association between auto insurance premium and car ownership

	Owning at least one car in HH (Logit)		No. of cars owned by HH (Negative binomial)		Cars per HH member (OLS)
	Logit	Odds ratio	Coefficient	Marginal effect	
Auto insurance (tract average premium): 0-10 percentile	Omitted category				
Auto insurance: 10-20 percentile	-0.03 (0.18)	0.97	-0.01 (0.02)	-0.02	-0.00 (0.01)
Auto insurance: 20-30 percentile	-0.54 ** (0.19)	0.58	-0.01 (0.02)	-0.02	-0.01 (0.01)
Auto insurance: 30-40 percentile	-0.25 (0.19)	0.78	-0.03 (0.02)	-0.06	-0.01 (0.01)
Auto insurance: 40-50 percentile	-0.52 ** (0.20)	0.59	-0.04 ^ (0.02)	-0.08	-0.03 * (0.01)
Auto insurance: 50-60 percentile	-0.48 ** (0.22)	0.62	-0.06 * (0.03)	-0.13	-0.05 *** (0.01)
Auto insurance: 60-70 percentile	-0.82 *** (0.24)	0.44	-0.06 ^ (0.03)	-0.11	-0.04 ** (0.01)
Auto insurance: 70-80 percentile	-0.71 ** (0.26)	0.49	-0.07 * (0.03)	-0.14	-0.05 ** (0.02)
Auto insurance: 80-90 percentile	-0.63 * (0.28)	0.53	-0.08 ** (0.03)	-0.16	-0.05 ** (0.02)
Aito insurance: 90-100 percentile	-0.91 ** (0.28)	0.40	-0.10 ** (0.04)	-0.19	-0.07 *** (0.02)
Subprime loan (tract proportion)	0.01 (0.02)	1.0	0.01 ** (0.00)	0.01	0.01 *** (0.00)
No. of licensed drivers in HH	2.7 *** (0.07)	15.5	0.28 *** (0.01)	0.55	0.08 *** (0.00)
HH size	0.08 * (0.03)	1.1	0.01 * (0.01)	0.03	-0.19 *** (0.00)
HH income: 0-10k	Omitted category				
HH income: 10k-25k	0.54 *** (0.09)	1.7	0.02 (0.03)	0.04	-0.00 (0.01)
HH income: 25k-35k	1.2 *** (0.12)	3.4	0.10 ** (0.03)	0.16	0.01 (0.01)
HH income: 35k-50k	1.6 *** (0.13)	5.2	0.14 *** (0.03)	0.24	0.04 ** (0.01)
HH income:	2.0 ***	7.7	0.22 ***	0.39	0.09 ***

50k-75k	(0.14)		(0.03)		(0.01)
HH income: 75k-100k	2.2 *** (0.18)	9.1	0.25 *** (0.03)	0.46	0.10 *** (0.01)
HH income: 100k-150k	1.8 *** (0.17)	5.8	0.29 *** (0.03)	0.53	0.12 *** (0.01)
HH income: 150k-200k	1.7 *** (0.25)	5.3	0.32 *** (0.03)	0.60	0.14 *** (0.01)
HH income: 200k-250k	1.7 *** (0.36)	5.3	0.35 *** (0.03)	0.67	0.17 *** (0.02)
HH income: 250k+	2.3 *** (0.47)	10.0	0.38 *** (0.03)	0.73	0.19 *** (0.02)
Socio-economic controls					
White HH			Omitted category		
Asian HH	0.18 (0.2)	1.2	0.0 (0.02)	0.0	0.01 (0.01)
Black HH	-0.63 *** (0.13)	0.54	-0.04 (0.02)	-0.08	0.0 (0.01)
Hispanic HH	-0.21 * (0.1)	0.81	0.0 (0.01)	0.0	0.03 *** (0.01)
Mixed/other race HH	-0.32 ** (0.11)	0.73	0.0 (0.01)	0.0	-0.03 *** (0.01)
Employed	0.61 *** (0.08)	1.8	0.03 ** (0.01)	0.07	0.03 *** (0.01)
Bachelor's degree or higher	0.11 (0.09)	1.1	-0.06 *** (0.01)	-0.11	-0.01 * (0.01)
Less than high school	0.26 * (0.13)	1.3	-0.06 * (0.02)	-0.12	-0.19 *** (0.01)
Male	-0.17 * (0.08)	0.85	0.12 *** (0.02)	0.23	0.14 *** (0.01)
Over 65	0.39 *** (0.09)	1.5	-0.02 (0.01)	-0.05	-0.01 * (0.01)
Foreign born	0.06 (0.11)	1.1	-0.02 (0.02)	-0.04	-0.05 *** (0.01)
Disabled	-0.71 *** (0.09)	0.49	-0.06 ** (0.02)	-0.11	-0.08 *** (0.01)
Neighborhood controls					
Mixed use			Omitted category		
Old urban	-0.07 (0.13)	0.93	0.0 (0.03)	-0.01	0.01 (0.01)
Urban residential	0.44 *** (0.12)	1.5	0.05 * (0.02)	0.09	0.04 *** (0.01)
Established suburb	0.87 *** (0.13)	2.4	0.07 *** (0.02)	0.14	0.06 *** (0.01)

