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The Personal City: The Experiential, Cognitive Nature of Travel and Activity and Implications for Accessibility

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2013

UNIVERSITY OF CALIFORNIA

Los Angeles

The Personal City:

The Experiential, Cognitive Nature of Travel and Activity

and Implications for Accessibility

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Urban Planning

by

Andrew Samuel Mondschein

2012

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ABSTRACT OF THE DISSERTATION

The Personal City:

The Experiential, Cognitive Nature of Travel and Activity

and Implications for Accessibility

by

Andrew Samuel Mondschein

Doctor of Philosophy in Urban Planning

University of California, Los Angeles, 2012

Professor Brian D. Taylor, Chair

Transportation planning research addresses accessibility from diverse approaches, focusing varyingly on the usability of the transportation system as a whole, a particular mode, the pattern of land uses, or the wherewithal of individuals and communities to make use of those systems. One aspect of accessibility that has received relatively little attention from planners is its cognitive, experiential aspect. Individuals' activity and travel choices require not just money and time but also information about opportunities in the city. This component of an individual's accessibility is highly personal but also dependent on the terrain of land uses and transportation options shaped by planners and policymakers. I seek to extend current accessibility research, addressing shortcomings in how the literature deals with individual experience of the city and knowledge. Through a series of empirical analyses of activity patterns and cognitive maps of the

Los Angeles region, I explore the factors that shape individual accessibility. The first analysis investigates the spatial nature of personal cities, using the activity spaces of respondents to explore the types of opportunities that different populations within a city can access. The second demonstrates the differences – depending on mode of travel – among individuals' perceptions of the city, even when location is held constant. The third analysis continues an exploration of the personal city by considering its fundamental components.

Overall, the analyses support the relevance of the personal city framework to accessibility research, highlighting in particular that planning interventions are filtered through experiential and cognitive processes. The findings highlight that the accessibility impacts of transportation and land use patterns are felt not just in the instantaneous calculations of a microeconomic choice framework, but also in the long-term, developmental processes of cognition and experience. For urban planners, the implications of this research include evidence of how the built environment can effectively reduce travel while maintaining accessibility and how different transportation modes afford varying levels of functional accessibility. Overall, I find that experience, information, and learning are elements of urban daily life traditionally neglected by planners but with potential to increase opportunity and accessibility for diverse urban populations.

The dissertation of Andrew Mondschein is approved.

Evelyn Blumenberg

Rick Paik-Schoenberg

Brian D. Taylor, Committee Chair

University of California, Los Angeles

2012

To Krista

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The research presented in Chapter 6 is based in part on previously published work:

Mondschein, Andrew, Evelyn Blumenberg, Brian D. Taylor. (2010). "Accessibility and Cognition: The Effect of Transport Mode on Spatial Knowledge." *Urban Studies* 47(4): 845-866.

I gratefully acknowledge the contributions of my coauthors to this research.

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Mondschein, Andrew. 2011. "Passegiata Nuova: Social Travel in the Age of the Smartphone." Presented at the Association of Collegiate Schools of Planning Conference, October 2011, Salt Lake City, UT.

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Mondschein, Andrew, Evelyn Blumenberg, and Brian D. Taylor. 2010. "Accessibility and Cognition: The Effect of Transportation Mode on Spatial Knowledge," *Urban Studies,* 47(4): 845-866.

Mondschein, Andrew, Evelyn Blumenberg, and Brian D. Taylor. 2007. "Cognitive Mapping, Travel Behavior, and Access to Opportunities," *Journal of the Transportation Research Board*, 1985: 266-272.

> In vain, great-hearted Kublai, shall I attempt to describe Zaira, city of high bastions. I could tell you how many steps make up the streets rising like stairways, and the degree of the arcades' curves, and what kind of zinc scales cover the roofs; but I already know this would be the same as telling you nothing. The city does not consist of this, but of relationships between the measurements of its space and the events of its past… As this wave of memories flows in, the city soaks it up like a sponge and expands. A description of Zaira as it is today should contain all Zaira's past.
>
> Italo Calvino, *Invisible Cities* (1974, 10-11)

Chapter 1

Introduction

Cities are big. More than 400 cities globally have surpassed one million in population, and nineteen cities have more than ten million residents (Population Reference Bureau 2010). In the US, more than half (54%) of the population lives in metropolitan areas with more than one million residents (U.S. Census Bureau 2009). With increasing populations have come cities of vast geographic extents. By 2000, twenty-five US urbanized areas encompassed more than 500 square miles (U.S. Census Bureau 2010). Such complex and sprawling conurbations are filled with opportunities. However, no individual, over the course of a day or a lifetime, could possibly partake of all the opportunities offered within today's cities, even small ones. Any individual can engage in only a tiny subset of the opportunities the city provides.

Urban planners seek, under the rubric of accessibility, to ensure that the subset of the city that people can reach is sufficient for them to meet their needs and their desires. Planning addresses accessibility from diverse approaches, focusing varyingly on the usability of the transportation system as a whole, a particular mode, the pattern of land uses, the wherewithal of individuals and communities to make use of those systems, or some combination of these foci.

One aspect of accessibility that has received relatively little attention from planners is its cognitive, experiential aspect. Individuals' activity and travel choices require not just money and time but also information about opportunities in the city. This component of an individual's accessibility is highly personal, but, I would also argue, dependent on the terrain of land uses and transportation options shaped by planners and policymakers.

In this dissertation, I seek to extend current accessibility research, addressing shortcomings in how the literature approaches individual choice and knowledge. Rather than count opportunities along aggregate scales, an accessibility researcher may also ask: Is a person's city a "complete" city? What's missing from their daily routine? Despite its complexity and fluidity, this personal city can be empirically analyzed, drawing on methods developed within activity time-space and cognitive mapping research. Through a series of empirical analyses of activity patterns and cognitive maps of the city, I explore the factors that shape individual accessibility, with particular emphasis on the factors over which planners have some input and control. I find that, despite being highly personalized, an experiential, cognitive approach to accessibility is not dependent just on socioeconomics and other personal characteristics but is also shaped by the interventions of urban planners in terms of land use, transportation, and possibly even urban design. I call this conceptualization of increasing accessibility through enhanced individual experience and knowledge "the personal city."

I employ "the personal city" as an encompassing term for a conceptual framework that describes how individual activity and cognitive processes combine to shape access to urban opportunities. This conceptualization is built from literatures in several fields—urban planning, geography, and psychology most notably—on accessibility, activity patterns, and cognitive mapping. I explore several facets of the complete city through empirical analysis, looking at results from a large travel survey of the Southern California region and a focused cognitive mapping survey of neighborhoods in South Los Angeles and at UCLA. The first analysis investigates the spatial nature of personal cities, using the activity spaces of respondents to explore the types of opportunities that different populations within a city can access, framing accessibility in terms of whether each individual's personal city is a "complete" city. The second analysis underscores the cognitive nature of the personal city, surveying the differences between individuals' perceptions of the city even when location is held constant. The third analysis continues an exploration of the personal city by considering its fundamental components. Do different elements of the city vary in importance for individuals in constructing their personal cities? Combined, the three analyses empirically suggest that travel patterns both influence and are influenced by personal and environmental factors not accounted for in standard socioeconomic analyses but that instead are dependent on individuals' access to information and experiences of the city.

Overall, the analyses support the relevance of the personal city framework to accessibility research, highlighting in particular that planning interventions are filtered through experiential and cognitive processes. Among several implications for planning, the findings highlight that the accessibility impacts of transportation and land use patterns are felt not only in the instantaneous calculations of a microeconomic choice framework, but also in the long-term, developmental processes of cognition and experience.

This introductory chapter provides a preview of some of the key components of the dissertation. Like the chapters of the dissertation itself, the preview addresses the literature on accessibility, activity patterns, and cognitive mapping research, as well as the conceptual framework of the complete city. Following that, I introduce the three empirical analyses – their questions and methods – in more detail. The first analysis (Chapter 5) draws on a large travel survey of Southern California, and the final two (Chapters 6 and 7) rely on a small survey of cognitive mapping and spatial knowledge conducted in South Los Angeles and on the UCLA campus. This chapter ends with a brief description of findings and some of the major contributions of the dissertation in terms of research approach and implications for planning.

1.1 Literature

The dissertation draws on theory and research from several academic fields including urban planning, environmental psychology, and geography. The literature review (Chapter 2) emphasizes three primary areas of research: accessibility, activity patterns, and cognitive mapping.

1.1.1 Accessibility and Activity Patterns

While the concept is longstanding, over the past two decades accessibility research has exploded in the variety of conceptual approaches and methods applied to it (Hansen 1959; Webber 1964; Levinson and Krizek 2005). Accessibility can imply far more than "the ease of movement between places" as termed by Giuliano (2004). Accessibility research can be roughly categorized by whether it is place-based or person-based. Place-based accessibility is concerned largely with impedances between places and surrounding opportunities as set by the transportation and land use patterns around them (Handy and Niemier 1997; Levinson and Krizek 2005). Person-based accessibility is concerned with how the ability to reach opportunities varies by the individual or household, due to the particular constraint on those individuals – including cognitive constraints. Boarnet and Crane (2001), among other scholars, propose a microeconomic framework for understanding how personal utility and resources shape accessibility. While the microeconomic framework for person-based, or individual, accessibility has seen application in the development of activity-based models of individual travel behavior, it still has shortcomings in explaining some of the complexities of individual travel behavior (Arnott, de Palma et al. 1999; Jain and Lyons 2008). A framework for individual accessibility that also draws on cognitive processes and the availability of information has been proposed by transportation geographers, particularly Kwan (Kwan, Murray et al. 2003; Kwan and Weber 2003; Weber and Kwan 2003). These researchers have made strides in highlighting how accessibility may vary due to personal constraints such as household responsibilities, scheduling conflicts, and available information.

Individual accessibility concepts and measures are developed to a great extent from activity time-space theory and methods. Activity time-spaces are a conceptualization of individuals' relationships to their environment proposed initially by Hägerstrand (1970). He argued that researchers could understand the person-environment interaction in part by how they moved through that environment over the course of the day or other timeframe. Qualities of a person's activity time-space, or just activity space, such as its size, contents, complexity, and otherwise, can reveal personal opportunities and obstacles and can be defined as a measure of accessibility (Kwan 1998; Kwan 2002). In general, urban planners have yet to fully incorporate some of the lessons of geography-based individual accessibility research, such as the fact that accessibility may vary significantly from individual to individual yet vary little from place to place within a city (Weber and Kwan 2003).

1.1.2 Cognitive Mapping

Cognitive mapping research spans several fields, including urban planning and design, behavioral geography, and environmental psychology. Cognitive maps are those mental processes which allow individuals to store, recall, and utilize information about the built environment to make daily activity and travel choices (Downs and Stea 1973). Some of the literature on cognitive mapping, such as that of Lynch (1960), shows that individuals interpret their surrounding environment, breaking it down into discrete elements. Importantly, those elements vary across individual and group, and are prone to distortion (Liben, Patterson et al. 1981). Group differences may be relevant to the social welfare concerns of planners, such as differences by race or socioeconomic status (Banerjee and Baer 1984).

Geography and psychology researchers have found that cognitive maps are shaped to a large degree by individuals' experience of the city, particularly in how they travel through the city (Golledge and Stimson 1997; Kitchin and Blades 2002). A theory of spatial learning has grown to explain how travel results in better or worse information about opportunities and routes in the city. This theory posits that knowledge of the city accrues through a developmental, experiential process with distinct phases that can be measured. Further development of the cognitive map through spatial learning facilitates improved navigation and an ability to take advantage of opportunities in the city (Golledge 1998).

The importance of spatial learning to planning stems from the differences in spatial knowledge potentially attributable to urban structure and mode of travel. While research in this area is more limited, researchers have found that people accrue knowledge more easily when more actively engaged in navigation and locations where travel choices must be made (Stern and Portugali 1999; Golledge and Gärling 2004). These findings suggest that different travel modes may result in different levels of cognitive map development. The literature, however, has yet to directly address how everyday travel by different modes shapes cognitive maps.

1.2 Conceptual Framework: The Personal City

The personal city framework (Chapter 3) posits that each individual possesses a city of their own experience and knowledge. In the parlance of environmental psychologists, the personal city is an urban-scale "lifeworld," and its contents and extents are a measure of each individual's past experience, future opportunity, and present quality of life (Seamon 1979). The personal city also shares kinship with activity time-spaces as developed by geographers such as Hägerstrand and Kwan. Cognitive mapping research, pursued by planners, geographers, and psychologists, also contributes significantly to the nature of personal cities, establishing cognitive maps as the internal repositories of personal cities.

I conceptualize the personal city as an aspect of the self, that aspect which extends into the built environment. It is the city as the individual lives and knows it, and contains both practical information and subjective outlook. The activities in which individuals engage, whether a part of daily life or exceptional events, link the personal city to the planned city. As such, the personal city possesses measurable dimensions in space and time. However, stored as it is in the cognitive map, the personal city is replete with distortions, errors, and non-spatial, qualitative components. The personal city can be understood as sufficient or insufficient for an individual to meet their needs and wants. Thus, the personal city can be complete or incomplete. As such, this concept is aligned with the normative outlook of accessibility research, as something which planners seek to maximize, or at least facilitate, for all urban residents.

The personal city framework suggests a number of conceptual hypotheses, which in turn guide the empirical analysis that follows. With the first hypothesis, I propose that socioeconomics, urban form, and accessibility are intertwined more deeply than just in the straightforward increase in resources and leisure time that a microeconomic framework suggests. Instead, the experiential aspect of travel creates a long-term advantage for those who travel widely, controlling for urban form, in terms of awareness and ability to take advantage of urban opportunities. With the second hypothesis, I emphasize that not all travel is the same. Rather, I expect that because different modes of travel require different levels of cognitive effort, they will result in varying levels of spatial knowledge and accessibility. Third, I hypothesize that the built environment does play a role in the construction of the complete city, serving as a framework for organizing spatial knowledge and opportunities.

1.3 Empirical Analyses

The conceptual hypotheses derived from the personal city framework lead to a set of empirical analyses that comprise the heart of the dissertation. Each analysis addresses a different aspect of the relationship between the individuals, their experience of the city, and access to opportunity. Each analysis finds distinctive linkages between the planned city, the personal city, and accessibility outcomes. Chapter 4 describes data and methods in detail, with the three analyses in following chapters.

1.3.1 Activity Spaces

The first empirical analysis (Chapter 5) explores the activity spaces of residents of the Los Angeles metropolitan region. I hypothesize that the extents of individuals' activity spaces vary not just due to socioeconomic status, but also based on where an individual lives in the city and the nature of the built environment around them. I use activity, travel, and location data from a major regional travel survey for the Los Angeles region conducted by the Southern California Association of Governments (SCAG). The dataset enables me to construct a variety of measures of individuals' activity spaces and compare them to their socioeconomic status. The descriptive analysis shows a powerful correlation between activity spaces and socioeconomic status.

Following the basic descriptive exploration of the data, I construct a set of models where activity space extent is predicted based on travel patterns, personal characteristics, and area land use and neighborhood characteristics. Unsurprisingly, travel factors such as number of trips and mode, as well as socioeconomic status, play an important role in explaining the extent of people's daily activity patterns. However, I also find that neighborhood characteristics, including density, have a significant effect on activity patterns. Those effects are intriguing, in that different density measures, including population density, employment density, and an "opportunity density" accessibility measure each have distinct and not always concentrating effects on activity patterns.

The models of activity space extent draw on both ordinary least squares (OLS) and geographically-weighted regression (GWR) methods. GWR is a means to address spatial dependence in the relationship among the dependent and independent variables. GWR operates, essentially, by allowing the regression to vary across space. Allowing the regression coefficients to vary across a study region is highly appropriate to urban research, where certain factors, such as access to transit, may be highly relevant in one part of a city, and not very meaningful elsewhere. The GWR model is an advance over the OLS models, explaining more of the variability in the dependent variable and reducing clustering in the residual values.

1.3.2 Spatial Knowledge and Travel Mode

The second empirical analysis (Chapter 6) examines the effect of travel mode on the accuracy of information about opportunities stored in the cognitive map. I hypothesize that travel mode, which provides individuals with widely varying experiences of travel and navigation, significantly shapes the accuracy of individual's cognitive maps. Drawing on data from a focused survey of roughly 400 individuals across two Los Angeles neighborhoods, I find that multiple measures of spatial knowledge do indeed vary significantly depending on a person's dominant travel modes. These modes can be categorized, broadly, as "active" or "passive" in terms of cognitive burden, with auto driving and walking being active modes and public transit and auto passenger being passive.

This analysis draws on a survey I conducted with co-investigators Evelyn Blumenberg and Brian Taylor of residents and workers in South Los Angeles, around Watts and Compton, and on the UCLA campus. The survey extracted information from individuals' cognitive maps using a variety of techniques, including sketch mapping and verbal questions on locations, absolute distances, and relative distances across the Los Angeles region. In addition, we collected data on travel mode and socioeconomic status.

The results show that travel mode influences cognitive knowledge in a distinctive way, with drivers and walkers having more accurate knowledge of the region than public transit users and auto passengers. These results hold across several measures of cognitive knowledge, though the patterns do vary slightly between South Los Angeles and UCLA. These differences may be attributable to the substantially different demographics and urban forms of the two survey locations. The differences in cognitive knowledge do not appear to be biased by the spatial location of respondents and their residences.

1.3.3 Cognitive Mapping and Urban Form

The third and final empirical analysis (Chapter 7) examines into the structure of individuals' cognitive maps, seeking to understand how their composition may vary by mode of travel. Drawing on the same survey used in the analysis of cognitive map accuracy, this analysis focuses on the sketch maps drawn by survey respondents. I hypothesize that, based on the developmental process laid out in spatial learning theory, the elements with which an individual constructs their cognitive maps will vary along with travel mode. I find that, much like the differences in map accuracy, the elements used to construct cognitive maps vary by mode. Active travelers, drivers, and walkers infuse their maps with more routes and navigation nodes, while passive travelers, public transit users, and auto passengers are more heavily reliant on landmarks within their cognitive maps.

The analysis, when comparing South Los Angeles and UCLA, suggests that the overall built environment must certainly play a role in the construction of the cognitive map. However, beyond these gross differences, the way in which a person experiences that built environment still matters, and mode of travel changes how people think about the city. In the framework of spatial learning theory, passive travelers have fundamentally less developed cognitive maps. I cannot address potential long-term impacts on accessibility with this analysis. However, the analysis does suggest that different and perhaps more intensive efforts to provide useful information about urban opportunities would benefit those whose cognitive maps are less well developed.

1.4 Implications and Contributions

Implications for cities and planning follow from the conceptual framework and empirical findings in this dissertation. In addition, the dissertation makes distinctive contributions to the urban planning literature in several ways. These contributions are summarized below, along with potential threats to the validity of the research. Implications and contributions are briefly previewed here, with a detailed discussion in the concluding chapter (Chapter 8).

1.4.1 Implications for Urban Planning

In this dissertation, I emphasize conceptually and empirically that individuals do not just make activity and travel choices based on short-term economic calculations. Instead, their choices also depend on medium- and long-term impetuses and constraints due to prior experiences in the city, embedded in cognitive maps. As such, planners should seek to provide urban dwellers with the best possible experiences to develop familiarity and facility with city, giving individuals a more complete personal city. This general implication filters down into several more specific planning and policy recommendations.

As the analysis of activity spaces shows, larger activity spaces are associated with higher socioeconomic status. While agglomerations of opportunities appear to foster smaller activity spaces indicative of less auto travel, the findings of this research suggest that attempts to reduce auto travel in order to increase urban sustainability should be pursued cautiously. Increasing the price of auto travel may reduce vehicle miles traveled (VMT), but it may disproportionately affect those of lower socioeconomic status whose cognitive maps and activity spaces are already constrained. Policies to reduce travel should be crafted to allow some minimum amount of travel for those most at risk of being "trapped" within an incomplete city. For example, taxes on travel, whether a gas tax, congestion fee, or otherwise, could potentially be rebated for the most poor.

Similarly, public transit appears to foster a different cognitive relationship with large urban regions than does driving, resulting in different activity choices. Transit's association with reduced cognitive map accuracy and a greater reliance on landmarks suggests that increased public transit use should be accompanied with efforts to incorporate regional scale information into the public transit travel experience. Intriguingly, just as the push for increased transit use is gaining strength in the US, the adoption of information technologies for travel and activity decisions is taking off. This provides a potential opening for keeping transit users well-apprised of their opportunities in ways that the mode does not naturally facilitate.

1.4.2 Contributions and Threats to Validity

While the analyses and conceptualizations presented in this dissertation are in some ways exploratory, they contribute to the body of knowledge on accessibility and urban planning research. Most broadly, the personal-city concept draws on findings in geography and psychology and synthesizes them into a model of accessibility that has relevance to urban planners. The concept shows how interventions in the built environment are filtered through individuals' experiences, but still result in measurably different levels of accessibility. The concept provides a needed complement to the standard microeconomic model of individual accessibility by explaining how information and experience shape activity and travel in the medium- to long-term, and not just during the instantaneous calculation of an activity's utility and trip cost.

Focusing specifically on the cognitive aspects of the dissertation, the empirical analyses begin to fill in a gap between geographical research on cognitive maps and travel and urban planning's focus on promoting specific modes such as public transit and walking. This multimodal research, set in actual urban neighborhoods, is thus far quite rare in the literature. Furthermore, the concepts and findings are well-timed in terms of their applicability to the increasing use of information technologies in cities, and will be useful in explaining how increased availability of information via technology may shape opportunities and the urban experience. Methodologically, the dissertation draws on methods from other fields, such as activity space analysis from geography and geographically-weighted regression from spatial econometrics. These methods are fairly well established outside planning, but have yet to see extensive application in the field. This dissertation helps highlight how they may be used productively for planning research questions.

Despite the many potential contributions of this work, threats to validity persist at several points. The analysis of activity spaces relies on a single day's activity and travel, and cannot fully reflect the complete urban experience of the respondents. The two cognitive mapping analyses rely upon a relatively small sample with many exploratory questions and results that may or may not be replicable in other settings. However, despite these potential threats, this dissertation presents a perspective on accessibility and how people experience their city that is distinctive in transportation and urban planning research. The findings tell us that the benefits people derive from their city are due in part to how well they learn the system of opportunities and linkages dictated by planners. It will take effort and time beyond the scope of this dissertation to fully understand how planners can meaningfully improve the urban experience to increase accessibility, but this dissertation is a step along that journey.

Chapter 2

Literature Review

This review establishes a basis for my thinking and research on activity, accessibility, and cognitive mapping. I highlight the central concepts and recent findings on these topics. The literature spans several fields of research, starting with urban and transportation planning and extending into environmental psychology, human geography, and urban economics. At the conclusion of the review, I discuss what is missing from the literature, particularly with regard to how conceptual or experimental findings may be applied to everyday life, travel, and urban form.

2.1 Accessibility and Activity

To understand cities, theorists have explored the social construction of space as well as the spatial dimension of society (Thomlinson 1969; Suttles 1972; Vernon 1972; Soja 1989; Young 2002; Amin 2007). The role of the individual in social and spatial processes has been less well defined. Individuals' collective choices are the direct causes of congestion, pollution, segregation, and other urban ills, but solutions proposed by planners sometimes place formal, functional, or socio-cultural considerations before behavioral outcomes (Hägerstrand 1970; Miller 2007; Franzini, Caughy et al. 2008). For example, a transit investment may be proposed not because of the expectation that individuals are likely to use it but because it meets the social objectives and formal vision of planners or policymakers. Yet even in transportation planning, a focus on behavior has come to the fore. In particular, economic behavioral theories have increasingly guided transportation and urban research (Boarnet and Crane 2001; Lyons 2004; Hunecke, Haustein et al. 2007; McFadden 2007).

Urban economists posit that microeconomic theory can explain much of individual choice and behavior in cities (Alonso 1964; Mills and Hamilton 1994; Anas, Arnott et al. 1998; Boarnet and Crane 2001). Most importantly, urban economists highlight that choices are shaped by individual constraints, such as available resources, time, location, and preferences or utility. This model has supplied parts of urban planning, particularly transportation planning, with a means of linking urban structure to individual choice. However, the model does have its weaknesses, particularly in that the utility of a particular choice is underspecified (Quigley 1998; Brueckner, Thisse et al. 1999; Boarnet and Crane 2001). Most microeconomic models of travel behavior utilize budget constraints and household characteristics such as family structure and ethnicity to explain travel behavior, yet they still must rely on a large random component to explain the great amount of variability still observed between similarly specified households (Chorus, Arentze et al. 2008). Thus, the opportunity exists for alternative, potentially complementary, models of behavior to join with the economic perspective.

2.1.1 Accessibility

The concept of accessibility has been employed by planners for decades (Hansen 1959; Webber 1964). Giuliano simply defines accessibility as "the ease of movement between places" (2004, 240), and Taylor provides a more thorough definition of accessibility as "the ability of people or firms to avail themselves of social interactions and economic transactions via proximity, mobility, or digital link" (2012). Accessibility is more than mobility; destinations matter as well. The transportation system should be understood as serving an urban context, because individuals do not simply use the transportation system to move. Rather, they use it to gain access to destination opportunities, whether people, places, or resources, which are embedded in the urban form (Lynch 1981; Levine 1998). Giuliano characterizes accessibility in an interdependent circuit along with transportation, land use, and activity (see Figure 2.1). She describes:

> The characteristics of the transportation system determine accessibility, or the ease of moving from one place to another. Accessibility in turn affects the locations of activities, or the land use pattern. The locations of activities in space affect daily activity patterns, which in turn result in travel patterns (daily trips within the region). These travel patterns, expressed as flows on the transportation network, affect the transportation system (239).

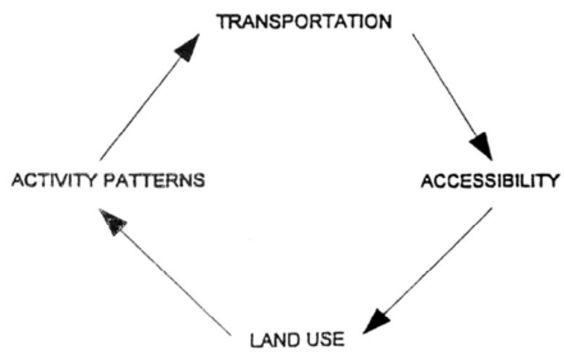

FIGURE 2.1 Transportation-Land Use Relationship. (Giuliano 2004, 239.)

Giuliano thereby invokes the wide range of factors that can influence accessibility, including the transportation system, land use patterns, and activity patterns themselves.

If accessibility is the ease of movement between places, then measuring accessibility is possible via spatially-based measures of opportunities. A large literature has grown up around the desire to quantify accessibility by measuring opportunities with regard to location and the means to reach them (Allen, Liu et al. 1993; Bureau of Transportation Statistics 2001; Handy 2002; Levinson and Krizek 2005). While the measures have innumerable permutations, most are based on methods for counting opportunities along a transport network, or a transport and information network, and weighting those opportunities based on some kind of impedance, whether distance, time, or average cost. Only a few researchers to date have explicitly accounted for access as perceived by the individual (Morris, Dumble et al. 1979; Theriault and Des Rosiers 2004).

The "gravity model," represented here in equation form, is one of the most fundamental methods for calculating this type of accessibility (El-Geneidy and Levinson 2006):

$$A_{im} = \sum_j O_j f(C_{ijm})$$

Where:
A_{im} = accessibility at point i to potential activity at point j using mode m;
O_j = the opportunities at point j; and
$f(C_{ijm})$ = the impedance or cost function to travel between i and j using mode m.

Accessibility is measured as an additive function, summing the product of all opportunities (defined variously) and the impedance between those opportunities and a given location, where the impedance is defined in terms of distance, time, or other cost function.[1]

As with urban behavior generally, economists have made strides in modeling accessibility in specifically behavioral terms (Boarnet and Crane 2001; Giuliano 2004). "As movement becomes less costly – either in terms of money or time – between any two places, accessibility increases" (Giuliano 2004, 240).[2] Importantly, this economic model of accessibility allows for the consideration of individuals' variable access to opportunities, rather than a particular place's overall accessibility. Individuals possess specific constraints, budgets in terms of time and money that vary across individuals and groups. Therefore, the set of potential opportunities varies from individual to individual. The structure of a behaviorally-based model of individual accessibility follows (El-Geneidy and Levinson 2006):

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[1] This type of accessibility measure does not account for price, demand, supply, or competition among individuals for a given opportunity, whether a job or any other activity in space. Thus, while a given location may have many jobs in proximity, ability to actually take advantage of the opportunity is also dependent on the wherewithal of an individual or household in terms of resources and context. This highlights the value of measuring accessibility not just in terms of spatial or network impedance, but also individual constraints.

[2] This formulation of accessibility may imply that as income and the availability of fast, reliable transportation rises, accessibility also increases. However, this accessibility benefit depends on the value of a given individual's time. If travel time has a high cost or high opportunity cost for an individual, then his personal accessibility may not increase. However, someone with less sensitivity to the time cost of travel (such as a wealthy retiree) would have all the benefits of good transportation without the personal costs of travel time.

$$A_n^i = \ln\left[\sum_{\forall \in C_n} \exp(V_{n(c)})\right]$$

Where

A_n^i	Accessibility measured for individual *n* measure at location *i*
$V_{n(c)}$	Observable temporal and spatial component of indirect utility of choice *c* for person *n*
C_n	Choice set of person *n*

This type of model accounts for the utility, or at least the *observable* portion thereof, derived by a particular individual for all choices from a set of choices. Increased complexity arises from the need to specify a choice set and the utility derived from specific choices. However, this model of accessibility is arguably an improvement over place-based models because it acknowledges the significant variability among individuals' calculi of accessibility.

While more refined than area-based measures of accessibility, cost-based models do not necessarily address all of the possible variability in individuals' choice sets. Even the value of travel time, a key component of microeconomic behavior models, is debated by transportation economists as either a cost or a benefit (Batley 2007; Jain and Lyons 2008).[3] A particularly important constraint that is usually absent or poorly specified in microeconomic models is information. Individuals cannot make an economically rational choice without complete information, but no individual possesses complete information about all opportunities available

[3] Economists have had difficulty ascribing a straightforward value to the cost of travel time, despite the importance of this value to so many urban economic models. Essentially, while it would seem that the time required to travel should be a linearly associated with an increasing cost of reaching a destination, empirical studies (as elaborated in the citations above) find a set of "complications" in how individuals value travel time, including abrupt increases in perceived cost after a given length of time, effects associated with the reliability of travel time, and even findings that in certain cases, individuals view travel and associated time as a benefits in themselves, not costs. (Mokhtarian and Salomon (2001).

and all means to reach them in a given environment (Arnott, de Palma et al. 1999; Gobillon, Selod et al. 2007).

While the information constraint can be included in economic models of accessibility, economic theory neither directly addresses how individuals acquire their information about the built environment, nor how such spatial information is utilized to make activity choices (Kwan and Weber 2003). Kwan and her co-authors stand out for having explored alternative behavioral conceptualizations of accessibility. Kwan specifically has emphasized a conceptualization based on cognitively-mediated knowledge of the built environment (Kwan 1998; Kwan 2002; Weber and Kwan 2003). The means by which individuals assemble and employ information to make activity and travel choices in discussed in detail below, in Section 2.2.

Recently, a new generation of research on the impact of information technologies on travel behavior has increased emphasis on the link between information and travel behavior, complementing the work of Kwan (Gaspar and Glaeser 1998; Golob and Regan 2001; Axhausen 2005; Alexander, Hubers et al. 2011; Aguiléra, Guillot et al. 2012). These studies revisit the theoretical importance of information in shaping how individuals organize their activity and travel patterns. Empirical findings have been limited so far, but these researchers hypothesize that access to information plays a large role in daily activity and individual accessibility.

2.1.2 Travel Behavior and Activity Time-Spaces

Predicting travel behavior is a long-standing, significant part of transportation planning research. Travel demand modeling is a legally-required component of regional transportation planning and major publicly-funded transportation investments (FHWA 2011). Most traditional travel demand models – called four-step models – are based on aggregate, area-based data about populations and traffic flows. Over the past two decades, however, a new type of travel demand modeling, called disaggregate activity-based modeling, is increasingly viewed by travel behavior researchers and practitioners as a more conceptually sound and robust way to predict travel behavior than aggregate four-step models (Kitamura and Supernak 1997; Lee-Gosselin and Pas 1997; Mahmassani 1997; Pas and Harvery 1997; Stopher 1997; Meyer and Miller 2001). Central to the disaggregate activity models is the notion of "random utility maximization" (Marschak 1960; Manski 1977). These models predict travel choice in part on a randomized model of activity. The random component is necessary because available models cannot perfectly account for the way in which an individual will derive benefit from a set of choices.

Essentially, so much of the actual travel choice is unexplained by existing activity-based models that the observed range of behaviors has to be randomly assigned to modeled actors, rather than predicted based on casual factors. As a result, demand modeling researchers continue to seek "alternative behavioral frameworks for modeling traveler behavior" (Chorus, Arentze et al. 2008, 2). Thus, a cognitive behavioral framework may be a useful contribution to the field as it may account for a significant portion of the unexplained variation in current models. However, to this point, only Kwan and a few other behavioral geographers have begun to explore how cognitive processes might shape such choices (Golledge and Stimson 1997; Kwan and Weber 2003; Golledge and Gärling 2004).

Associated with travel demand modeling but more expansive in its scope, theorization of individuals' urban-scale activity is also associated with the concept of activity time-spaces (Hägerstrand 1970; Kwan and Weber 2003; Miller 2007). An activity time-space is the spatial and temporal distribution of an individual's presence and activity in a given environment, such as a city. Figure 2.2 is a classic illustration of an activity time-space. The critical conceptual contribution of activity time-space literature, at least for the purposes of this research, is the dimensionality of an individual's behavior – dimensions that can be measured and analyzed. According to Kwan and Weber, the dimensionality and constraints of activity time-spaces are indicative of and associated with an individual's accessibility (Kwan and Weber 2002; Kwan and Weber 2003; Kwan and Weber 2008). In this interpretation, accessibility is potential action while activity time-spaces represent the action taken.

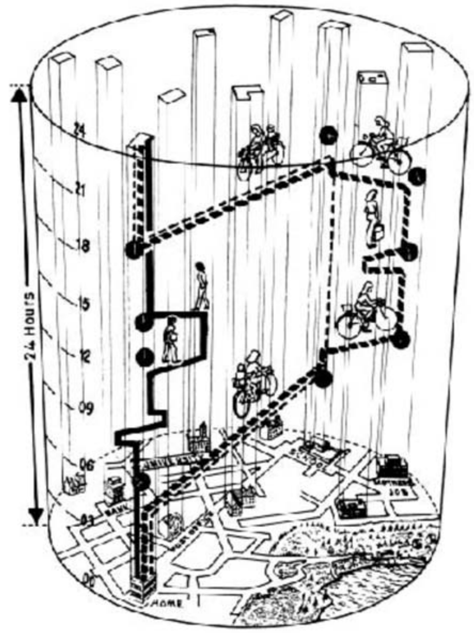

FIGURE 2.2 Hägerstrand's Time-Space Fishbowl

Several transportation and urban researchers have embraced the notion that components of the activity time-space can be empirically measured and tested for relationships to traditional measures of travel behavior and key personal and household characteristics such as income, sex or race. Activity patterns can also be considered solely in terms of their spatial dimensions, thus termed "activity spaces" rather than "activity time-spaces." Activity space concepts and analysis are appropriate to research questions that focus on the extensiveness of a person's travel behavior and activity patterns. Activity space concepts are employed in urban and transportation research to analyze topics including social exclusion, opportunity, leisure activity, and access to health (Schlich, Schoenfelder et al. 2004; Novák and Sýkora 2007; Kwan and Weber 2008; Zenk, Schulz et al. 2011). Schoenfelder and Axhausen (2003) use elements of activity spaces, such as their size and the frequency of travel, to explore whether they vary across socioeconomic groups. Activity spaces have also been used in analyses of physical activity and the built environment, facilitating a more refined understanding of how individuals make use of varying configurations of the urban environment (Zenk, Schulz et al. 2011). Fan and Khattak (2007) find that the size of activity spaces varies depending on the density of the built environment, influencing the distance to which individuals travel to accomplish daily activities.

2.1.3 Extensions to Other Fields and Relationships to Other Planning Concepts

Importantly, the activity space concept extends beyond geographic and transportation research. Similar concepts exist in other disciplines, suggesting new directions for activity space theorization and analysis. In environmental psychology, the spatial extension of the individual has been termed the "lifeworld" (Seamon 1979). The lifeworld is constructed of both physical and cognitive space. The psychological nature of this space suggests that activity spaces can be acknowledged as having a cognitive component, the space within which a person has knowledge of, or perhaps a level of comfort with, pathways and destinations.

One of the primary challenges in studying activity spaces has been the development of empirical measures (Newsome, Walcott et al. 1998; Rai, Balmer et al. 2007). The raw data used to construct activity spaces can be collected over a variety of time periods and at different levels of geographic precision. Further, diverse quantitative and qualitative measures can be extracted, depending on the characteristics of the raw spatial data and the conceptual questions being asked. In transportation research, the standard deviational ellipse has often been the measure of choice for interpreting the extensiveness of individuals' activity spaces (Newsome, Walcott et al. 1998; Rai, Balmer et al. 2007). Other measures of activity spaces include path length and kernel density estimates (Schönfelder and Axhausen 2003).

