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Congestion and Accessibility: What's the Relationship?

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CONGESTION AND ACCESSIBILITY: WHAT'S THE RELATIONSHIP?

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ABSTRACT

This project conceptually and empirically explores the complex relationship between congestion and accessibility. While congestion alters individual access to opportunities, its effects vary significantly across people, places, and time – variations that remain relatively understudied. This report begins by proposing a conceptual framework with three components. First, congestion can constrain mobility and thus indirectly reduce accessibility. Second, congestion is associated with agglomerations of activity and with increased accessibility. Finally, congestion is in part a phenomenon of perception and behavior, cognitively altering an individual’s choice set of destinations and altering actual access to opportunities. Congestion and individual travel data for the Los Angeles region are used to explore the localized spatial relationship between congestion and accessibility. As our multifaceted framework suggests, congestion does not have a uniform effect on accessibility, but varies substantially by neighborhood. Our analysis finds that in some neighborhoods congestion appears to be associated with depressed levels of access, as conventional wisdom would suggest. Other neighborhoods, however, appear to be more “congestion adapted,” allowing high levels of activity participation despite high levels of congestion. To account for personal characteristics such as income that may influence the spatial analysis, we construct a model of the number of daily trips as a function of an array of personal and household characteristics. Residuals from the model suggest that place-based neighborhood effects explain the relatively higher levels of travel by residents found in the “congestion adapted” neighborhoods.

KEYWORDS

accessibility,

congestion,

travel

behavior

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EXECUTIVE SUMMARY

Congestion in U.S. metropolitan areas has increased steadily in recent years (Schrank and Lomax 2007). While nobody likes to sit in traffic, congestion levels are at best an indirect and imperfect measure of people's and firms' access to opportunities. As such, widely cited measures of the economic costs of congestion that simply tally people's time spent in traffic are conceptually problematic and perhaps misleading. Congestion measures reflect potential mobility, but do not reveal individuals' relative access to jobs and activities, or firms' relative access to suppliers and customers. A growing chorus of transportation planning researchers—among them Wachs and Kumagai (1973), Handy (2002), and Levine and Garb (2002)—argue that transportation planning should focus on increasing access to destinations rather than increasing mobility on transportation networks. While conceptually distinct, congestion and accessibility are related. But what is the nature of this relationship? The perception that congestion makes it harder for individuals to access opportunities is rational on its face, yet congestion also arises because an area offers attractive opportunities to large numbers of people and firms. A central tenet of urban economics is that cities form and grow because they foster such agglomeration economies, which increase productivity but also introduce negative externalities such as congestion (Vernon 1972; Fujita 1996; Anas, Arnott et al. 1998; Glaeser and Kahn 2003). Furthermore, a traveler's perceived burden of congestion is highly variable, depending on the purpose, timing, and other aspects of the trip (Werner, Evans et al. 2005). As a result, the relationship between congestion and accessibility is complex and far from a simple inverse relationship.

In the empirical exploration of the accessibility/congestion relationship described in this report, we find that some neighborhoods appear to be more “congestion-adapted” than others by facilitating higher levels of personal and economic activity across shorter distances. In contrast, the relative accessibility of other, less congestion-adapted locations may be strongly inversely related to congestion levels. Still, the causal relationships among congestion, patterns of urban form, and human behavior are intricate, thorny, and understudied. Many planners assume that better land use and transportation integration will reduce congestion by promoting alternatives to private vehicle travel. Such integration, however, are more likely to actually increase traffic congestion, but in ways that foster accessibility—or at least not impede it.

Thinking about Accessibility and Congestion

The concept and measurement of accessibility contrasts importantly from the concept and measurement of traffic congestion in at least two ways. First, the units of analysis in accessibility measurement are typically individuals, households, firms, or places, while those for congestion are usually transportation networks, links, or vehicles. Second, by emphasizing opportunities and potential, the concept of accessibility is necessarily abstract, ephemeral, and, as a result, difficult to measure. Traffic congestion metrics, on the other hand, typically measure the volume and velocity of vehicles on links in networks (Papacostas and Prevedouros 2000). While conceptually straightforward, such measures make traffic patterns the ends themselves, rather than the means to economic transactions and social interactions. The result

of this dichotomy may be competing and contradictory definitions of transportation functionality (Levine and Garb 2002).

Accessibility is a broad concept with a wide range of interpretations, some of which reflect benefits and costs to individuals and others more concerned with social welfare. Hansen (1959) introduced the concept of accessibility to transportation planning by defining it as “the potential of opportunities for interaction” enabled by urban transportation systems. Lynch (Lynch 1981) expanded upon the concept, ascribing social prerogatives to accessibility such as diversity of choice, equity among grounds and individuals, and individual control. The wide variety of ways that accessibility can be defined means that “improving” accessibility has uncertain effects on travel behavior. Because of its conceptual broadness, how accessibility is defined and measured becomes essential to understanding a particular perspective on accessibility. Transportation researchers have developed a range of methods to quantify accessibility (Levinson and Krizek 2005). One of the most important distinctions among these methods is between place-based accessibility and person-based accessibility (Kwan, Murray et al. 2003). Measures of place-based accessibility, such as cumulative-opportunity and gravity measures, generally measure the spatial and temporal distribution of activities relative to a point, adjusted by the ease of reaching these activities (Hansen 1959; Handy and Niemier 1997). Such measures of accessibility may be focused on a particular mode, such as evaluating transit versus auto accessibility (Handy 2002).

We propose a conceptual framework that enumerates the potential influences that congestion and accessibility exert on one another. This framework contains three major components:

1. Congestion tends to decrease mobility and indirectly reduce accessibility.
2. Congestion is associated with agglomeration and with increased accessibility, even if congestion detracts from the benefits of agglomeration.
3. Experiences with congestion cognitively alter an individual's opportunities choice set and access to opportunities.

These factors create a complex relationship between congestion and accessibility—a relationship that varies substantially among individuals and small areas within a given region.

Research and Findings

Notorious for its traffic, the Los Angeles region offers ample opportunity to explore how congestion may alter both travel behavior and access to opportunities. To analyze potential connections between congestion and accessibility at subregional scales, we use the 2003 Southern California Association of Governments (SCAG) Travel and Congestion Survey and SCAG estimates of traffic and congestion for freeways and arterial streets. We first explore the overall spatial relationships between congestion and accessibility within a Geographic Information System (GIS). To complement the spatial analysis, we test a basic regression model of individual activity patterns to better understand the relationship between person- and location- based variation in activity patterns.

Accessibility, as operationalized in this analysis, includes all types of trips and all modes of travel. All trips are valued equally, regardless of purpose, and we measure accessibility in a fundamentally simple way, based on the number of activities engaged in, where additional activity engagement implies increased accessibility. The focus on distance traveled, in addition

to number of trips made, addresses the potential social costs of increased accessibility, including the potential for travel by different modes. This analysis uses the maximum volume-to-capacity (V/C) value for a given road segment during either peak period in either travel direction as a basic congestion measure. Estimated V/C in the SCAG dataset can range from zero in the absence of any to traffic to more than one in situations where estimated demand for a given segment exceeds actual capacity. One challenge in analyzing congestion is differentiating between the potential effects of traffic delays on two related, yet distinct road networks: arterials versus freeways. The analyses below treat congestion on these two networks separately unless otherwise noted.