Patchwork	0.72 *** (0.14)	2.1	0.06 ** (0.02)	0.12	0.06 *** (0.01)
New development	0.99 *** (0.14)	2.7	0.08 *** (0.02)	0.15	0.06 *** (0.01)
Rural	1.29 *** (0.17)	3.6	0.13 *** (0.02)	0.25	0.11 *** (0.01)
County fixed effects	Y		Y		Y
Constant	-3.1 *** (0.28)	0.05	-0.31 *** (0.05)		0.96 *** (0.02)
Observations	37,415		35,270		35,270

Notes: significance codes: ***p < 0.001, **p < 0.01, *p < 0.05, ^p < 0.1; standard errors in parentheses. Socio-economic controls: male, 65 or older, foreign born, disabled, employed, bachelor's degree or higher, less than high school, all calculated as fractions of HH; neighborhood controls: neighborhood typologies (Voulgaris et al. 2017) of home locations; county fixed effects are counties of home location.

Table A-2. Differences between geographical contexts regarding the associations between auto insurance and car ownership

	Owning at least one car in HH (Logit)	No. of cars owned by HH (Negative binomial)	Cars per HH member (OLS)
Auto insurance (tract average premium): 0-10 percentile		Omitted category	
Auto insurance: 10-50 percentile	-0.2 (0.2)	-0.04 (0.03)	-0.02 (0.01)
Auto insurance: 60-100 percentile	-0.51 * (0.23)	-0.08 * (0.03)	-0.04 ** (0.02)
Urban		Omitted category	
Suburban	0.63 *** (0.18)	0.02 (0.02)	0.03 * (0.01)
Rural	1.1 *** (0.23)	0.07 * (0.03)	0.07 *** (0.01)
Auto insurance: 10-50 percentile * Suburban	-0.1 (0.21)	0.02 (0.03)	0.01 (0.01)
Auto insurance: 60-100 percentile * Suburban	0.17 (0.21)	0.05 (0.03)	0.01 (0.01)
Auto insurance: 10-50 percentile * Rural	0.0 (0.32)	0.04 (0.03)	0.04 ** (0.02)
Auto insurance: 60-100 percentile * Rural	-0.36 (0.55)	0.02 (0.05)	0.01 (0.03)
Subprime loan (tract proportion)	0.03 ^	0.01 **	0.01 ***

	(0.01)	(0.0)	(0.0)
No. of licensed drivers in HH	2.75 ***	0.28 ***	0.08 ***
	(0.07)	(0.01)	(0.00)
HH size	0.08 *	0.01 *	-0.19 ***
	(0.03)	(0.01)	(0.0)
Socio-economic controls			
HH income: 0-10k	Omitted category		
HH income: 10k-25k	0.53 *** (0.09)	0.03 (0.03)	0.0 (0.01)
HH income: 25k-35k	1.2 *** (0.12)	0.1 ** (0.03)	0.01 (0.01)
HH income: 35k-50k	1.6 *** (0.13)	0.14 *** (0.03)	0.04 *** (0.01)
HH income: 50k-75k	2.0 *** (0.14)	0.22 *** (0.03)	0.09 *** (0.01)
HH income: 75k-100k	2.2 *** (0.17)	0.26 *** (0.03)	0.11 *** (0.01)
HH income: 100k-150k	1.8 *** (0.17)	0.29 *** (0.03)	0.12 *** (0.01)
HH income: 150k-200k	1.7 *** (0.25)	0.32 *** (0.03)	0.14 *** (0.01)
HH income: 200k-250k	1.7 *** (0.35)	0.35 *** (0.03)	0.17 *** (0.02)
HH income: 250k+	2.4 *** (0.46)	0.38 *** (0.03)	0.19 *** (0.02)
White HH	Omitted category		
Asian HH	0.18	0.0	0.01
	(0.2)	(0.02)	(0.01)
Black HH	-0.64 ***	-0.05 ^	-0.01
	(0.13)	(0.03)	(0.01)
Hispanic HH	-0.2 *	0.0	0.03 ***
	(0.1)	(0.01)	(0.01)
Mixed/other race HH	-0.32 **	0.0	-0.03 ***
	(0.11)	(0.01)	(0.01)
Employed	0.6 ***	0.03 *	0.03 ***
	(0.08)	(0.01)	(0.01)
Bachelor’s degree or higher	0.09	-0.06 ***	-0.01 *
	(0.08)	(0.01)	(0.01)
Less than high school	0.26 *	-0.06 *	-0.19 ***
	(0.13)	(0.02)	(0.01)
Male	-0.19 *	0.12 ***	0.14 ***
	(0.08)	(0.02)	(0.01)
Over 65	0.39 ***	-0.02	-0.01 ***