Ecological and animal researchers have made use of the "home range" concept (Burt 1943). The home range is the space or territory within which an animal or group of animals live and carry out their daily functions. While the home range concept is evidently similar to the activity space concept, researchers in the field have developed a separate set of methods for analyzing home ranges that may be useful for human activity researchers as well (Worton 1989; Getz and Wilmers 2004). The measure of an animal's home range is called a "utilization distribution," and methods to develop utilization distributions include both parametric and non-parametric methods, including minimum convex polygons, kernel density maps, and local convex hulls.

Observed travel and activity patterns can delineate how individuals or groups are able to take advantage of opportunities distributed through the urban environment. Thus, activity spaces are a possible measure of accessibility (Kwan 2002). Inasmuch as accessibility is important for positive socioeconomic outcomes, activity spaces should be correlated in some way with outcomes for urban dwellers. Some urban and transportation research has addressed similar issues. The Spatial Mismatch hypothesis proposed that for inner-city blacks, housing segregation was more prevalent than employment segregation, meaning that blacks were less able than others to follow job opportunities into the suburbs (Kain 1968; Holzer 1991; Ihlanfeldt and Sjoquist 1998; Gobillon, Selod et al. 2007). Subsequent research has suggested that spatial distance in itself may not be the problem, but rather poor access to automobiles to traverse those long distances to the suburbs (Taylor and Ong 1995; Ong and Miller 2005). Regardless, both the original Spatial Mismatch and its transportation revision underscore that, at least in the case of regional employment, an ability to flexibly travel long distances is associated with positive economic outcomes.

The diverse literature on neighborhoods has also concerned itself with activity patterns and residents' well-being. Early literature emphasized the importance of organizing land uses and activities so that accessibility would be maximized, often without need for a car (Jacobs 1961; Johnson 1996). This thread in the literature has continued to evolve, leading in part to movements and strategies like the New Urbanism and transit-oriented development that seek to organize cities and transportation networks to maximize accessibility with minimal auto use (Congress for the New Urbanism 2001; Cervero and Arrington 2008). However, a countervailing movement can be detected in fields from urban economics to design, in which the hierarchical organization of cities, and with it the constrained travel patterns of traditionally conceived neighborhoods, are no longer appropriate to contemporary cities and lifestyles (Gordon and Richardson 1996; Vale and Warner 2001). Collectively, this literature underscores that activity patterns and urban form are intertwined, and that the resulting interaction can result in diverse outcomes for urban dwellers.

2.2 Cognition and Cognitive Mapping

In *Image and Environment: Cognitive Mapping and Spatial Behavior*, Roger Downs and David Stea define cognitive mapping:

> Cognitive mapping is a construct which encompasses those cognitive processes which enable people to acquire, code, store, recall, and manipulate information about the nature of their spatial environment. This information refers to the attributes and relative locations of people and objects in the environment, and is an essential component in the adaptive process of spatial decision making (1973, xiv).

Both a process and a product of the mind, cognitive mapping is essential for spatial behavior and decision-making whether rummaging in a refrigerator or travelling across a continent. The primary purpose of cognitive mapping is to enable individuals to make choices related to the spatial environment. These choices are based on sensory perceptions of space and qualitative preferences, whether for places, experiences, people, or otherwise (Golledge and Stimson 1997). Cognitive mapping relates perceptions and preferences within a spatial matrix. This mixture of qualitative and spatial information in the cognitive map allows individuals to make decisions in a spatial context (Suttles 1972). Greater understanding of cognitive mapping facilitates greater understanding and more accurate prediction of human spatial behavior (Kitchin and Blades 2002).

2.2.1 The Nature of Cognitive Mapping

A cognitive map includes spatial information about the environment, including places' and routes' identity, location, distance, direction (Downs and Stea 1977). Both person-to-object relationships and object-to-object relationships are contained within the cognitive map (Golledge and Stimson 1997). The cognitive map is the end product of a cognitive mapping process. Liben (1981) has termed the space within a cognitive map as "psychological space." It is:

> Any space which is attributed to the mind…and which would not exist if minds did not exist… In contrast, physical space is any space attributed to the external world independent of minds (Liben, Patterson et al. 1981, 5).

Cognitive maps embody the space actually experienced by individuals. Its features are mental representations of the physical, external environment. Because cognitive mapping internalizes geography, the temptation to interpret a cognitive map as a mental version of a cartographic map is strong. "In western cultures, however, much emphasis is placed on interpreting and using space represented as a Euclidean metric" (Golledge 1999, 7). However, there is no simple, one-to-one relationship between cognitive mapping and a cartographic representation of space.[4] Instead, the cognitive map should be taken as a metaphor for a cognitive construct that is much less literal than a cartographic map (Downs 1981; Gattis 2001).

As a mental construct, the cognitive map is not a flawless or photographic representation of physical space:

> So it can be expected that spatial representations in humans are incomplete and error prone, providing the distortions or fragmentations frequently mentioned by research on human spatial representation (Golledge 1999, 13).

The incomplete and error-prone nature of cognitive mapping causes variability between the cognitive maps of individuals and serves to explain the "bounded rationality" of spatial behavior (Golledge and Stimson 1997). Individuals may choose seemingly irrational routes or destinations that, within the framework of their cognitive map, are completely logical. Error and incompleteness are not completely random in individuals' cognitive maps. Rather, the variations between individuals are in part due to external factors such as experience, social processes, and demographic factors.

While the realms of activity time-space and cognitive mapping research have overlapped to a degree in the research of Kwan and her co-authors, environmental psychologists have also contributed to the linkage between the mind and activity spaces through the concept of the "lifeworld" (Seamon 1979). The lifeworld concept originates from phenomenological theory, which in a psychological context posits that there is no absolute barrier between person and environment (Gifford 2002). Thus, lifeworlds are the extensions of self into surrounding geographic space. The concept goes beyond a notion of personal space immediately surrounding

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[4] While not a literal map, neuroscientists have shown that cognitive mapping has a real physical location in the human brain, in the hippocampus. Research in neurobiology has shown that this area of the brain grows as cognitive maps become larger and more refined. In the study, researchers found that London cabbies have some of the largest hippocampi – thus cognitive maps – in the world (Maguire, E. A., D. G. Gadian, et al. 2000).

the body to include the idea that people are, in part, their experiences and perceptions of the environment (Tuan 1977). While philosophical in its origins, phenomenology and the lifeworld concept also undergird important foci of urban psychology research such as territoriality and place attachment (Gifford 2002). Critically, the lifeworld concept underscores that the built environment can be understood as a highly personalized phenomenon, with perception and response varying across individuals.

2.2.2 Components of the Cognitive Map

Notwithstanding the caveats that cognitive mapping is metaphorical and error prone, cognitive researchers generally accept that cognitive maps are composed of basic geometric features such as points, lines, areas, and surfaces (Golledge 1999). In a cognitive map, these geometric features represent aspects of the physical environment. "Landmarks" are the major point feature of cognitive mapping and can be any notable, relatively stationary point feature. Landmarks are associated with information such as identity, location, dominance in the hierarchy of all landmarks. Landmarks are also used in the cognitive map as navigation aids: They are travel decision points (e.g. turn here, go a little further) in addition to being origins or destinations.

Lines also play a major role in cognitive mapping, both as boundaries/edges and as routes (Golledge 1999). As routes, lines possess multiple features including length, connecting nodes, directionality from landmarks, linearity or curvature, and assemblages into networks and hierarchies. Areas are used as two dimensional spatial classification devices. They include regions, neighborhoods, communities, urban places, and other arbitrary or political districts. As cognitive constructs, areas are containers of layouts of landmarks and routes and help establish hierarchies of scale. Finally, surfaces are areas with gradient information. Surfaces can simply represent physical topography such as changes in slope or elevation, or they can represent more social, qualitative features such as gradients of perceived crowding, accessibility, or safety.

The geometric nature of the cognitive map is also reflected in the work of Kevin Lynch. In the *Image of the City*, Lynch introduced a typology of cognitive map elements that echoes the one- and two-dimensional geometries described above (1960). Lynch links these geometries to components of urban form familiar to urban designers and planners. Figure 2.3 illustrates one of Lynch's classic representations of a neighborhood – downtown Los Angeles in the mid-20th century – as it might be perceived in a typical cognitive map. The map includes five basic elements: paths, edges, nodes, districts, and landmarks. These features can be used to organize how an individual understands the built form surrounding him or her, and make predictions about how they might behave within a space. Major paths will be well traveled, while edges will block travel. Nodes and districts will be sites of activity, while landmarks are notable but not necessarily activity locales in themselves.

2.2.3 Spatial Learning

Like other mental processes, cognitive mapping develops over time. Developmental psychologist Jean Piaget found that environmental perception and cognition are different in children than in adults (Downs and Stea 1977).

> The cognitive processes are not constant but undergo change with age (or development) and use (or learning). Similarly, a cognitive map is an abstraction which refers to a cross-section, at one point in time, of the environment as people believe it to be (xiv).

FIG. 14. *The visual form of Los Angeles as seen in the field*

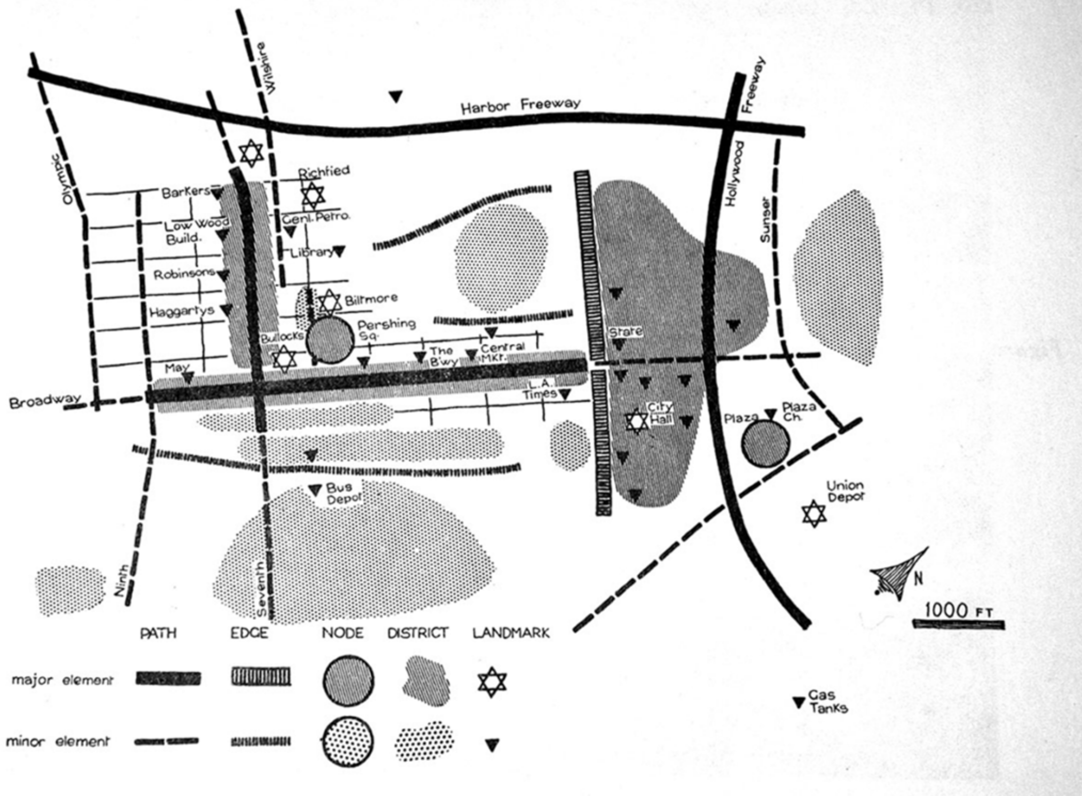

FIGURE 2.3 Downtown Los Angeles as Represented in *Image of the City (Lynch 1960)*

Influenced not only by age but also experience, cognitive mapping is an interactive process, learned mainly "on the fly" through experience and much less through reflection (Downs and Stea 1977). Variations in spatial experience will result in variations in cognitive mapping. While visual information is the primary spatial sense, cognitive mapping has no particular sensory modality but instead spans all of the senses (Golledge and Stimson 1997). For example, the sense of distance in a cognitive map may draw upon multiple sensory and cognitive inputs, including motor response timing, sensation time and velocity, the utilization of patterns in the structure of the physical environment, and interpretation of symbolic representations, such as maps and road signs (Downs and Stea 1977).

In general, spatial learning occurs in a progression from “landmark” to “route” to “survey” knowledge (Shemyakin 1962). After learning of a landmark, isolated landmarks are linked in routes, but individual routes in the cognitive map remain unrelated. However, with greater experience and spatial facility, more systematic knowledge of the environment can be learned, often called survey or configurational knowledge (Golledge 1999). This type of knowledge incorporates isolated routes into a system:

> Sectoral or local regional knowledge may accrue in the vicinity of a route. Initially, therefore, knowledge of an area may develop as a series of strips or corridors surrounding specific routes. This facilitates knowledge integration if the routes are known and are overlapping. Evidence exists that integration of information learned from different routes is not automatic, and may be achieved only partially (11).

As linkages are made between individual routes and locations, increased functionality is added to the cognitive map, such as the ability to devise shortcuts between destinations and create complex trip chains.

Not all individuals reach the same level of development in their cognitive maps. As suggested above, different individuals will have varying abilities in wayfinding and cognitive mapping (Allen 1999). Differences in individual spatial abilities explain some differences in the development of cognitive mapping, such as the ability to think geometrically, image complex spatial relations, recognize spatial patterns, perceive three-dimensional structures in two dimensions, and understand network structures (Golledge and Stimson 1997). Similar personal characteristics that influence the spatial learning process include spatial-sequential memory, topological knowledge, motor capabilities, spatial perception, and general information-processing capabilities. Such capabilities are partly innate in individuals, but researchers have also found that they can be developed and extended through training and use (Golledge and

Stimson 1997). Other mediating factors that influence individuals' cognitive mapping include social and cultural factors including education and income (Kitchin and Blades 2002).

The process of spatial learning is tied to the experiential process of moving through space, in other words, travel:

> A transactionally-based hypothesis concerning our knowledge of urban environments would be that one obtains knowledge about the city according to the type of interactions that one has with it. Thus, urban knowledge accumulates as a result of the various trips undertaken as part of the everyday process of living. Whereas other conceptualizations focus more on the node and landmark structure or areal pattern of urban knowledge, the conceptualization is path based (Golledge and Stimson 1997, 251).

This path-based theory of spatial learning gives travel and navigation a primary role (Kitchin and Blades 2002). Secondary spatial learning comes from books, maps, and conversation.

The cognitive process of wayfinding allows humans expand their cognitive map:

> Wayfinding is taken more generally to involve the process of finding a path (not necessarily previously traveled) in an actual environment between an origin and a destination that has previously not necessarily been visited. Wayfinding can thus be identified with concepts such as search, exploration, and with incremental path segment selection during travel. Wayfinders can also use technical assistance (e.g., compass, global positioning system, network map) but, more often, use cognitive maps (Golledge 1999).

Each of these acts allow individuals to learn about their environment (Downs and Stea 1977). This process is shaded by emotional, value, and belief considerations. As the product of the wayfinding process, route-based knowledge is the most basic type of spatial knowledge (Golledge 1999). Landmarks and routes between places and/or people are usually the first things learned when traveling through a new environment.

Not only route knowledge is developed through the wayfinding process. Landmark knowledge of the environment such as potential destinations and other opportunities are also learned through traveling. Navigation through the environment occurs through a systematic process of movement along vectors defined at their beginnings and ends by “choice points.” Choice points are the locations where individuals make some necessary decision in navigation, such as a change in direction. Interestingly, “environmental cues or other features of the environment have the highest probability of being perceived and recognized if they are in the immediate vicinity of choice points” (Golledge and Stimson 1997, 165). Therefore, individuals are most likely to learn about opportunities in the environment if those opportunities are near choice points. Hence, nodal points in the transportation network are important locations in the landscape of daily life. Some have proposed defining spatial behavior in terms of “activity spaces” which are defined by the dispersion and frequency trips taken on a daily basis, with home at center of each activity space (Golledge and Stimson 1997).

The hierarchical nature of land use patterns and transportation systems in urban environments can also affect the cognitive mapping process. In general, the more significant a particular pathway or landmark is to an individual’s navigation, the more it will dominate the cognitive map (Golledge and Stimson 1997). The hierarchies of pathways in a region, such as highway and freeway segments dominating arterial and main roads, which in turn dominate local community and neighborhood street systems, contribute to the hierarchical organization of cognitive maps. In fact, individuals will recognize elements in the environment more quickly if “primed” by a cue from the same portion of their regional hierarchy. Zannaras (1973) found that the layout of a city significantly explained variations in the accuracy of wayfinding and location tasks. Sectorally-organized cities proved the more effective for remembering locations, while concentrically-organized cities made wayfinding and location tasks more difficult.

2.2.4 Travel Behavior and Cognitive Mapping

Travel and wayfinding are integral parts of spatial learning and behavior. In spite of this connection, transportation researchers have only engaged with cognitive mapping to a limited degree. Cognitive mapping research, however, has the potential to address the enduring focus on accessibility in transportation research. While accessibility has traditionally been conceived as proximity of (or impedance cost of travel between) one location and others, cognitive mapping research shows that physical distances are only one factor shaping how individuals make choices in a spatial context (Kwan and Weber 2003). Individual differences, including prior travel experiences, cultural preferences, and spatial abilities, shape the cognitive map and, thereby, the cognitive proximity and accessibility of potential destinations in a region. As a result, travelers don't necessarily follow the "rational" path selection routines of standard travel models (Golledge 1995).

Golledge suggests that different degrees of spatial ability and knowledge are required for different types of travel:

> Knowing places and routes suffices for everyday behavior. But when interpretation of an environment is needed, or when spatial inferences (such as taking shortcuts through unknown areas or deciding where an urban function might be found) is required, I suggest that another type of spatial knowledge – configurational or relational knowledge – is essential (Golledge 1992, 212).

Stern and Portugali (1999) summarize the factors that influence travel behavior, specifically route choice (as opposed to the decision to make a trip in the first place):

> Decision-making and choice behavior in urban navigation is affected by four components:
>
> 1. The trip purpose that actually determines the frequency of the individual's navigation. Commuting to work or daily travel to school, for example, would be the most frequently practiced navigation, while visiting a city in a foreign country for the first time would be the least practiced form of navigation.
> 2. The navigator, including his or her personality, sociodemographics, and especially spatial knowledge and experience. These personal characteristics

would govern, in various ways, the retrieval of information, the spatial ability of the navigator, and the speed of data processing.

3. The means of navigation, which entail various constraints on the physical options of choice. Owing to legal or physical restrictions, truck drivers, for example, would have fewer routes available in the city than drivers of small vehicles, but more routes than cyclists.
4. The specific situation in which navigation is practiced, which determines the choice set and the choice setting. The situation may refer, for example, to location (i.e., choice setting) in space and time, thus determining the number of available and feasible alternate routes. (101)

A combination of physical and practical considerations mediated through a person's particular cognitive map, shapes route choice. Importantly, "travelers can only choose from options of which they are aware, so information affects choice set generation and is instrumental in defining feasible opportunity sets for each trip purpose" (Kwan 1998). Familiarity becomes an important part of route choice, and familiarity is dependent on experience. Stern and Portugali highlight two aspects of route familiarity: (1) specific experience of a given locality and (2) general familiarity with city structures, the hierarchy of roads, traffic and signage (1999).

Researchers have found various features of cognitive mapping that influence individuals' travel behavior in ways that do not always fit within traditional, economically-derived models of travel behavior. For example, the rate of cognitive distance increase slows as actual physical distance increases (Golledge and Stimson 1997). The further one goes, the less one feels it. However, in terms of work trips there are limits beyond which people are not prepared to commute. "These limits are perceived distances, and they vary in accordance with individual travel preferences, the access of an individual to various modes of transportation, and the structure of the transportation system available in the city." (284) Some transportation research has also picked up on the psychological complexity inherent in how travelers value time and distance. For example, research shows differences in how transit users perceive time while moving and while waiting, with waiting time being more onerous (Iseki and Taylor 2009).

Others have found that drivers perceive transit travel time to be longer than it actually is when asked to compare between modes (Exel and Rietveld 2010).

Fragmentary evidence suggests that cognitive maps are shaped differentially by alternate modes. For example, individuals who rely extensively on public transit or walking, on average travel shorter distances and travel less frequently than those who travel by motor vehicle (Boarnet and Crane 2001; Pisarski 2006). Therefore, one can hypothesize that the scope of their spatial knowledge would be differently scaled and configured than those who rely on automobiles and travel longer distances at greater speed and route flexibility. The characteristics of travel by transit, which include indeterminate waiting at transfer points and walking trips between services, may add to cognitive distance in ways that auto travel does not (Iseki and Taylor 2009).

While cognitive mapping researchers have recognized the connection between travel and spatial learning, little is yet known about how the existing transportation infrastructure shapes cognitive mapping. In general:

> Little research has been completed on the creation of network knowledge and the relationship between network knowledge systems and real world transportation systems. We all realize from personal experience that our knowledge of existing networks is partial. (Golledge and Gärling 2001, 6).

Most research on the relationship between cognitive mapping and transportation has not attempted to compare the effects of varying transportation infrastructure or modes but has taken such networks as constants in the analysis. However, the research that does compare transportation modes' effects on spatial knowledge indicates that different modes do shape cognitive maps in different ways. In a study of children traveling to school, active modes of travel appear to contribute more to the development of spatial knowledge than passive modes of travel. Walking and cycling to school facilitated increased knowledge of the environment relative to those children who were bused (Hart 1981). These results suggest that differences in transportation mode may result in different types of accessibility for individuals from otherwise similar socioeconomic or cultural backgrounds.

The literature on cognitive mapping and travel choices also meshes with the small body of literature on "habit" in travel choices (Verplanken, Aarts et al. 1997; Bogers, Viti et al. 2005). Habit encompasses the idea that individuals may limit their travel choices to a set of familiar choices with which they are psychologically comfortable. In this literature has found that those with strong habits acquire less information when they travel and do not make as many active choices about mode and destination. Those with strong habits may be correlated with individuals that cognitively are highly reliant on landmarks and more constrained in their knowledge of destinations and routes.

2.2.5 Cognitive Mapping and Social Differences

This review has so far focused on the cognitive mapping process in isolation from social factors. However, society is structured in a spatial framework, and cognitive mapping is a component of social organization. Social groups can have "collective" cognitive maps with distinctive characteristics which define social spaces and relationships to other groups (Golledge and Stimson 1997). Individuals within a social group can exhibit similarities in their cognitive mapping that do not extend to other groups. The conceptual structuring of spatial information varies not only with individual experience but also across cultures (Ramadier and Moser 1998; Kita, Danziger et al. 2001). For example, a 1971 study of Los Angeles neighborhoods found that different racial-ethnic groups in the city had different perceptions of overlapping physical spaces

(Orleans 1973). Portugali and Haken (1992) found that rival cultures "eliminated" their rivals' areas from their own cognitive maps.

In *Beyond the Neighborhood Unit: Residential Environments and Public Policy*, Banerjee and Baer also found that characteristics of an individual's cognitive map are related to their socioeconomic characteristics (1984). Specifically, different groups tended to draw different size neighborhood maps. In their study, while upper-income white residents often drew broad ranging maps that encompassed large areas of many square miles, many lower income residents (of varied ethnic/racial groups) drew maps that were focused on smaller areas, sometimes just an intersection or apartment complex. Banerjee and Baer found that such variations in neighborhood map size reflected not only different spatial locations in the city but the varied level of mobility and access associated with different communities. I found similar results in my own analysis of the neighborhood boundary maps of residents of Los Angeles' Koreatown (Mondschein 2004). In Koreatown, I found that Koreans had much more spatially expansive view of Koreatown than Latinos who actually comprise most of the residential population of the area.

Loukaitou-Sideris and Gilbert also explore the depth and complexity of cognitive maps, including how different socio-cultural groups may perceive the same place differently:

> …the rich diversity of people's perceptions and views. People attach meanings to the spaces where the live or work in varying ways; they use and appreciate some spaces but dislike and avoid others. These different readings of the built environment, which are influenced by various factors, ultimately affect people's use of space (2000, 22).

Loukaitou-Sideris and Gilbert point out that each individual's cognitive map includes a variety of information associated with a place, including typical services and activities available, preferred patterns of movement, as well as more subjective perceptions, such as the level of safety and personal comfort. Different socio-cultural groups exhibit significant differences in their perceptions of urban space, in this case downtown Los Angeles. For example, street vendors tended to feel less safe downtown when compared to office workers. Different groups not only have access to different portions of the environment, but construct their cognitive maps differently. For example, office workers tended to focus more on buildings as defining characteristics of a place while street vendors attributed spatial character more to people and qualities of place such as dirtiness and hostility. Similarly, Ramadier and Moser found that in a study of cognitive mapping in Paris, Europeans tended to utilize physical attributes of places in their cognitive maps while Africans tended to focus on functional qualities of places (1998).

2.3 Building on the Literature

The literature contributes a set of principal findings that I will draw on throughout the dissertation. Foremost is the idea that accessibility can be defined in terms of the individual, both in terms of their location and their personal characteristics. In addition, individual accessibility can be conceptualized and analyzed in terms of personal activity spaces, the zone within the city that a person covers in order fulfill their needs and wants. Kwan contributes the idea that information plays a central role in how people make their activity and travel choices.

Other key findings flow from the review of cognitive mapping and environmental psychology research. The literature shows that cognitive maps vary among diverse urban populations, whether categorized by income, ethnicity, or sex – populations among whom access to opportunities also varies. Most important for this dissertation is the idea that the cognitive map, with its role in activity and travel choices, develops to a great degree through the experience of travel, where wayfinding and navigation are needed to accumulate spatial information. Researchers have also theorized a spatial learning process that facilitates cognitive map development, proceeding from landmark to route to survey knowledge.

While the literature provides an important foundation for the proceeding research, it also contains several gaps and unanswered questions to explore. One of the foremost questions is what the role of urban form and planning interventions in daily activity patterns might be. Answering this question would help address whether the built environment has much role in shaping individual accessibility. Additionally, there has been little development of a cognitive framework for understanding activity patterns, particularly in comparison to the dominant microeconomic approach. While cognitive research in geography and psychology has created a fairly detailed schema for explaining how the cognitive map develops through travel experience, there has been relatively little exploration of how this process unfolds in large, contemporary cities where multiple modes of travel are available. Again, much like activity space research, even if there is a typology for explaining cognitive maps in terms of urban features, there has been little exploration of the role of urban form in cognitive map development.

The literature and its gaps contribute to a conceptual framework for thinking about accessibility, activity, and cognitive maps. I describe this framework, termed “the personal city,” in great detail in the next chapter. The personal city framework links information about opportunities and routes with individual accessibility. It posits that accessibility is in some ways a learned facet of daily life, fostered primarily through active travel experiences. This conceptualization establishes a bridge from the literature to the empirical research that follows.

Chapter 3

Conceptual Framework: The Personal City

Planners commonly deal with geographic, legislated, and functional boundaries that define a space for policies and interventions. Those useful boundaries exist at many scales, from parcel to neighborhood to city to region, and they establish an orderly scheme for thinking about cities. However as the activity space and cognitive mapping literatures suggest, the life of the individual or household may not be so easily slotted into this classic urban hierarchy. Not even neighborhoods, much less whole cities or regions, look the same for people who may live next door to each other, but have different demographics or just different lives (Banerjee and Baer 1984; Vale and Warner 2001; Mondschein 2004). In this dissertation, I seek to understand variability among people's relationships to the city. I argue that the extent of a person's travel and activity patterns, and the underlying spatial knowledge that goes with that behavior, can tell us something original about the way planners serve urban residents through transportation and land use interventions. The scale of a person's activity and spatial knowledge is a measure of opportunity and of planners' success in getting people to those opportunities. We can thus ask whether we as planners facilitate access to a complete personal city within the geographic one, or just a partial sliver of what might be possible, needed, or desired.

This chapter presents a conceptual framework, I call "the personal city," that links the empirical analysis chapters that follow to a distinct way of thinking about cities, behavior, and opportunity. This conceptual framework is built upon the literature review (Chapter 2), and largely deals with the concepts introduced there, including accessibility, activity spaces, and cognitive mapping. I seek to understand what planning actions remain relevant to accessibility when controlling for human factors and to locate instances where planners may have been successful or failed in changing the nature of the human relationship to the city, and thus their access to opportunities.

In this chapter, I address some of the central themes that arise from the literature review with a framework that supports empirically testable hypotheses such as those in the later chapters of this dissertation. First, I draw on the literature review to establish a conceptualization of a person's relationship to urban living that I term "the personal city." Then, I discuss the types of research hypotheses that may be informed by the personal city framework. I conclude by describing the potential contributions of this framework to planning research, as well as its potential weaknesses in light of the literature and planning practice.

3.1 Personal City: The Zone of Experience

The personal city concept emphasizes the spatial component of individual accessibility and everyday life. It suggests that the urban area within which an individual has regular experiences is distinct from the city outside that area, and by assessing this area and its composition, we can better understand an individual's ability to successfully make use of opportunities in the urban setting. The personal city is informed to some degree by the environmental psychological concept of the "lifeworld." The lifeworld is the extracorporeal, extensible part of the self (Seamon 1979; Gifford 2002). From the lifeworld concept derives the notion that there are some places with which a person is familiar and comfortable, while other places lie outside the zone of experience. That zone of experience comprises "the city," not as defined by municipal boundaries but by its usefulness and accessibility to the individual.

I argue for a normative component to the personal city, in line with the norms of transportation planning and research as it has prioritized *access* over the past decades. Does the space of experience and familiarity contain a full complement of destinations – opportunities – that would allow individuals to fulfill their needs and desires? A complete personal city would putatively encompass a wide range of opportunities, readily reached by available modes of transport. An incomplete, stunted personal city would leave an individual with few options and difficulty in meeting their needs, due to a lack of opportunities, inadequate knowledge of opportunities, and/or an inability to reach them.

To employ the personal city concept in social scientific research requires detailed explication. One of the most important aspects of the personal city is that it can be alternately defined in terms of actual activity and behavior or in terms of the potential for activity. Whether pertaining to action or potential action, the research discussed in the literature review provides theories and associated methods that mesh with the personal city concept. Activity space theory and methods are appropriate for understanding the personal city in terms of everyday activity and travel, while cognitive mapping research embodies the personal city as the range within which an individual has the potential for action.

3.1.1 Complete City: Action

One way to operationalize the personal city is as an activity time-space. Kwan and others have already laid much of the groundwork for a complete city measured in terms of activity patterns, under the rubric of individual accessibility (Hägerstrand 1970; Kwan 1998; Kwan, Murray et al. 2003; Weber and Kwan 2003). An activity-time space is the aggregate of an individual's (or household's, or group's) activity and travel patterns over the course of a day, week, month, or other time period. While time of activity is certainly significant as opportunities themselves are time-dependent, the spatial aspect of activity time-spaces is most important for the personal city concept. Each new action or trip typically results in the incorporation of more "territory," defined in terms of space or opportunities, into the personal city.

Thus activity spaces (leaving out time, for the moment) are synonymous with the personal city, much as Kwan uses activity spaces to measure individual accessibility. The personal city is the product of long-term experience, so an activity space measured over an individual's entire life course, or at least from their moment of arrival in a city, would be most descriptive of the personal city. Whether that personal city is complete or not depends on its dimensions and contents. How far must a person go to meet their daily needs and wants? How much time (and money) costs must been paid to reach needed and desired destinations? How does one's personal city compare to a neighbor's, or someone of different socioeconomic status? Does the personal city contain a full complement of services and opportunities that are considered to be essential to a "good" life? These aspects of the personal city can be observed in activity spaces.

3.1.2 Complete City: Potential Action

As Kwan and her coauthors (Kwan 1998; Kwan 1999; Kwan, Murray et al. 2003; Kwan and Weber 2003) have argued, activity patterns are a good measure of an individual's accessibility. Past behavior can be used to predict future opportunities. The reason why prior patterns describe the future is due to the experiential and habitual nature of urban-scaled behavior. As the discussion of spatial learning in the literature review explains, travel is the primary means by which individuals learn about their surrounding environment. Over time, travel patterns establish an area within the city for which a person has better information and greater familiarity. As described above, this area can be defined in terms of the activity space. However, in terms of its predictive power for future travel, and thus accessibility, an activity space may be a second-order approximation of the primary motivator of activity and travel choices: the cognitive map.

The cognitive map can be understood as the repository of a person’s urban lifeworld, or their personal city. Compared to an activity space, the personal quality of the cognitive map is inherent. The contents of the cognitive map, much like the boundaries of an activity space, may be indicative of the parts of the larger city with which a person is familiar and comfortable. Liben, Patterson et al. (1981) term the cognitive map “psychological space,” and in this sense the personal city is urban psychological space. The cognitive map describes the potential to take part in the city, in that people use the cognitive map to make their decisions of where to go and how to get there (Downs and Stea 1973).

Particularly useful for the conceptual framework are the developmental theories that underlie cognitive mapping. For most individuals, cognitive maps accrete over time, primarily through the experience of travel (Golledge and Stimson 1997). Thus, the personal city is learned, building and becoming more refined over time, as an individual travels more throughout the city. However, this development process also ensures that major leaps in spatial knowledge, or expansions in the personal city, cannot occur instantaneously, but must be cultivated over time and experience. This process suggests that individual accessibility can be altered, but insofar as the cognitive map drives activity and travel choices, only gradually.

The cognitive nature of the personal city gives it dimensions beyond physical extent or destination counts. Cognitive maps have multiple qualities that differentiate them from physical maps, including error and distortion (Kitchin and Blades 2002). Thus, the personal city may not just be constrained, but it also may be wrong, or at least inaccurate, vis-à-vis the physical geography and arrangement of cities and transport networks. Furthermore, the personal city can be colored with qualities that are distinctively human, such as emotion and opinion that may shape choices in visceral ways that may not hew to standard economic rationality.

The cognitive component of the personal city requires that individuals possess within their cognitive maps a wide range of destinations and enough information about those destinations and the transportation network to be able to choose and travel to them with relative ease. The nature of a "complete" cognitive map is, in itself, a topic of research, and one on which relatively little progress has been made since *Image of the City* (Lynch 1960). However, as the hypotheses below describe, cognitive mapping research can at least facilitate comparisons between the maps of individuals and groups, helping to determine whether some individuals' personal cities are more complete than others'.

3.2 Conceptual Hypotheses

The proceeding chapters of empirical analysis include distinct hypotheses, tested using relevant data and methods. However, the personal city framework elicits hypotheses at a more conceptual level, providing predictions of this framework's implications for cities and their residents. Overall, the most central "prediction" of the personal city hypothesis aligns with the findings of prior individual accessibility analyses. Accessibility cannot be measured solely in terms of spatial location, but also must account for variations in individual characteristics. Beyond this fundamental argument, in line with individual accessibility research, the framework gives rise to several more focused hypotheses, distinctive to the personal city concept.

3.2.1 The Value of Travel for Personal Opportunity

The personal city framework posits that more is better. The personal city becomes more complete as it incorporates more destinations and information. Whether modeled in terms of activity space or the cognitive map, both models require – all else being equal – more activity and travel to increase the size of the personal city, and thus accessibility.[5] Thus, travel in the personal city is not just a derived demand, engaged in to get from home to a set of destinations, but an integral part of the process by which individuals increase their ability to take advantage of the city's opportunities. Transportation planners already expect that increased travel will be associated with higher socioeconomic status, because better resources typically allow individuals to avail themselves of both of better transportation options (e.g. reliable car access) and potentially more leisure time to travel (Boarnet and Crane 2001). The personal city framework suggests that these advantages are reinforced by the experience, familiarity, and increased knowledge made possible by increased travel.

The fact that there may be an iterative process at work, with increased travel resulting in better accessibility, leading to better individual outcomes, which in turn result in increased travel, makes testing this causal hypothesis more difficult. The first step is to observe a positive relationship, regardless of causality, between larger personal cities and higher socioeconomic status, controlling for other factors including land use density. Also important is to determine whether measures of the personal city explain variation in socioeconomic status differently or more accurately than other, less spatially-definite measures of travel such as number of trips or

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[5]Land-use densities, patterns, and transportation infrastructure – the "planned city" – affect how far and how frequently one must travel to access opportunities. Thus, a dense, mixed-use city may require less travel to access a given number of destinations than a low-density regimented area. However, for any given urban setting, the personal city concept would argue that more travel is better for long-term accessibility.

vehicle miles traveled (VMT). This may be possible using a large regional travel survey, as I do in Chapter 5.

To fully untangle causality is this hypothesis would require an experimental design that separates the derived demand for travel from the experiential benefits posited by the personal city framework. For example, it may be possible to find differences in economic outcomes for a population like welfare recipients. In an experiment, one group of welfare recipient might be given personal access to a car and the other group would be provided unlimited access to transit and paratransit. The personal city concept supplies the hypothesis that even with unlimited modal access, the transit group may have poorer outcomes than the auto group. Such an experiment is beyond the scope of this dissertation, but the value of the personal city may be more completely untangled from other relationships between travel and personal opportunity with experiments like this.