Our spatial analysis of activity and traffic patterns in Los Angeles and Orange Counties reveals that congestion's impact on accessibility varies substantially by locale. Some places or neighborhoods may be more "congestion-adapted" than others by facilitating high levels of activity participation in the midst of chronic traffic delays. Places where less vehicle travel is required to access an equivalent set of opportunities should be of great interest to planners concerned with auto dependence, traffic congestion, and accessibility. Our analysis finds that survey respondents' median trip lengths vary substantially across the region, as do the number of trips, which highlights neighborhoods where individuals make many, short trips, as well as neighborhoods with the opposite behavior – few, long trips. If higher levels of tripmaking reflect higher levels of individual accessibility, but longer distance trips reflect higher personal and social costs to complete a given trip, then an ideal locale would be one where individuals make many, short trips. Other than in the urban core where tripmaking, regardless of trip distance, is low, places where individuals tend to make both more than average and shorter

than average trips are scattered throughout the region. In these places, tripmaking is higher than the median (4 trips) for survey respondents and average trip lengths are below the median (approximately 3.7 miles / 6 kilometers). In these places, accessibility is less tightly linked to mobility. Some of these locations, such as Santa Monica, West Hollywood, and Newport Beach, are among the most well-known and popular areas in Los Angeles. Other locations, however, like Reseda, Whittier, and Garden Grove, are lower-income ethnic enclaves. Conversely, the areas where individuals make few, long trips – an undesirable situation for individuals and for society – include some of the poorest neighborhoods in the region such as Watts, the port areas near Long Beach, and Van Nuys/Pacoima.

Is localized congestion associated with specific travel behavior patterns? More to the point, do people living in congested areas tend to make shorter trips frequently? For the Los Angeles basin as a whole, shorter trips are indeed correlated with higher levels of congestion, controlling for the number of trips made. However, because increased congestion also appears to be associated with fewer trips, the highest V/C ratios are associated with neighborhoods where individuals make fewer, shorter trips. This is not surprising given that several of these neighborhoods are concentrated around downtown Los Angeles, which has relatively high congestion and relatively poor residents. However, the association between congestion and shorter trips in better-off neighborhoods may be evidence of individuals maximizing opportunities despite congestion rather than a result of limited means.

To test the independent effects of individual, household, and neighborhood effects on tripmaking, we constructed a log-linear ordinary least-squares regression model of the number of daily trips as a function of an array of personal and household characteristics. The model

results suggest that personal characteristics are indeed correlated with activity patterns and the effects observed in the model are as expected, though, as with most models of this sort, the explanatory power of socio-demographic characteristics on individual behavior for a single day is not strong ($R^2 = 0.0715$). The spatial pattern of model residuals opens the possibility that one or more neighborhood effects explain the relatively higher levels of tripmaking by residents in the “many, short trip” neighborhoods. However, whether that neighborhood effect is itself, or related to, localized congestion remains unresolved. Other non-congestion-related place-based effects encouraging a surfeit of short trips could be high levels of non-mobility-based access opportunities, higher development densities, an adroit mixing of land uses to foster walking trips, and other amenities that make areas especially attractive to employers, shoppers, vacationers, and other travelers. In relatively dense, congested, high-cost, high-amenity areas like Newport Beach and Santa Monica, congestion may be secondary to such factors in explaining the tripmaking behavior of residents. Other “many, short trip” neighborhoods, like Norwalk and Reseda, are distant from high-cost, high-amenity areas, but may function as important ethnic enclaves for subsets of the extraordinarily diverse residents of metropolitan Los Angeles. Yet other neighborhoods in which individuals make many, short trips are not in high amenity locations or distinct ethnic districts; in these neighborhoods, perhaps congestion plays a role in encouraging individuals to remain close to home when choosing destinations, but without a loss in accessibility.

Conclusions

Research exploring the relationship between congestion and accessibility is in its infancy. This analysis, however, does find consistent, if complex, relationships between congestion and activity patterns, even after accounting for individual characteristics. If one accepts that activity participation, operationalized here by tripmaking, benefits individuals and society, this analysis suggests that traffic congestion should not be viewed as a uniform drag on accessibility. These data from Los Angeles suggest that residents of some areas enjoy high levels of accessibility despite high levels of congestion, while in other areas congestion appears to contribute to low levels of accessibility. Exploring this congestion/accessibility relationship further will yield fertile ground for transportation and urban scholars. Congestion is by no means an unmitigated negative, yet with the right local conditions, a certain level of congestion may foster – or at least not prevent – patterns of tripmaking that benefit both individuals and society. Improving our understanding of the relationships between congestion and accessibility may help planners and policy makers develop a clearer picture of how transportation systems can deliver greater benefits to travelers who frequently find themselves stuck in traffic.

1. INTRODUCTION

Congestion in U.S. metropolitan areas has increased steadily in recent years. According to the Texas Transportation Institute (TTI), which publishes the most well-known measures of congestion in the United States, travel in large metropolitan areas has increased 105 percent in the last 20 years, yet roadway capacity has only increased 45 percent (Schrank and Lomax 2007). The TTI also estimates that congestion imposes significant costs on society: according to their estimates for 2005, congestion cost America's urban areas \$78.2 billion in wasted time and fuel. This measure is based on estimated delay due to congestion relative to free-flow travel speeds, even if free flowing traffic is a hypothetical, rather than achievable, condition on most urban roads. While nobody likes to sit in traffic, congestion levels are at best an indirect and imperfect measure of people's and firms' access to opportunities. As such, widely cited measures of the economic costs of congestion, like those published by the TTI, are problematic and perhaps misleading. Congestion measures reflect potential mobility, but do not reveal individuals' relative access to jobs and activities, or firms' relative access to suppliers and customers. A growing chorus of transportation planning researchers—among them Wachs and Kumagai (1973), Handy (2002), and Levine and Garb (2002)—argue that transportation planning should focus on increasing access to destinations rather than increasing mobility on transportation networks.

While conceptually distinct, congestion and accessibility are related. But what is the nature of this relationship? The perception that congestion makes it harder for individuals to access opportunities is rational on its face, yet congestion also arises because an area offers

attractive opportunities to large numbers of people and firms. Manhattan may have some of the worst traffic congestion in the country, yet people flock there because it offers access to many economic, cultural, and lifestyle attractions. A central tenet of urban economics is that cities form and grow because they foster such agglomeration economies, which increase productivity but also introduce negative externalities such as congestion (Vernon 1972; Fujita 1996; Anas, Arnott et al. 1998; Glaeser and Kahn 2003). Furthermore, a traveler's perceived burden of congestion is highly variable, depending on the purpose, timing, and other aspects of the trip (Werner, Evans et al. 2005). As a result, the relationship between congestion and accessibility is complex and far from a simple inverse relationship.

In this empirical exploration of the accessibility/congestion relationship, we find that some neighborhoods appear to be more “congestion-adapted” than others by facilitating higher levels of personal and economic activity across shorter distances. In contrast, the relative accessibility of other, less congestion-adapted locations appear to be strongly inversely related to congestion levels. Still, the causal relationships among congestion, patterns of urban form, and human behavior are intricate, thorny, and understudied. Many planners assume that better land use and transportation integration will reduce congestion by promoting alternatives to private vehicle travel. Such integration, however, may actually increase traffic congestion, but in ways that foster accessibility—or at least don't impede it.

This report begins by reviewing research on accessibility and the tentative steps other researchers have made to link it to congestion. We then propose a conceptual framework linking congestion and accessibility. The Los Angeles region is then used to test some of the relationships suggested by the conceptual framework, and present findings on the links

between tripmaking and congestion patterns. Finally, the report concludes with discussion and avenues for future research.

2. THINKING ABOUT ACCESSIBILITY AND CONGESTION

The concept and measurement of accessibility contrasts importantly from the concept and measurement of traffic congestion in at least two ways. First, the units of analysis in accessibility measurement are typically individuals, households, firms, or places, while those for congestion are usually transportation networks, links, or vehicles. Second, by emphasizing opportunities and potential, the concept of accessibility is necessarily abstract, ephemeral, and, as a result, difficult to measure. Traffic congestion metrics, on the other hand, typically measure the volume and velocity of vehicles on links in networks (Papacostas and Prevedouros 2000). While conceptually straightforward, such measures make traffic patterns the ends themselves, rather than the means to economic transactions and social interactions. The result of this dichotomy may be competing and contradictory definitions of transportation functionality (Levine and Garb 2002).