	(0.09)	(0.01)	(0.01)
Foreign born	0.04	-0.02	-0.05 ***
	(0.11)	(0.02)	(0.01)
Disabled	-0.71 ***	-0.06 **	-0.08 ***
	(0.09)	(0.02)	(0.01)
County fixed effects	Y	Y	Y
Constant	-2.97 ***	-0.26 ***	0.99 ***
	(0.28)	(0.05)	(0.02)
Observations	37,382	35,237	35,237

Notes: See Table A-1 notes for significant codes and controls; Neighborhood controls excluded from these models to reduce multi-collinearity with geographical context variable (urban vs. suburban vs. rural).

Table A-3. Differences between income levels regarding the association between auto insurance premiums and vehicle ownership

	Likelihood of owning at least one car	
	Logit	Odds ratio
Auto insurance (tract average premium): 0-10 percentile	Omitted category	
Auto insurance: 10-50 percentile	0.26 (0.29)	1.3
Auto insurance: 60-100 percentile	0.10 (0.30)	1.1
Lowest income census tract	Omitted category	
Lower income census tract	0.79 ** (0.28)	2.2
Middle income census tract	0.92 *** (0.26)	2.5
High income census tract	1.30 *** (0.37)	3.7
Auto insurance: 10-50 percentile * Lower income census tract	-0.68 * (0.31)	0.66 †
Auto insurance: 60-100 percentile * Lower income census tract	-0.63 * (0.30)	0.59 †
Auto insurance: 10-50 percentile * Middle income census tract	-0.48 ^ (0.29)	0.80 †
Auto insurance: 60-100 percentile * Middle income census tract	-0.49 ^ (0.29)	0.68 †
Auto insurance: 10-50 percentile * High income census tract	-0.83 * (0.42)	0.57 †
Auto insurance: 60-100 percentile * High income census tract	-0.74 ^ (0.41)	0.53 †

Subprime loan (tract proportion)	0.03 * (0.02)	1.03
No. of licensed drivers in HH	2.73 *** (0.07)	15.4
HH size	0.09 * (0.03)	1.1
Socio-economic controls		
HH income: 0-10k	Omitted category	
HH income: 10k-25k	0.54 *** (0.09)	1.7
HH income: 25k-35k	1.2 *** (0.12)	3.3
HH income: 35k-50k	1.6 *** (0.13)	5.0
HH income: 50k-75k	2.0 *** (0.14)	7.3
HH income: 75k-100k	2.1 *** (0.18)	8.6
HH income: 100k-150k	1.7 *** (0.17)	5.4
HH income: 150k-200k	1.6 *** (0.25)	4.9
HH income: 200k-250k	1.6 *** (0.36)	5.0
HH income: 250k+	2.2 *** (0.47)	9.4
White HH	Omitted category	
Asian HH	0.21 (0.2)	1.2
Black HH	-0.57 *** (0.13)	0.57
Hispanic HH	-0.15 (0.1)	0.86
Mixed/other race HH	-0.31 ** (0.1)	0.73
Employed	0.61 *** (0.08)	1.8
Bachelor’s degree or higher	0.09 (0.09)	1.1
Less than high school	0.28 * (0.13)	1.3
Male	-0.17 *	0.84

	(0.08)	
Over 65	0.39 *** (0.09)	1.5
Foreign born	0.08 (0.11)	1.1
Disabled	-0.71 *** (0.09)	0.49
Neighborhood controls		
Mixed use	Omitted category	
Old urban	-0.07 (0.13)	0.93
Urban residential	0.4 *** (0.12)	1.5
Established suburb	0.72 *** (0.14)	2.1
Patchwork	0.62 *** (0.14)	1.9
New development	0.81 *** (0.15)	2.2
Rural	1.1 *** (0.18)	3.0
County fixed effects	Y	
Constant	-2.7 *** (0.36)	0.02
Observations	11,063	

Notes: See Table A-1 notes for significant codes and controls.
† Unlike the coefficients of interaction terms that represent differential effects (e.g. the differential in the association between auto insurance and owning a car between households in lower and higher income tracts), these odds ratios measure the combined effect (e.g. the likelihood of households in census tracts that are higher income and higher premium as compared to the reference group, i.e. households in tracts that are the lowest income and lowest premium).

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