3.2.2 Not all Travel is the Same

In line with the experiment described above and with the argument that travel is not just a derived demand, the personal city framework suggests that not all modes of travel would have the same effect on the development of the personal city, all else being equal. Because the personal city depends on the experience of travel, differences in how an individual experiences the city via his predominant mode of travel will also modify the city in cognitive terms. Even if geographic extent is the same among modes of travel, the literature shows that different modes require different degrees of cognitive way-finding effort (Golledge and Stimson 1997). Those modes requiring more cognitive effort facilitate greater spatial learning, and thus a more complete personal city.

The conceptual framework thus leads to the hypothesis that for a given amount of travel or activity, more cognitively demanding modes, such as walking and driving, will result in a more complete, accurate personal city relative to modes that do not require significant navigation effort, such as public transit or being a passenger. This hypothesis underscores that size is not everything for the personal city, and the contents matter as well. Importantly, this hypothesis accounts for the effects of travel mode without addressing mediating factors such as externally-obtained information (maps, signage, information technologies) or urban form, and it also does not consider the complex multimodal lifestyles lead by many city dwellers (Kenyon and Lyons 2003). It may be that such factors modify the effects of using transit or being a car passenger on the development of a complete personal city in ways that mitigate or undermine this hypothesis.

3.2.3 The Role of the Built Environment in Individual Accessibility

Weber and Kwan (2003) conclude that individual characteristics are far more important than geographic context for understanding accessibility, so much so that, per their findings from the Portland, Oregon area, they describe the influence of urban context on individual accessibility as "weak." However, they also acknowledge that there are limits to their findings. They do not consider the role of mode and its potential interaction with urban form, and Portland is a relatively small metropolitan area with more limited variations in density and form across its breadth. Most fundamentally, they treat urban form as a geographic characteristic, but do not explore how urban form functions for the individual in their experience of the city. In addition, other researchers have found, in other contexts, a significant relationship between the built environment and travel behavior (Ewing and Cervero 2010). Ewing and Cervero's meta-analysis finds that proximity to opportunities does in fact reduce travel and a regional scale.

With the personal city framework, I seek to integrate theorization and findings about how urban form is perceived and used by individuals in their daily activity and travel, such as those of Lynch and Golledge, with the more geographic view of individual accessibility propounded by Kwan. Thus, I hypothesize that the power of urban form in modifying accessibility is likely to be found in differences among individuals in how they use cues in the built environment to make choices about where to go and how to get there. I would expect to find that those individuals with a more limited personal city, in terms of its accuracy and contents, would also have a more rudimentary way of perceiving the built environment. Along the lines of spatial learning theory, I would expect that more limited personal cities would be reliant on landmarks, while more complete personal cities would be built of a wide range of elements, including a more knowledge of networks.

3.3 Consequences for Urban Planning

The personal city framework has the potential to reframe how planners view several of the issues that urban planners emphasize in research and practice. If the conceptual hypotheses described above are borne out, they may – as discussed below – call into question, or at least complicate, policies and prescriptions that are currently widely accepted by transportation planners and urban planners more broadly. The personal city framework is a synthesis of a variety of theories and findings dealing with accessibility, activity, and cognitive mapping. I argue that its potential contribution to urban planning lies in its ability to emphasize that desired urban outcomes often rely on how individuals are likely to respond to various configurations of transportation and land use. While our goals may be citywide in scale and societal in scope, those goals can only be reached by changing the way individuals relate to the city. The personal city framework helps planners focus on that relationship.

Each of the hypotheses described above has a potential implication for how we plan cities and transportation networks. The first hypothesis, which posits that a more extensive, complete personal city is associated with positive outcomes for the individual, has the potential to complicate the way planners pursue the current goal of reducing auto use and increasing sustainability in cities. If additional travel results in enhanced accessibility, then we may need to be more thoughtful about how we seek to reduce overall travel to curb the many environmental externalities of private and commercial vehicle use. Particularly if one of the means of reducing auto use is raising its cost, then those strategies may have a disproportionate impact on those who already have the least well developed personal cities, increasing the negative consequences of travel reductions.

The second hypothesis extends the potential problems of reducing VMT to the issue of encouraging transit use over auto use, a nearly universal objective of transportation planners. If transit travel, compared to auto travel, is less conducive to learning about and becoming adept at navigating the urban environment, that should give planners some pause. Conversely, encouraging biking and walking would appear to be physically healthy and environmentally less damaging modes, that may also enhance cognitive maps and the personal city. Again for those at the bottom of the socioeconomic scales, reliance on transit may be particularly penalizing, limiting not just their flexibility, but their ability to develop a robust, fleshed-out understanding of their city and its opportunities. Importantly, I would not argue that the automatic conclusion be abandonment of transit, but perhaps compensatory solutions, such as better information about opportunities, be coupled with any efforts at increasing transit use.

The third hypothesis states that the built environment plays an important role in how individuals perceive and navigate to opportunities in the city. If valid, the most important consequence here would be to reinforce that urban form may have an important role to play in accessibility. Whether urban form matters for the social outcomes desired by planners, particularly for the reduction of auto-based travel, is a continuously debated topic in the field (Boarnet and Crane 2001; Handy, Boarnet et al. 2002; Krizek 2003; Ewing and Handy 2009; Ewing and Cervero 2010). The personal city framework may serve as a distinctive pathway for integrating urban form and accessibility within a conceptually and empirically robust framework.

While I believe these implications for planning are significant, they are hypothetical and conceptual and must be borne out by empirical research. However, it is also important to acknowledge the potential weaknesses in the personal city concept. Foremost, it is a synthesis of several concepts in the field that may in fact be more succinctly expressed in their original forms. It melds individual accessibility and cognitive mapping research in a way that may be conceptually appealing, yet only have marginal impact on actual behavior and outcomes. It privileges the role of the individual in a field where overall, social outcomes are the objective. Whether these weaknesses negate the value of the complete city framework depends to a large degree on the strength and significance of the findings in the empirical research that follows.

The succeeding chapters of this dissertation translate the conceptual hypotheses described in this chapter into empirical hypotheses and analysis. The first conceptual hypothesis is tested (Chapter 5) in the relationship between activity space extensiveness, socioeconomic status, and land use. I hypothesize that when controlling for density, activity space area is positively related to socioeconomic status. The second conceptual hypothesis, on the role of travel mode, is empirically realized as a test (Chapter 6) of the hypothesis that cognitively active travel modes are associated with higher levels of spatial knowledge and accuracy. Finally, I analyze the third conceptual hypothesis on the role of urban form in the personal city with a test (Chapter 7) of the hypothesis that cognitively passive travelers are more reliant on landmarks in the cognitive maps than active travelers.

Chapter 4

Data and Methods

4.1 Introduction

In this dissertation I use the term "personal city" to describe the urban spatial dimension of daily life. It is the area within which opportunities are knowable and accessible. This dimensionality can be measured in terms of both actual and potential activity patterns across the city. In practice, actual and potential patterns are contained within wholly different datasets, and they are analyzed through different methods. Thus, I draw upon two separate data sources to understand the actual and potential qualities of activity and accessibility, and I employ separate sets of methods to analyze these datasets. The first dataset, a large travel survey developed by the Southern California Association of Governments (SCAG), records the activity patterns of thousands of households and individuals for one or two days, associating those patterns with a wide range of socioeconomic and travel data. The second dataset contains the results of a cognitive mapping survey that explores the spatial knowledge of respondents from two Los Angeles neighborhoods, South Los Angeles and UCLA and its environs. The methods appropriate for analysis of these datasets vary, ranging from spatial statistical model building to the distinctive methods of cognitive mapping analysis.

4.2 Setting

The setting for the dissertation's empirical research is Los Angeles, both at the regional scale and within two neighborhoods at its heart. Los Angeles is the second most populated urban region in the United States, and as with any major city, certain axioms have congealed over the years regarding how people there live and get around. Los Angeles has a reputation as a sprawling, car-dependent city (Gordon and Richardson 1996; Ewing 1997). True, the city does not for the most part look like the eastern cities that are commonly thought to be denser (Hall 2002; Eidlin 2005). However, the Los Angeles metropolitan area has the highest residential density in the nation, nearly seven thousand people per square mile, compared to about five thousand three hundred people per square mile in the New York metropolitan region (U.S. Census Bureau 2012). As for car dependence, Los Angeles lies somewhere in the middle, with the car dominating trips as in most American cities, but still within the top ten transit cities as a percentage of total trips (U.S. Department of Transportation 2011).

Rather than thinking in terms of averages, it is more important for this exploration of the nature of the personal city that the form and activity patterns of Los Angeles are diverse. There are high- and low-density neighborhoods spread throughout, and some neighborhoods are as walking- and transit-oriented as much as almost any other in country, while others are highly auto dependent (Gordon and Richardson 1996; Ewing 1997; Eidlin 2005; Morris 2009). Los Angeles' diversity in form, travel, and socioeconomics increases the possibility that activity patterns and lifestyles will also vary tremendously throughout the built environment and across individuals. This variability is what I seek to understand in this dissertation.

4.3 Datasets

I use two primary datasets, and I describe them in the order they are used in the dissertation, first addressing the SCAG travel survey (used primarily in Chapter 5), and then the Cognitive Mapping survey (used in Chapters 6 and 7).

4.3.1 SCAG Travel Behavior Survey

In its role as a metropolitan planning organization, SCAG develops the Regional Transportation Plan (RTP) for southern California. The SCAG area includes most of Southern California excluding San Diego – Los Angeles County, Ventura County, Orange County, San Bernardino County, Riverside County, and Imperial County. As a part of this process, SCAG collects regional travel behavior data and models regional travel patterns for current and future years. In 2001 and 2002, SCAG conducted an extensive "Travel and Congestion Survey," collecting detailed travel patterns and a wide range of personal information for over 15,000 households in Southern California. The SCAG survey demonstrates variations in activity patterns by location and associates 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 other characteristics of the associated trips to and from the activity (NuStats 2003). Respondent households are weighted according to known demographics for the region, including county of residence and race/ethnicity. The version of the SCAG dataset I use is the internal SCAG version, geocoded at the level of street address, rather than to the census tract level available in the public dataset. This level of spatial specificity allows for the construction of more precise measures of activity patterns than would be possible with census tract level data. In order to preserve the anonymity of survey respondents, I present no individual's disaggregate spatial data in the analysis.

The survey was conducted by a consulting firm, NuStats, for the Southern California Association of Governments (NuStats 2003). The survey collects events from each household for one or two travel days. If two days were collected, one day is a weekday and the second is a weekend day. Because weekday and weekend travel patterns are so different for working adults, I explore both in Chapter 5. To control for variations in activity and trip-making that result from major differences in phase of life, I limit the sample to individuals 18 or more years old. I also eliminate individuals who were not in the region the entire survey day.

Figures 4.1 and 4.2 show the overall spatial contours of respondents' residential locations and the relative density of their daily activities. I estimate these illustrative maps using a simple density – events divided by area – function for the entire sample within a circular area of 2.5 square kilometers around each map cell. Note that these maps show the urbanized portions of the Southern California region, excluding lightly-populated desert and farming areas to the east and north. Figure 4.1 shows where respondents, and thus the Southern California population, are concentrated. The most significant clusters of respondents are around downtown Los Angeles west to Santa Monica and Venice, but other dense residential clusters include the South Bay around Torrance and northern Orange County around Garden Grove.

Figure 4.2 shows the relationship between where respondents live and where they engage in activities as a whole for the entire regional sample. The map highlights that certain places are clusters of activity rather than just population density. Downtown Los Angeles and the west side around UCLA and Santa Monica stand out again, as do a wide range of other locales throughout the region. This map shows that there isn't a constant positive relationship between population density and activity density. However, because the value represented is a ratio, it's important to be cognizant of the fact that absolute activity density is much higher in some clusters than others. For the ratio to be so large in high population density areas like Santa Monica or Torrance requires an especially high number of activities reported per square mile. Conversely, though

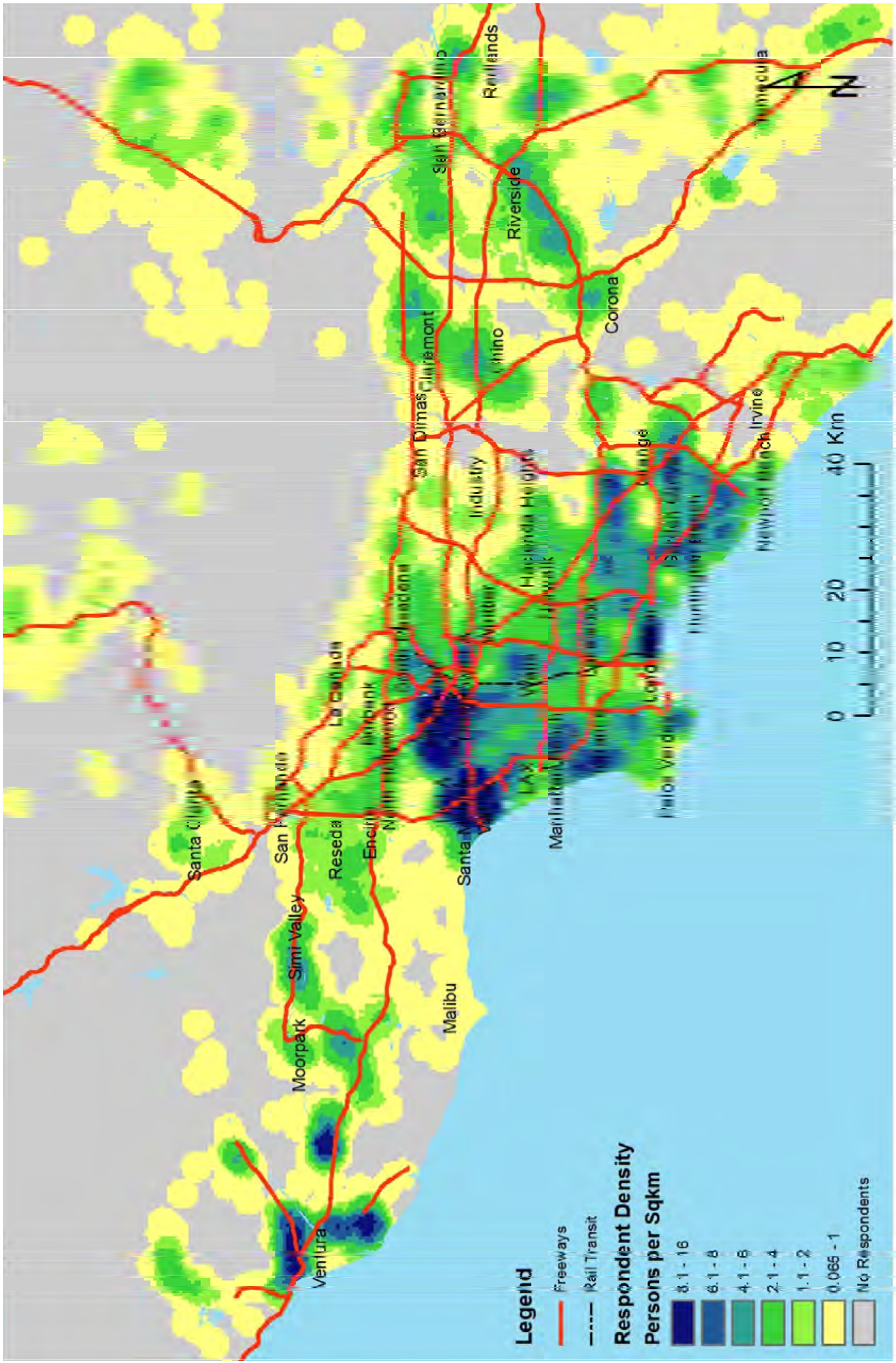


FIGURE 4.1 SCAG Respondent Density (Residential Locations)

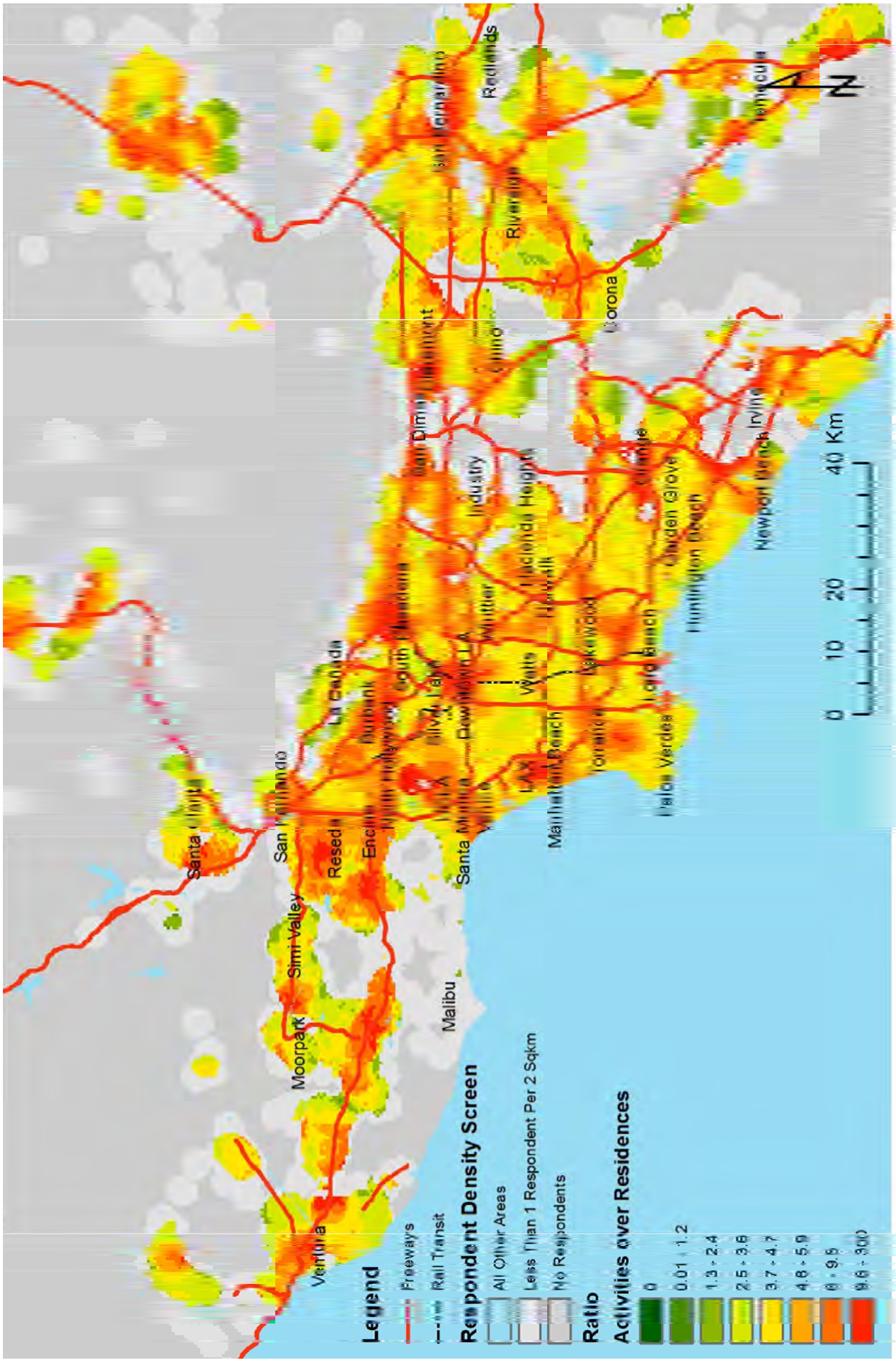


FIGURE 4.2 Activity Density/Residential Density Ratio

relative to total population the number of activities in San Bernardino is high, the absolute number of activities is fairly low.

4.3.2 Cognitive Mapping Survey

The cognitive mapping data presented and analyzed in Chapters 6 and 7 were developed as part of a research project conducted at the UCLA Institute of Transportation Studies entitled "Cognitive Mapping, Travel Behavior, and Access to Opportunity." Professors Evelyn Blumenberg and Brian D. Taylor were co-principal investigators on the project, and I have published some of the results from the survey with them, in addition to using the data here (Mondschein, Blumenberg et al. 2010). We designed the survey to extract from respondents information both on travel behavior and spatial knowledge.[6]

We conducted the in-person survey at two locations, one site in South Los Angeles and the other on the UCLA campus. Figure 4.3 locates the survey sites in their regional context. The South Los Angeles survey site is the Kenneth Hahn Shopping Center, a large commercial center directly adjacent to the Rosa Parks Transit Center. Two light rail lines (the north-south Blue Line links downtown Los Angeles and downtown Long Beach, and the east-west Green Line links LAX with the working-class suburb of Norwalk) and nine local and express bus lines converge at the transit center, supplying the shopping center with a relatively high proportion of transit users compared to Los Angeles overall. To give a sense of transit use in the area, Table 4.1 compares respondents to the SCAG survey living within 5km of the South LA survey site to the trip characteristics of the entire SCAG survey sample. As the table shows, the average

[6] The survey used here was preceded by a telephone-based pilot survey, conducted in the three Los Angeles neighborhoods of Pacoima, Pico Union, and Westwood. The findings of the pilot survey helped refine our understanding of cognitive map data collection for travel research, particularly the need for diverse methods in order to internally validate findings from one question or another.

FIGURE 4.3 Cognitive Mapping Survey Sites and Regional Context

TABLE 4.1 Tripmaking (Average Trips per Day) by Mode in South Los Angeles (within 5km of Survey Site) versus the LA Conurbation as a Whole		
	South LA (<5km from survey site)	Los Angeles Region (entire SCAG sample)
Driving	2.10	3.20
Public Transit	0.20	0.07
Walking	0.50	0.24

individual living near the survey site uses transit three times as much as someone in the region as a whole. In addition, this person drives less and walks more.

Figure 4.4 includes images of the South Los Angeles survey site and its environs. The aerial view provides a sense of the connection between the Rosa Parks Transit Center and the survey site, located just to the south at the Kenneth Hahn Shopping Center. Transit users can use a pedestrian pathway to get directly from the transit center to the shopping center. The transit center itself is a significant complex, built under and in the median of the I-105 freeway. While one of the most important transfer centers in Los Angeles' rail system, the complex as a whole is quite austere in appearance and amenities, with the Blue Line platform in constant shadow from the freeway, and the noise of the freeway inundating the Green Line platform. The view from the station to Downtown Los Angeles highlights the relatively undifferentiated quality of the built environment surrounding the station. While obvious landmarks are few in the area, one of great cultural significance stands just a few blocks to the north of the complex: Watts Towers. This world-renowned work of folk art is a landmark in that it symbolizes the neighborhood and much of South Los Angeles, though its role as a navigational landmark may be limited, sitting as it does on a residential cul-de-sac.

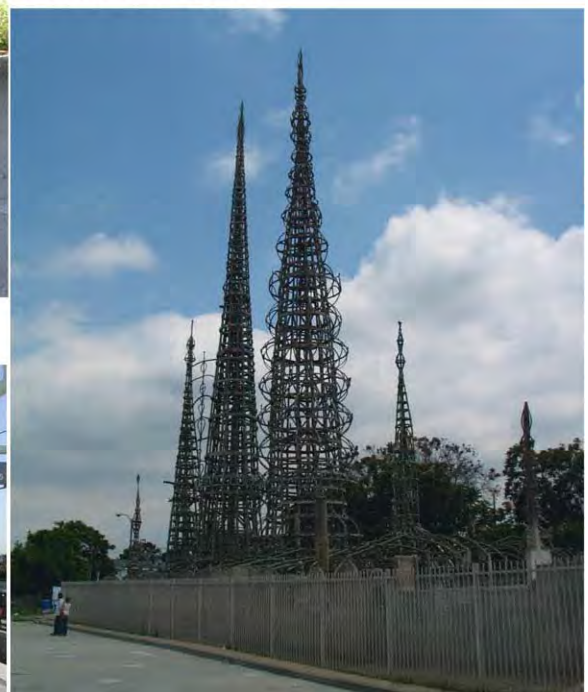
We also conducted the survey at the central transit hub of the UCLA campus, another location with a relative abundance of transit users (see Figures 4.5 and 4.6). The university is a major activity center, and over fifty-four thousand people commute to the campus every day (UCLA Transportation 2012). As Table 4.2 shows, however, the campus has a relatively low

FIGURE 4.4 South Los Angeles Survey Site and Environs

Aerial View of Transit Center and Kennth Hahn Shopping Center

View over South LA to Downtown LA from Green Line Platform

Blue Line Station Underneath I-105



Watts Towers

Green Line Platform in I-105 Median

FIGURE 4.5 UCLA Campus and Survey Site

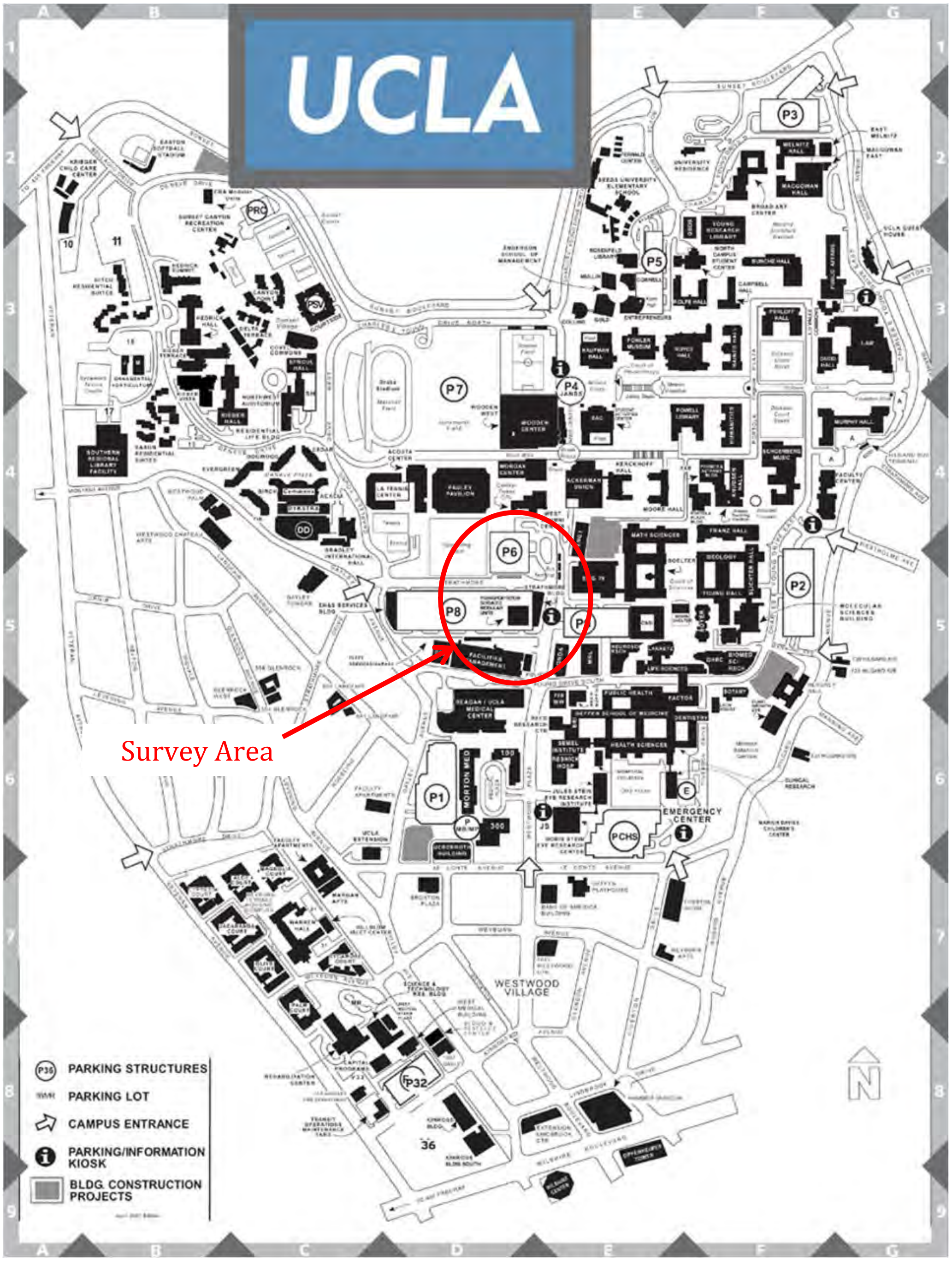
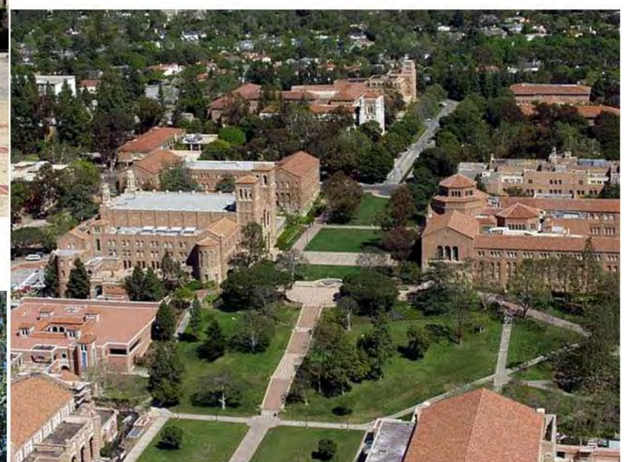


FIGURE 4.6 UCLA Survey Site and Environs

Central Plaza Survey Site



Aerial View of Quad

Royce Hall

Student Union Near Survey Site

Bruin Walk

All Images Source: UCLA

TABLE 4.2 UCLA 2011 Mode Split			
	Overall	*Employees*	*Students*
Drive Alone	39.1%	52.9%	25.5%
Carpool	8.8%	10.7%	5.6%
Vanpool	3.1%	4.6%	1.1%
Public Transit	23.3%	14.2%	30.3%
Bicycle	3.2%	2.1%	4.4%
Walk	19.1%	12.9%	29.3%
Other	3.4%	2.6%	3.8%
Source: UCLA Transportation (2012). University of California, Los Angeles State of the Commute: Transportation Statistics January - December 2011. Los Angeles, CA, University of California, Los Angeles.			

auto commute rate. Only a bit more than half of employees drive alone to campus, and only one-quarter of students drive alone to get to school. Public transit and walking both have high use-rates, particularly among students.

In South Los Angeles, the survey was administered in both English and Spanish, and at UCLA it was administered only in English. At both survey locations, unless already assisting a respondent with a survey, surveyors approached all potential respondents passing by them in high-traffic locations at the shopping center and transit hub, respectively. Surveys were typically conducted over three hour periods in the late afternoon and early evening on approximately ten days between April and August 2007. The surveys include questions about a wide variety of travel and spatial cognition factors and took approximately 10 minutes to complete. We encouraged participation with a ten-dollar gift card to Starbucks, a vendor in the Hahn Shopping Center and near the UCLA campus. In South Los Angeles, approximately one-third of those approached participated in the survey. At UCLA, the participation rate was somewhat lower, about one fifth of those approached. In total, we collected one hundred ninety-six responses in South Los Angeles and one hundred ninety-nine at UCLA.

At both survey sites, respondents were asked a variety of questions about their experience of travel (largely mode of travel), and their knowledge of the region, in order to mitigate the risk that the particulars of survey design might influence the results more than the constructs being investigated. To extract cognitive information, we employed an array of data collection techniques, including questions about the location of destinations and the distance to generic and specific destinations by both absolute and relative measures, as well as sketch map exercises. In order to understand how travel mode dominates an individuals' cognitive mapping over their lifespan, we asked questions about mode traveled that day, mode to employment, mode to hypothetical destinations, and the respondent's access to autos. We also included questions about length of time residing in one's neighborhood and various personal characteristics including age, education, nativity, race/ethnicity, and sex. Both the South Los Angeles and UCLA versions of the survey are attached as Appendices A and B.

Overall, the success of the survey efforts in capturing a population that reflects the demography of South Los Angeles or UCLA, respectively, was mixed. For both survey sites, the sample collected was highly female at roughly two-thirds of respondents.[7] In addition, the sample from South Los Angeles is 70 percent African American, despite the fact that the census tract encompassing the transit center is half African American and half Hispanic (U.S. Census Bureau 2010), despite the availability of Spanish-speaking survey takers at the survey site. This result may be due to the fact that the Kenneth Hahn Shopping Center is largely comprised of a mix of national chain stores, and may attract a more English-speaking, and thus more African-American, clientele. Regardless, it remains critical to keep in mind the nature of the sample collected when drawing broader conclusions in the upcoming analyses.

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[7] Though UCLA's student population is majority female, it is far less than the two-thirds ratio collected in the survey. In Fall 2011, UCLA reports the student population as fifty-two percent female. Source: UCLA AIM. (2012). "UCLA Student Enrollment Unduplicated Headcount By Degree Level." Retrieved March 29, 2012, from http://www.aim.ucla.edu/enrollment/enrollment_demographics_fall.asp..

4.3 Methods

Two groups of methods used in this dissertation are essential for validly testing the hypotheses described in the conceptual framework (Chapter 3). The first group is comprised of spatial statistical methods for use when spatial dependence is a factor in the analysis. The second group of methods facilitates reliably and validly extracting spatial information from individuals' cognitive maps. This section reviews these methods, their strengths, and caveats.

4.3.1 Spatial Statistical Analysis

This section introduces the concept of spatial autocorrelation and the Moran's I test for measuring it. Moran's I is used throughout the empirical analyses (Chapter 5, 6, and 7). In addition to the Moran's I test, I employ geographically weighted regression (GWR) as a means for understanding spatial dependence among the relationships modeled in Chapter 5. Because that analysis is specific to Chapter 5, GWR is discussed in detail there.

Cognitive mapping and accessibility are spatial concepts, but the empirical analysis of the complete city involves both spatial and aspatial data. Analysis of spatially distributed phenomena should address spatial autocorrelation – the statistical finding that observed values vary over space and are not independent of each other – and employ methods that test or control for this spatial dependence among observations. Research on activity patterns and spatial knowledge should also be able to distinguish between spatial autocorrelation in the data and other potential sources of variation in the results, such as variation due to socioeconomic or individual characteristics.

Spatial autocorrelation can be defined as nonrandom variability in the values of a variable when considered at a range of distances between observations (Legendre 1993).

Spatial autocorrelation exists whenever a variable exhibits a regular pattern over space in which its values at a set of locations depend upon values of the same variable at other locations” (Aitken and Prosser 1990, 318).

For example, individuals may exhibit similarities in their cognitive map because they all live near one another. However, an analysis that does not address the locations of respondents may mistakenly attribute variations to some ostensibly aspatial factor, such as socioeconomic status,. Spatial autocorrelation is a statistical measure of the dependence of the values across space. The presence of autocorrelation means that traditional statistical tests, where the independence of the observations is assumed, are not applicable. However, a variety of tests have been developed both to measure spatial autocorrelation as a statistical measure of interest in itself and to address it in inferential statistical analyses.

To measure spatial autocorrelation, observed as the degree of clustering of values across observations, I employ the Moran’s I test. The Moran’s I coefficient can be used to evaluate spatial autocorrelation and can therefore help separate out its significance relative to the other factors being explored (Cliff and Ord 1981; Aitken and Prosser 1990). Moran’s I is a basic test of spatial autocorrelation, and researchers have used it to test spatial processes in the social sciences, including transportation and urban planning research (Haider and Miller 2000; Hewko, Smoyer-Tomic et al. 2002; Zhang, Luo et al. 2008). The form of the Moran’s I test that I use in this dissertation is the global Moran’s I, which measures the degree of clustering or dispersion – or randomness – in the distribution of values across the entire set of observations.

Formulae for the Moran’s I coefficient, as well as the associated z-test for whether the measured coefficient is significantly different from zero (spatially random distribution of values), are shown in Figure 4.7. Moran’s I is a basic measure, but appropriate to circumstances where the concern is that values of interest may not be spatially randomly distributed. The Moran’s I test can help determine the role that space plays in individual's distance estimates, relative to other, aspatial processes.

FIGURE 4.7 Moran's I Formulae

The Moran's I statistic for spatial autocorrelation is given as:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2} \qquad (1)$$

where z_i is the deviation of an attribute for feature i from its mean $(x_i - \bar{X})$, $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features, and S_0 is the aggregate of all the spatial weights:

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} \qquad (2)$$

The z_I-score for the statistic is computed as:

$$z_I = \frac{I - \mathrm{E}[I]}{\sqrt{\mathrm{V}[I]}} \qquad (3)$$

where:

$$\mathrm{E}[I] = -1/(n-1) \qquad (4)$$

$$\mathrm{V}[I] = \mathrm{E}[I^2] - \mathrm{E}[I]^2 \qquad (5)$$

Source: ESRI, 2010, ArcGIS 10.0, Redlands, CA: Environmental Systems Research Institute.

Moran's I can test for the significance of spatial autocorrelation among observed values, and it can also be used to understand whether the results of multiple regression may have problems with spatial dependence. If regression residuals are found to exhibit significant nonrandom spatial distribution, then interpretation of the regression results is imperiled due to a lack of independence among the residuals. Scholars have developed several methods for addressing spatially-dependent processes in a multiple regression framework. One set of methods to control for spatial correlative effects in a traditional inferential statistical analysis is termed "spatial regression" (Anselin, Syabri et al. 2004). This type of analysis allows for the inclusion of a spatial weights matrix calculated between observations in an ordinary least-squares (OLS) regression, resulting in either a spatial error or spatial lag term. This method has been used previously for analyzing activity time-spaces, travel behavior, and other individual characteristics (Fan and Khattak 2007).