2.1 Accessibility: An Individual and Social Phenomenon

Accessibility is a broad concept with a wide range of interpretations, some of which reflect benefits and costs to individuals and others more concerned with social welfare. Hansen (1959) introduced the concept of accessibility to transportation planning by defining it as “the potential of opportunities for interaction” enabled by urban transportation systems. Lynch (Lynch 1981) expanded upon the concept, ascribing social prerogatives to accessibility such as diversity of choice, equity among groups and individuals, and individual control. The distribution of and changes in accessibility levels can inform policy makers about the winners and losers of proposed transportation projects, information that mobility measures largely fail

to convey. Accessibility may also serve as the most important factor in explaining regional form and function: access to activities shapes how people use a site and determines its value (Wachs and Kumagai 1973; Giuliano 2004).

The wide variety of ways that accessibility can be defined means that “improving” accessibility has uncertain effects on travel behavior. Although some researchers depict accessibility improvements as tools to decrease the absolute and relative amounts of vehicle travel (Handy 2002), such improvements do not necessarily lead to reduced vehicle use. If increased accessibility means that a person may travel more easily to a preferred, more distant destination, then travel and congestion may grow. Finding the right balance between increasing accessibility and fostering travel patterns that minimize personal and social costs is a challenge.

Because of its conceptual broadness, how accessibility is defined and measured becomes essential to understanding a particular perspective on accessibility. Transportation researchers have developed a range of methods to quantify accessibility (Levinson and Krizek 2005). One of the most important distinctions among these methods is between place-based accessibility and person-based accessibility (Kwan, Murray et al. 2003). Measures of place-based accessibility, such as cumulative-opportunity and gravity measures, generally measure the spatial and temporal distribution of activity sites relative to a point, adjusted by the ease of reaching these activity sites (Hansen 1959; Handy and Niemier 1997). Such measures of accessibility may be focused on a particular mode, such as evaluating transit versus auto accessibility (Handy 2002).

Person-based accessibility measures also account for how an individual's characteristics shape his or her access to opportunities. One obvious characteristic is personal income: regardless of location or available transportation, low-income individuals are less able to take advantage of available opportunities (Redmond and Mokhtarian 2001). Similarly, language, gender, age, ethnicity, and other factors may limit or alter accessibility (Kwan and Weber 2003). Generally, individuals have specific time and cost constraints; therefore, the set of accessible opportunities varies from individual to individual. El-Geneidy and Levinson (2006) offer a structure for a behaviorally-based model of individual accessibility that accounts for the utility derived by a particular individual for all choices from a set of destination choices. While more complex, this model is an improvement over place-based models because it acknowledges the significant variations in how individuals themselves value accessibility. Importantly, this model suggests that overall accessibility is tied to the utility, or benefit, of a choice or set of choices. It follows that observed choices, or activities, can inform researchers as to the types and level of activity that provide utility to a given individual, as well as suggest – in the aggregate – whether social goals are being met by a particular transportation-land use pattern.

2.2 Congestion and Accessibility: A Limited Empirical Literature

Although congestion and accessibility both have large bodies of literature devoted to their study, very little research explores the relationship between the two. The available research generally presents congestion as the factor affecting accessibility levels. Using travel diary data for Portland residents and a network model with estimates of free-flow and congested travel times, Weber and Kwan (2002) discovered that incorporating the temporal

effects of congestion increases the spatial variability of access, suggesting the importance of incorporating congestion levels into access measures for places and, in particular, individuals.

One can also study how accessibility, defined as a set of alternative opportunities, affects the ways in which people react to congestion. Casas (2003) created a simulation in which 83 participants had to leave the Ohio State University campus, run two errands, and return to their homes. In this simulation, participants had to choose among a set of alternatives to deal with congestion they encountered at a certain point on the main road. Cumulative-opportunity accessibility measures taken at the point of congestion successfully predicted the choices participants made in responding to the congestion, suggesting that increasing accessibility through adjusting land use may reduce congestion costs as borne by individuals without necessarily reducing congestion levels.

Links between congestion and accessibility also appear in research on congestion pricing. The accessibility-mobility distinction is central to the equity impacts of congestion pricing policies. Levine and Garb (2002) argue that, by using revenues to improve alternatives to driving in tolled areas, congestion pricing can lower the cost of access. Such an accessibility-based policy would spread benefits more broadly and equitably than a mobility-based policy that used revenues to expand roadways, concentrating benefits among wealthier families with high automobile ownership.

3 CONCEPTUALIZING THE RELATIONSHIP BETWEEN CONGESTION AND ACCESSIBILITY

We propose a conceptual framework that enumerates the potential influences that congestion and accessibility exert on one another. This framework contains three major components. First, congestion tends to decrease mobility and indirectly reduce accessibility. Second, congestion is associated with agglomeration and with increased accessibility, even if congestion detracts from the benefits of agglomeration. Finally, experiences with congestion cognitively alter an individual's opportunities choice set and access to opportunities. These factors create a complex relationship between congestion and accessibility—a relationship that varies substantially among individuals and small areas within a given region.

3.1 Congestion and Mobility

By reducing mobility, congestion may limit accessibility as well. However, the relationship between mobility and accessibility is likely not unitary. An area can have high levels of accessibility even without high levels of mobility if destinations are near one another; conversely, an area can have high levels of mobility and low levels of accessibility in areas where destinations are more remote. Accessibility and mobility could also have an inverse relationship. Traditional congestion relief policies attempt to increase mobility by expanding transportation capacity. Some capacity expansion critics claim that increasing mobility has a perverse effect because it induces destinations to move further apart from each other, ultimately leading to higher travel times and costs (Levine and Garb 2002). In a framework that depicts most travel as a derived demand, that result becomes all the more pernicious because it means that travelers have less time and money to spend at their destinations. Correspondingly,

some accessibility improvements may directly reduce some types mobility, such as narrowing streets and reducing parking availability to improve pedestrian accessibility at the expense of driver mobility (Crane 2007).

3.2 Congestion and Agglomeration

While congestion has undeniably negative effects, it is also associated with positive economic outcomes and social vitality (Wachs 2002; Taylor 2004). Vibrant, growing cities have large amounts of traffic, while depressed and declining cities generally do not, so congestion is perhaps best framed as a drag on otherwise high levels of economic and social activity. Whether reduced congestion is actually beneficial depends to a large degree on the causes of the reduced traffic delays. Increasing capacity or regulating travel demand through pricing can reduce delays while increasing economic productivity. Likewise, reducing vehicle travel by providing individuals and firms with attractive alternative access choices (such as the Internet or walking) may also reduce traffic delays while increasing productivity. On the other hand, an economic recession or efforts to reduce driving that increase overall access costs (such as when non-mobility access options are perceived by travelers as clearly inferior to driving) may reduce congestion, but in ways that hurt the prosperity and vitality of a region.

If one accepts this view of congestion as a drag on otherwise high levels of productivity, how bad does congestion have to be before the congestion costs begin to outweigh the agglomeration benefits? *Prima facie* evidence suggests that the answer is not simple. Since some large, congested cities like London and New York are among the most economically robust, the agglomeration advantages of such places must be very high. Despite claims that Los

Angeles has long suffered the worst traffic congestion in the nation (Schrank and Lomax 2007), it experienced the greatest population between 1990 and 2000 —1.8 million residents—of any metropolitan area in the United States (U.S. Census Bureau 2000). But in a provocative paper, Glaeser and Kahn (Glaeser and Kahn 2003) speculate that Los Angeles may be nearing the end of a long run of growth largely because it may be the first American city where congestion costs have begun to exceed the benefits of agglomeration.

3.3 Congestion and Perception

Kwan (Kwan 1998; Kwan and Weber 2002; Kwan and Weber 2003) has proposed an alternative cognitive framework for accessibility based on how an individual perceives the built environment. In this framework, an individual's experience with local congestion affects his or her perception of the destinations (or opportunities) available, even when absolute levels of congestion may not be high (Werner, Evans et al. 2005). In fact, psychologists have found perceptions of congestion to be tied as much to individual characteristics as to conditions on the road (Hennessy 2000). The power of congestion as a perceived phenomenon also helps explain why policy makers focus so much on reducing congestion levels. The public, which sees the effects of congestion every day when they navigate their daily lives, dislikes congestion immensely because of the slower traveling speeds and the resulting unreliability in travel time, regardless of total social welfare or individual utility arising from a particular pattern of urban form. Thus, residents of the San Francisco Bay area have repeatedly rated congestion as the most important problem affecting their quality of life (Wachs 2002).

4. RESEARCH AND FINDINGS

Notorious for its traffic, the Los Angeles region offers ample opportunity to explore how congestion may alter both travel behavior and access to opportunities. To analyze potential connections between congestion and accessibility at subregional scales, we use the 2003 Southern California Association of Governments (SCAG) Travel and Congestion Survey and SCAG estimates of traffic and congestion for freeways and arterial streets. We first explore the overall spatial relationships between congestion and accessibility within a geographic information system (GIS). To complement the spatial analysis, we test a simple regression model of individual activity patterns to better understand the relationship between person- and location- based variation in activity patterns.

4.1 Data Sources

In its role as a metropolitan planning organization for the greater Los Angeles region, SCAG develops the Regional Transportation Plan (RTP) for most of southern California. As a part of this process, SCAG collects regional travel behavior data and develops models to predict regional travel patterns—including congestion—for current and future years. In 2001 and 2002, SCAG conducted an extensive “Travel and Congestion Survey,” collecting detailed data on travel patterns and a wide range of personal and location information for over 15,000 households in Southern California. In addition, SCAG developed estimates of traffic flows and congestion along freeways and arterial streets throughout the region in a “Regional Screenline Traffic Count,” for the 2003 base year of the RTP (Meyer Mohaddes Associates 2004).

The SCAG Travel and Congestion Survey allows us to observe variations in activity patterns by location and to associate those patterns with person and household characteristics such as age, sex, race/ethnicity, income, employment status, household size, and auto availability. The survey includes substantial detail on activity patterns, listing each activity for each person in over 15,000 survey households. Each activity also has associated data on the duration, location, and the characteristics of the trips (mode, links, duration, cost) to and from the activity (NuStats 2003). Because the SCAG region is complex and spans over 38,000 square miles (98,400 square kilometers), we narrowed our sample to the 5,830 surveyed households in the coastal plains and foothills of Los Angeles and Orange Counties (see Figure 1); these are the most densely developed and most congested parts of the region. To control for variations in activity and tripmaking that result from differences in phase of life, we limit our sample to households in which the primary respondent was employed and between the ages of 18 and 65.

The SCAG Regional Screenline Traffic Count includes estimated traffic flows for local segments of all freeways and major surface streets in the region. The estimates, for morning and evening peaks, midday, evenings, and weekends, are based upon automated traffic counts along freeways and roadways and are modeled to reflect estimated traffic levels for all segments (Meyer Mohaddes Associates 2004). The estimates include traffic volumes and road capacities in both directions, as well as volume-to-capacity (V/C) ratios.

4.2 Definitions and Methods

4.2.1 Accessibility

As the literature review suggests, we ascribe both individual and social components to accessibility. Congestion is a spatial phenomenon, but we want to evaluate its effect in terms of variations in human activity patterns. Activity patterns are evidence of the utility of a given choice set, or a range of opportunities for an individual and they also reflect the potential social costs of those choices (El-Geneidy and Levinson 2006). The SCAG survey offers a potentially enormous number of ways to quantify individual accessibility, including the number of activities for each individual, the characteristics of those activities, the area within which activities occurred, the means of reaching an activity, and (coupled with land use or census data) the number of opportunities available within activity spaces. Given the exploratory nature of this initial analysis, we use a limited set of basic measures of activity—namely, the number of daily activities and the distance traveled to those activities.

Accessibility, as operationalized in this analysis, includes all types of trips and all modes of travel. All trips are valued equally, regardless of purpose, and we measure accessibility in a fundamentally simple way, based on the number of activities engaged in, where additional activity engagement implies increased accessibility. Each activity-accessing trip, whether part of a chain or standalone, is counted as its own trip. While there may not be a precise, linear relationship between number of activities and individual utility (and in some cases, there may be a disutility associated with certain activities or an excessive number of total activities), the correlation found between tripmaking and activity spaces (Schoenfelder and Axhausen 2003) suggests a strong relationship between tripmaking and access to potential opportunities. The

focus on distance traveled, in addition to number of trips made, addresses the potential social costs of increased accessibility, including the potential for travel by different modes.

Group	Number of Daily Activities²		Mode of Access to Activities (Avg. Individual)			Avg. Distance Travelled on Survey Day (km)
	Median	25-75 pct.	Driving	Walking	Transit	
<i>Income</i>						
Below \$50k	4	2-6	3.7	0.39	0.19	17.3
Above \$50k	4	2-6	3.0	0.22	0.037	20.6
<i>Gender</i>						
Male	4	2-5	3.4	0.26	0.10	20.4
Female	4	2-6	3.4	0.31	0.092	17.5
<i>Race/Ethnicity</i>						
White NH	4	2-6	3.8	0.27	0.042	19.0
Latino/a	3	2-5	2.8	0.35	0.20	17.1
African-American	3	2-5	3.0	0.26	0.14	16.3
Asian/Pacific Islander	3.5	2-5	3.4	0.23	0.062	20.5
<i>Education</i>						
11th grade or less	2	2-4	2.0	0.41	0.36	18.0
High school	3	2-5	3.0	0.31	0.15	17.4
2 yr. College	4	2-6	3.6	0.26	0.078	19.8
4 yr. College	4	2-6	3.7	0.25	0.040	18.4
Post-graduate	4	2-6	3.9	0.31	0.61	21.3
1 – Activities reported in SCAG 2003 Travel Survey.						
2 – Activites reported by employed adults in survey.						

Table 1 presents activity patterns, by number of activities, mode of access, and total distance travelled, for socio-economic groups categorized by income, gender, race/ethnicity, and education. The table shows that, across many traditionally employed socio-economic categories, the total number of activities engaged in on the survey day is relatively flat. Notably, however, level of education reveals the greatest differences between groups in

absolute number of activities. Mode of access to the activities varies slightly more among groups, with poorer and minority groups relying more on walking and transit relative to driving. Again, the differences between groups defined by level of education is particularly stark. Average distance travelled on the survey day varies similarly to mode; longer distances are associated with driving versus walking and transit.

4.2.2 Congestion

As with accessibility, this analysis takes a straightforward approach to defining congestion. One of the most commonly accepted measures of localized road congestion is the volume-to-capacity (V/C) ratio, available for all freeways and arterial road segments in the SCAG Regional Traffic Screenline study area (Papacostas and Prevedouros 2000). This analysis uses the maximum V/C value for a given road segment during either peak period in either travel direction as a basic congestion measure. Estimated V/C in the SCAG dataset can range from zero in the absence of any to traffic to more than one in situations where estimated demand for a given segment exceeds actual capacity. One challenge in analyzing congestion is differentiating between the potential effects of arterial versus freeway congestion. Accordingly, the analyses below treat the two types separately unless otherwise noted.

Table 2 presents congestion levels during the morning and afternoon peak travel periods on roads in Los Angeles and Orange Counties. The data show that congestion is quite high, particularly on the region's freeway system. Most of the freeway system approaches saturation during rush hours, particularly in the afternoon/evening when many segments exceed the "fully congested" V/C of 1.0. The street system is relatively less congested,

particularly the minor streets, but arterial highways and major roads in many parts of the region are clogged during peak periods.