Another set of methods, which also draws upon a basic OLS framework is "geographically-weighted regression" (GWR) (Fotheringham, Brundson et al. 2002). Geographically-weighted regression allows the coefficients of a multiple regression to vary over space. Conceptually, it addresses the idea that certain relationships – such as between the independent and dependent variables – may not be the same locally as globally. In cases where there is spatial dependence in the relationships being modeled, GWR can improve the overall model fit. Like other forms of spatial regression, it has seen increasing use in urban research including in transportation, infrastructure, and land use analysis (Wentz and Gober 2007; Wang, Kockelman et al. 2011; Lu, Sullivan et al. 2012). I have chosen to use GWR to model activity patterns in Chapter 5. I provide more detail on the method in that chapter, but I argue that GWR is particularly appropriate to urban research where socioeconomic and personal characteristics may have different effects on outcomes depending on where one lives.

4.3.2 Cognitive Mapping Methods

This section introduces methods used in cognitive mapping research broadly. In Chapters 6 and 7, I describe how I operationalize these methods in those analyses.

As a mental construct, a cognitive map is not directly accessible for research purposes. Information must first be extracted from it. In order to extract cognitive mapping information:

> Internal representations of places and environments are externalized as a variety of 'spatial products.' These come in different forms based on using verbal, sketching, estimation, reproduction or modeling techniques (Golledge 1999, 14).
>
> Spatial products refer to the external products that represent space in some way. This term is meant to encompass any kind of external representation, regardless of medium; it includes, for example, sketch maps, miniature models, and verbal descriptions (Liben, Patterson et al. 1981, 11).

The "spatial products" derived from cognitive maps can be used to answer a wide variety of questions, including the implications of cognitive mapping contents and difference for social-scientific research (Golledge and Stimson 1997).

An immense variety of methodologies have been developed or proposed for extracting empirically analyzable spatial products from cognitive mapping. The myriad spatial products generated by these methods draw upon the wide range of geometries, orientations, perceived quantities, and qualitative characteristics contained within a cognitive map. Golledge and Stimson provide a list of the broad techniques that have been used to extract information from cognitive mapping (1997):

- Experimenter observes or tracks movements through actual environments.
- Experimenter infers degrees of cognitive knowledge from behavior in unstructured "clinical" situations.
- Subjects reveal environmental knowledge in the process of sorting or grouping elements of actual or simulated environments.
- Subjects adopt roles or perform acts in simulated and/or real environments.
- Subjects arrange toys or objects representing environmental elements or model environments.
- Subjects draw sketches or sketch maps representing environments.

- Subjects arrange toys or make model representing environments.
- Subjects show existence, location, proximity, or other spatial relations of environment elements, including the use of symbols to represent such elements.
- Subjects are asked to identify photographs, models, etc.
- Selection of constructs that reveal environmental information; adjective checklists, semantic differentials, repertory grid test.
- Subjects make paired proximity judgments and other scaling devices.
- Subjects image scenes from different perspectives.
- Subjects list the best recognized or most frequently visited places.
- Subjects reconstruct images of unseen objects, estimate lengths of streets and angles of intersections.

The wide variety and overlapping purposes of many methodologies make it difficult to choose a methodology to address a particular research question. Some methods are particularly attractive because of the breadth of information that they provide for analysis. For example, sketch maps can provide analyzable data such as the number of total features, a mix of point, line, and area features, indications of dominant functions as perceived by the sketcher, information such as sequences along routes, and the overall regularity or irregularity of features. Other methods, such as verbal questions about distance or location may provide fewer types of data but be more desirable because of low-skill requirements, cross-subject comparability, and ease of execution.

Sketch mapping is a commonly-used technique to extract information from cognitive mapping. Perhaps the most well-known sketching methodology is described in Lynch's *Image of the City* (1960). The methodology introduced by Lynch is the quintessential sketch mapping technique. His deconstruction of the visual city into five basic elements – paths, edges, nodes, districts, and landmarks – is well-known among planners and urban designers and has been widely used since its introduction (Banerjee and Baer 1984; Golledge and Stimson 1997). The open-ended mapping technique used in *Image of the City* gives an individual great flexibility to describe their cognitive map of the city, allowing for as much or as little detail as an individual is willing or able to provide. This technique, with its attention to detail, works well on the neighborhood-scale of urban space.

Lynch's sketch-mapping methodology, where drawings are made freehand on a blank page, is considered a "basic" sketch map (Kitchin and Blades 2002). "Normal" sketch maps provide simple cartographic information to the subject such as roads or landforms, giving the subject some structure from which to begin their drawing, reducing demands on drawing skill. "Cued" sketch maps are even more complete and operate like a "fill-in-the-blank" task. Subjects are only required to add a small amount to a largely completed map, further reducing the demands on drawing ability. The sketch maps included in the Cogntive Mapping survey presented here are "basic" in Kitchin and Blades' nomenclature. Respondents were given complete freedom to represent their routes to home and to a distant landmark as they saw fit on the blank page.

Sketch mapping is not the only methodology useful for extracting spatial knowledge from cognitive maps. Particularly for extracting route knowledge, other methods may be simpler and more powerful. Verbal or written methods, easily implemented in a traditional survey, can be used to gauge route knowledge such as distance, direction, and choice points (Golledge 1999). Distance tasks can be given to subjects in the form of absolute magnitude estimation, comparative ratio estimation, ranking, or rating (Kitchin and Blades 2002). "Multidimensional scaling" asks subjects to fill subjective estimates of the relative proximity various locations into a matrix (Golledge and Stimson 1997). Direction tasks can be undertaken verbally or in writing, or, even more simply, respondents can be asked to point. Completion tasks include techniques such as asking subjects to fill in the blanks or landmark names on a map. Recognition tasks include the identification of features on a map, asking respondents to select between correct and incorrect maps, or simple verification of statements, such as, “X is south of Y. True or false?” (Kitchin and Blades 2002).

In general, the methods used to extract information from cognitive mapping are subject to certain qualifications that should be addressed in research design. Importantly, research shows that the methodology chosen to extract data from cognitive mapping can skew research results (Kitchin 1996). Spatial products extracted from cognitive mapping reflect both the contents of the internal cognitive map and the overall “praxic” ability to perform requested tasks (Siegel 1981).

> The fundamental problem in understanding the acquisition and development of cognitive mapping is the externalization of cognitive maps – getting the spatial knowledge out in some public medium, unconfounded by (theoretically) ‘nonspatial’ task load. These externalized products are, in essence, “re-representations’ of spatial experience (Siegel 1981).

Therefore, variances between individuals are in part explained by task demands. Clearly freehand sketch maps are confounded by variance in drawing ability, but even verbal methods can be confounded by linguistic ability and ability to verbalize spatial knowledge.

While challenging, such ability-based impediments to cognitive mapping research can be addressed through research design. Kitchin (1996) recommends utilizing multiple, mutually supportive methodologies in order to isolate and remove variance based on task demands. Methods that place minimal demands on praxic ability can also be employed, either alone or in conjunction with more demanding techniques. For example, arranging objects on a tabletop and nonmetric ranking tasks both require little in terms of drawing or linguistic ability (Siegel 1981). Also, allowing repeated attempts at any task can reduce confounding effects of ability.

Other criticisms and caveats have arisen with regards to sketch mapping. The more free-form the sketch map, the more it falls foul of the set of problems involved in aggregating and disaggregating data (Golledge and Stimson 1997). Separate decomposed elements cannot be reassembled into a whole using conventional geometric or cartographic methods. Furthermore, sketching is unreliable for extracting information about directionality. Lynch defends the value of using sketch mapping to understand how individuals perceive the city: he asks, “Once you have a drawing, what can you do with it? A map or a sketch, however naively drawn, and often just because naively drawn, is eloquent in many ways beyond a mere counting of its named parts…” (Lynch, Banerjee et al. 1990, 235). He states that many aspects of a simple drawing can provide meaning, including elements such as size, scale, gaps, and connections.

Given the findings on reliably extracting valid spatial products from individuals’ cognitive maps, the Cognitive Mapping survey follows Kitchin’s advice to implement a variety of supportive methods within a single research design. Thus, the survey employs both sketch mapping methods and simple verbal questions about absolute distance, relative distance, and geographic location. An important finding in the overall results of the cognitive mapping analyses would be consistency in patterns observed in the data among the multiple methods employed. If these patterns are consistent, it buttresses the argument that the results are valid and not the product of the methods and their idiosyncrasies.

4.4 In Summary

I use a diverse group of datasets and methods to explore the nature of the personal city and how it interacts with the planned city. Their differences allow me to analyze the personal city both as a phenomenon of activity patterns and as a phenomenon of cognition and perception. Though varied, the datasets and methods all facilitate the exploration of everyday travel as a spatial, geographic phenomenon.

In each instance, I have endeavored to choose data that best addresses my conceptual questions within the constraints of resources, availability, and relevance to planning research generally. The SCAG travel survey, relative to public activity and travel surveys, provides the benefit of precise spatial information useful for activity space analysis. Still, its limited temporal scope (one or two days) and lack of cognitive or stated preference information represent drawbacks to more fully representing activity spaces and linking the activity to potential action in the personal city framework, respectively. The Cognitive Mapping survey, while developed to directly address the issues of the relationship between spatial knowledge and travel behavior, is limited in its size, and it remains an exploratory survey addressing topics little covered in planning research.

The following chapters demonstrate the methods introduced above. Chapter 5 shows the potential for spatial statistical analysis to improve and provide distinctive insights to transportation and planning research. The GWR method shows that urban-scaled processes do not necessarily function the same way from place to place, neighborhood to neighborhood. In Chapters 6 and 7, I use methods specific to cognitive mapping to understand how individuals construct their personal cities. In these chapters I employ spatial analytic methods to a more limited degree, but I still use a basic spatial statistical method, specifically as Moran's I, to confirm whether or not the phenomena I observed are spatially dependent.

Chapter 5

Activity Spaces and Access to Opportunities

5.1 Introduction

People do not live in neighborhoods anymore. Coopting the terminology of Banerjee and Baer (1984), many urban dwellers today live "beyond" neighborhoods, travelling long distances to meet their needs and wants. These extra-local trips are not just for work, which has traditionally been thought of as the primary long-distance trip, but for the wide range of trip purposes that fill most people's daily lives. People's proclivity to travel so broadly for everyday activities is at odds with urban planners' effort to reduce travel, particularly auto travel, in order to ameliorate the negative externalities that attend auto use and travel. The environmental and economic consequences of our transportation regime must undoubtedly be addressed. However, an examination of the breadth of people's daily activity patterns suggests that some value may be drawn from spatially extensive activity patterns and that those patterns are often associated with the most economically successful socioeconomic groups.

This chapter examines the extensiveness of everyday activity patterns in Los Angeles, California. The area within which a person conducts his or her daily activities is termed an "activity space" by geographers and transportation researchers. From the latchkey kids who cannot leave their homes to the urban neo-explorers who proudly "check in" to social media anywhere and everywhere they go, the size of one's activity space is an integral part not only of each person's relationship to the city but also their place in society and potential economic prospects. The exploration of the personal city framework begins here with an analysis of how far people must travel in order to complete their daily routine. Fundamentally, the research asks whether lives lived broadly are different from those lived within a smaller precinct. Are those possible differences associated with differences in socioeconomic status? Can planner's interventions counteract the desire to rove widely without reducing opportunity?

The analysis in this chapter makes use of spatial data, along with associated demographic data, on activity and travel from the Southern California Association of Governments' (SCAG) 2003 Travel Survey. Using a traditional travel survey presents potential challenges in activity space analysis because each respondent only provides one (sometimes two) days of activity and travel information. Only rudimentary activity spaces can be constructed for individuals, and those spaces likely do not cover the full range of an individual's routine over a week or longer time scale. Nevertheless, these measures, particularly when analyzed across a large sample, can provide compelling statistical evidence of relationships between activity spaces and personal and neighborhood characteristics. In addition to exploratory descriptive analysis, activity spaces are modeled using ordinary least squares (OLS) regression and geographically-weighted regression (GWR).

The analyses in this chapter point to the pervasive disparities among socioeconomic groups and the literal lengths to which people can and will go to accomplish a wide variety of activities. I find that controlling for other factors, low-income residents of the Los Angeles area have more constrained weekend activity spaces, even though income is not a significant factor in total distance travelled. The results also show that the built environment does play a significant role in keeping activity spaces small. Finally, the GWR analysis shows that global models of urban phenomena can potentially obscure localized phenomena. When coefficients are allowed to vary across space, a factor like income may have a positive effect on activity space size in one part of the region and a negative effect elsewhere.

The era of massive investment in transportation infrastructure appears to be winding down, and planners have largely turned towards policies and plans that have the effect of constraining travel in cities, such as raising the price of auto travel, and encouraging more local travel by less environmentally damaging means, such as biking and walking. Such policies may address a host of important challenges for cities, but their impact may be felt disproportionately by those who already struggle to accomplish their daily activities across the wide urban fabric. Planners need to consider strategies that ameliorate the isolating effects of activity-constraining policies. Furthermore, the GWR analysis shows that for planners who work at local scales, "your mileage may (indeed) vary," and interventions that shift behavior in one place may have different results in another.

Activity spaces are a dimension of people's experience of the personal city, the concept I introduce in Chapter 3. A wide-ranging experience of the city may have benefits that cannot be tallied directly in terms of number or value of activities carried out. As discussed in the literature review (Chapter 2), the experience of travel is associated with knowledge of the city. That knowledge, in turn, is a component of future travel decisions. This iterative relationship between travel, activity, and spatial knowledge is little understood, but is tied to a perspective on accessibility that views access not as a static quality of place, but as a developing trait of individuals' lives. Thus, the quantity and extensiveness of travel a person undertakes may make the difference between one who is able to effectively make use of the wide range of opportunities available in contemporary urban regions and one who cannot.

5.1.1 Hypotheses

The concepts addressed this chapter are discussed in the literature review (Chapter 2) and conceptual framework (Chapter 3). In this chapter, I hypothesize that:

1. *Socioeconomic status and Activity Space Extent* - Spatially extensive travel patterns are positively associated with higher socioeconomic status.
2. *Activity Space Extent Compared to Distance Traveled* – Like Kwan (1998), I argue that individual accessibility is measurable in activity patterns. I further argue that empirical measures emphasizing the spatial extent of activity, rather than just total distance travelled, result in a better, more complete model of everyday behavior and socioeconomic status, statistically, and conceptually.
3. *Role of the Built Environment* – Unlike Weber and Kwan (2003) but like Ewing and Cervero (2010), I expect to find that aspects of the planned city, particularly density, will have a significant effect on activity space size as well, with higher residential density associated with smaller activity spaces.

5.2 Defining and Measuring Activity Spaces

Beyond its conceptual intricacy, empirically defining an activity space presents an additional layer of complexity. In this analysis, I evaluate the worth of common transportation datasets to conduct activity space analyses, using the Southern California Association of Governments' (SCAG) travel survey to quantify individuals' activity spaces. The measure of an activity space will vary depending on when and how long a person's activity patterns are observed. Further, the degree of precision in the characterization of an activity space can vary tremendously, from complex patterns that hew closely the actual paths followed by an individual to a collection of generalized geographies such as census tracts or neighborhoods.

With the SCAG travel survey data, only a limited number of activity locations are available for each individual (median number of activities: 3, 95th percentile: 9), so any estimated activity space for an individual will necessarily be basic, and it will not likely span the full extent of that individual's regular activity patterns as they unfold over a typical week, month, or longer. Some measures of activity pattern extensiveness, however, require relatively few geographic points. Several approaches are possible, each with its advantages and disadvantages. Figure 5.1 illustrates the approaches. They are:

- *Minimum Convex Polygon (MCP)* is a single polygon whose area is the minimum needed to encompass all activity locations without any concavities in the shape (Getz and Wilmers 2004). The MCP requires at least three activity locations to have a valid area, thereby excluding those who make only one trip (home and destination being the two activity locations in that case). Because the MCP uses actual activity locations as polygon vertices, the polygon's area will be highly dependent on the precise locations of activities.
- *Standard Deviational Ellipse (SDE)* is an ellipse whose major and minor axes are defined by the standard deviation of each activity location's distance from the mean center point of all activities (Mitchell 1999). An SDE calculated to one standard deviation will encompass approximately 68 percent of all activity locations, assuming a normal distribution of activities from the mean center. An SDE calculation to two standard deviations will represent 95 percent of all activity locations. Whether calculated to one

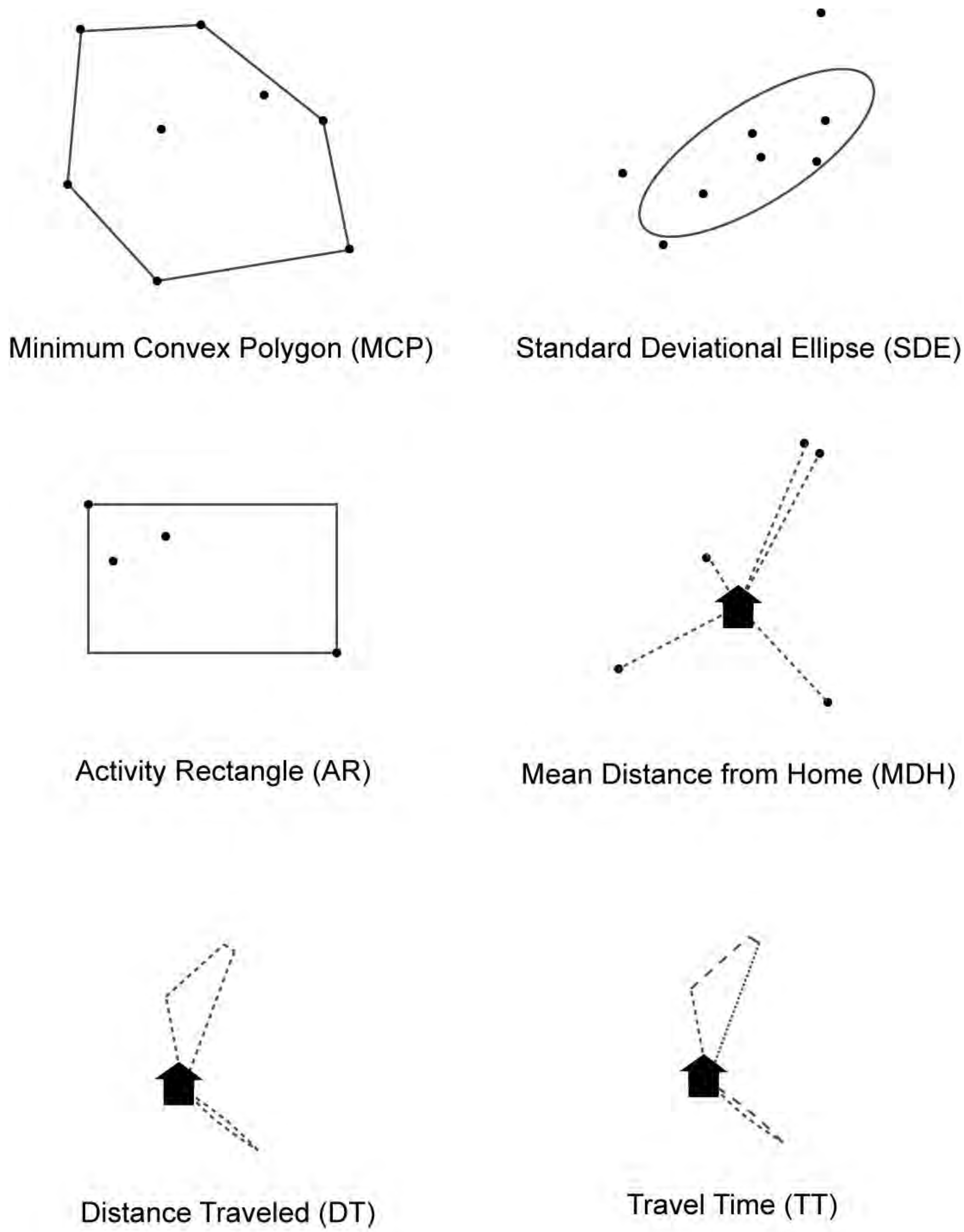


FIGURE 5.1 Activity Space and Travel Measures

or two standard deviations, an SDE's boundaries will not necessarily track as closely to sampled activity locations as the MCP. However, this parametrically estimated activity space may be more appropriate as a quantification of the zone of everyday activity and experience of which recorded activity locations are only a sample.

- *Activity Rectangle (AR)* is defined by the minimum and maximum x and y coordinates in the set of activity locations. The AR only requires two activity locations to define a rectangle and have a nonzero area. However, the resulting area will be less congruent with surveyed activity locations.
- *Mean Distance from Home (MDH)* is an alternative to measuring extensiveness in terms of geometric area. Instead, MDH is simply the average Euclidean distance from home of all activities undertaken by a respondent on the survey day. This measure can be applied to all respondents, regardless of numbers of trips taken. However, this measure would not be able to differentiate between those whose activities are widely distributed across the city and those who engage in a cluster of activities in one specific area that happens to be far from home.
- *Distance Traveled (DT)* is a traditional transportation measure, included for comparison with the activity space measures. It is the nearest equivalent of vehicle miles traveled (VMT), but comparable across all modes. It is simply the sum of the distance of all trips made in the survey day. Because the survey does not include actual routes taken, the distance is the sum of Euclidean distances between origin and destination for each trip link.
- *Travel Time (TT)* is another traditional transportation measure, again included for comparison with activity space measures. The total time a respondent spends travelling

on a given day is conceptually a measure of the opportunity cost of reaching the day's activities.

- *Number of Trips (NT)* is the final measure included for comparison with activity space extensiveness measures. Counting the number of trips taken is a straightforward measure of realized opportunity, the assumption being that every activity undertaken is a benefit to the respondent.[8]

The MCP and SDE measures are both useful methods for quantifying the extensiveness of one day's activity, and they are recognized by the literature. However, both methods would exclude potential respondents who have engaged in just one activity during the day (two locations including the home), a potentially significant component of the sampled population. The AR and MDH measures can provide nonzero values even if only one non-home activity is made during the day. However, these measures are not cited in the literature on activity space analysis, and they each have potential drawbacks, in that the AR may be geometrically quite different from the true underlying activity space, and the MDH does not capture activity extensiveness so much as its remoteness from home. Finally, DT and TT are included for comparison to traditional travel measures, and NT is included as a simple opportunity measure.

Table 5.1 compares activity space measures in terms of number of valid responses among adults, split by weekdays and weekends. Note that these measures include valid responses of zero, for example if a person does not go anywhere on the survey day. The NT measure is the

[8] Each measure can potentially be transformed for further analysis, such as by taking its log, square root, percentile, or other recalibration. In the subsequent statistical analyses I employ a number of transformations to improve the analysis and its interpretation. In the initial descriptive exploration of the data, however, I leave the values untransformed.

only measure that is "universally" valid within the SCAG sample. All the other measures, even those that do not require a minimum number of spatial locations, eliminate some respondents due to missing data. The TT measure has the next highest number of valid responses. The AR, MDH, and DT measures cover approximately 62% of all respondents on weekdays and 78% on weekends. The MCP and SDE measures, however, also eliminate those who have travel data but only made one trip. This gap is substantial, with the measures covering only 40% of respondents on weekdays and 67% of respondents on weekends.

TABLE 5.1 Activity Space Measure Valid Responses, Adults 18 or Older

Measure	*Weekdays*	*Weekends*
Minimum Convex Polygon (MCP)	12,469	2,908
Standard Deviational Ellipse (SDE)	12,469	2,908
Activity Rectangle (AR)	19,226	3,417
Mean Distance from Home (MDH)	19,226	3,417
Distance Traveled (DT)	19,226	3,417
Time Traveled (TT)	20,025	3,567
Number of Trips (NT)	30,624	4,357
Total Respondents	30,624	4,357

Among respondents with valid responses for all measures, Table 5.2 shows the correlations among those measures for weekdays and weekends. Importantly, the pattern of correlations is roughly consistent between weekday and weekend trip groups. The strongest correlations are between the MCP and SDE measures, at more than 0.93 for weekends and 0.94 for weekdays. Correlations are also relatively high – at least 0.50 – among MCP, SDE, and the alternative measures AR, MDH, and DT. The TT measure is less correlated with MCP and SDE, around 0.30 on weekdays and weekends. The measure least correlated with MCP and – most particularly – SDE is the NT measure. This suggests that the number of activities is only a minor factor in the extensiveness of a person's activity space.

TABLE 5.2 Activity Space Measure Correlations							
			Weekdays				
	MCP	*SDE*	*AR*	*MDH*	*DT*	*TT*	*NT*
MCP	1.0000						
SDE	0.9426	1.0000					
AR	0.7725	0.7637	1.0000				
MDH	0.5522	0.6003	0.6995	1.0000			
DT	0.6575	0.5892	0.6739	0.8291	1.0000		
TT	0.3120	0.2737	0.3005	0.2593	0.3534	1.0000	
NT	0.2291	0.1041	0.1261	-0.0174	0.3770	0.2954	1.0000
			Weekends				
	MCP	*SDE*	*AR*	*MDH*	*DT*	*TT*	*NT*
MCP	1.0000						
SDE	0.9332	1.0000					
AR	0.8207	0.7951	1.0000				
MDH	0.5704	0.6488	0.6794	1.0000			
DT	0.6648	0.6147	0.6518	0.7967	1.0000		
TT	0.3541	0.2951	0.3206	0.2593	0.4272	1.0000	
NT	0.2769	0.1718	0.1978	0.0770	0.3836	0.3557	1.0000

Minimum convex polygons or standard deviational ellipses may be closest conceptually to the construct of “activity space extensiveness,” and they are also very closely correlated. Neither measure, unfortunately, can accommodate those who only make one trip in a day. The activity rectangle can accommodate those who make only one trip, but AR is not as well correlated with MCP or SDE. Mean distance from home, distance traveled, time traveled, and number of trips are all even less correlated with MCP or SDE. Because no measure is ideal, I proceed with the analysis of activity extensiveness’ relationship to socioeconomic status and other factors using multiple measures, attempting to highlight where particular measures are most useful or suited to a given analysis, and compensating for missing respondents as needed.

5.3 Exploring Activity Space Extensiveness

5.3.1 Activity Spaces and Socio-Demographics

Figures 5.2 through 5.5 explore the remarkable variability in activity spaces among socio-demographic groups. The figures address four of the seven activity measures discussed above:

FIGURE 5.2 Standard Deviational Ellipse (SDE) Area by Personal Characteristics

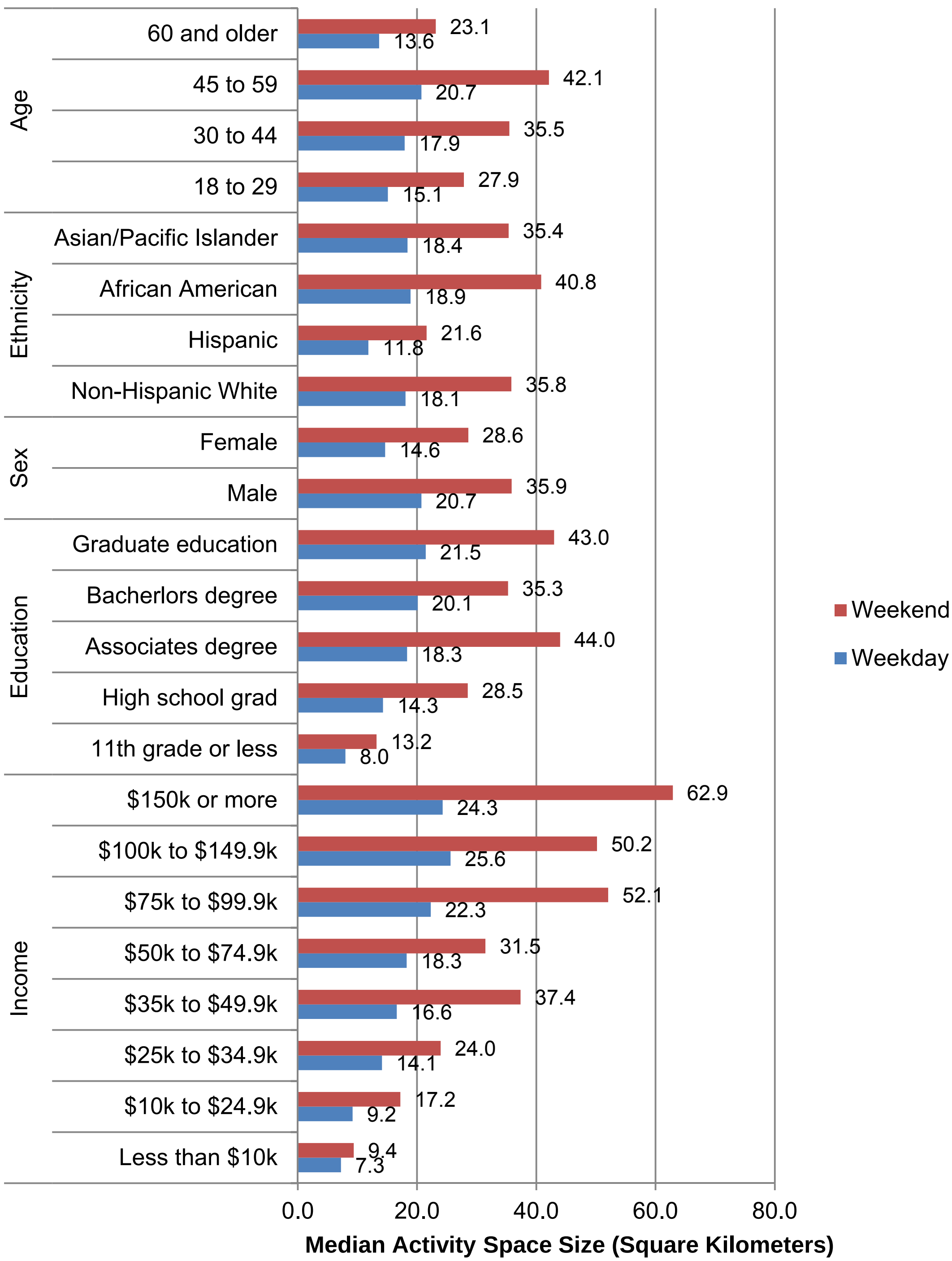


FIGURE 5.3 Activity Rectangle (AR) Area by Personal Characteristics

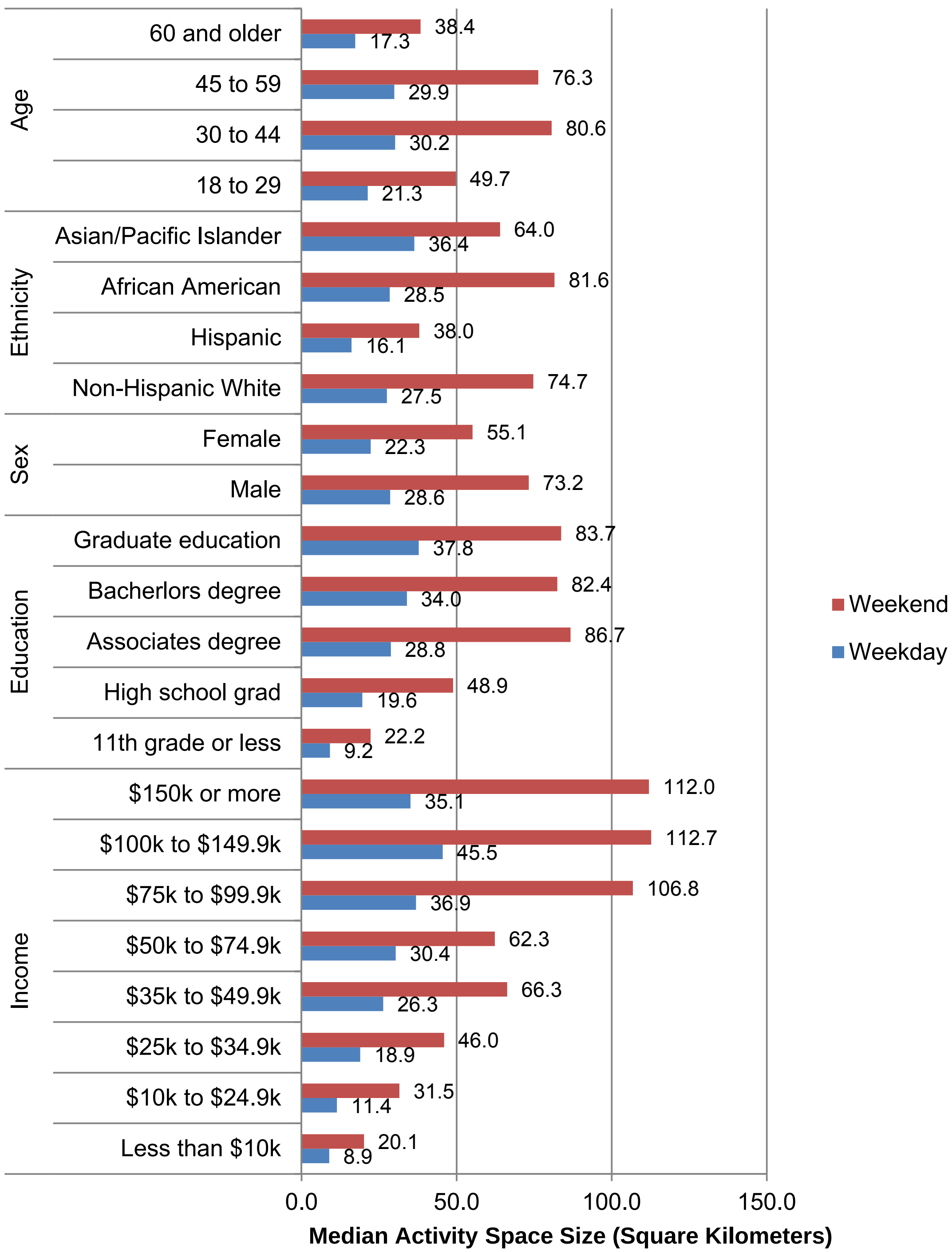


FIGURE 5.4 Distance Traveled (DT) by Personal Characteristics

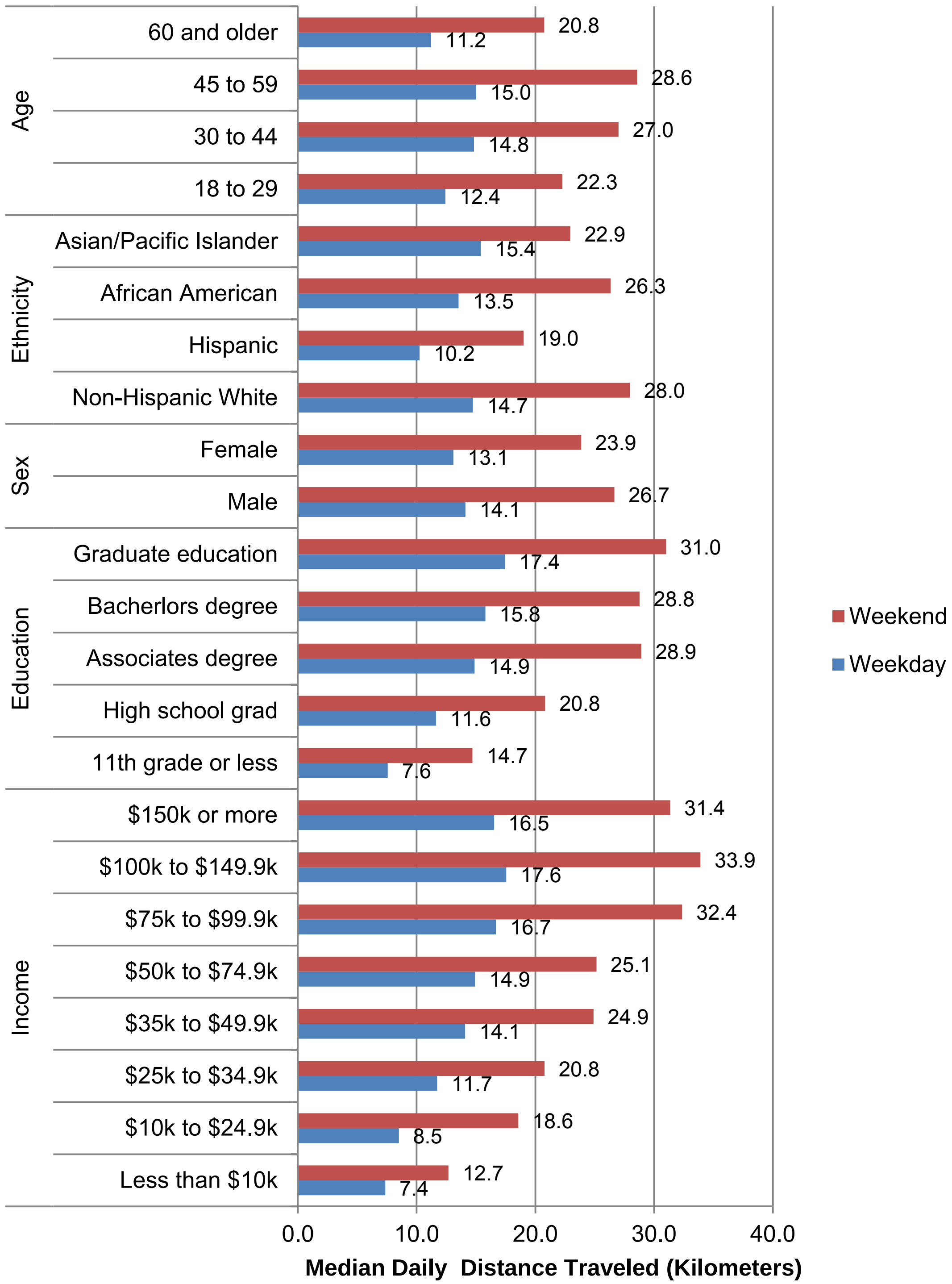
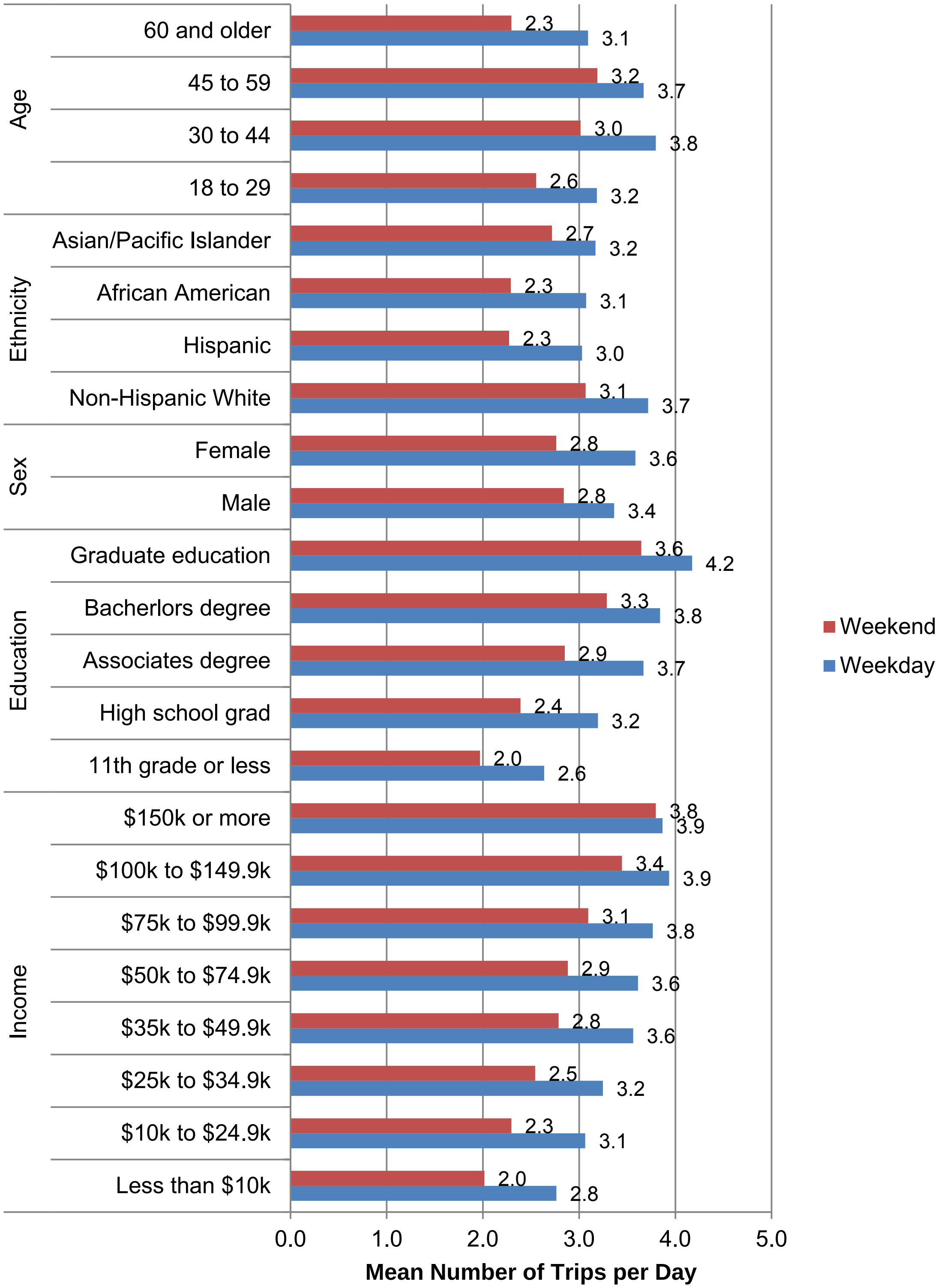


FIGURE 5.5 Number of Trips (NT) by Personal Characteristics



standard deviational ellipses (SDE), activity rectangles (AR), distance traveled (DT), and number of trips (NT). These measures span the range of potential measures in terms of relative levels of correlation (see Table 5.2), and they also encompass a broad range of empirical approaches to activity space measurement. Minimum convex polygons (MCP), mean distance from home (MDH), and travel time (TT) are not included because, according to the correlation analysis, they are relatively similar to other measures.