<i>Type</i>	<i>Total Lane-Miles</i>	<i>Morning Peak V/C²</i>		<i>Afternoon Peak V/C²</i>	
		<i>Mean</i>	<i>.25-.75 pct.</i>	<i>Mean</i>	<i>.25-.75 pct.</i>
Freeway	5,758	0.79	0.65-0.96	0.89	0.78-1.07
HOV lane	758	0.50	0.29-0.74	0.71	0.53-0.92
Freeway ramp	1,016	0.55	0.22-0.85	0.63	0.27-0.97
Arterial highway	6,204	0.61	0.41-0.80	0.79	0.57-1.02
Major road	6,238	0.41	0.20-0.59	0.58	0.31-0.81
Collector street	1,934	0.17	0.00-0.24	0.25	0.01-0.39

1 – Congestion as modelled on roads including in the SCAG Regional Screenline Traffic Count (2004), expressed in Volume over Capacity Ratios.
2 – Average volume over capacity ratios for all roads in category, weighted by lane-miles.

4.2.3 Spatial Interpolation

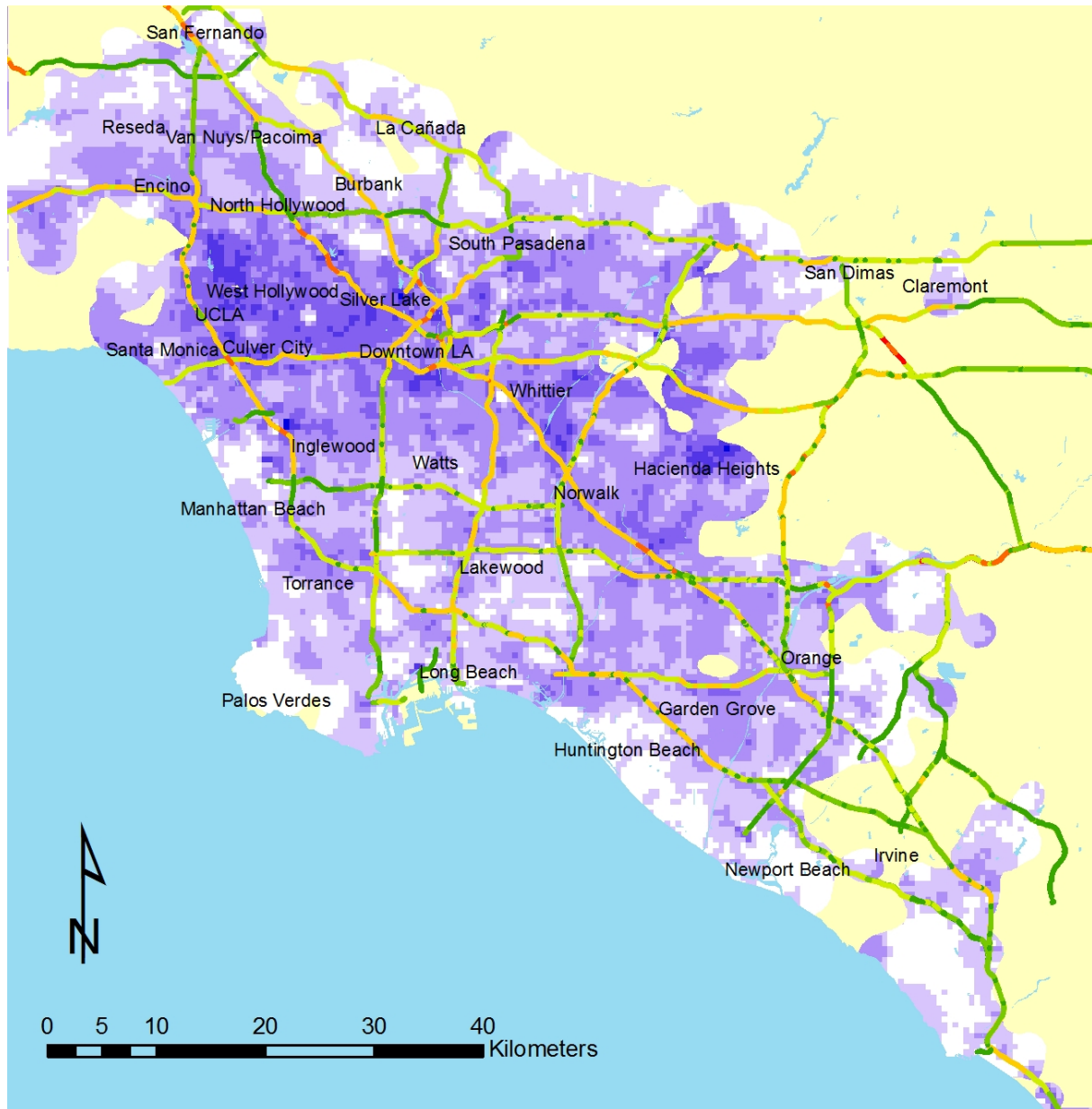
Our primary method for both visualizing and analyzing congestion and individual activity is surface interpolation. Because the study area contains over 40,000 road segments and activity data for over 5,800 individuals, we are primarily interested in the variation in aggregated patterns of activity participation over the study area. The particular method of surface interpolation used in this study is kriging. Like other surface interpolation methods, kriging is based on the estimation of a grid of values from available local known values, which facilitates surface interpolation in a statistical inference framework (Miller 2004). To increase the statistical validity of estimated surface values, we employed key aspects of the kriging methodology, such as testing for the normal distribution of input values and accounting for regional trends in spatial variation before kriging (Davis 1986).

4.3 Spatial Analysis

A spatial analysis of activity and traffic patterns in Los Angeles and Orange Counties reveals that congestion's impact on accessibility varies substantially by locale. Specifically, some places or neighborhoods may be more "congestion-adapted" than others by facilitating high levels of activity participation in the midst of chronic traffic delays.

4.3.1 Congestion

Figure 1 illustrates maximum congestion levels on arterial streets and freeways in the study area. Arterial street congestion is interpolated from the volume-to-capacity (V/C) ratios of all arterial streets in the SCAG Regional Traffic Screenline Study. Freeway congestion is mapped along the freeway segments themselves. For both arterials and freeways, the V/C value mapped is the maximum for either direction, for either the morning or evening peak, whichever is greatest. The map illustrates a distinct pattern for arterial congestion, with the most notable and largest cluster in west Los Angeles between Santa Monica in the west and downtown to the east. This is a large (250 square kilometers) and relatively densely developed (5,200 persons per square kilometer) area with significant concentrations of employment in Hollywood, Beverly Hills, Century City, and Westwood, as well as downtown and Santa Monica. Across the region, patterns of freeway congestion appear to track the distribution of arterial congestion, although in some locations, such as along the heavily-traversed goods movement corridor along the Long Beach (I-710) freeway north from the Ports of Long Beach and Los Angeles, freeway congestion tends to be heavier than on adjacent arterials.



Legend

Freeway Congestion	Arterial Congestion
Peak Period Max V/C	Peak Period Max V/C
Less than 0.50	Less than 0.50
0.50 - 0.75	0.50 - 0.75
0.75 - 1.00	0.75 - 1.00
1.00 - 1.25	1.00 - 1.25
1.25 - 1.50	1.25 - 1.50
1.50 or higher	1.50 or higher

FIGURE 1
Arterial and freeway
congestion in the
Los Angeles Region.

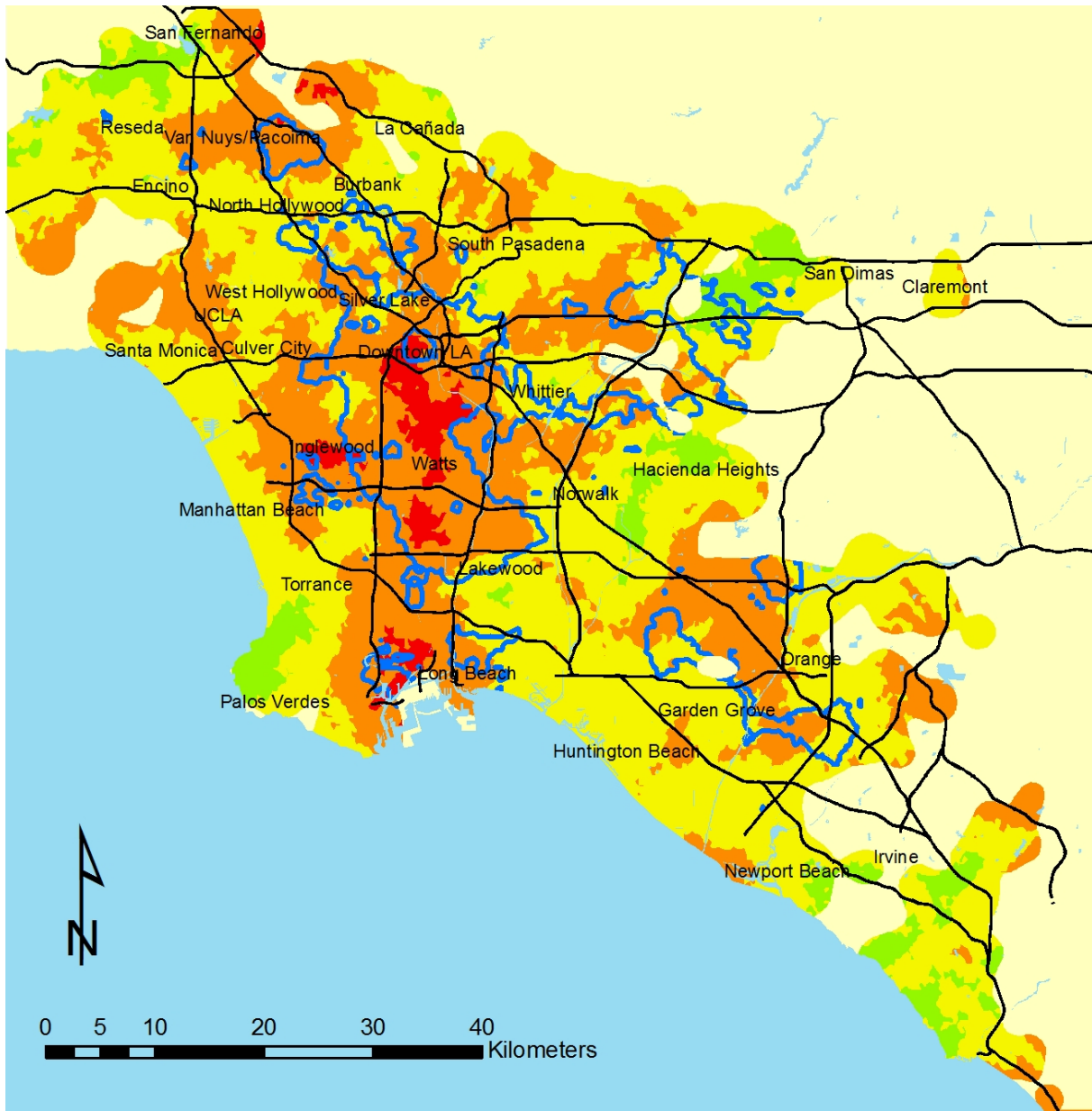
4.3.2 Number of Trips and Income

Figure 2 highlights clear spatial patterns in the distribution of tripmaking rates among survey respondents, who make a median of four trips per day, including work trips. Tripmaking tends to be particularly low in the central core of the region, from Downtown Los Angeles through Watts south to Long Beach. Higher-than-median tripmaking tends to dominate on the fringes on the region, with some notable pockets of variation. Perhaps not surprisingly, the spatial patterns of tripmaking align themselves substantially with spatial patterns of household income. This finding is consistent with previous research on travel behavior showing a strong, positive relationship between tripmaking and income (Redmond and Mokhtarian 2001).

4.3.3 Trip Lengths and Numbers of Trips

Places where less vehicle travel is required to access an equivalent set of opportunities should be of great interest to planners concerned with auto dependence, environmental quality, traffic congestion, and accessibility. Figure 3 incorporates how survey respondents' median trip lengths vary across the region along with the number of trips, highlighting neighborhoods where individuals make many, short trips, as well as neighborhoods with the opposite behavior – fewer, longer trips. Median trip lengths are estimated for each survey respondent from all trips of any mode, and include “trips” of no length (home-based activities). Here we see patterns that diverge from those seen with income and number of trips alone.

If higher levels of tripmaking reflect higher levels of individual accessibility, but longer distance trips reflect higher personal and social costs to complete a given trip, then an ideal locale would be one where individuals make many, short trips. Such places exist, even in Los



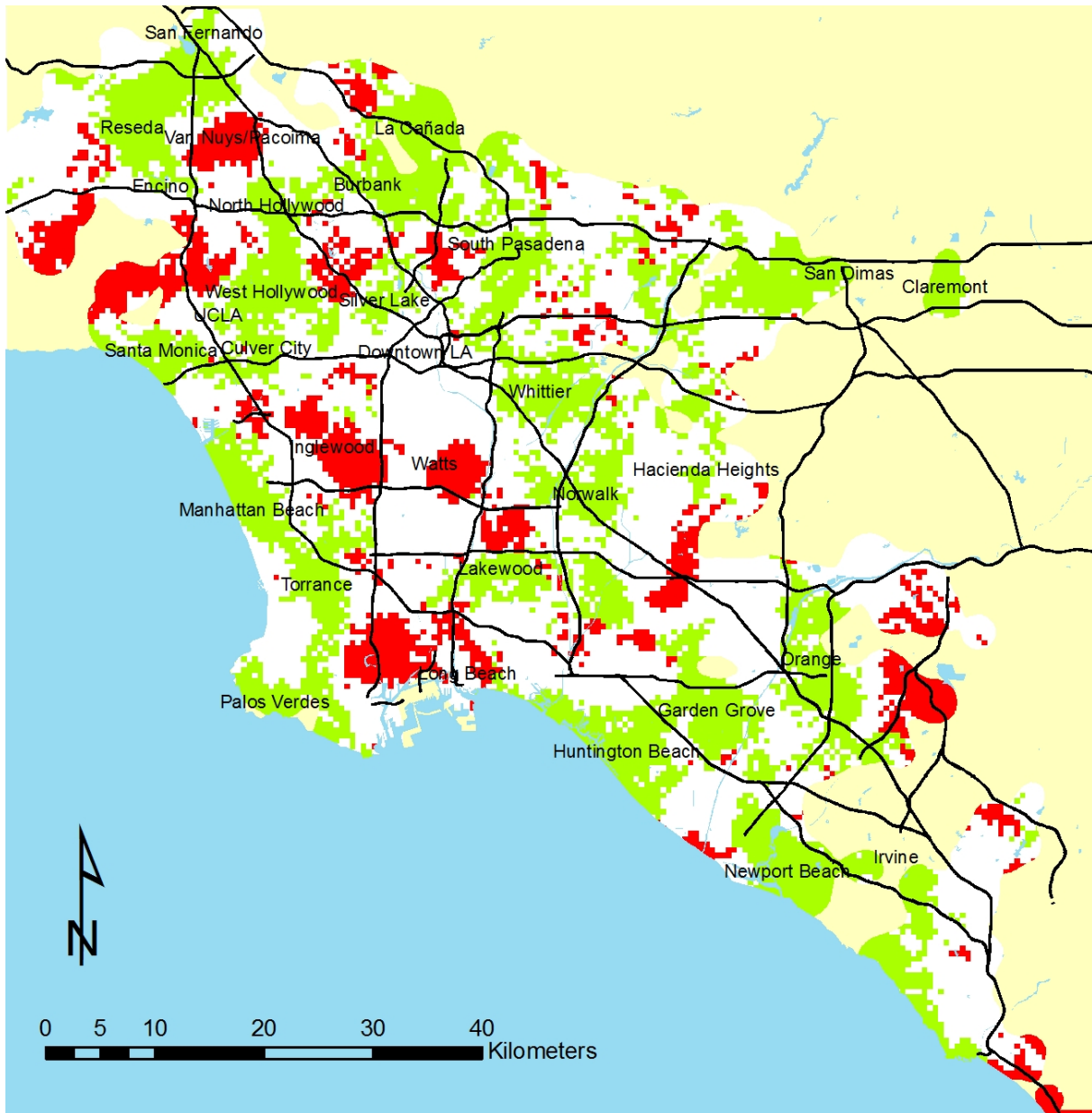
Legend

— Household Income Below \$50,000

Number of Person Trips, Weekdays, Employed Respondents

- 0 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 15.5

FIGURE 2
Rate of tripmaking
and household income.