For each chart in Figures 5.2 through 5.5, the given activity space measure is compared across a variety of basic socio-demographic categories. Activity spaces on weekdays and weekends are analyzed separately. Figure 5.2 is a chart of differences in SDE area by income, education, gender, ethnicity, and age on weekdays and weekends. The values are the median activity space area in square kilometers for each group. The median was chosen over the mean because of the positive skew of the distributions. Most noteworthy, weekend activity spaces are consistently larger than weekday spaces, regardless of socioeconomic status. For both income and education, a clear trend is evident, with larger-area activity spaces associated with higher levels of income and education. The relative size of weekend activity spaces compared to weekday also increases with rising income or education. Males' activity spaces are larger than females' on both weekdays and weekends. Different ethnicities have roughly similar activity spaces, except for Latinos, who have notably smaller activity spaces on weekdays and weekends than all other ethnic groups. Finally, age groups exhibit an unsurprising pattern, with activity spaces increasing in size up to 60 years of age and then decreasing precipitously as seniors begin to stay closer to home.

Figure 5.3 shows differences among socio-demographic groups for activity rectangle (AR) area, which, though less spatially precise than SDE or MCP, can include those individuals in the sample who traveled only once in a day. AR area is consistently larger than SDE for all categories. However, in terms of differences by category, the same essential patterns are evident. Weekends are larger than weekdays, activity spaces increase with income and education, males' activity spaces are larger than females', Latinos have substantially smaller spaces, and the young and old have smaller spaces than those in middle age. Figure 5.4 addresses distance traveled (DT) within the same categories. Patterns are again similar. However, the relative difference between males and females is reduced here compared to SDE and AR areas. This suggests that though women do not range as widely as men (SDE and AR), they do engage in a substantial amount of travel (DT) within that smaller area. This finding is consistent with the literature on the gender division of labor, which suggests that women operate in more spatially-constrained labor markets and are far more responsible for the upkeep of home and family than men, even if they hold a job outside the home as well (Hanson and Pratt 1988; Loo and Lam 2011).

Figure 5.5 shows differences among groups in mean number of trips (NT) taken (or activities engaged in) on a given day. This chart stands out among SDE, AR, and DT because weekdays see more activity in terms of sheer numbers of trips relative to weekends. Aside from the weekday/weekend flip, income, education, and age exhibit roughly similar patterns to the other measures. NT by sex and race/ethnicity, however, does show some major differences from the other activity measures. Women actually exceed or equal men in terms of number of activities on weekdays and weekends. As discussed above, this finding underscores the typically different nature of women's and men's travel, where women's travel is more frequent but constrained. In terms of race/ethnicity, Latinos do not exhibit a substantial difference compared to African Americans and Asian/Pacific Islanders, though all minority groups make fewer trips than non-Latino Whites. This finding suggests that Latinos do not necessarily engage in less activity, but stay closer to home to accomplish it.

Figures 5.2 through 5.5 indicate that socioeconomic status is strongly associated with a person's activity space. Further, the differences between the SDE and NT measures show that number and extensiveness of activities are separate facets of daily life. The major differences between activity space sizes on weekdays and weekends also suggest that activity type may have an important effect on activity space extensiveness. If people are traveling further from home on weekends than weekdays, what types of activities are motivating that behavior?

5.3.2 Activity Type and Extensiveness

Accessibility research is concerned with the ease with which individuals can take advantage of opportunities in the built environment. While such research has traditionally focused primarily on employment opportunities, work is just one component of most individuals' and households' complex lives. Here, therefore, I look at a range of activity types – work, logistical, household-serving, and social/recreational – and how they fit within different spatial extents. What do people do when they venture out into the city? When travel surveys ask respondents what they did for each activity, respondents can provide a wide range of responses, from work to running errands to eating a meal. In the SCAG travel survey, there were twenty-two such options for non-home activities. However, these options can be distilled into broader categories that reflect the different ways that people spend their days. For this analysis, six super-categories were developed:

(1) Work – Work and work-related activities, as well as adults going to school

(2) Household-serving – Activities considered “errands,” such as shopping, banking, medical, etc.

(3) Logistical – Transportation-based activities, primarily pick-ups and drop-offs of children or other household members

(4) Social/recreational – Leisure and “choice” activities, from visiting friends to volunteering to watching a movie

(5) Meals – Eating out, separate from household-serving or social/recreational

(6) Others – Any other non-home trips not included in the above categories

Figures 5.6 and 5.7 show the relationship between activity spaces and activity types on weekdays and weekends, respectively. Because the areal measures of activity are all relatively similar to each other, only the SDE measure is used here for this exploratory analysis. For weekdays, increasing SDE area appears to be associated with a shift from household-serving trips to work trips as the dominant component of respondents’ daily activity set. All the other trip types – logistical, social/recreational, meals, and others remain relatively stable in proportion regardless of activity space size. The weekday chart shows that people will often travel further for work than other activities in their daily lives, a finding reinforced by other research on daily travel and activity patterns (Handy 1992; Levinson 1998). Weekends, however, are a different story. As Figure 5.7 shows, work is only a minor factor on weekends, even for those with large activity spaces.[9] Household-serving trips dominate at all scales of activity, and social and

[9] Note, that Hispanics (10% of trips) and African Americans (8.0% of trips) do engage in work at a higher rate on weekends compared to Non-Hispanic Whites (5.4% of trips) and Asian/Pacific Islanders (6.4% of trips). Nevertheless, work is always less than social and recreational activity for all racial/ethnic groups.

FIGURE 5.6 Weekday Activities by Type and Activity Space Area

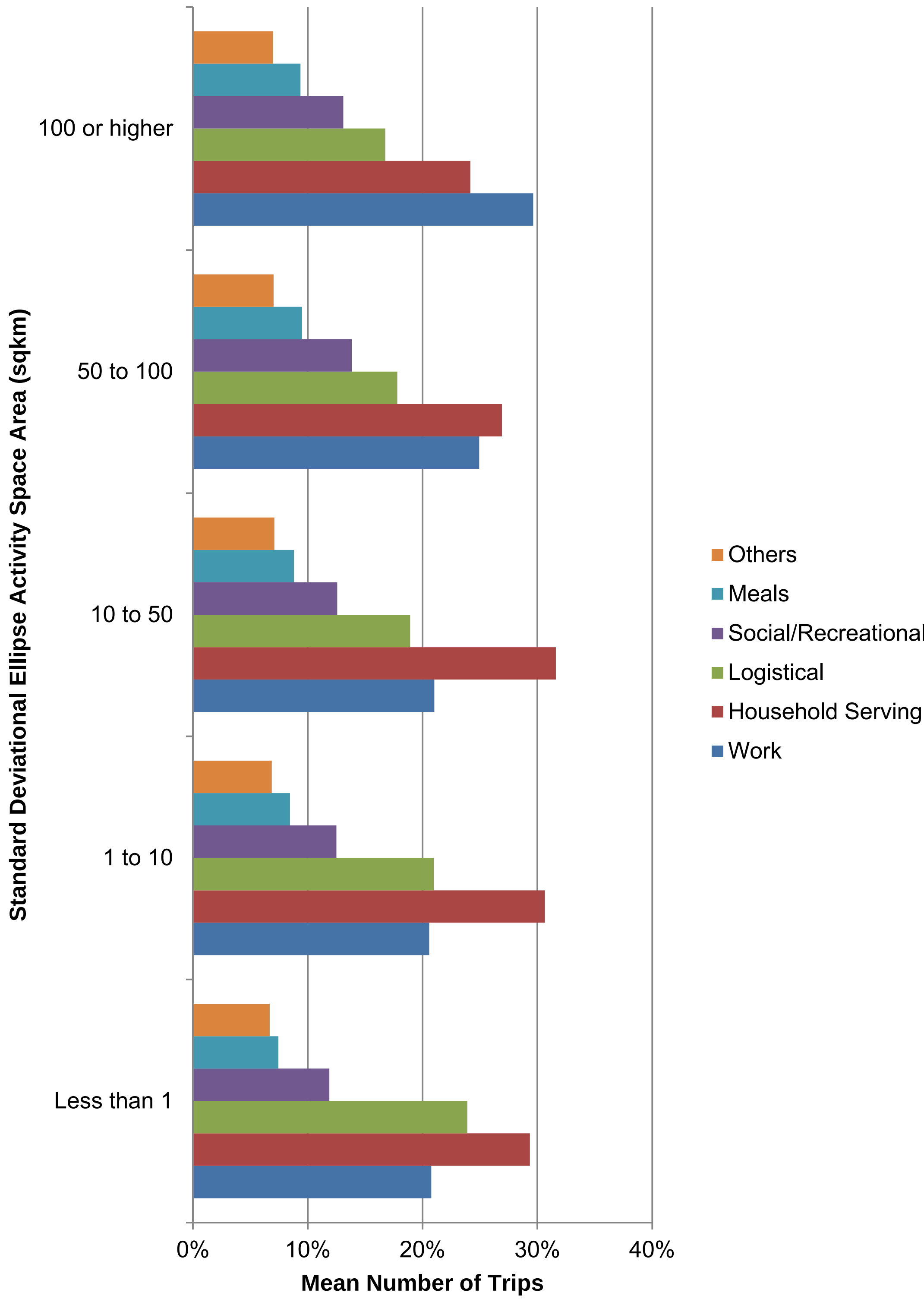
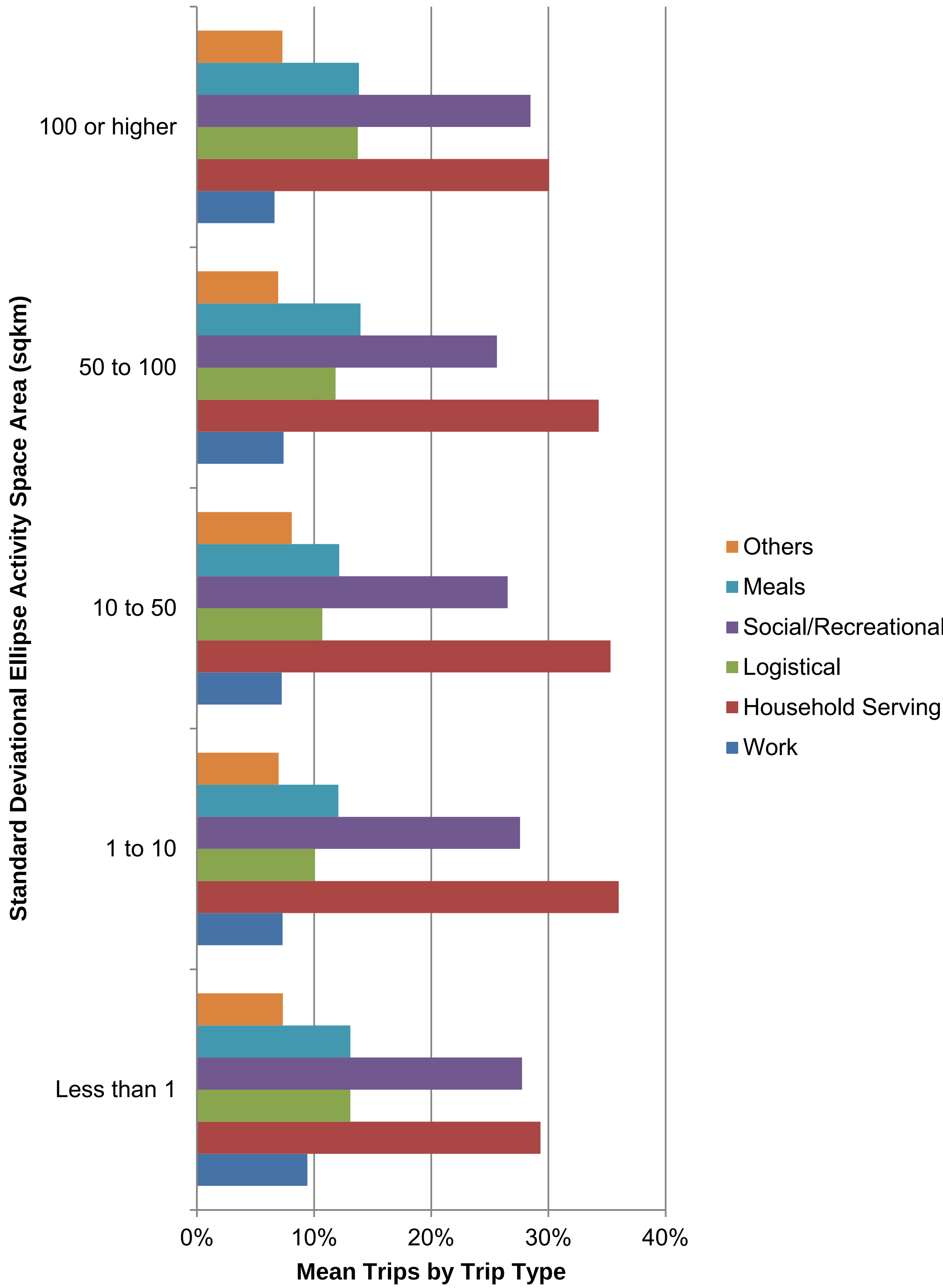


FIGURE 5.7 Weekend Activities by Type and Activity Space Area



recreational trips are the second major component of the day. The chart does suggest that household-serving trips may "peak" closer to home than social and recreational trips, which show a consistent increase as activity space size increases through all scales of activity.

Daily lives lived at different geographic scales do not appear to be substantially different from one another in terms of the balance of activities during a day, with the exception of work activities being more dominant for large weekday activity spaces. Nevertheless, as Table 5.2 shows, the number of trips taken is positively correlated with activity space size, so those with large activity spaces, particularly on weekends, are doing more of *everything*, even if at relative levels that are similar to those for small activity spaces. When controlling for other factors, different activity types may reveal a more significant role in activity space size, but, at least when viewed descriptively, activity patterns do not appear to shift significantly as activity space extensiveness increases.

5.4 Modeling Activity Space Extensiveness

In this section, I seek to better understand the relationships between activity space extensiveness and a range of personal and neighborhood characteristics. I construct several models to account for the interplay among the diverse factors shaping individual activity patterns and compare between activity space extensiveness and a more traditional transportation measure of total distance travelled. Models include both standard multiple regression and geographically-weighted regression to address spatial dependence among respondent characteristics. Results suggest that while higher socioeconomic status is associated with larger activity spaces (though not total distance travelled), neighborhood form is associated with activity space size as well.

The impact of urban form, however, is not straightforward, with density of "opportunities" being associated with smaller spaces.

5.4.1 Model Variables and Parameters

Personal characteristics and activity types are only part of the wide variety of factors that may influence activity space extensiveness. Other influences may include the daily number of activities, the mode taken to reach activities, personal characteristics such as knowledge of opportunities and personal preferences, and neighborhood and urban form characteristics such as density, land use patterns, urban design, and even person-place factors such as place attachment. A multivariate regression model can control for the myriad factors that likely influence activity space area and can facilitate a deeper understanding of how the spatial dimension of daily life relates to the host of socioeconomic, transportation, and land use issues with which planners grapple. The results could strengthen the validity of the hypotheses (see Section 5.1.1) that benefits accrue to those with more spatially extensive lifestyles, and that dense urban form and land use patterns are associated with smaller activity patterns.

I selected a subsample of the full SCAG Travel Survey sample to best capture the concept of activity space extensiveness as a function of everyday life. Critically, days dominated by work are less likely to reflect the complete spatial range of activity options available to an individual. Work takes up most adults' weekdays, and, as Figures 5.2 through 5.4 show, activity spaces on weekdays are more constrained than weekends. Therefore, the models focus on weekend activity patterns, which are evidently more flexible and extensive due to the relatively small role played by work on weekends for most people (see Figures 5.6 and 5.7). I would also argue, conceptually, that weekends are a particularly "formative" period of the week during which the personal city develops and potentially grows. As with all analyses in this dissertation, the sample is limited to adults over age 18.

Next, I selected outcome and predictor variables to best reflect the processes described in the conceptual framework. Table 5.3 describes the variables chosen for the models, how they have been operationalized, and the expected relationship to the predictor variables. The table shows which variables have been derived from datasets other than the SCAG Travel Survey. For the purposes of modeling, I chose two potential outcome variables: (1) Standard Deviational Ellipse (SDE) area and (2) Distance Traveled (DT). As prior discussion indicates, SDE area represents the best approximation of the activity space concept possible using the SCAG data. Distance traveled is the survey-derived measure most similar to VMT, which itself is a more typical measure of travel in transportation planning research. Modeling both SDE area and DT allows me to test the hypothesis that activity space extensiveness can provide distinctive insights that other measures, like VMT, may not be able to offer. Descriptive statistics for each model variable are included in Table 5.4. Appendix C provides a table of correlations among all of the potential model variables. Both Table 5.4 and Appendix C confirm that the variables as operationalized for the models are generally consistent with expectations and other researchers' findings, as discussed below.

Both the SDE area and DT variables are transformed to their natural logs, eliminating the right-hand skew of these area variables and resulting in normalized distributions. Other variable transformations to improve model fit are noted in the table. Three sets of predictor variables can be expected to shape activity space extensiveness. The first set is comprised of variables measuring activity and travel behavior on the weekend survey day. Activity intensity, or the

TABLE 5.3 Model Variables		
Conceptual Measure	*Operationalized Model Variable*	*Expected Relationship to Dependent Variable*
Dependent		
Standard Deviational Ellipse (SDE) area	Ln SDE area	
Distance Traveled (DT)	Ln DT	
Independent		
Activity / Travel Patterns		
Activity intensity	Number of trips (NT)	+
Vehicle ownership	Vehicles per household member (all ages)	+
Walking	% trips by walking	-
Social/recreational activity participation	% social/recreational of total activities	+
Household-serving activity participation	% household-serving of total activities	-
Personal characteristics		
Household Income	8 survey-defined income brackets (See Figure 5.2)	+
Sex	Female compared to male	-
Race/Ethnicity	Hispanic, African American, or Asian/Pacific Islander compared to Non-Hispanic White	-
Age	Age + Age^2	+ (Age), - (Age^2)
Education	5 survey-defined education brackets (See Figure 5.2)	+
Language	English compared to non-English speaking household	+
Occupation	Executive/professional and clerical/service job compared to manufacturing/physical labor	+
Neighborhood characteristics		
Population density	Ln Density (persons per sqkm) within activity space (2000 Census)	-
Opportunity density	Ln Density (activities per sqkm) within activity space (SCAG Activities Dataset)	-
Employment Density	Ln Density (jobs per sqkm) within activity space (2000 Census Transportation Planning Package)	-
Crime	Homicides per 10k population at zip code (CA Dept. Health)	-
Local Education Achievement	Local API Score Estimate (CA Dept. Education)	+
Transit Share	% Work Trips by Transit in Census Tract (2000 Census)	-

TABLE 5.4 Descriptive Statistics for Model Variables				
			Mean	
		N	*ln (SDE Area)*	*ln (DT)*
Number of trips (NT)	Quartile 1 (2 trips)	861	16.7	9.9
	Quartile 2 (3 to 4 trips)	825	17.2	10.3
	Quartile 3 (5 trips)	305	17.6	10.6
	Quartile 4 (6 to 20 trips)	640	17.9	10.9
Vehicles per household member	Quantile 1 (0 to 0.5)	843	16.9	10.2
	Quantile 2 (0.6 to 1)	1,462	17.3	10.4
	Quantile 3 (More than 1)	326	17.6	10.6
Walk Trips	No Walk Trips	2,135	17.4	10.4
	At Least One Walk Trip	260	16.5	10.2
Social/recreational %	Quartile 1 (No Socrec trips)	1,147	17.1	10.2
	Quartile 2 (6-11% of trips)	56	18.2	11.3
	Quartile 3 (13-33% of trips)	767	17.6	10.6
	Quartile 4 (36-100% of trips)	415	17.3	10.3
Household-serving %	Quartile 1 (No HHld trips)	1,164	17.2	10.3
	Quartile 2 (6-11% of trips)	37	18.0	11.2
	Quartile 3 (13-33% of trips)	712	17.6	10.6
	Quartile 4 (36-100% of trips)	472	17.1	10.3
Income	Less than $10k	89	16.4	10.0
	$10k to $24.9k	310	16.7	10.1
	$25k to $34.9k	272	16.9	10.2
	$35k to $49.9k	293	17.3	10.4
	$50k to $74.9k	591	17.3	10.3
	$75k to $99.9k	339	17.6	10.5
	$100k to $149.9k	267	17.6	10.6
	$150k or more	189	17.7	10.6
Sex	Male	1,293	17.4	10.4
	Female	1,336	17.1	10.3
Race/Ethnicity	Non-Hispanic White	1,655	17.3	10.4
	Hispanic	551	17.0	10.2
	African American	154	17.4	10.3
	Asian/Pacific Islander	149	17.4	10.4
Age	18 to 29	461	17.1	10.2
	30 to 44	960	17.3	10.4
	45 to 59	694	17.4	10.4
	60 and older	516	16.9	10.2
Education	11th grade or less	245	16.5	9.9
	High school grad	634	17.1	10.2
	Associates degree	527	17.5	10.4
	Bachelors degree	735	17.4	10.4
	Graduate education	421	17.5	10.5

TABLE 5.4 Descriptive Statistics for Model Variables (continued)				
			Mean	
		N	*ln (SDE Area)*	*ln (DT)*
Language at Home	Non-English	259	16.7	10.1
	English	2,372	17.3	10.4
Occupation	Executive/professional	915	17.5	10.5
	Clerical/service	575	17.4	10.4
	Manufacturing/physical labor	225	17.0	10.2
Ln Opportunity Density (activities per sqkm)	Quartile 1 (-3.0 to 2.6)	659	17.8	10.6
	Quartile 2 (2.6 to 3.2)	658	17.7	10.6
	Quartile 3 (3.2 to 3.6)	659	17.5	10.4
	Quartile 4 (3.6 to 8.1)	655	15.9	9.8
Ln Population Density (persons per sqkm)	Quartile 1 (3.5 to 7.2)	658	16.7	10.2
	Quartile 2 (7.2 to 7.9)	658	17.5	10.4
	Quartile 3 (7.9 to 8.3)	661	17.7	10.5
	Quartile 4 (8.3 to 12.2)	654	17.0	10.2
Ln Employment Density (jobs per sqkm)	Quartile 1 (1.1 to 6.1)	657	16.5	10.1
	Quartile 2 (6.1 to 6.9)	659	17.3	10.3
	Quartile 3 (6.9 to 7.5)	660	17.9	10.6
	Quartile 4 (7.5 to 12.7)	655	17.2	10.3
Homicides per 10,000 population	Quartile 1 (0.0 to 0.2)	650	17.3	10.4
	Quartile 2 (0.2 to 0.5)	651	17.4	10.4
	Quartile 3 (0.5 to 0.8)	651	17.1	10.3
	Quartile 4 (0.8 to 190)	650	17.2	10.3
Local API Score Estimate	Quartile 1 (463 to 652)	650	16.9	10.1
	Quartile 2 (653 to 705)	652	17.2	10.3
	Quartile 3 (705 to 772)	650	17.3	10.4
	Quartile 4 (772 to 923)	650	17.5	10.5
Local Transit Share	Quartile 1 (0 to 10%)	647	17.5	10.5
	Quartile 2 (10 to 15%)	646	17.3	10.4
	Quartile 3 (15 to 23%)	648	17.1	10.3
	Quartile 4 (23 to 80%)	642	17.1	10.2

number of trips (NT), is an important component of extensiveness, already seen to have a positive, if relatively low, correlation to SDE and DT. Vehicle access, as operationalized by cars per household member, is another important characterization of respondents' access to and use of cars for travel. I expect that increased levels of auto ownership and access will increase SDE area and DT, in line with a large body of research on auto access and travel (Ewing and Cervero 2010). The percentage of trips by walking is also included in the model. I would logically expect SDE and DT to decrease as walking trips increase as a share of all trips. Note that the percentage of trips taken by public transit or bicycle is generally extremely low among respondents, particularly for the weekend, and therefore excluded.[10] Instead, I included a local transit share variable, described below. The data in Figure 5.7 show that the two dominant activity types on weekends are household-serving and social/recreational activities. Therefore, I included the percentages of each of these trip types from among all activities. The literature on trip purpose suggests that household-serving trips should occur close to home, and thus be inversely related to SDE and DT (Handy 1992). Researchers have found that social and recreational trips also tend to occur close to home, at least relative to work trips (Guest and Wierzbicki 1999). However, I have found in research on the 2009 National Household Travel Survey that social and recreational trips have more potential to occur far from home than household-serving trips (Mondschein 2011). Thus, all else being equal, I expect social and recreational trips to be positively related to SDE and DT.

The second set of predictor variables are personal characteristics. The simple, descriptive relationship between most of these variables and spatial activity extensiveness is explored in Figures 5.2 through 5.5. Income, sex, race/ethnicity, age, and education all show specific relationships with activity space extensiveness, at least in descriptive analysis. Income and education appear to be positively related to SDE and DT, while being female, being Hispanic (as opposed to other race/ethnicities), and being either a young adult or over 65 should have a negative relationship with SDE and DT. I base these expectations both on the descriptive

[10] Earlier versions of this analysis also included a percentage of trips by car variable. However, the percentage of trips by car was found to have an insignificant relationship to activity space extensiveness and was replaced by the car ownership, vehicles per household member, variable. I argue that vehicles per household member is more appropriate to understanding activity space extensiveness because it is a more long-term measure of car availability, rather than measuring car use on a particular day.

analysis and on the socioeconomics of travel literature which reinforce the increased travel of high income, male, and Non-Hispanic white individuals (Pucher and Renne 2003). I add two additional variables: language (English or non-English speaking household) and occupation. Language spoken at home is a useful proxy for immigration status (Stevens 1992), and it may shed light on whether, for example, Latinos' divergent activity spaces are due to a relatively recent arrival in the city or country or whether other factors may be at play. Occupation, divided into categories of executive/professional, clerical/service, or manufacturing/physical labor, is correlated with income and education, but it may also highlight differences in extensiveness for reasons beyond resource availability, such as differences resulting from social structure or culture.

The third set of variables takes into account the neighborhood contexts of respondents. Three of the variables measure activity space density. Population density is a straightforward measure of persons per square kilometer within the SDE activity space, using the 2000 Census (closest measure to the 2003 SCAG survey). Employment density is, likewise, a basic measure of jobs per square kilometer in the SDE activity space, using the 2000 Census Transportation Planning Package. Opportunity density is a count of activity locales for the entire SCAG sample that lie within a given respondent's activity space, divided by activity space area. Conceptually, opportunity density is an accessibility measure, indicating the intensity of opportunities within the activity space. Living somewhere with a high opportunity density would indicate that many people come to your neighborhood to engage in activities. All the density measures are normalized using a natural log function. I expect opportunity density to have an inverse relationship with travel distance, and potentially with activity space size. Ewing and Cervero find just this relationship between accessibility measures like opportunity density and VMT

(2010). Like opportunity density, I would expect increased population and employment density to generally be associated with smaller SDE area and DT.

The final three neighborhood variables attempt to capture potentially hard-to-measure aspects of a person's activity space. Crime, as homicides per 10,000 in the respondent's zip code, may capture levels of comfort and place attachment, with high crime potentially keeping a respondent close to home due to perceived insecurity.[11] I base this expectation on research, generally focused on transit use, that shows people will forgo a transit trip if the threat of crime is prevalent (Kim, Ulfarsson et al. 2007). While I expect an inverse relationship, I also acknowledge that if local crime is a problem but a trip is not forgone, it may actually cause the opposite effect and drive individuals further from home to complete their daily activities. Increases in local education achievement, based on California Academic Performance Index (API) scores in the vicinity of each respondent, may increase travel extensiveness for the same reasons as cited for high income and personal education above. Finally, local transit share, taken from the 2000 Census, is representative both of the local transportation infrastructure and potentially the lifestyles of local residents. I expect a negative relationship of local transit share to SDE area and DT because transit trips are typically slower and on a more constrained network than auto trips, and locales with higher transit use may engender local activity patterns that remain closer to home.

5.4.2 Model Form

The dependent variables, SDE area and DT, are both continuous. The range of potential independent variables includes continuous, ordinal, and categorical forms. Therefore, an

[11] Note, however, there is almost no correlation, positive or negative between crime rate and total number of trips made in the day, whether on the weekend or weekday.

Ordinary Least Squares (OLS) multiple regression would be appropriate for the initial phase of model building. One primary drawback of an OLS model in this context, as in much urban research, is the necessary assumption of the independence of observations. Here, observations are likely to be spatially correlated and therefore not independent. I describe below my attempts to address spatial correlation among the observations and the relationships between variables in Section 5.4.4. However, the OLS model provides a useful baseline for subsequent refinement with spatial models, not least because GWR and other spatial regression tools are based upon linear regression, in terms of inputs and model structure. The OLS regressions were run in the Stata statistical environment (StataCorp 2011).

The OLS model specification can be represented as:

$$
\begin{aligned}
y_i = \quad & \beta_0 + \\
& \beta_{ACT1} x_{ACT1} + \dots + \beta_{ACTj} x_{ACTj} + \\
& \beta_{PER1} x_{PER1} + \cdots + \beta_{PERk} x_{PERk} + \\
& \beta_{NBR1} x_{NBR1} + \cdots + \beta_{NBRl} x_{NBRl} + \\
& \varepsilon_1
\end{aligned}
$$

where y_i is the dependent variable, $x_{ACT1} \dots x_{ACTj}$ are activity variables, $x_{PER1} \dots x_{PERk}$ are personal characteristics variables, $x_{NBR1} \dots x_{NBRl}$ are neighborhood characteristics variables, β_0 is a constant term, all other β are coefficients, and ε_1 is an error term for $1 \dots i$ observations. Model variants include different sets of variables in order to capture each set's contribution to activity space size.

5.4.3 Global Model Results

Table 5.5 displays the results of six separate OLS model runs, categorized by dependent variable – SDE area or DT – and the set of independent variables included to explain variation in activity and travel patterns. For ease of comparison across independent variables, standardized coefficients (betas) are provided. Models 1 (SDE area) and 2 (DT) show the relationship of activity to other respondents' activity patterns and socioeconomic factors. Models 3 (SDE area) and 4 (DT) introduce a range of neighborhood factors to the models, including local population and employment densities. Models 5 (SDE area) and 6 (DT) add one final local accessibility measure, "opportunity density."

For the activity and socioeconomic models (Models 1 and 2), the most powerful and significant effects are seen with the daily number of activities, which increases activity space size, and the percent of trips taken by walking, which reduces activity space size. Household vehicle ownership increases the activity measures, but does not rise to significance at the 0.05 level. Social and recreational trips, as the percent of all trips, also significantly increases SDE area and DT. Household-serving trips have a negative relationship with activity space size or distance traveled, but are not significant at the 0.05 level. Many of the socioeconomic variables do not come across as significant in either model. Only income and the executive/professional or service industry categories (versus manual labor) are significant,and positively associated with activity extensiveness, as expected. The extent of women's activities are more constrained in either model, but the result is not significant at 0.05. While not identical, the coefficients in Models 1 and 2 do not diverge much from each other. Overall, Model 2 (DT) explains more of the variation in activity space size than Model 1 (SDE area) as measured by adjusted R-squared, 0.192 compared to 0.115.[12]

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[12] Note that the Akaike Information Criterion, Corrected (AICc) measure for Models 1 and 2 are not comparable. AICc is a measure of the relative goodness of fit of a statistical model, where lower values are superior to higher values. The measure also penalizes the inclusion of additional parameters in the model. Because the dependent variables for Models 1 and 2 are different, they cannot be compared using AICc.