Legend

Neighborhood Tripmaking Characteristics

- Others
- Few, Long Trips
- Many, Short Trips

FIGURE 3
Many, short trip and
few, long trip
neighborhoods.

Angeles. Other than in the urban core where tripmaking, regardless of trip distance, is low, places where individuals tend to make both more than average and shorter than average trips are scattered throughout the region (shown in green in Figure 3). In these places, tripmaking is higher than the median (4 trips) for survey respondents and average trip lengths are below the median (approximately 3.7 miles / 6 kilometers). In these places, accessibility is less tightly linked to mobility. Some of these locations, such as Santa Monica, West Hollywood, and Newport Beach, are among the most well-known and popular areas in Los Angeles. Other locations, however, like Reseda, Whittier, and Garden Grove, are lower-income ethnic enclaves. Conversely, the areas where individuals make few, long trips – an undesirable situation for individuals and society – include some of the poorest neighborhoods in the region such as Watts, the port areas near Long Beach, and Van Nuys/Pacoima.

4.3.4 Congestion and Tripmaking

Is localized congestion associated with specific travel behavior patterns? More to the point, do people living in congested areas tend to make shorter trips? Table 3 presents mean V/C ratios for neighborhoods defined by trip-making characteristics. For the Los Angeles basin as a whole, shorter trips are indeed correlated with higher levels of congestion, controlling for the number of trips made. However, because increased congestion also appears to be associated with fewer trips, the highest V/C ratio is associated with neighborhoods where individuals make fewer, shorter trips. This is not surprising given that several of these neighborhoods are concentrated around downtown Los Angeles, which has relatively high congestion and relatively poor residents. However, the association between congestion and

shorter trips in better-off neighborhoods may be evidence of individuals maximizing opportunities despite congestion rather than a result of limited means.

<i>Number of Trips</i>	<i>Length of Trips</i>	
	Short Trips (Less than 6km)	Long Trips (More than 6km)
Few Trips (Less than 4)	0.84 V/C	0.76 V/C
Many Trips (More than 4)	0.77 V/C	0.69 V/C

4.4 Accounting for the Individual

The travel data show a spatial relationship between activity patterns and congestion. However, spatial analysis alone does not address whether congestion directly influences activity patterns or whether other factors play a greater role. As noted in the literature review, individual accessibility and activity may be shaped to a great degree by personal, and not place, characteristics. Perhaps individuals with similar personal characteristics are spatially clustered such that their travel behavior is only indirectly related to local or other neighborhood congestion. To test the independent effects of individual, household, and neighborhood effects on tripmaking, we constructed a log-linear ordinary least-squares regression model of the number of daily trips as a function of an array of personal and household characteristics (Table 4). The log transformation of the dependent variable normalizes the right skewed distribution of number of trips. Other researchers (Kawamoto 2003; Kwan, Murray et al. 2003; Schoenfelder and Axhausen 2003) have constructed similar models to understand tripmaking patterns. The model results suggest that personal characteristics are indeed correlated with activity patterns and the effects observed in the model are expected, though, as with most models of this sort, the explanatory power of socio-demographic characteristics on individual

behavior for a single day is not strong ($R^2 = 0.0715$). Appendix A includes more detailed regression results, including coefficients.

Table 4. Log-Linear Model Controlling for Personal and Household Characteristics in Tripmaking		
Dependent Variable	Natural Log of Weekday Person Trips	
		Effect
Independent Variables	Age	+**
	Female	+**
	English Speaker	+*
	White	+**
	College Education	+**
	Number of Students in Household	+**
	Income	Not Sig
	Works Outside the Home	-.**
	Number of Jobs Held by Respondent	Not Sig
	Total Hours Worked (on day of survey)	-.**
Model	OLS	
N	4187 employed 18-65 year olds	
F	21.75***	
R-squared	0.0715	
* - Significant at least at 0.05 probability ** - Significant at least at 0.001 probability *** - Significant at least at 0.0001 probability		

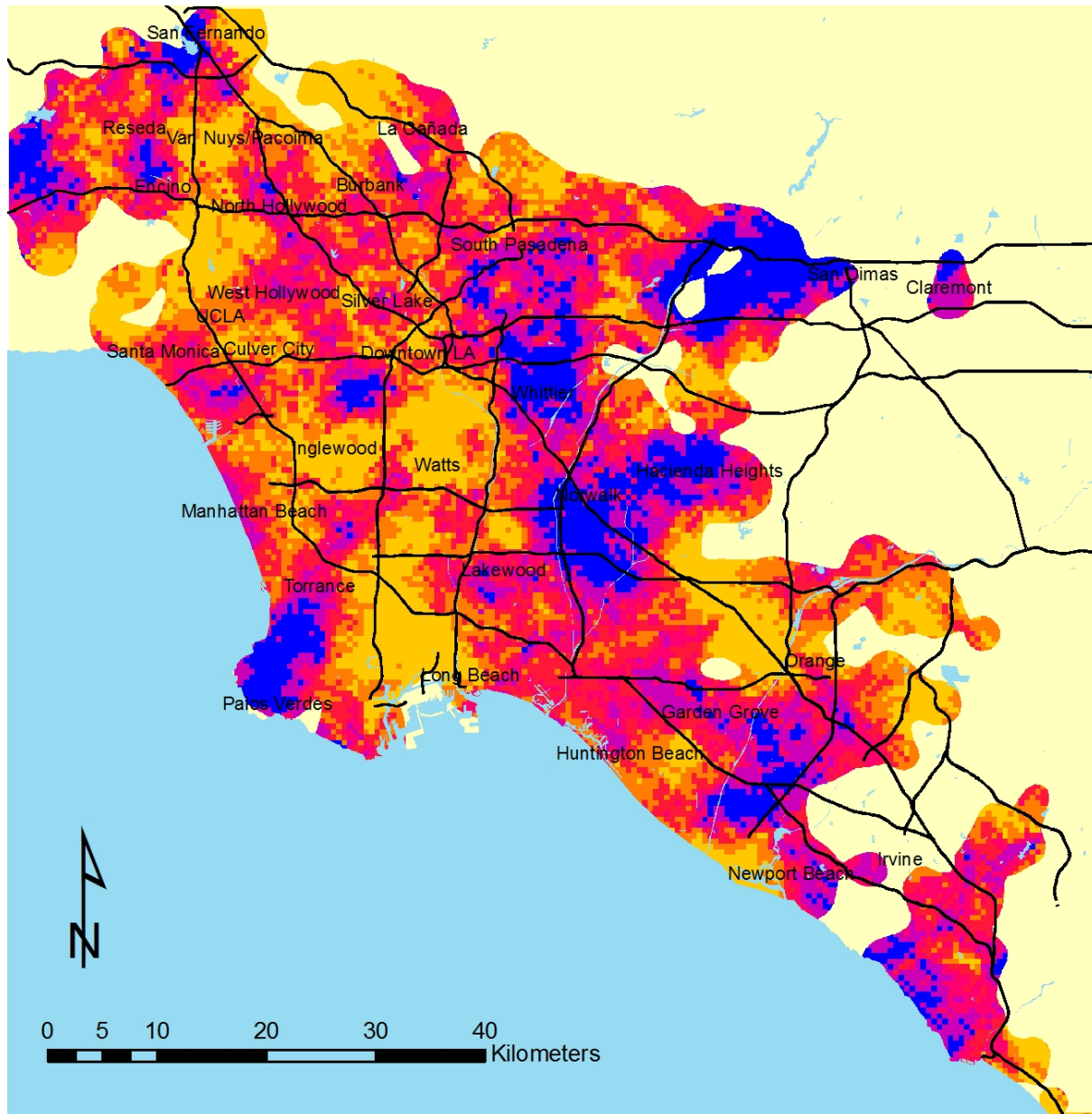
Given that all respondents are working adults describing tripmaking on a weekday, the factors associated with increased tripmaking are: age, being female, an English speaker, white, college educated, and having (primary, secondary, or college) students in the household (which we use as a proxy for children). Working outside the neighborhood and working longer hours are statistically significantly associated with reduced tripmaking. Income (as a standalone variable) in this model is not statistically significantly associated with tripmaking because so

many of the personal characteristics included in the model are themselves highly correlated with income, in particular education.

While the model is highly significant overall and for individual variables, the R-squared for the model (and most others of this sort reported in the literature) remains a relatively low 0.07; this is largely because a given person's travel behavior on a given day is subject to enormous number of site- and situation-specific circumstances unrelated to socio-demographic or place characteristics. Because this model does not fully explain the variability in individual tripmaking, excluding, among other factors, locational variables, we mapped the residuals from this model, interpolated with kriging, by survey respondent residential location (see Figure 4). The locations with predominantly positive regression residuals are remarkably aligned with the neighborhoods where individuals make many, short trips (see Figure 3). In these neighborhoods, more trips are made than would be predicted by socio-demographic characteristics alone.

The spatial pattern of model residuals opens the possibility that one or more neighborhood effects explain the relatively higher levels of tripmaking by residents in the "many, short trip" neighborhoods. Whether that neighborhood effect is itself, or related to, localized congestion remains unresolved. Other non-congestion-related place-based effects encouraging a surfeit of short trips could be high levels of non-mobility-based access opportunities, higher development densities, an adroit mixing of land uses to foster walking trips, other amenities that make areas especially attractive to employers, shoppers, vacationers, and other travelers. In relatively dense, congested, high-cost, high-amenity areas like Newport Beach and Santa Monica, congestion may be secondary to such factors in

explaining the tripmaking behavior of residents. Other “many, short trip” neighborhoods, like



Legend

Regression Residuals



FIGURE 4
Residual rate of tripmaking
(natural log) after controlling
for personal characteristics.

Norwalk and Reseda, are distant from high-cost, high-amenity areas, but may function as important ethnic enclaves for subsets of the extraordinarily diverse residents of metropolitan Los Angeles. Yet other neighborhoods in which individuals make many, short trips are not in high amenity locations or distinct ethnic districts; in these neighborhoods, perhaps congestion plays a role in encouraging individuals to remain close to home when choosing destinations, but without a loss in accessibility.

5. FUTURE RESEARCH AND CONCLUSIONS

5.1 Future Research

While this report outlines a basic conceptual and empirical relationship between congestion and accessibility, the research described in this report represents the beginning of what we hope will be a long-term examination of this underexplored area of transportation research. Some planned elements of the future research program include:

- Expand the research to include additional metropolitan areas, increasing external validity.
- Refine and expand the model of the relationship between activity and congestion.
- Based on the finding that activity patterns vary spatially at a neighborhood scale, focus on neighborhood characteristics (land use patterns, transportation network, urban design, social factors such as crime) that may modify the congestion/accessibility relationship.
- Create a typology of congestion in urban areas that moves beyond measures of link and network delays to a broader characterization of congestion as it affects neighborhoods and cities. Such a typology would account for the differences between freeway and arterial congestion, as well as its effect on different types of activities and local land uses.

5.1.1 *Public Transit and Metropolitan Congestion*

In addition to the research reported here, we are also expanding the overall exploration of the relationship between accessibility and congestion to emphasize how transit investment and ridership both influence and are influenced by congestion in major metropolitan areas.

This research addresses the longstanding claim that investments in transit can reduce congestion. While evidence of the ability of transit investments to reduce road congestion is mixed, public transit likely provides residents of a congested region with alternatives to traveling on clogged roadways; alternatives that facilitate increased activity in the face of ongoing congestion.

5.1.2 Reviewer Input

The authors have solicited a input from other researchers in the field as they have conducted this research, both in writing and through public presentations of this work. A list of public research presentations is included in Appendix B. Comments from other researchers in presentations and in review of conference papers have strengthened the analysis while reaffirming the value of this line of research to the field generally.

5.2 Conclusions

Research exploring the relationship between congestion and accessibility is in its infancy. This analysis, however, does find consistent, if complex, relationships between congestion and activity patterns, even after accounting for individual characteristics. If one accepts that activity participation, operationalized here by tripmaking, benefits individuals and society, this analysis suggests that traffic congestion should not be viewed as a uniform drag on accessibility. These data from Los Angeles suggest that residents of some areas enjoy high levels of accessibility despite high levels of congestion, while in other areas congestion appears to contribute to, or at the very least exacerbates, low levels of accessibility. The picture of Los

Angeles as a congested dystopia painted by regional congestion measures like the TTI Mobility Index is misleadingly simplistic; the real story is far more nuanced and interesting.

Exploring this congestion/accessibility relationship further will yield fertile ground for transportation and urban scholars. Congestion is by no means an unmitigated negative, yet with the right local conditions, a certain level of congestion may foster – or at least not prevent – patterns of tripmaking that benefit both individuals and society. Improving our understanding of the relationships between congestion and accessibility may help planners and policy makers develop a clearer picture of how transportation systems can deliver greater benefits to travelers who frequently find themselves stuck in traffic.

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APPENDIX A:

Full Regression Results (From Section 4.4)

Linear regression

Number of obs = 4187
 F(10, 4176) = 21.75
 Prob > F = 0.0000
 R-squared = 0.0715
 Root MSE = .50736

Natural Log Person Trips	Coef.	Robust Std. Err.	t	P> t	[95% Conf. Interval]	
age	.0028311	.0006846	4.14	0.000	.0014889	.0041734
students	.0626256	.0111844	5.60	0.000	.0406982	.0845531
numjobs	.0120352	.0308608	0.39	0.697	-.0484685	.0725389
workhours	-.0019411	.0009179	-2.11	0.035	-.0037407	-.0001415
englishhome	.0823245	.0334662	2.46	0.014	.0167129	.1479362
female	.0803833	.0193121	4.16	0.000	.0425213	.1182452
whiteNH	.0932774	.0204645	4.56	0.000	.0531562	.1333986
college	.088641	.0229275	3.87	0.000	.043691	.133591
worknothome	-.1475207	.0327337	-4.51	0.000	-.2116962	-.0833453
income	-.0229109	.0422925	-0.54	0.588	-.1058266	.0600049
constant	1.253186	.0747827	16.76	0.000	1.106572	1.3998

APPENDIX B:

Public Research Presentations

- Mondschein, Andrew. “Congestion and Accessibility: What’s the Relationship?” 2010 World Conference on Transportation Research, Lisbon, Portugal, July 2010.
- Taylor, Brian D. “Bad Congestion, Good Congestion? Examining Traffic Congestion in Los Angeles,” Institute of Transportation Studies Seminar Series, University of California, Irvine, California, April 2010.
- Mondschein, Andrew. “Congestion and Accessibility: What’s the Relationship?” 2010 Annual Meeting of the Association of American Geographers, Washington, DC, April 2010.
- Taylor, Brian D. “Re-Thinking Traffic Congestion in Los Angeles,” at *Changing Lanes: Bold Ideas to Solve LA’s Traffic Problems*, UCLA Rosenfield Forum, Japanese-American National Museum, Los Angeles, California, March 2010.
- Mondschein, Andrew, Stephen Brumbaugh, and Brian D. Taylor. “Congestion and Accessibility: What’s the Relationship?” 2009 Annual Meeting of the Transportation Research Board, Washington, DC, January 2009.
- Brumbaugh, Stephen. “Congestion and Accessibility: What’s the Relationship?” 2008 ACSP/AESOP Joint Congress, Chicago, IL, July 2008.