TABLE 5.5 OLS Regression Results, Activity Space Extensiveness

	Model 1 Depvar: SDE		Model 2 Depvar: DT		Model 3 Depvar: SDE		Model 4 Depvar: DT		Model 5 Depvar: SDE		Model 6 Depvar: DT	
	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
Daily # of Weekend Activities	**0.208**	**0.000**	**0.365**	**0.000**	**0.185**	**0.000**	**0.371**	**0.000**	**0.179**	**0.000**	**0.365**	**0.000**
Vehicles per Household Member	0.041	0.068	0.039	0.069	**0.059**	**0.011**	**0.049**	**0.026**	**0.052**	**0.016**	**0.043**	**0.041**
% Trips by Walking	**-0.188**	**0.000**	**-0.155**	**0.000**	**-0.119**	**0.000**	**-0.100**	**0.000**	**-0.109**	**0.000**	**-0.090**	**0.000**
% Social/Recreational Trips	**0.074**	**0.001**	**0.058**	**0.007**	**0.059**	**0.011**	0.042	0.055	**0.067**	**0.002**	**0.050**	**0.018**
% Household-Serving Trips	-0.043	0.061	-0.034	0.113	**-0.055**	**0.018**	**-0.038**	**0.090**	-0.035	0.115	-0.019	0.381
Income (Ordinal Scale)	**0.101**	**0.000**	**0.062**	**0.010**	**0.088**	**0.001**	0.045	0.079	**0.066**	**0.008**	0.025	0.295
Education (Ordinal Scale)	0.001	0.968	0.004	0.871	0.012	0.659	0.008	0.759	0.023	0.353	0.018	0.459
Female	-0.032	0.127	-0.028	0.163	**-0.051**	**0.018**	**-0.043**	**0.037**	**-0.048**	**0.017**	**-0.041**	**0.036**
Hispanic (vs. NHWhite)	0.043	0.112	0.017	0.513	**0.058**	**0.042**	0.026	0.337	0.026	0.342	-0.003	0.919
African American (vs. NH White)	0.034	0.106	-0.001	0.943	**0.065**	**0.004**	0.018	0.389	**0.054**	**0.010**	0.009	0.667
Asian-PI (vs. NH White)	0.018	0.393	0.008	0.708	0.029	0.177	0.006	0.769	0.012	0.558	-0.010	0.628
English at Home	0.019	0.443	0.012	0.609	0.012	0.639	0.015	0.548	0.011	0.656	0.012	0.591
Age	0.115	0.339	0.165	0.151	0.088	0.472	0.114	0.330	0.136	0.238	0.153	0.168
Age-Squared	-0.130	0.281	-0.184	0.110	-0.105	0.391	-0.145	0.217	-0.185	0.109	-0.213	0.056
Executive/Prof. (vs. Man Labor)	**0.067**	**0.010**	**0.091**	**0.000**	**0.088**	**0.001**	**0.099**	**0.000**	**0.067**	**0.008**	**0.082**	**0.001**
Service Industry (vs. Man Labor)	**0.064**	**0.008**	**0.099**	**0.000**	**0.069**	**0.005**	**0.105**	**0.000**	**0.067**	**0.004**	**0.104**	**0.000**
Population Density (ln)					**-0.328**	**0.000**	**-0.246**	**0.000**	**-0.114**	**0.004**	-0.052	0.179
Employment Density (ln)					**0.117**	**0.003**	**0.086**	**0.021**	**0.319**	**0.000**	**0.267**	**0.000**
Opportunity Density (ln)									**-0.498**	**0.000**	**-0.448**	**0.000**
Homicide Rate					**0.047**	**0.027**	0.029	0.155	0.034	0.087	0.017	0.368
School Achievement (API Score)					0.032	0.262	0.050	0.069	0.042	0.121	**0.059**	**0.024**
Local Transit Share					**0.064**	**0.046**	0.054	0.079	0.044	0.146	0.036	0.224
Constant	**.**	**0.000**	**.**	**0.000**	**.**	**0.000**	**.**	**0.000**	**.**	**0.000**	**.**	**0.000**
N	2081		2077		1920		1916		1920		1916	
F	17.81		31.75		17.48		27.17		29.52		38.08	
Prob > F	**0.000**		**0.000**		**0.000**		**0.000**		**0.000**		**0.000**	
R-squared	0.121		0.198		0.162		0.232		0.255		0.307	
Adj R-squared	0.115		0.192		0.153		0.223		0.246		0.299	
AICc	8303.2		5524.8		6950.2		4698.3		6726.3		4502.9	

Note: Coefficients significant at the 0.05 level are shown in bold. Beta coefficients are standardized for comparison among variables.

Models 3 (SDE area) and 4 (DT) incorporate neighborhood characteristics in addition to activity and socioeconomic information. The overall explanatory power of these models is increased, with an adjusted R-squared of 0.153 for Model 3 and 0.223 for Model 4. The AICc values for both models also decrease substantially from the models without neighborhood factors. Critically, the addition of the neighborhood factors does not just increase overall explanatory power but it brings many of the activity and socioeconomic coefficients into significance. All of the activity variables become significant, with the exception of social/recreational trip share in Model 4, which is just on the other side of the 0.05 threshold. Some of the socioeconomic variables also become significant. In both models, being female becomes significantly associated with constrained activity space or patterns, as expected. In Model 3, being Hispanic or African American relative to Non-Hispanic White is significantly associated with *larger* activity patterns (whether SDE area or DT). This is an unexpected result, based on the descriptive exploration showing smaller activity spaces for Hispanics and no substantial difference between African Americans and Non-Hispanic Whites. The result suggests that travel patterns that vary by race and ethnicity may be understood as varying to a great degree due to differences in residential location rather than some other more personal or social factor. Notably, for Model 4, the income variable actually drops *out* of significance, though the occupational categorical variables do remain significant. This result underscores that higher income does not itself necessarily compel long trips, but that the choice to live in desirable, less dense areas by may be the source of longer distance traveled (and higher VMT) by the well off. On the other hand, income remains significant in Model 3 (SDE area), indicating that regardless of mileage covered within an activity space, the relationship between income and *area* covered in the activity space persists.

The two density variables included in Models 3 and 4 are population and employment density. They are significant in both models, but they have opposite effects. Increased population density lessens activity area or distance traveled, while increased employment density in the vicinity of the residence increases it. The effect of population density is as expected. While I also expected employment density would be associated with smaller activity areas, as its correlation with the dependent variable is negative, it may also be true that controlling for other factors, living in a job-rich area would serve to actually increase activity extensiveness *on the weekend*, when activities are largely non-work and many job locations near the home are essentially obstacles rather than opportunities. In fact, I find that the negative correlation between activity space size and employment density is fifty percent stronger on weekdays than weekends (r = -0.21 versus r = -0.14), implying that during the week, employment density could have a negative relationship to activity space size as expected.

Only two of the other neighborhood factors, homicide rate and local transit share, are significant, and they are only significant in Model 3 (SDE area). Unlike expectations, however, these factors are actually associated with increased activity space size. As discussed in the previous section, it is plausible that rather than keep individuals close to home, a higher crime rate is driving people further from home to accomplish their weekend activities. Increased transit share contributing to large activity spaces is also challenging to explain. At the least, this suggests that in Los Angeles areas of high transit use and compact lifestyles are not synonymous, as the concept of transit-oriented development might idealize. However, also possible is that areas of high transit use in Los Angeles also have high levels of automobile mobility and thus larger activity spaces. Figure 5.8 shows that the areas with the highest levels of transit use, most particularly Downtown Los Angeles, also have good access to freeways. Thus, the transit share variable may just function as a proxy for places with good rail *and* freeway access, and thus more ability to range widely.

Models 5 (SDE area) and 6 (DT) introduce only one additional independent variable, the accessibility measure of opportunity density. As previously discussed, opportunity density captures the density of all destinations in the SCAG survey within each respondent's SDE-defined activity space. It is a measure of collective activity and its concentrations throughout the region. In line with expectations and Ewing and Cervero (2010), opportunity density has a very strong, significant inverse relationship with either SDE area or DT. In fact, it has the strongest effect of any dependent variable in the model. Furthermore, adjusted R-squared goes up substantially for both models (particularly Model 5) and AICc decreases again. Adding opportunity density shifts some of the other coefficients into or out of significance. For both models, household-serving trip share is no longer significant at the 0.05 level. For Model 5 (SDE area), being Hispanic is no longer significant, though being African American remains so. The homicide rate and transit share variables also drop out of significance, implying that both measures may have been accounting for a dearth of opportunities in the neighborhood. For Model 6 (DT), the addition of opportunity density continues to decrease the significance of income to distance travelled, a marked difference from Model 5 (SDE area). Population density also becomes an insignificant coefficient with the addition of opportunity density. Finally, local school achievement does become significant in Model 6, with a positive effect on distance traveled, as expected.

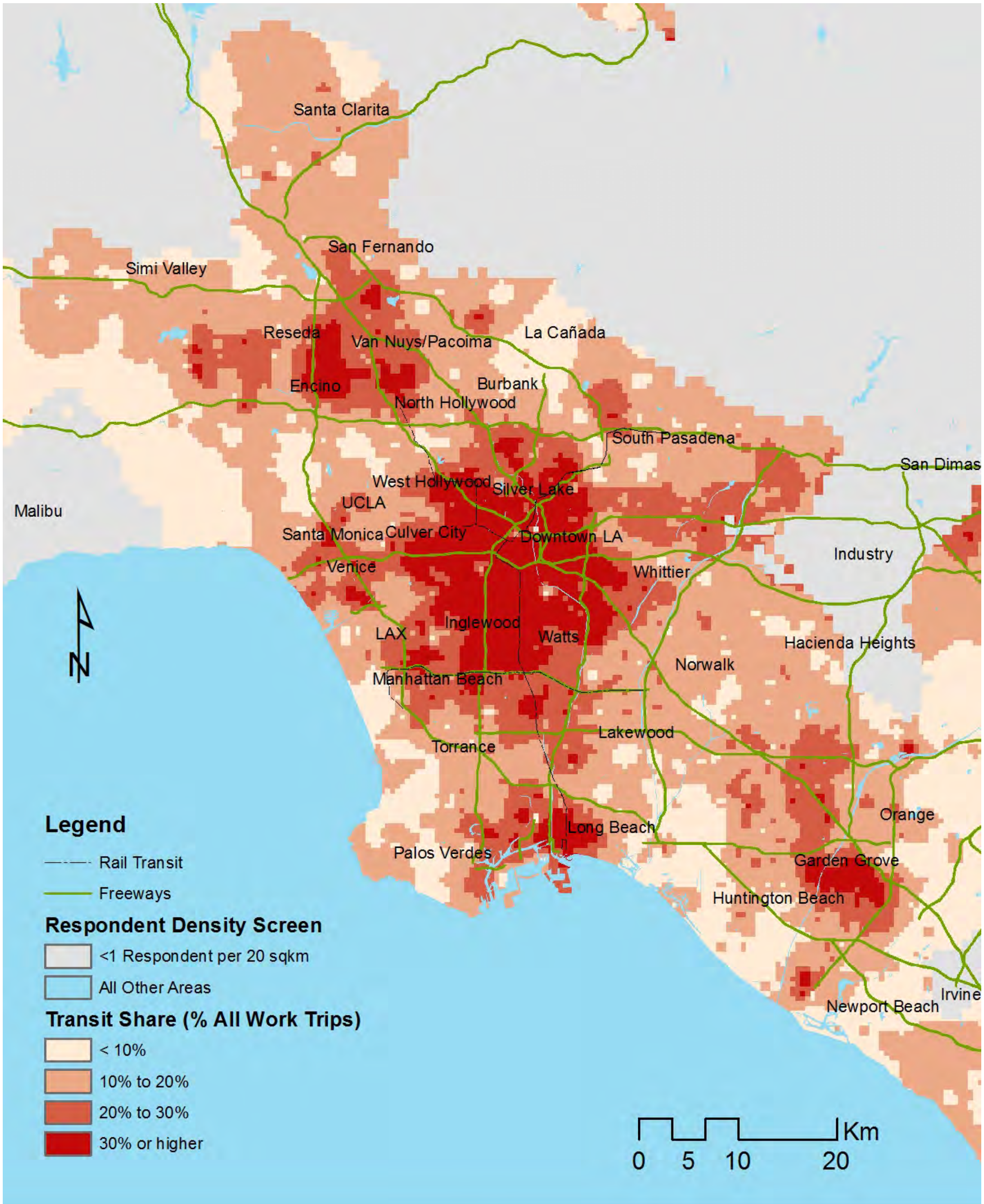

FIGURE 5.8 Transit Share across the Region (2000 Census Data)

5.4.4 Model Evaluation

In this section I evaluate the statistical and conceptual validity of the global OLS models before proceeding onto the geographically-weighted regression. Beyond the tests of model and coefficient significance, an examination of the model residuals can shed light on whether the model indeed fits the data well. One important assumption in OLS regression is that the variance of the error is constant across observations, or homoscedastic. In multiple regression, one important way of testing for homoscedasticity is to compare, in a scatter plot, the predicted values of the outcome variable to the residuals. If the variation in the residuals appears relatively random but consistent across all predicted outcomes, then the assumption of homoscedasticity is met. Figure 5.9 is a scatterplot of the predicted values of Model 5 (SDE) versus the residuals. I focus model validation on Model 5 because it is the most conceptually apt of the six OLS models (see discussion in this section) and because it also serves as the basis for the GWR analysis that follows. The distribution of the residuals across all predicted values appears relatively random, if a bit wider in the middle of the distribution. A Breusch-Pagan test for heteroscedasticity

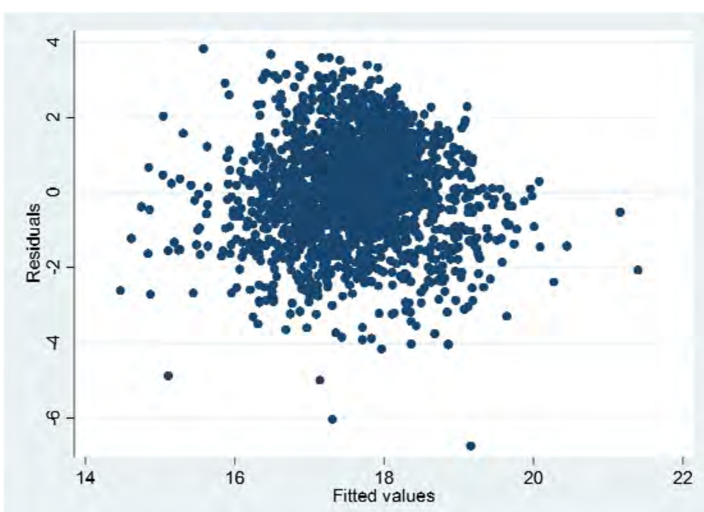

FIGURE 5.9 Model 5 (SDE area) Homoscedasticity Plot

echoes my visual assessment, failing to reject the null hypothesis ($p = 0.126$) that the model is homoscedastic.

Another important assumption of OLS models is that the residuals are normally distributed, so that the hypothesis testing of the coefficients and overall model will be accurate. Figure 5.10 is a plot of the residual values for Model 5 compared to a normal distribution. The distribution of the residuals is evidently close to a normal distribution, suggesting that the model sufficiently meets the requirement that residuals be normally distributed. The homoscedasticity and normality plots contribute to the impression that Model 5 is statistically appropriate for the relationships being investigated. I also addressed other assumptions of linear regression in further testing, including an exploration of potential data outliers skewing the analysis and checking for potential multicollinearity with a variance-inflation-factor test. These investigations did not reveal any significant issues. Of course, another very important assumption with OLS regression is that observations are independent of each other. That assumption is certainly violated, despite the random sampling on the SCAG survey, in that

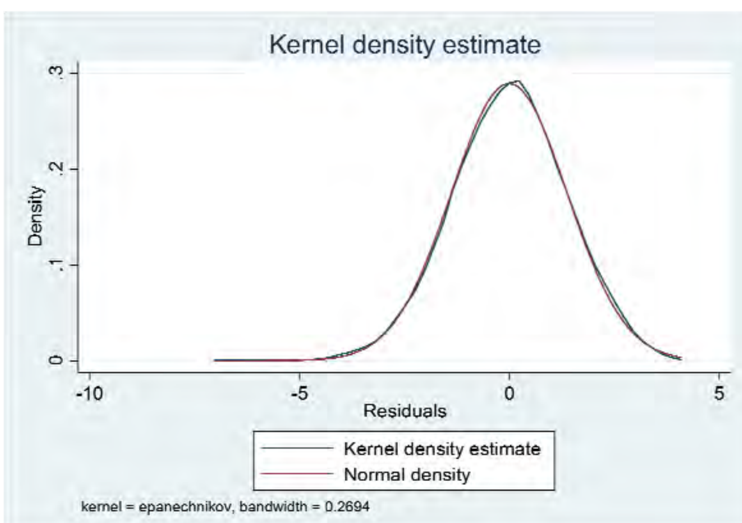

Figure 5.10 Model 5 (SDE area) Normality of Residuals Plot

respondents live in spatial proximity to one another. I discuss this problem of spatial autocorrelation further in the next section of this chapter.

In addition to their statistical validity, the global OLS models effectively address the three hypotheses, set out in this chapter's introduction, linking the conceptual framework to the empirical analysis. The first hypothesis posits a relationship between socioeconomic status and activity space extent, where spatially extensive travel patterns are positively associated with higher socioeconomic status. The SDE area models (1, 3, and 5) do in fact show a significant positive relationship between income and activity space size, even when controlling for built environment factors like density. This finding is important in large part because of the second hypothesis which states that activity space extent provides a more conceptually and statistically valid model of everyday behavior and socioeconomic than simply using distance traveled. Indeed, as variables were added to the models, the DT models (2, 4, and 6) showed an increasingly insignificant relationship to income, suggesting that distance traveled is less associated with income than with the size of one's activity space. Of course, the measures generated for activity space extent, distance traveled, and socioeconomic status do not fully capture their conceptual ideals, but even this straightforward use of single-day travel data reveals an intriguing difference between activity space extent and distance traveled. Finally, the OLS analysis confirmed the third hypothesis about the importance of the built environment in activity space size. It thus reinforces Ewing and Cervero's meta-analytic finding that the built environment does matter in travel behavior. In this case, greater opportunity density, primarily, and population density, secondarily, do lead to smaller activity spaces.

5.5 Controlling for Location

While this chapter's analysis focuses on activity space size and distance travelled, the location of activity spaces analyzed may have a relationship to their size. In other words, I expect spatial autocorrelation among the sizes of activity spaces, and those with similarly sized spaces are more likely to live near one another. In Figure 5.11, even observationally, it is clear that similar activity space sizes are somewhat clustered. The visualization shows the variation in the natural log of activity space (SDE, sqkm) size across the region, using a basic inverse-distance weighting function for the visualization. A Moran's I spatial autocorrelation test of ln(SDE area) shows that clustering is present, with a Moran's Index of 0.323 (z-score of 6.209, p-value 0.000), indicating moderate but significant clustering of values. The spatial distribution of different sized activity spaces does not necessarily match expectations. Notably, activity space sizes appear to be larger in some parts of Los Angeles that are known for their relative poverty. For example, Watts and Inglewood show particularly large activity spaces, in contradistinction to smaller activity spaces in West Hollywood or Santa Monica, whose residents are generally relatively well off. These well-off areas, though, also have a higher density of destinations.

5.5.1 Spatially-Dependent Modeling with Geographically Weighted Regression (GWR)

Of course, the simple observation of spatial clustering does not control for the many factors already discussed and explored as relevant to activity space extensiveness in the OLS models. Many of the values of interest in this analysis, and in urban planning generally, are spatially nonstationary, such as income, school performance, the auto and transit networks, and urban density. However, a well-constructed model of an urban phenomenon can account for this spatial nonstationarity. If well-specified, the residuals from the model will not show significant

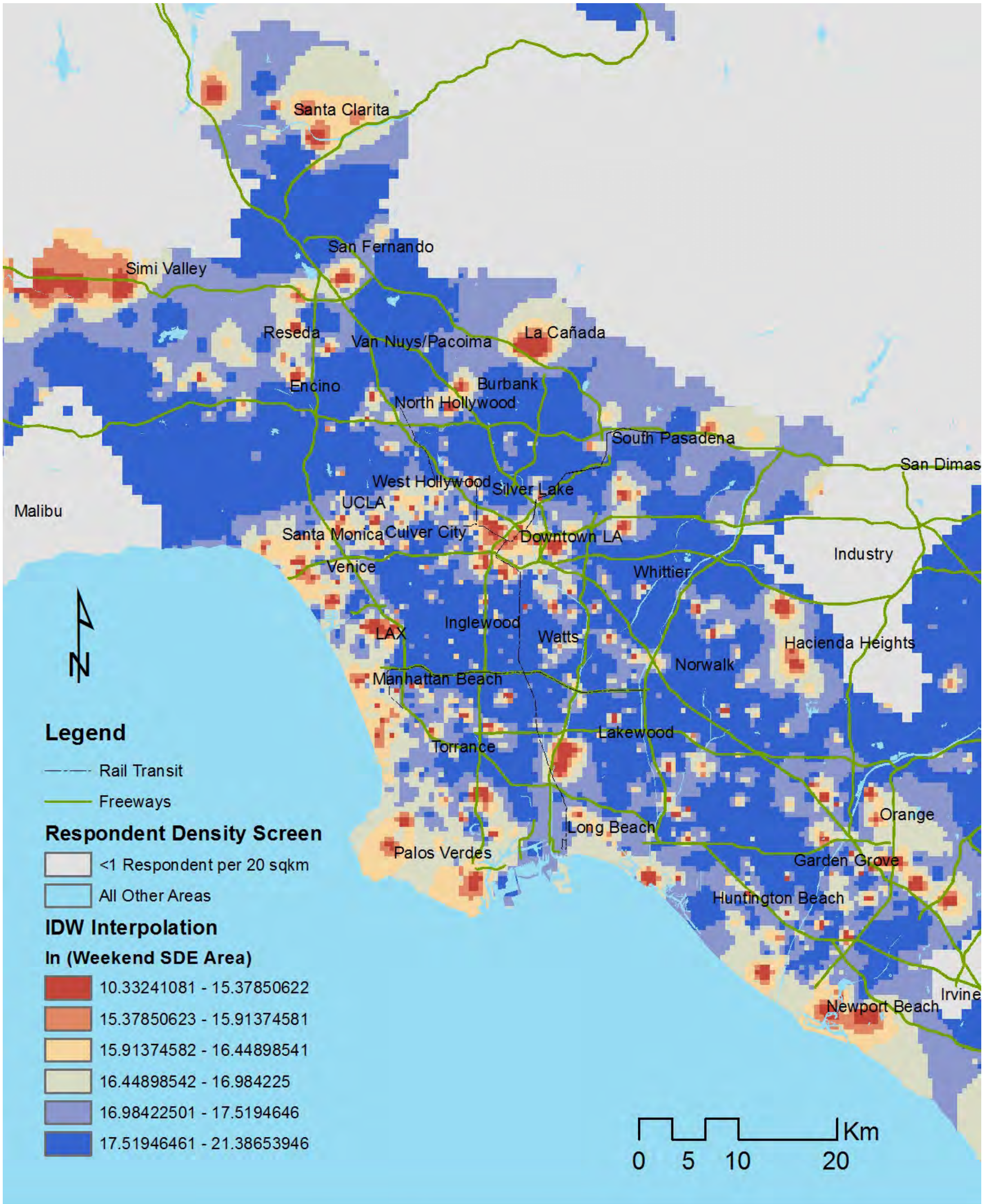

FIGURE 5.11 Spatial Distribution of Activity Space Sizes (Inverse Distance Weighting Method)

clustering or dispersion. In the case of the OLS models developed in Section 5.4 above, the model residuals do show significant clustering. The residuals in Model 5, which has the highest adjusted r-squared (0.246) and lowest AICc (6726.3) values of the SDE area models, has a Moran's index of 0.392 (z-score 10.87, p-value 0.000). This significant clustering of the model residuals suggests that the model is not completely specified.

A geographically-weighted regression (GWR) is one way of potentially addressing some of the spatial dependence in the model. As discussed in Chapter 4, GWR is not the only spatial econometric method for modeling spatially-dependent relationships. However, it has the potential to provide its own distinctive set of results to the overall analysis. GWR can potentially address the statistical validity threat of spatial dependence in the processes being modeled and also contribute specifically to an understanding of spatial processes important to urban and transportation researchers. GWR allows regression coefficients to vary across space. It is conceptually appropriate when particular parameters of a model may be more influential in some places than in others. It opens up the possibility that some of the travel, socioeconomic, and neighborhood factors often considered by analysts and planners do not have consistent effects throughout a region. For example, one can ask whether income has roughly the same effect on activity or travel everywhere, or whether it is less important in places that have high densities of opportunities. Such spatial variability is inherent to the complexity of the city and the difficulty in establishing one-size-fits-all policies for improving accessibility.

As discussed in Chapter 4, researchers have used GWR in a range of urban research applications. The basic form of the model is:

$$y_i(\boldsymbol{u}) = \beta_0(\boldsymbol{u}) + \beta_1(\boldsymbol{u})x_1 + \beta_2(\boldsymbol{u})x_2 + \ldots + \beta_n(\boldsymbol{u})x_n + \varepsilon(\boldsymbol{u})_i$$

It is much like a traditional linear regression, but in the case of GWR, all parameters are estimated around a location **u**. A separate linear regression is run at each observation's location, with the set of observations determined by spatial proximity. In this way, different coefficients are derived for each observation in the dataset. The results thus derived can be compared to the results of a global OLS regression, in terms of explanatory power and goodness-of-fit. In addition, the GWR model may address the problem of spatial dependence among the residuals, improving the interpretability of the model.

Model 5 (SDE area) has the best fit and explanatory power of all activity space models, so I have chosen it for the GWR analysis as well. I implemented GWR in the software package GWR3, developed by the statisticians who originated the GWR model. Aside from the inclusion of dependent and explanatory variables, GWR allows for some flexibility in the establishment of a spatial context for each local regression (Fotheringham, Brundson et al. 2002). The sample subset, or kernel, can be set at a fixed distance from each observation, or allowed to vary but include a fixed number of neighbors. The kernel "bandwidth," whether in terms of distance or number of neighbors, can either be set manually or optimized to minimize the AICc value for the model. In cases where observations are relatively irregularly distributed about the study area, as with residents in the Los Angeles region, Charlton and Fotheringham (2008) recommend using an adaptive kernel size (fixed number of neighbors), and setting the bandwith size to minimize AICc.

5.5.2 GWR Model Results

Table 5.6 shows the GWR model run results, along with the results of Model 5, for easy comparison. Here I include the non-standardized coefficients of Model 5 (unlike in Table 5.5)

TABLE 5.6 OLS and GWR Regression Coefficients: Ln(Weekend SDE Area)						
	OLS	*GWR Coefficients*				
	(Model 5)	*Minimum*	*Lower Quartile*	*Median*	*Upper Quartile*	*Maximum*
Daily # of Weekend Activities	0.117	0.051	0.096	0.117	0.126	0.152
Vehicles per Household Member	0.172	-0.286	0.046	0.134	0.271	0.589
% Trips by Walking	-0.996	-3.094	-1.083	-0.671	-0.452	0.196
% Social/Recreational Trips	0.545	-0.528	0.230	0.559	0.806	1.943
% Household-Serving Trips	-0.263	-0.998	-0.523	-0.290	-0.008	0.721
Income (Ordinal Scale)	0.056	-0.137	-0.015	0.042	0.064	0.251
Education (Ordinal Scale)	0.030	-0.189	-0.026	0.051	0.144	0.377
Female	-0.154	-0.502	-0.243	-0.153	-0.062	0.125
Hispanic (vs. NHWhite)	0.102	-0.559	-0.086	0.188	0.392	0.852
African American (vs. NH White)	0.362	-0.889	-0.236	-0.025	0.170	0.734
Asian-PI (vs. NH White)	0.083	-0.707	-0.275	0.069	0.331	1.271
English at Home	0.060	-1.683	-0.189	0.129	0.395	1.020
Age	0.014	-0.079	0.002	0.018	0.042	0.083
Age-Squared	0.000	-0.001	-0.001	0.000	0.000	0.001
Executive/Prof. (vs. Man Labor)	0.223	-0.272	-0.008	0.122	0.346	0.583
Service Industry (vs. Man Labor)	0.256	-0.379	0.020	0.168	0.486	1.063
Population Density (ln)	-0.220	-1.542	-0.705	-0.157	0.155	0.670
Employment Density (ln)	0.483	-0.264	0.360	0.531	0.823	1.603
Opportunity Density (ln)	-1.004	-3.009	-2.078	-1.170	-0.849	-0.084
Homicide Rate	0.008	-0.581	-0.021	0.011	0.181	0.833
School Achievement (API Score)	0.001	-0.004	0.000	0.001	0.002	0.006
Local Transit Share	0.601	-5.366	-1.640	0.264	1.392	4.423
Constant	16.937	9.909	16.226	18.697	21.296	26.946
N (Global)	1920	1920				
N (Local)	--	456				
Parameters	22	251.7 (Effective)				
R-squared	0.255	0.449				
Adj R-squared	0.246	0.424				
R-squared (Local)	--	0.349	0.438	0.488	0.548	0.681
AICc	6726.3	6498.4				

for clear comparison to the GWR outputs. The AICc kernel bandwidth optimization determined that using 456 neighbors in each local regression would be optimal. This is roughly 24 percent of the full sample included in each local regression. The "effective" number of parameters in the model is estimated to be 251.7. The effective number is roughly analogous to the number of coefficients in an OLS model, but accounts for the increased complexity of the GWR model. The effective number of parameters is evident in the difference between r-squared and the adjusted r-squared for the model, which drops from 0.449 to 0.424. Regardless, the adjusted r-squared is substantially higher than that of the OLS model. Similarly, the GWR AICc is substantially lower, at 6498.4. This suggests that the GWR model is an improvement over Model 5 in terms of model fit and explanatory power.

As mentioned earlier, GWR allows all coefficients to vary across space, at each observation. Interpretation of that variability can provide additional insights into the processes that underlie activity and travel in cities. In essence, the GWR model produces a full OLS regression for each observation, including (in this case) the 456 nearest neighbors in the local sample. The coefficients produced at each observation can be compared against one another to see how they vary from observation to observation and place to place. Table 5.6 includes the minimum, lower quartile, median, upper quartile, and maximum values of the set of estimated coefficients for each of the variables. One way of interpreting the results is to observe whether the sign (positive/negative) of the coefficients change over space. Within the lower to upper quartile range, the daily number of weekend activities, vehicles per household member, walk trips, social/recreational trips, household-serving trips, being female, being a service employee, employment density and opportunity density coefficients do not change their signs. Further, within the lower to upper quartile range, the signs of all these coefficients are consistent with the global model. The other coefficients, such as income and population density, while similar to the OLS model at the median coefficient, change sign within the range.[13]

Figure 5.12 illustrates variability in income's influence on activity space size. Again, the story told by the global model – income increases weekend activity space size – is not always true locally. In places like north Orange County (Huntington Beach, Garden Grove), southeast Los Angeles County (Norwalk), and the eastern San Fernando Valley (near North Hollywood and Burbank), the model indicates that higher income actually decreases activity space size. Further, in much of Los Angeles County, income has little effect either way. In these places, perhaps local activities hold particular appeal for local higher income residents. In order to better understand what might be different about these places, I conducted a small descriptive analysis of what might set apart areas where the income coefficient is lower than average. Table 5.7 shows the mean income coefficient for several socioeconomic categories. It shows that staying closer to home when more well off is associated with places that are more Latino, non-English speaking, low education, but solidly middle class.

A neighborhood with these demographic characteristics may be an immigrant or ethnic "enclave" (Light, Sabagh et al. 1994). Blumenberg has examined the travel behavior of immigrants, including those in enclaves, and has found that they tend to use non-auto based modes of travel far more than native born travelers (Blumenberg 2009). In addition to travel mode differences, which may in part be captured by the auto ownership and walking variables in

[13] A change in a coefficient's sign across the spatial distribution of the sample does not mean that the coefficient is not statistically significant or globally the same as zero. It simply means that when these phenomena are modeled locally, a factor that appeared to have a particular relationship to the dependent variable actually has a complex, variable relationship to the dependent variable, depending on location.

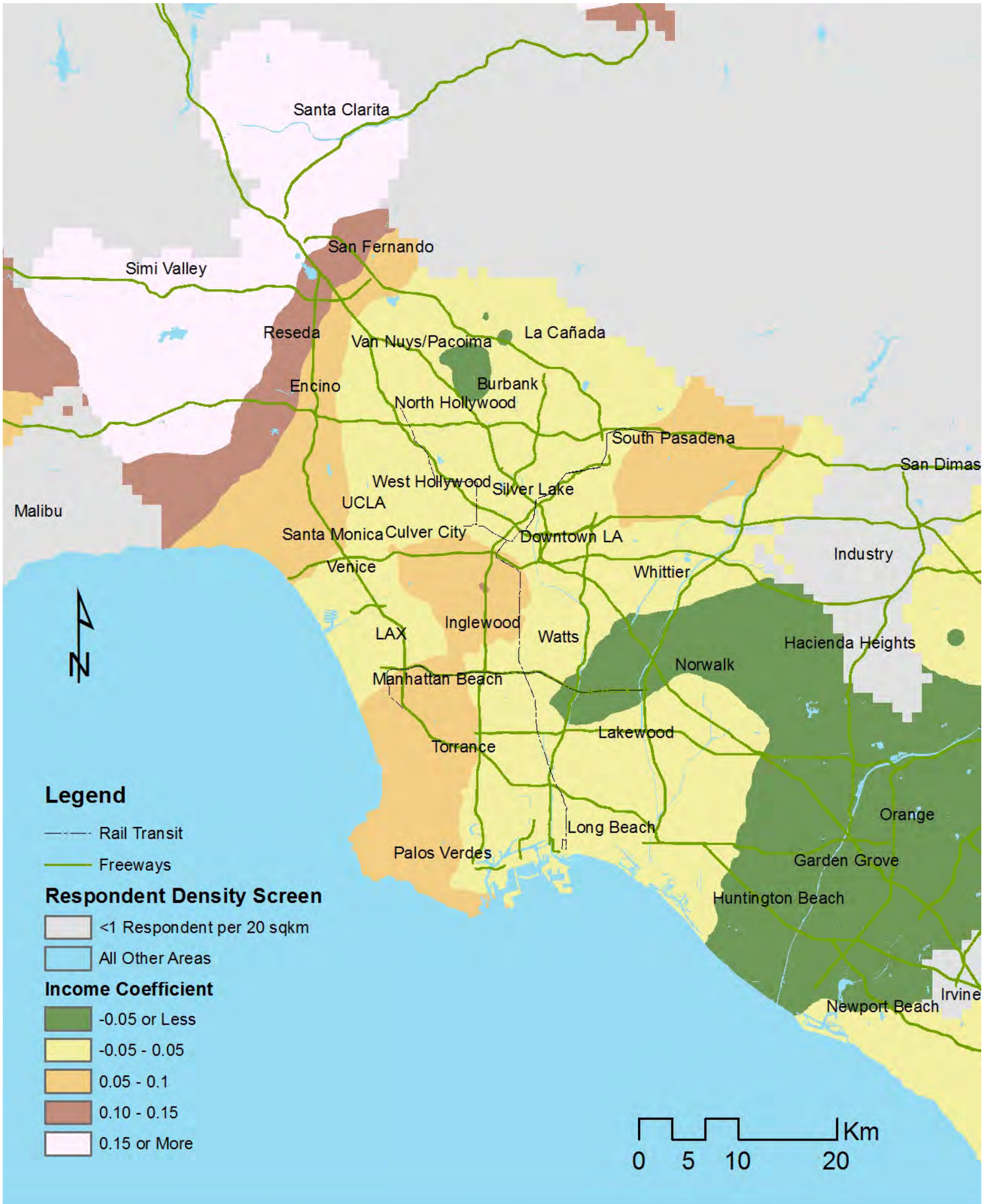

FIGURE 5.12 Spatial Distribution of Income Coefficient in GWR Model (Inverse Distance Weighting Method)

TABLE 5.7 Income Coefficient (GWR Model) Variations by Socioeconomic Group		
Category	*Group*	*Mean Income Coefficient (Low Value by Category Bolded)*
Race/Ethnicity	Non-Hispanic White	0.036
	Hispanic	**0.022**
	African-American	0.046
	Asian/Pacific Islander	0.034
Language at Home	English	0.036
	Non-English	**0.022**
Education	11th Grade or Less	**0.027**
	High School	0.034
	Associates	0.035
	Bachelors	0.033
	Graduate	0.035
Household Income	Less than $10k	0.045
	$10k to $24.9k	0.032
	$25k to $34.9k	0.038
	$35k to $49.9k	**0.024**
	$50k to $74.9k	0.033
	$75k to $99.9k	0.032
	$100k to $149.9k	0.033
	$150k or more	0.039

the model, immigrant neighborhoods have many businesses and other destinations that cater specifically to that group (Zhou 2004). Local residents with higher incomes could plausibly be staying relatively closer to home, especially on the weekend, to take advantage of these within-group opportunities, all else being equal. Put broadly, some populations may have different responses to opportunities in the city than would be typically expected.

Figure 5.13 illustrates the variability of the population density coefficient across the Los Angeles region. In this case, the coefficient varies in a clear spatial pattern, with population density being negatively associated with activity space size, as in the global OLS model, in the middle of the city, as well as in places like Reseda, San Fernando, and Long Beach. Conversely, in several pockets around the city, including areas like Orange County, Torrance, Santa Monica, Encino and La Cañada, higher population density is associated with larger activity spaces. Table 5.8 is a descriptive analysis of the relationship between the population density coefficient and

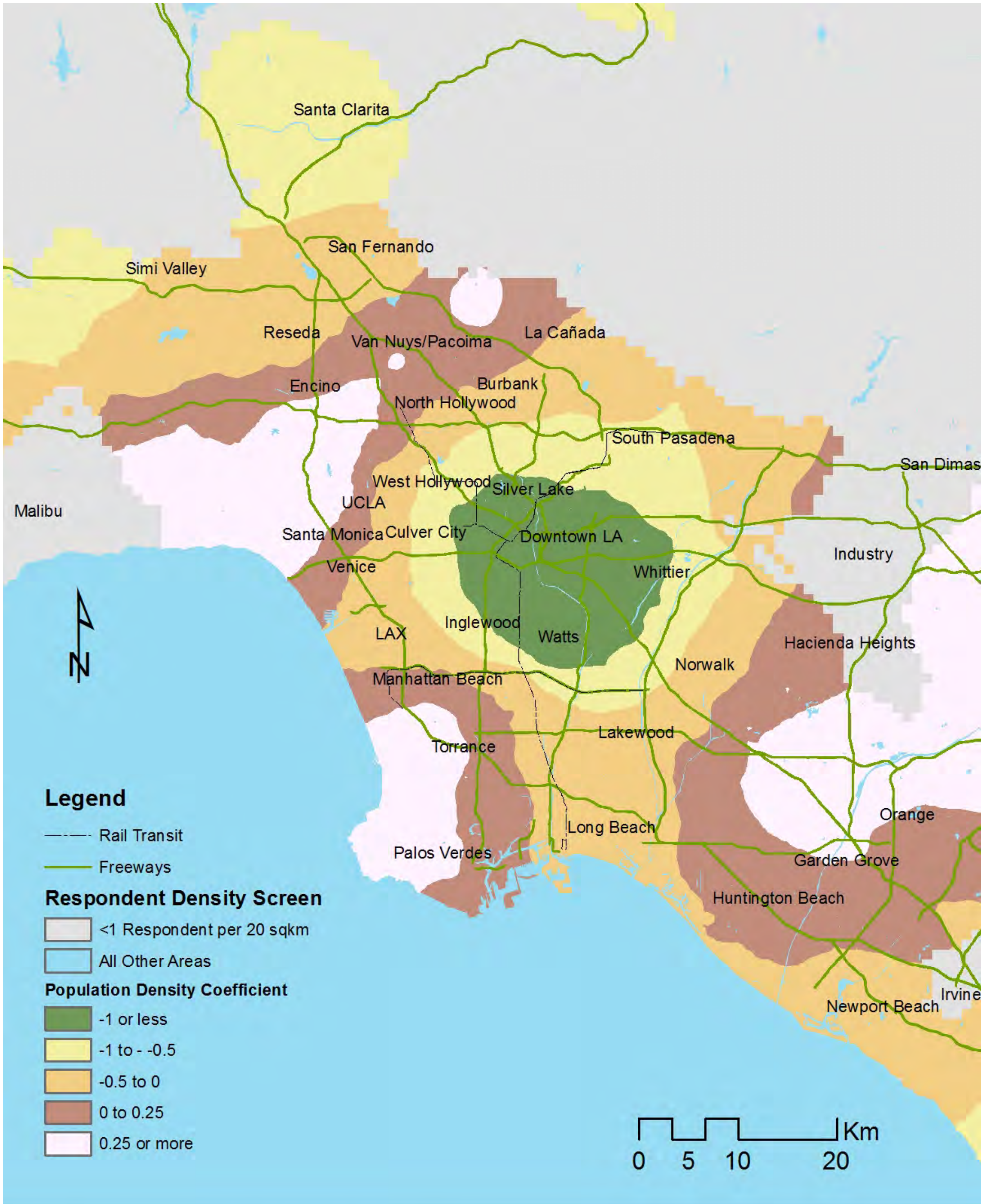

FIGURE 5.13 Spatial Distribution of Population Density Coefficient in GWR Model (Inverse Distance Weighting Method)

TABLE 5.8 Population Density Coefficient (GWR Model) Variations by Socioeconomic Group		
Category	*Group*	*Mean Income Coefficient (High Value by Category Bolded)*
Race/Ethnicity	Non-Hispanic White	**-0.21**
	Hispanic	-0.57
	African-American	-0.34
	Asian/Pacific Islander	**-0.21**
Language at Home	English	**-0.27**
	Non-English	-0.54
Education	11th Grade or Less	-0.62
	High School	-0.35
	Associates	-0.31
	Bachelors	**-0.17**
	Graduate	-0.20
Household Income	Less than $10k	-0.61
	$10k to $24.9k	-0.51
	$25k to $34.9k	-0.39
	$35k to $49.9k	-0.31
	$50k to $74.9k	-0.23
	$75k to $99.9k	-0.19
	$100k to $149.9k	-0.23
	$150k or more	**-0.15**

socioeconomic status. Places where density is associated with larger, rather than smaller, activity spaces are also some of the most wealthy, white or Asian/Pacific Islander, English-speaking, and educated parts of the city. Controlling for other factors, the nature of daily life in these places means that residential density does not hold people nearby on weekends the way it does elsewhere. Perhaps the phenomenon here is almost the opposite of that seen in the working class immigrant areas; here the weekend is an opportunity to "get away." The literature on the sociology of mobility may address this phenomenon, where among the wealthy, travel is pursued as an end in itself, and local ties are tenuous (Urry 1992).

5.5.3 Model Evaluation

At the outset of this section, I described GWR's potential to address spatial dependence in modeled relationships. I can now examine the model residuals to determine whether spatial autocorrelation has in fact been reduced as a result. In these terms, the GWR model is an

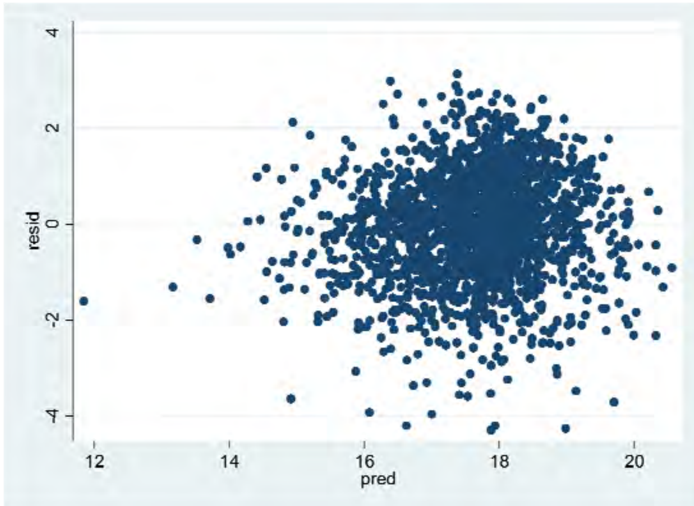

FIGURE 5.14 GWR Model Homoscedasticity Plot

improvement over Model 5, though only modestly. The Moran's Index decreases from 0.392 to 0.289, and the z-score drops from 10.87 to 8.10. While not an enormous improvement, the reduced Moran's I does suggest that spatial heterogeneity in the modeled processes was at least partly the source of spatial autocorrelation in the residuals. While interpretation of the model is still compromised by unresolved spatial dependence, it is improved.[14] Beyond the question of spatial autocorrelation, the same tests of model validity apply to the GWR model as to the OLS models. Figures 5.14 and 5.15 are the residual plots for evaluating model homoscedasticity and normality. Like the OLS Model 5, the GWR model does not display major heteroscedasticity, and the residuals are distributed in a roughly normal pattern. While I was not able to examine each local submodel of the GWR model for multicollinearity, I know from validation of the global model that multicollinearity was not a problem when N=1,920. Thus, though somewhat smaller, the N=456 submodels should not have multicollinearity problems either.

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[14] The spatial distribution of the residuals' clustering was explored with an Anselin Local Moran's I. The results showed no large clusters, but instead small pockets of clustered observations throughout the study area. This finding suggests that significant clustering is not due to any major variable omissions from the model but is instead due to difficult-to-capture similarities in the activity patterns of those living near one another. For example, the specific configuration of the street grid in a small area may influence all individuals in that area similarly, without any means of explaining these variations in the model.

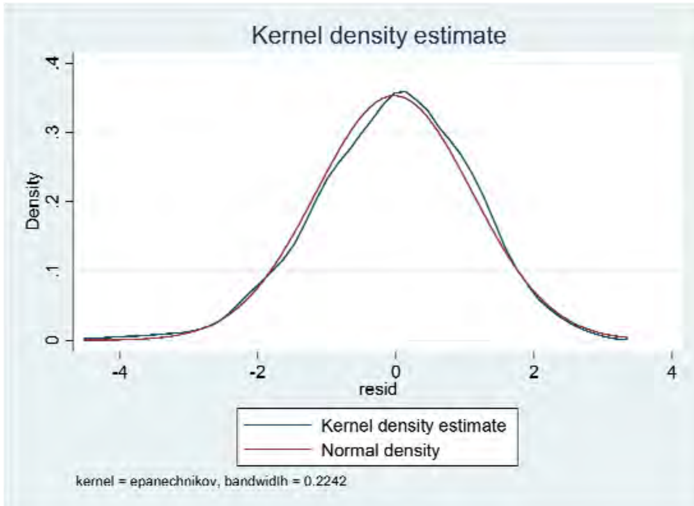


FIGURE 5.15 GWR Model Normality of Residuals Plot

Overall, the GWR analysis shows the ways in which even statistically significant coefficients at the global scale can vary tremendously over space when allowed to do so. The results are compelling, if complex and challenging to interpret in some instances. When considering the income and population density coefficients collectively, some neighborhoods and the people living in them, appear to function differently than others. A global model will have tremendous difficulty capturing both the behaviors of immigrants and high status individuals with a single set of coefficients. For planning researchers, the GWR results underscore the spatial variability in urban causes and effects, and imply that the reasons why people leave home and travel through the city vary not just by personal characteristics, but also by sometimes highly localized relationships of person to place.

5.6 Conclusion

A person's activity space is the end result of a system of the practical, the personal, and the environmental. While potentially complex and nuanced, the basic dimensions of activity spaces can be derived from travel survey datasets such as SCAG's. These activity space dimensions, specifically activity space extensiveness, help us see how far individuals and households will go to meet their daily needs and wants. Income and profession remain critical determinants of how far a person will range to accomplish their daily rounds. Still, the analysis in this chapter cannot determine whether activity spaces are a luxury enjoyed by high status individuals, whether large activity spaces themselves lead to benefits, or whether the truth is some combination of both explanations. The direct implication for planning and cities is that constraining travel, through higher costs or public policy, may have indirect effects on individuals' ability to take advantage of the range of opportunities availability in the city, particularly those of low socioeconomic status.

In addition, the OLS models show that activity space size is not empirically identical to distance traveled, but instead possesses its own relationship to socioeconomic and neighborhood characteristics. Notwithstanding the global relationship between income and activity presented in the OLS models, the GWR analysis shows that in some places, even those of high income do not travel widely to engage in activities. Those places, instead, may be places of tight social bonds, where income does not impel more travel. Conversely, in some communities, population density is not a reason to stay close to home, but instead to get out on the weekends. Regardless, the analysis shows that activity patterns are tightly linked to both person and place. In the next two chapters, I examine how that relationship may function internally, in cognitive maps.

Chapter 6

Active and Passive Travel: The Foundation of Spatial Knowledge

6.1 Introduction

Knowledge of the urban environment is essential for spatial behavior and decision-making. To take part in the non-home activities that make up a typical day, a person needs information about destinations' locations and the routes to access them. Prior research posits that such knowledge resides in psychological constructs called cognitive maps (Tolman 1948; Downs and Stea 1973). Cognitive maps develop primarily through wayfinding and travel experience (Golledge and Gärling 2004). In this chapter, I explore whether cognitive maps, specifically their accuracy, vary by travel mode. I hypothesize that spatial knowledge within cognitive maps varies neither by transportation modes' speeds nor their relative geographic scales, but by how much effort they demand from the traveler to be cognizant of her surroundings and make active navigation choices. More "active modes," such as driving and walking, should be associated with more accurate regional spatial knowledge. How variations in knowledge affect a person's *future* spatial behavior and accessibility remains an important area for further research.

Data for this analysis were collected as part of a research effort by the UCLA Institute of Transportation Studies at two disparate survey sites, near a light trail station in low-income South Los Angeles and on the UCLA campus in affluent West Los Angeles. The results show systematic variation among individuals and groups, including in terms of previous travel experience. The implications for planning and cities lie in urban dwellers' ability to act on the information they possess. If those who travel passively – without significant cognitive effort –

have inherently poorer cognitive maps, then facilitating access to opportunities by modes like transit may require not just good service, but compensatory forms of information about local and regional opportunities.

Following this introduction, I establish a set of hypotheses regarding the accuracy of cognitive maps due to previous travel experience. I use the 2007 Cognitive Mapping and Travel Behavior Survey, collected as part of a UCLA Institute of Transportation Studies to construct measures of travel mode and cognitive map accuracy. The findings show a significant relationship between spatial knowledge and travel experience. These cognitive differences are an important aspect of variation among individuals' personal cities, which may be built not just of the physical dimensions of activity and travel, but the potential for future activity, as encoded in the cognitive map.

6.1.1 Hypotheses

I review the literature on cognitive mapping and the process of spatial learning in detail in Chapter 2. The literature suggests that those who travel by different modes will process their travel experiences differently. These differences likely influence the accuracy of the cognitive map, including perceptions of distance. Prior research highlights variations in the cognitive burden that different modes place on the traveler. Thus, travel by modes that require active navigation and wayfinding behavior may facilitate greater awareness and absorption of information the surrounding environment, particularly at choice points, those locations where navigation decisions are being made. This style of *active* travel can be contrasted with *passive* travel, where the traveler need not engage in substantial wayfinding.

Within the modal palette of contemporary American cities, major transportation modes can be painted as either active or passive, in the cognitive sense described above. Driving a car is clearly active, as are walking and biking. Being an auto passenger, on the other hand, is passive. Transit travel may be more challenging to cognitively categorize, lying somewhere between passive and active. Transit users often must navigate, on foot, to their local stop, but once onboard, they ride largely passively, other than watching for their stop or transfer. I hypothesize that individuals who travel primarily by driving, walking, and biking[15] will have more accurate knowledge of distances in the built environment, while passive travelers, including transit users, will be less accurate. These differences should persist controlling for geographic scale and location, time spent in the neighborhood, and socioeconomic status.

6.2 Data and Methods

Survey data were collected from respondents in South Los Angeles and on the UCLA campus, areas with relatively high levels of non-single-occupant private vehicle travel, though very different in many other respects. The survey and the data collection process are described in greater detail in Chapter 4. The survey questionnaires can be reviewed in Appendices A (South Los Angeles) and B (UCLA campus). The survey included questions on spatial knowledge and travel behavior, as well as a variety of socioeconomic controls.

[15] Although biking conceptually would be categorized with driving and walking, I was not able to reliably test biking's relationship to spatial knowledge in this analysis due an overall small sample of bike riders. However, Chorus and Timmermans (2010) find that bike riders do indeed have more accurate spatial knowledge than transit users (see Chorus, C. G. and H. J. P. Timmermans (2010). "Determinants of Stated and Revealed Mental Map Quality: An Empirical Study." Journal of Urban Design **15**(2): 211-226.

6.2.1 Cognitive Data Extraction

Numerous methods have been developed to extract empirically analyzable spatial products from cognitive maps (Golledge and Stimson 1997; Kitchin and Blades 2002). The spatial products generated by available methods draw upon the complex geometries, orientations, perceived quantities, and qualitative characteristics contained within a cognitive map. The variety and overlapping purposes of many methodologies suggest that employing a diverse set of techniques to extract cognitive information is preferred (Kitchin 1996). Some methods are particularly attractive because of the breadth of information they provide. For example, sketch maps can provide data on the number of total features, a mix of point, line, and area features, indications of dominant functions perceived by the sketcher, sequences along routes, and the overall regularity or irregularity of features. Such maps, however, can be a challenge to analyze in the aggregate because common map elements such as scale, extent, symbolization, and orthogonality may not be consistent from sketch map to sketch map (Golledge and Stimson 1997). Other methods, like verbal questions about distance and location, provide more limited data but are desirable because of low skill requirements, cross-subject comparability, and ease of execution.

For this analysis of map accuracy, verbal techniques were the primary means of cognitive map data extraction, including questions about the distance to specific destinations in Los Angeles by both absolute and relative measures. One question (#12 in the survey) asked respondents for an *absolute* distance estimate (in miles or kilometers) from the survey site to a well-known landmark, itself representative of a major regional activity center. For South Los Angeles, this landmark was Los Angeles City Hall in downtown Los Angeles. For UCLA, the landmark was the Santa Monica Pier at the heart of the Santa Monica shopping, entertainment, and office district (see Figure 4.3). Another set of questions (#13 in the survey) asked respondents to estimate *relative* distance, selecting the closer of two landmarks for five or six pairs in total.

Table 6.1 summarizes the responses to the absolute and relative distance questions. For the absolute distance questions, the right-tailed skew is notable. The means are inflated relative to the medians due to the fact that upper-end estimates deviate substantially further from the median than low estimates. However, the median distance estimates for both South LA and UCLA are remarkably close to the actual travel distance, which is operationalized as an average of the transit travel and car travel distances as provided by the Los Angeles County Metropolitan Transportation Authority (Metro) and MapQuest, respectively. The relative distance pairs cover a range of geographic scales, from within the survey sites' "neighborhoods" to more than twenty miles from the survey sites. Note that high numbers of incorrect selections are not in themselves surprising or indicative of an inherently inferior cognitive map, as the pair members often share roughly equivalent distances from the survey site. However, comparing accuracy across groups does have the potential to reveal significant differences in this distance-oriented aspect of map quality.

6.2.2 Measures of Modal Experience

At the conceptual level, groups can be broadly defined by their travel mode experience. To operationalize this concept empirically, I explored several measures to characterize modal experience, based on the questions in the survey:

- *Auto availability* – The first measure is auto availability, which is based on how often individuals reported having access to cars (possible responses: "always," "usually," "sometimes," or "never"). Respondents' reported level of auto availability is

TABLE 6.1 Cognitive Distance Measures					
Absolute Distance[1]	*Mean*	*10th*	*Median*	*90th*	*Actual Dist.*[1]
South LA: Survey Site to LA City Hall	14.76	5	10	25	10.1
UCLA: Survey Site to Santa Monica Pier	8.55	4	7	15	6.0
Relative Distance[3]	*# Pick Opt. A*	*# Pick Opt. B*	*Equi-distant*	*Don't Know*	*Correct Answer*
South LA					
(A) Watts Towers v. (B) Compton City Hall	145	32	12	7	A
(A) Home Depot Center v. (B) Hollywood Park	130	44	4	18	A
(A) Crenshaw Shopping Center v. (B) South Bay Galleria	110	61	9	15	B
(A) LA City Hall v. (B) Long Beach City Hall	103	70	12	11	A
(A) Los Angeles Zoo v. (B) Santa Monica Pier	98	83	7	8	A
UCLA					
(A) Hammer Museum v. (B) Sculpture Garden	36	139	11	13	B
(A) Getty Center v. (B) Mormon Temple	91	85	3	20	B
(A) Grauman's Chinese Theater v. (B) Santa Monica Pier	30	155	5	9	B
(A) Downtown LA v. (B) LAX Airport	62	112	21	4	B
(A) Universal City Walk v. (B) Staples Center	74	101	6	18	A
(A) Home Depot Center v. (B) Rose Bowl	93	62	9	35	B

1 - Responses possible in miles or kilometers, all responses in miles
2 - Actual distance is average of Metro Transit Route Planner and MapQuest Driving Distances. To LA City Hall: 10.5 by transit and 9.6 by auto. To Santa Monica Pier: 6.1 by transit, 5.9 by auto.
3 - Responses to question of which - A or B - is closer

hypothesized to relate to their propensity to travel by a particular mode or set of modes, but does not directly measure modal experience. A related measure that was collected is number of cars available in the household. Auto availability and number of cars in the household are positively correlated (r = 0.25).

- *Travel mode* – The second measure is "travel mode," which is the mode respondents named when asked about (1) their mode when traveling to the survey site, (2) their typical mode to work/school, and (3) their hypothetical mode to a landmark destination. This measure directly tests the basis of my hypothesis. Many individuals responded differently to various modal questions, but travel mode can be categorized by those who *consistently* answered that they did or would travel by a particular mode across all three questions, resulting in clearly contrastable groups. This filter does result in a smaller sample size, however, with N=94 (out of 196) for South Los Angeles and N=46 (out of 199) for UCLA.

- *Cognitive travel style* – The third measure, cognitive travel style, extends the travel mode measure by categorizing respondents by the hypothesized cognitive burden of various modes, rather than by the modes themselves. This categorization is consistent with the literature on cognition and travel. Specifically, driving an auto and walking are "active" modes, because travelers must actively navigate during their journey, while public transit and being an auto passenger are "passive" modes, because travelers need not engage in the same level of cognitively challenging wayfinding. As with the travel mode measure, the "passive" and "active" categories include only respondents who *consistently* selected either driving and walking or using transit and being a passenger. However, I also report the results of respondents belonging to the "mixed" category, comprised of those who responded to the mode questions with both passive and active modal choices.

6.2.3 Respondent Characteristics

Table 6.2 shows the distribution of respondents by the modal measures described above. The table also describes key socioeconomic characteristics of the respondents by modal category. For the South Los Angeles respondents, key characteristics that may explain variations in cognitive mapping and spatial knowledge are relatively equally represented across modal groups. Respondents in all of the groups have lived in their current neighborhood on average for nearly 10 years. Average age is similar, as is percent female and average grade in school completed. Respondents in the modal categories in the UCLA sample were more heterogeneous. For example, those having no access to cars tend to be younger, less educated, and more likely students, while those who consistently use transit or drive are older, more educated, and more likely staff or faculty. In addition to the demographic characteristics described in Table 6.2, respondents were also asked to indicate their current residential neighborhood with the question, "What neighborhood do you live in?" While relatively open-ended, the question allowed respondents to provide a range of answers that were spatially specific and identifiable, whether responding with traditional neighborhood names, small city names, or situationally meaningful terms such as "the dorms." For both survey sites, respondents tended to live relatively close by (in a regional context), with only 12% reporting a neighborhood beyond 10km for UCLA and merely 2% reporting a neighborhood beyond 10km for South Los Angeles (perhaps not a surprising result as this survey was conducted at a local-serving shopping center).

6.3 Results

The analysis explores relationships among spatial knowledge and travel mode revealed by the Cognitive Mapping and Travel Survey in South Los Angeles and at UCLA. The experiences encoded within individuals' cognitive maps produce differences in how individuals think about their environment. I find evidence that travel mode influences how individuals perceive the built environment, both in how they estimate distance and in the relative refinement of their cognitive maps. The analysis focuses on how measures of cognitive accuracy in the survey vary across modally-defined groups.

TABLE 6.2 Characteristics of Respondents by Auto Availability, Travel Mode, and Cognitive Travel Style

Mode Category	*N*	*Years in Neighborhood*		*Age*		*Years of Education*		*% Female*	*% African-American*
		Mean	*25th – 75th pct.*	*Mean*	*25th – 75th pct.*	*Mean*	*25th – 75th pct.*		
South Los Angeles									
Auto Availability									
Never	40	9.7	1-12	34.1	25-41	11.6	11-12	77%	65%
Always	91	14.0	3-25	38.0	28-48	12.8	12-14	69%	69%
Travel Mode									
Public Transit	49	10.6	1-15	33.2	22-39	12.1	12-13	68%	69%
Auto Driver	45	13.4	3-25	35.1	26-42	13.3	12-14	68%	76%
Cognitive Travel Style									
Passive	68	11.5	1-19	34.0	22-44	12.0	12-13	74%	72%
Mixed	78	11.6	2-19	37.7	28-48	12.3	12-13	72%	69%
Active	50	13.8	3-25	34.3	26-42	13.2	12-14	67%	74%
UCLA									
Auto Availability									
Never	39	2.2	1-2	21.7	19-22	14.3	13-15	79%	2.6%
Always	97	5.4	1-7	29.0	22-31	16.3	15-17	59%	11%
Travel Mode									
Public Transit	16	7.1	1-4	32.0	23-33	16.8	15-18	63%	19%
Auto Driver	29	7.0	2-11	30.9	23-33	16.9	16-18	53%	10%
Cognitive Travel Style									
Passive	24	5.9	0.7-4	29.3	22-32	16.0	15-18	62%	17%
Mixed	116	3.5	0.6-3	25.5	20-25	15.1	13-16	68%	8.5%
Active	57	4.5	0.8-3	26.7	22-28	16.2	15-17	58%	6.0%

6.3.1 Distance Estimation by Mode

In this survey, all respondents were asked to estimate the distance from their respective survey site to a major, well-known landmark – Los Angeles City Hall for South Los Angeles respondents and Santa Monica Pier for UCLA respondents (see Figure 4.3). This measure provides information both about the accuracy of cognitive mapping with regards to distance and the prominence of a particular location in the cognitive map. Asking a distance question from common points (the survey sites) to well-known landmarks serves to minimize route unfamiliarity and increase comparability across respondents. The survey sites, Los Angeles City Hall and Santa Monica Pier, are located at major transit nodes, so relatively direct travel is possible by both public transit and private vehicle and actual travel distances (if not travel times) are quite similar regardless of mode. Table 6.1 introduces the responses to this distance question, without regard to modal grouping.

Table 6.3 shows that, while tied to actual, geographic distance, respondents' estimates of the distance to the landmarks vary significantly by modal experience. Two patterns in respondents' estimates are evident, consistent between the South Los Angeles and UCLA samples and between the measures of modal experience, whether characterized by auto availability, travel mode, or cognitive travel style. First, median distance estimates for each group by each modal measure, as well as the samples in their entireties, are not significantly different but tend toward the actual geographic distance. This finding suggests that the distance estimates are not arbitrary in the mind but relate to an experience of urban geography. Second, while each group estimate tends toward the "real" median distance, the variability among the passive, transit-oriented respondents' estimates is generally much higher than the variability in the responses of the active, more auto-oriented respondents. This result indicates that those who usually travel by less active modes are, as a group, more inaccurate about the distance to major landmarks.

The differences among groups are more pronounced for the South Los Angeles sample. The difference between standard deviations by the various modal measures is almost always statistically significant, using an F-test of the null hypothesis that the variances of the two groups are equal. The high variability in the estimates of passive travel respondents suggests that while most individuals in those groupings did provide a distance estimate, it may be more of a guess than the responses provided by the active travel respondents. Note that while there is a right-tailed skew in the responses, passive respondents are equally likely to guess too high or too low

TABLE 6.3 Distance Estimated to "Landmark" Destination, Grouped by Measures of Modal Experience						
Survey Population	South Los Angeles (10 miles[1])			UCLA (6 miles[2])		
Statistic	Median[3]	SD	N	Median[3]	SD	N
Auto Available						
Never	10	30.6	30	8	6.5	33
Always	10	9.0	80	7	6.8	90
Relative Difference	0%	-70.6%*		-14.3%	4.6%	
Travel Mode						
Public Transit	13	11.4	39	6.5	5.5	16
Auto Driver	12	8.0	40	7	2.5	27
Relative Difference	-8.3%	-29.8%*		7.1%	-54.6%*	
Cognitive Travel Style						
Passive	13	23.4	55	7	8.2	24
Mixed	10	11.8	65	8	7.3	105
Active	13	7.8	45	7	2.9	54
Relative Difference (Passive vs. Active)	0%	-66.7%*		0%	-64.6%*	
All Respondents	10	16.1	165	7	6.5	183

1 – Actual approx. distance by auto or transit from survey site (Kenneth Hahn Shopping Center) to LA City Hall.
2 – Actual approx. distance by auto or transit from survey site (Transit Center at UCLA) to Santa Monica Pier.
3 – Median used as central tendency as responses are right-skewed and mean not representative.
* - Denotes significantly different standard deviation at the 0.05 significance level.

relative to the correct answer, reinforcing the likelihood that incorrect estimates are, in part, guesses.

The variability of the distance estimates is significantly different between modal groups regardless of whether it is defined in terms of auto availability, travel mode, or cognitive travel style. Do these differences, however, persist when controlling for other respondent characteristics? Table 6.4 presents the results of a series of ordinary least squares (OLS) regression models addressing this question for South Los Angeles and UCLA. I examine how the accuracy of respondents' distance estimates to the landmark of Los Angeles City Hall varies with regard to a variety of demographic and experiential variables. The OLS form of the model is similar to that described for the OLS models in Chapter 5. The dependent variable, described below, is continuous and normally distributed, suggesting that OLS is appropriate for this application.

TABLE 6.4 Regression Modeling of Distance-to-Landmark Estimates

Dependent Variable, All Models	Accuracy of landmark distance estimate (Ln absolute difference between estimated distance to landmark and measured network distance, standardized for comparison between survey sites)[1]					
Survey Site	*South LA*				*UCLA*	
Model Number	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Independent Variables	*Coef.*	*Coef.*	*Coef.*	*Coef.*	*Coef.*	*Coef.*
Driving (versus Public Transit)	-0.418**	-0.418**				
Active Travel Style (versus Passive)			-0.533***	-0.532***	-0.410	-0.383
Mixed Travel Style (versus Passive)			-0.355**	-0.381**	-0.328	-0.258
Knows How to Drive	-0.122		-0.174		0.141	
Number of Cars in Household	-0.215***	-0.181***	-0.058		-0.138**	-0.148**
Years in Neighborhood	-0.006	-0.008	-0.008	-0.010*	-0.006	-0.013
Employed	0.688****	0.780****	0.361**	0.384**	0.030	0.006
Student	0.326	0.457**	0.398**	0.457**	-0.13	-0.333*
Years of Education	0.028		0.028		-0.046	
Female	0.480**	0.586***	0.539***	0.593****	-0.188	-0.177
Age	-0.013		-0.010		-0.013	
African American	0.415*	0.424**	0.352**	0.329*	0.133	0.191
Constant	-0.279	-0.706***	-0.224	-0.525**	1.87	0.856***
Number of obs.	74	76	155	155	177	177
F	4.82****	6.96****	4.16****	6.05****	1.84**	1.72*
R-squared	0.434	0.417	0.242	0.224	0.110	0.075

* - 0.10 level of significance, ** - 0.05 level of significance, *** - 0.01 level of significance, **** - 0.001 level of significance

1 – For South LA, respondents estimated distance from survey site to Los Angeles City Hall, and for UCLA respondents estimated distance from survey site to the Santa Monica Pier.

The dependent variable is the difference between a respondent's estimate and the true distance to the landmark (absolute value), so a larger number would imply greater *inaccuracy*. Thus, for interpreting the coefficients, negative values imply greater accuracy associated with a particular variable and positive values imply greater inaccuracy. In South LA, both travel mode (auto driver versus public transit) and cognitive travel style as the primary independent variables. For UCLA, it was not possible to construct a consistent driver versus transit variable for a viable N, as many respondents reported using multiple modes across all three modal questions.

The models include both expansive and parsimonious versions. For South Los Angeles, the set of independent variables found to significantly influence distance estimation are travel mode or cognitive style of travel, number of cars in the household (Models 1 and 2), time spent in the neighborhood (Model 4), being employed or a student, sex, and being African-American. Travelling consistently by active modes significantly reduces the inaccuracy of the distance estimate relative to passive travelers, while those traveling by mixed modes also show greater accuracy than passive travelers. The other characteristic observed to improve accuracy is length of time spent in the neighborhood. As discussed in the literature review, spatial learning is a process, so it is not surprising that it takes time to learn about the urban environment.

Other variables are associated with increased inaccuracy. Both those who described themselves as employed and those who described themselves as students showed significantly greater inaccuracy. While the result for students is consistent with the expectation that students are typically younger and less experienced (although age itself was not found to be significant), the result for employed persons is harder to explain.[16] Though the literature does not shed light on the issue, it may be possible that – all else being equal – having a job restricts daytime

[16] A correlation analysis did not show any statistically significant relationship between employment and other variables included in the survey.

exploration and way-finding. Female respondents showed significantly greater inaccuracy in their estimates, controlling for other factors, consistent with a longstanding literature on sex differences in spatial knowledge and ability (McGuiness and Sparks 1983; Dabbs Jr, Chang et al. 1998). Some degree of inaccuracy was also associated with African-American respondents relative to those of other race/ethnicities, again consistent with the literature (Maurer and Baxter 1972; Banerjee and Baer 1984). Overall, the South Los Angeles models were highly statistically significant and explained between twenty-two percent and forty-three percent of the variation in estimate accuracy.

The UCLA model results were substantially different from those for South Los Angeles. Most importantly, for both UCLA models, though the coefficients are negative, as with South Los Angeles, the active and mixed travel groups do not show significantly more accurate estimates of the distance to Santa Monica Pier. Instead, number of cars in the household stands out as significantly explaining more accurate estimates. This finding suggests that at UCLA, those with cars, whether staff and faculty or more settled students, may know more about distances in the area. For UCLA, perhaps the strangest result is that those respondents who identified as students, all else being equal, actually had significantly *more* accurate estimates of the distance to Santa Monica Pier. It would seem more likely that students, who would assumedly have spent less time in the area than employees or faculty, would have less accurate estimates. Without additional data on students' actual time spent in the Los Angeles region rather than just their current neighborhood, or the relative popularity of the Pier as a student recreational destination, this result is difficult to explore. Generally, the UCLA results are more challenging to interpret. As the exploration of respondent demographics showed, the UCLA population was particularly heterogeneous. Within a sample of this relatively small size, overall

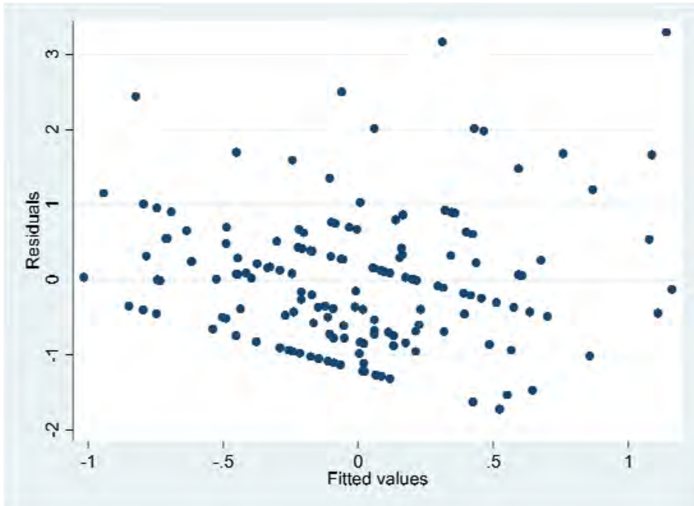


FIGURE 6.1 Model 4 Homoscedasticity Plot

significance is marginal (only at the 0.10 level). Nonetheless, while not as clear, a relationship between travel and spatial knowledge remains evident.

Model 4 for South Los Angeles is the terminal end of model development and the most important to confirming the validity hypothesized relationship between spatial knowledge and mode of travel. Therefore, I have evaluated the statistical validity of this model with a set of diagnostics plots and tests. I undertook this process for the main models in Chapter 5, and the purpose of validation is discussed further in Section 5.4.4. First, I examine the relationship between predicted values of dependent variable and the residuals to test for homoscedasticity. Figure 6.1 is a scatterplot comparing the predicted values of the distance accuracy estimate to the Model 4 residuals. While some patterns are evident, likely due to the heavy use of dummy variables in the model, the distribution of the residuals appears fairly constant across all the predicted values, suggesting that the model is homoscedastic. Figure 6.2 is a graph of the distribution of residual values compared to a normal curve. Though a bit rough, the residual distribution is generally close to normal. Beyond these tests, I also checked the model for multicollinearity with a variance-inflation-factor test, which did not reveal multicollinearity.

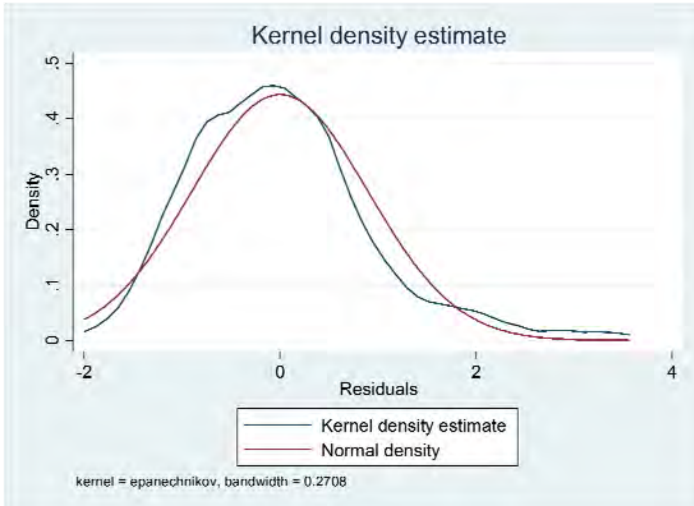


FIGURE 6.2 Model 4 Normality of Residuals Plot

Regardless, another important assumption of OLS modeling is that the observations be independent of one another. Unfortunately in this case, the sampling method which surveyed people at a single shopping center in South Los Angeles, suggests that respondents are likely linked by spatial location, personal habit, and numerous other factors not accounted for in the model. I investigate the issue of spatial dependence further in Section 6.3.3, and discuss other potential threats to the validity of the analysis at the end of the chapter.

6.3.2 Pair Estimates

In addition to the absolute distance estimation exercise, respondents were asked to pick the closer of two widely known local or regional destinations (relative to the survey site). For each destination pair, respondents could (1) select one or the other as closer, (2) designate them equidistant, or (3) report they did not know which was closer. The overall responses are summarized in Table 6.1. The pair exercises facilitate exploration of the overall accuracy and clarity of respondents' cognitive maps, as well as the relative distribution of destinations in respondents' maps. These measures extend the analysis beyond a single destination (regardless of that destination's importance in the region) to a broad set of opportunities distributed throughout the Los Angeles region. The pairs were selected to test knowledge at various scales (local, subregional, regional) and of various types of destinations (employment, shopping, cultural, etc.).

Table 6.5 highlights the accuracy and clarity of individuals' cognitive maps in the relative distance exercises, grouped by passive and active cognitive travel styles. Accuracy is defined by the total number of correct responses to the pair questions, and clarity is defined by the number of "don't know" responses to the pair questions. The table summarizes the responses of the South Los Angeles and UCLA samples. Active travelers chose correctly more often than the passive travelers, and the passive travelers tended to be wrong more often than the active travelers. Much like the landmark distance estimation task, those living in their neighborhood for less than five years tended overall to be less able to choose correctly and more likely to answer "don't know." Furthermore, the relative difference between active and passive groups was consistently wider in terms of both accuracy and clarity for those having spent less time in the neighborhood.

While the overall accuracy and clarity measures compared between modal groups is consistent with the hypothesis, the pair estimation measures also allow a closer look at the spatial variation in cognitive knowledge by modal experience. Tables 6.6 and 6.7 disaggregated the differences between those who stated they would take public transit or drive themselves to the hypothetical modal question posed to them in the survey. Because these measures are specific to particular destinations and attendant transportation networks and hierarchies, they provide an opportunity to explore how mode alters individuals' cognitive geographies (see Figure 4.3). As this exploration of the results highlights, the effect of mode on the cognitive map varies

TABLE 6.5 Overall Accuracy and Clarity in Responses to Distance Pairs, Grouped by Cognitive Travel Style				
	South Los Angeles[1]		UCLA[1]	
	Mean	N	Mean	N
Correct Responses (Accuracy)				
Passive	52.2%	67	48.5%	24
Mixed	53.6%	78	53.0%	116
Active	60.4%	50	53.2%	59
Relative Difference (Passive vs. Active)	15.7%*		9.6%	
Correct Responses for those Living in Neighborhood <5 Years				
Passive	44.8%	25	45.8%	20
Mixed	54.8%	38	51.2%	97
Active	57.6%	17	53.7%	45
Relative Difference (Passive vs. Active)	28.6%*		17.1%	
Don't Know Responses (Clarity)				
Passive	5.8%	68	9.7%	24
Mixed	7.2%	78	9.2%	116
Active	4.8%	50	5.5%	59
Relative Difference (Passive vs. Active)	-17.2%		-43.1%	
Don't Know Responses for those Living in Neighborhood <5 Years				
Passive	11.2%	25	10.8%	20
Mixed	10.6%	38	9.2%	97
Active	9.4%	17	5.5%	45
Relative Difference (Passive vs. Active)	-19.2%		-49.2%	
1 – Note: Five pairs total for South Los Angeles, six pairs for UCLA. * - 0.05 level of significance				

TABLE 6.6 Destination Pair Choices by Stated Mode Choice for South Los Angeles Respondents					
Pair A	Watts Towers (1.1 mi.)*	Compton City Hall (2.5 mi.)	Equidistant	Don't Know	N
Public Transit	72.7%	18.0%	6.0%	3.4%	117
Auto Driver	76.6%	10.9%	7.8%	4.7%	64
Pair B	Home Depot Center (5.8 mi.)	Hollywood Park (8.1 mi.)	Equidistant	Don't Know	N
Public Transit	59.8%	29.1%	2.6%	8.6%	117
Auto Driver	79.7%	12.5%	1.6%	6.4%	64
Pair C	Crenshaw Shopping Ctr. (11.4 mi.)	South Bay Galleria (9.1 mi.)	Equidistant	Don't Know	N
Public Transit	59.5%	28.5%	4.3%	7.8%	116
Auto Driver	53.1%	32.8%	6.3%	7.8%	64
Pair D	Los Angeles City Hall (9.6 mi.)	Long Beach City Hall (12.9 mi.)	Equidistant	Don't Know	N
Public Transit	48.7%	39.3%	7.7%	4.3%	117
Auto Driver	61.0%	31.3%	3.1%	4.7%	64
Pair E	Los Angeles Zoo (18.7 mi.)	Santa Monica Pier (20.2 mi.)	Equidistant	Don't Know	N
Public Transit	50.4%	41.0%	3.4%	5.1%	117
Auto Driver	50.0%	46.9%	3.1%	0.0%	64
* - Actual distance from survey site in parentheses for all destinations.					

substantially between pairs, with marked effects in some instances and little relevance in others, including pairs where both transit users and drivers "misperceive" the relative proximity of a landmark.

Table 6.6 contains the destination pairs for the South Los Angeles survey. For Pair A, public transit users were substantially more likely to incorrectly choose Compton City Hall as the closer destination, despite the large relative difference in the two destinations' distances from the survey site. However, Compton City Hall is located on an MTA Blue Line light rail stop, while Watts Towers is located on a side street, a ten to fifteen minute walk from the Watts Blue Line station. Similarly, transit users were much more likely to incorrectly select Hollywood Park Race Track as closer to the survey site than the Home Depot Center sports stadium, potentially

TABLE 6.7 Destination Pair Choices by Stated Mode Choice for UCLA Respondents					
Pair A	Hammer Museum (1.2 mi.)*	UCLA Sculpture Garden (0.6 mi.)	Equidistant	Don't Know	N
Public Transit	24.1%	63.2%	7.0%	5.8%	87
Auto Driver	12.0%	77.1%	4.4%	6.5%	92
Pair B	Getty Center (2.9 mi.)	Mormon Temple (1.9 mi.)	Equidistant	Don't Know	N
Public Transit	42.5%	42.5%	1.2%	13.8%	87
Auto Driver	47.8%	43.5%	2.2%	6.5%	92
Pair C	Chinese Theater (7.7 mi.)	Santa Monica Pier (5.8 mi.)	Equidistant	Don't Know	N
Public Transit	18.4%	75.9%	1.2%	4.6%	87
Auto Driver	13.0%	79.3%	4.4%	3.3%	92
Pair D	Downtown Los Angeles (11.8 mi.)	LAX Airport (10.5 mi.)	Equidistant	Don't Know	N
Public Transit	33.3%	52.9%	12.6%	1.2%	87
Auto Driver	27.2%	63.0%	8.7%	1.1%	92
Pair E	Universal City Walk (10.5 mi.)	Staples Center (11.6 mi.)	Equidistant	Don't Know	N
Public Transit	37.9%	46.0%	2.3%	13.8%	87
Auto Driver	35.9%	55.4%	4.4%	4.4%	92
Pair F	Home Depot Center (22.3 mi.)	Rose Bowl (20.5 mi.)	Equidistant	Don't Know	N
Public Transit	54.0%	25.3%	3.5%	17.2%	87
Auto Driver	45.7%	34.8%	5.4%	14.1%	92
* - Actual distance from survey site in parentheses for all destinations.					

because Hollywood Park is only about a mile from the MTA Green Line, while the Home Depot Center is both newer and does not have as direct mass transit access. The other pair with a notable difference between modal groupings was the comparison of Los Angeles and Long Beach City Halls. While both are relatively accessible by transit, Long Beach City Hall is directly adjacent to the Blue Line terminus, while Los Angeles City Hall requires a transfer. As a result, transit users appear to "collapse" the greater distance to Long Beach City Hall somewhat; thirty-seven percent more public transit users designate Long Beach City Hall as closer to or equidistant from the survey site than auto drivers.

Table 6.7 contains the results from the six pairs tested at UCLA, differentiated by public transit and auto drivers. Unlike the South Los Angeles survey site, UCLA is not accessible by rail transit, but it is well served by many bus routes. Pair A demonstrates the possible effect of the distribution of those bus routes around the UCLA campus. Public transit users were two times more likely to incorrectly select the Hammer Museum, south of the campus in Westwood Village, as closer to the survey site than the UCLA Sculpture Garden located at the northeastern corner of UCLA's campus. Despite the fact that the Hammer Museum is two times as far from the survey site as the sculpture garden, most of the bus routes serving the campus pass right by the museum, while relatively little transit serves the northern end of campus. Both Pairs C and D are examples where transit users are more likely to incorrectly select destinations in the more densely developed areas east of UCLA as being closer than destinations to the south or west of campus.

6.3.3 The Role of Location

Travel experience is not the only spatial experiential process. If prior experience shapes the cognitive map, the predominant geographic locations of those experiences will also affect spatial knowledge. In fact, cognitive mapping research has repeatedly found that cognitive mapping is more detailed and accurate around the home (Golledge and Stimson 1997).[17] For this analysis of cognitive map accuracy, the underlying assumption is that variations in spatial knowledge are due to the way a person travels, controlling for how long a person has lived in their current neighborhood. However, the analysis does not address the possibility that precisely where a person lives will shape their spatial knowledge.

[17] One noteworthy effect is that travelers will often route themselves through their own neighborhood, even if another route may be more direct, due to greater familiarity with streets near home.

The power of residential location to shift the cognitive map is clearly evident in some of the survey results. The first distance pair for South Los Angeles asks respondents to determine whether Watts Towers or Compton City Hall is closer to the survey site at Kenneth Hahn Shopping Center. Separately, residents were asked what neighborhood they lived in, and many reported either Watts, to the north of the survey site, or Compton, to the south. Overall, 49 respondents reported living in Watts and 59 in Compton. In this subsample, 88% of Watts residents reported Watts Towers as closer while on 61% of Compton residents did – a highly significant (0.001 level) difference. In this case, it is unlikely that residential location biased the finding that public transit users tended to incorrectly rate Compton City Hall as closer at higher rate than drivers. As it turns out, Watts respondents have a substantially higher rate of transit use (48%) than Compton respondents (30%). Nevertheless, the possibility of a home location effect is clearly demonstrated.

Outside the potential bias of a particular distance pair, the distance pair exercises as a whole are insulated from cognitive location bias by its breadth of scales and spread. However, the absolute distance exercise is potentially more subject to bias, as it only asked about a single route, from the survey site to Los Angeles City Hall or, in the case of UCLA, Santa Monica Pier. This warrants a more thorough test of potential spatial dependence in the models of distance estimate accuracy. Such an investigation is possible for South Los Angeles, where I coded the residential locations of most respondents based on their statements of neighborhood, home location, and sketch maps of the route from home to the survey site. For UCLA, however, with its highly heterogeneous and student-heavy sample, it was not possible to reliably code residential locations for the respondents.

The variables included in the analysis can be tested for spatial dependence using the Moran's I measure of spatial autocorrelation. This measure can help assess if the dependent variable in the accuracy model, or the residuals from the model, vary significantly over space. Table 6.8 shows the results of Moran's I tests for both the dependent variable and the residuals of Model 3, the parsimonious regression of distance to Los Angeles City Hall accuracy (see Table 6.4 for regression results). As the results show, neither the dependent variable nor the residuals show significant clustering or dispersal. This suggests that spatial dependence due to respondents' residential location is not likely a major source of bias in the South Los Angeles models.

TABLE 6.8 Moran's I Tests for South Los Angeles Distance Estimate Accuracy Model (Model 3)

Value	*Moran's Index*	*Z-Score*	*P-Value*
Ln Estimate Accuracy (Dependent Variable)	0.126	-0.895	0.371
Model 3 Residuals	-0.203	-1.316	0.188

6.4 Discussion and Conclusion

This chapter shows that a relationship likely exists between travel mode and the cognitive map, where travel by active modes results in a more accurate map, whether measured in terms of absolute or relative distances. This relationship persists when controlling for other factors, including time spent in the neighborhood and sex, and the results do not show high levels of spatial autocorrelation. Significant differences in knowledge accumulation between modes have potential implications for the way cities plan for and provide transportation to their populaces. First, however, I discuss threats to validity and how they may be linked this chapter's conceptual argument that better spatial information leads to increased accessibility.

6.4.1 *Internal and External Validity*

The findings in this analysis bring a relatively unexplored area of urban research into sharper focus. However, as the literature review shows, this type of research is novel, and the Cognitive Mapping and Travel Behavior survey was in many ways exploratory. The data collected on socioeconomic status, travel mode, and – most importantly – spatial knowledge are constrained by relatively limited number of variables collected to reinforce the internal validity of the findings. The most notable issue is that only a single absolute distance estimate was requested from the respondents. The results are reinforced by the pair estimates, as well as the sketch map findings reported in Chapter 7, but ideally multiple distance estimates would have made the findings more robust, reinforcing internal validity. Overall, the sample size in South Los Angeles was sufficient to demonstrate differences between modal groups with statistical validity. However, the complexity of the UCLA sample meant that a larger sample size would have facilitated more statistical certainty around the smaller differences or more complex patterns observed in the data.

Beyond the research's internal validity, its applicability to other populations – its external validity – is arguable. Even within this study, the findings from the UCLA sample were not nearly as clear as for the South Los Angeles sample, though some relationship between travel mode and spatial knowledge was evident at UCLA, as well. In this case, the best evidence as to this research's external validity comes from outside research, conducted after the fact and in response to the findings presented here. Chorus and Timmermans (2010) present the findings from research conducted among students at a university in the Netherlands. They find that the active and passive characterization of travel accurately predicts cognitive map quality with this population as well, defining active travel as driving and biking and passive travel as transit use.

This independent finding from across the globe is itself one data point, but it goes a long way to reinforcing the potential validity of the findings in this analysis.

6.4.2 Implications for Cities

With respect to cognitive mapping, this research underscores that differences in spatial knowledge due to the spatial learning process are not only the result of *where* we travel, but *how* we travel. Differences between active and passive travel and their effects on learning are realized in the everyday travel modes of individuals in the city. Travel modes, even when providing relatively equivalent mobility to a given destination, can differentially shape awareness of that destination and intervening opportunities. These effects persist even when controlling for other factors already known to shape spatial knowledge including length of experience (time spent in the neighborhood) and gender.

While accessibility has traditionally been conceived as proximity of (or impedance/cost of travel between) locations, cognitive mapping research shows that physical distances are only one factor shaping how individuals make spatial choices (Kwan and Weber 2003; Golledge and Gärling 2004; Weston and Handy 2004). The expanding body of literature on individual accessibility includes multiple factors found to shape accessibility including personal time constraints, activity duration, activity scheduling and time-of-day effects, as well as social and familial constraints, such as gender roles (Kwan 1999; Dijst and Vidakovic 2000). Kwan and Hong (1998), in fact, establish a specifically cognitive framework for incorporating individual constraints into a network-based accessibility measure.

To this stream of individual accessibility research, this analysis adds the experience of travel, differentiating that experience by travel mode. Differences in prior modal travel experience are associated with differences in the content and construction of individuals' cognitive maps. These differences in the experience of travel, as well as spatial location, and social, cultural, and economic characteristics, shape the cognitive map and, thereby, the cognitive proximity and accessibility of potential destinations in a region. Using the terminology of Kwan and Hong (1998), modal experience would play a role in shaping the "cognitive feasible opportunity set" when measuring individual accessibility. A potential transformation of a spatial set of opportunities that would reflect the findings in this research could be to add an attractiveness penalty to all potential destinations for passive travelers, to reflect their lack of spatial knowledge generally, but to alleviate that penalty near modal choice points, such as transit stops for public transit users.

These findings on travel mode have implications for improving access for disadvantaged populations. The findings of this analysis are consistent with research on job search behavior among low-wage workers. Those with regular access to private vehicles tend not only to search larger geographic areas for work, but also tend to perceive job opportunities in less spatially constrained ways (Stoll 1999; Holzer and Reaser 2000). To remedy such cognitive barriers to job opportunities experienced by those without regular access to autos, "compensatory" solutions could be implemented, such as trip-planning services, car-share programs, guaranteed-ride-home services at large worksites, or even facilitating the use of new urban-scaled information and communication technologies.

Chapter 7

Building a Better Cognitive Map: Travel Experience and Reliance on Landmarks

7.1 Introduction

Cognitive maps can be exquisitely complex, but they are built from basic components. Those components are inscribed into cognitive maps, in a large part, through travel experience. How we travel, whether by car, transit, or on foot, whether as a driver or a passenger, influences what goes into the map. Spatial learning theory argues that these elements are laid down during successive phases of an experiential, developmental process. Individuals rarely fully flesh out their cognitive maps of a given place, and the degree to which cognitive maps develop can vary by mode of travel. In this chapter, I demonstrate that travelers by passive modes have different, less-developed cognitive maps than active travelers, evidenced by a reliance on landmarks for navigation.

The differences in the “construction” of cognitive maps for active and passive travelers have relevance for planning. If a given mode is associated with dependence on landmarks and the lack of detail and accuracy that landmark-focused knowledge entails, then compensatory measures to increase spatial knowledge may be needed. Second, despite drawbacks, spatial learning theory suggests that landmarks are critical components of urban legibility. As such, planners and designers need a better understanding of the role of these urban features, and of their prevalence in the contemporary built environment. A diversity of urban features, including distinctive landmarks and well-designated routes may be valuable not just for newcomers but for those residents, such as those without access to reliable transportation, who have the least control over their urban travel experiences.

This chapter presents the results of the sketch map exercises included in the Cognitive Mapping and Travel Behavior Survey. The survey, conducted both in South Los Angeles and on the UCLA campus, asked respondents to sketch two maps, one of their path from home to the survey site, and the second of the path they would take from the survey site to a common location. I analyzed these maps both quantitatively and qualitatively to understand differences between individuals in terms of travel mode, demographic differences, spatial location, and drawing ability. In this chapter I include key findings regarding the sketch maps, highlighting the reliance of passive travelers on landmarks for navigation. I then explore the potential consequences of such reliance, including the role of urban design in navigation and way-finding.

7.1.1 Hypothesis

I review the literature on cognitive mapping, navigation, and spatial learning theory in Chapter 2. Cognitive maps develop and become more effective as people actively navigate their environment. The analysis in Chapter 6 has already shown that cognitive map accuracy suffers among regular users of cognitively passive modes such as transit and being driven, relative to the maps of drivers and walkers. However, I hypothesize that this inaccuracy is not simply a matter of cognitive clarity, but that the fundamental "construction" of active and passive travelers' maps are different. Drawing on the spatial learning process that has been described in geographical and psychological research, I argue that the passive travelers' cognitive maps are relatively arrested in the landmark phase of spatial knowledge development. Active travelers, on the other hand, have progressed to the use of more coherent route networks in their cognitive maps.

The differences between the construction of active and passive travelers' cognitive maps should be observable in how they represent navigation sequences during sketch mapping tasks.

The elements they include in those maps, specifically landmarks or route segments, should vary significantly from one another depending on travel experience. These differences should remain even when controlling for other factors including time spent in the area and socioeconomic status.

7.2 Data

As described in Chapter 4, the sketch maps were developed as a part of the Cognitive Mapping and Travel Behavior Survey. The sketch maps are the product of open drawing exercises, only guided by the instructions to draw a map of a route between two defined places. The surveys are attached as Appendices A (South Los Angeles) and B (UCLA), and the sketch map exercises are the final two pages of each survey, including the instructions and drawing space provided to respondents. Without any template, respondents had the freedom to be as detailed or sparse in their maps as they wished. As the figures show, the instructions direct respondents to "include" drawing elements from a range of streets, businesses, bus lines, and landmarks. However, no particular map element was emphasized, and the only required inclusions were the origin and destination themselves. As a part of the entire survey, the sketch maps are linked to verbal responses to cognitive survey questions, as well as travel and demographic information.

Figures 7.1 through 7.4 are examples to illustrate the range of sketch maps drawn by respondents, for the South LA "home to survey site," South LA "survey site to LA City Hall," UCLA "home to survey site," and UCLA "survey site to Santa Monica Pier" tasks, respectively. The maps in the figures are reduced to half their actual size. The figures highlight the remarkable diversity of the sketch maps, in terms of their level of detail, the modes of travel

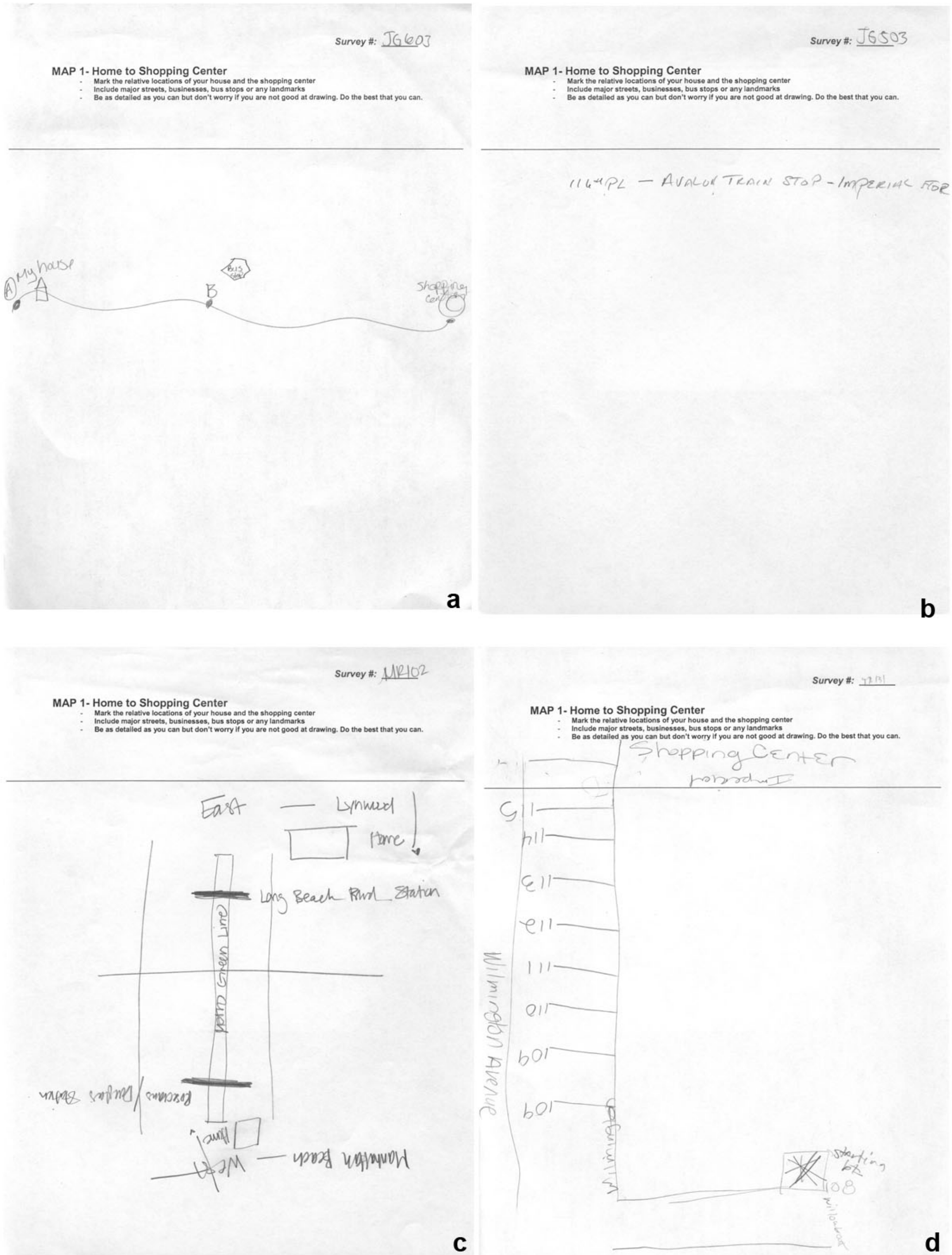


FIGURE 7.1 South Los Angeles "Home to Survey Site" Maps

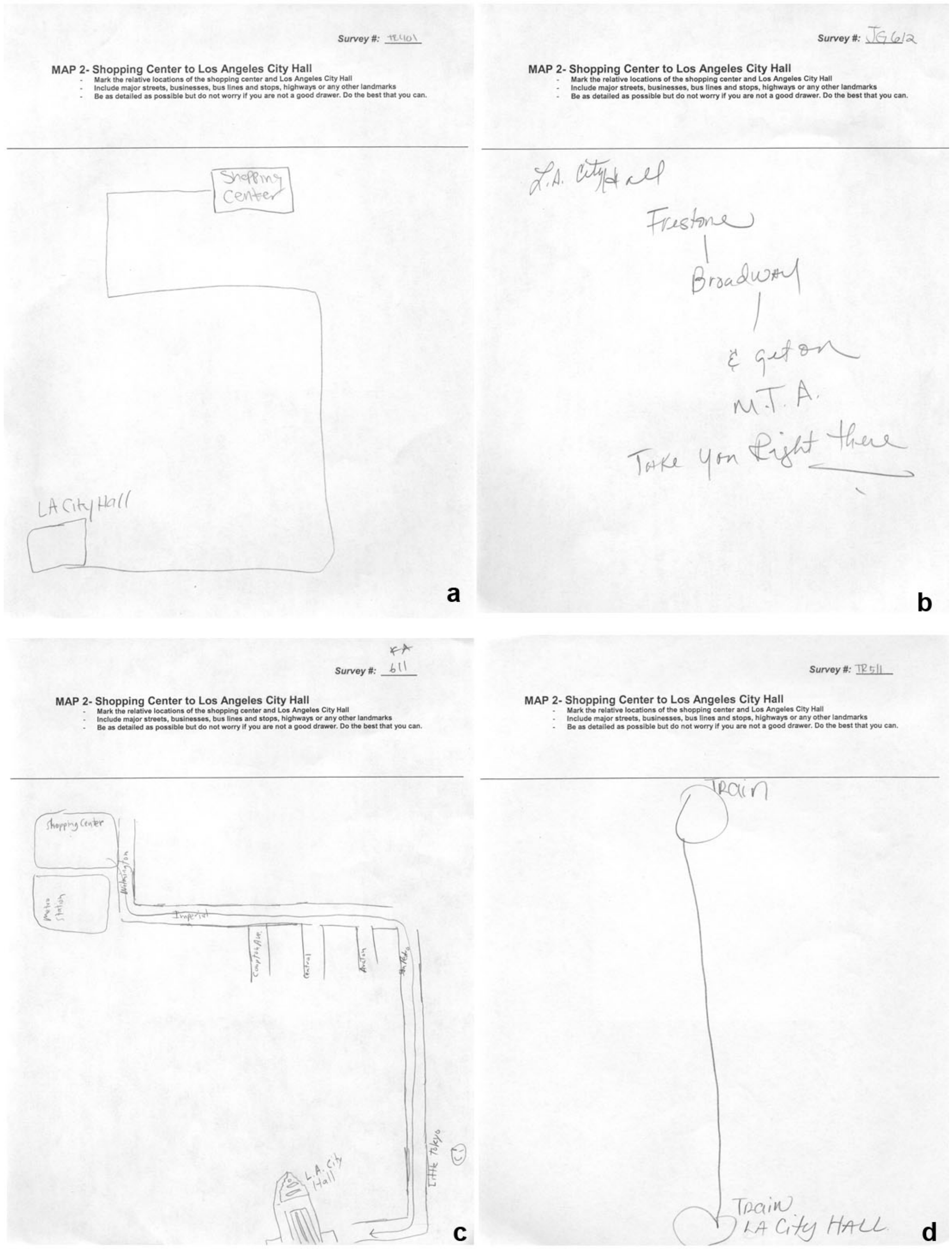


FIGURE 7.2 South Los Angeles "Survey Site to LA City Hall" Maps

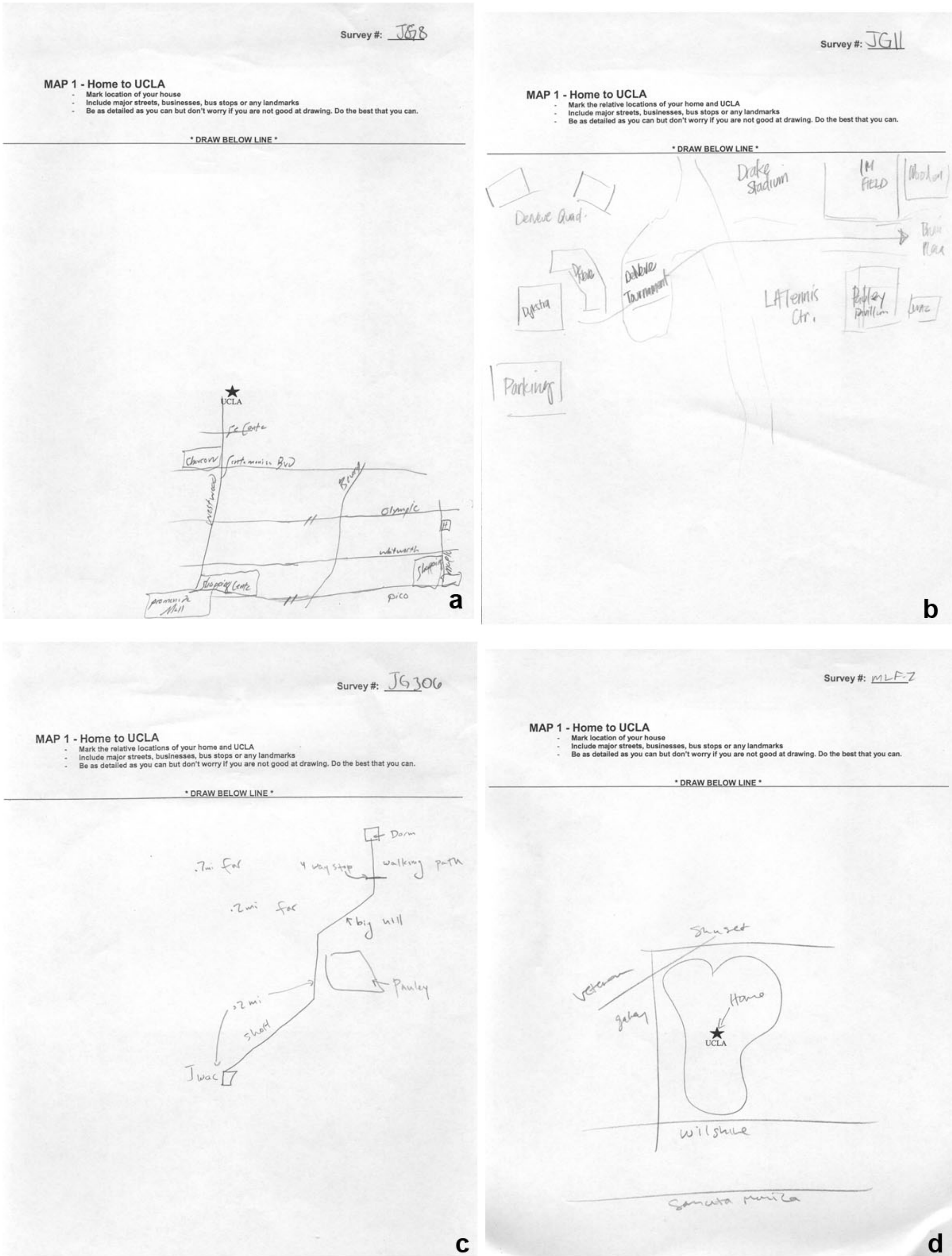


FIGURE 7.3 UCLA "Home to Survey Site" Maps

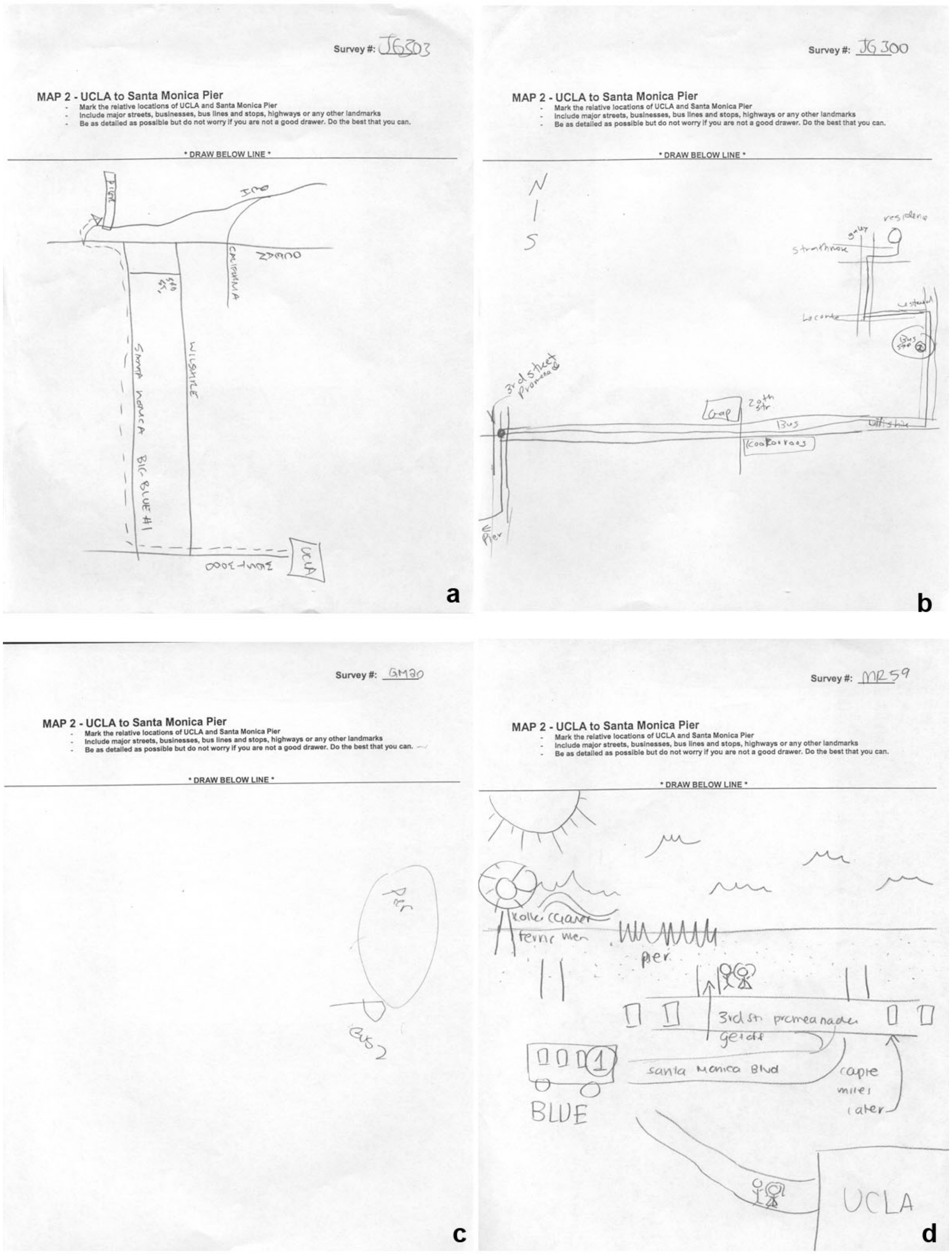


FIGURE 7.4 UCLA "Survey Site to Santa Monica Pier" Maps

path. However, open sketch maps do increase the potential for error due to the wide variability in individuals' drawing ability. Not all individuals can easily externalize their spatial knowledge as images on paper, and open sketch maps do not provide any support for those with limited drawing skills. If poor drawing ability leads to error, and those errors are correlated in some way with variables of interest, then the analysis will be biased.

To determine whether drawing error could result in bias, I evaluated a subset (N=99) of the sketch maps for drawing quality. I used the "home to survey site" from the South Los Angeles sample. On a scale from 1 to 10, I scored the drawing quality of the sketch maps. In order to minimize my own error in assessing map quality, I developed a set of rules for awarding points. Maps received points for five different qualities:

- Complete route between origin and destination – 4 points possible
- Clear delineation of origin and destination – 2 points possible
- Congruence with cartographic map of area – 2 points possible
- Inclusion of local context for route – 1 point possible
- Inclusion of map keys – 1 point possible

Within each category, maps could be rewarded partial points for incomplete attainment of a particular map quality.

Table 7.1 shows the correlation between the quality scale and several variables of interest in the analysis, as well as the mean values for those variables categorized by individuals with no valid map, a map with quality from 1 to 5, and a map rated from 6 to 10. Note that the subset for whom all "home to survey site" maps and variables are valid is approximately half of the total South LA sample, at 99 out of 196 respondents. An additional 80 respondents have valid travel and demographic data, but no map.

TABLE 7.1 Quality Scale Correlations and Mean Comparisons					
	Quality Scale				
Variable of Interest	*Correlation*		*No Map (N=80)*	*1 to 5 (N=40)*	*6 to 10 (N=59)*
Female	-0.0784		64%	83%	69%
African American	-0.0528		70%	73%	69%
Years in Neighborhood	-0.0476		12.7	11.5	11.8
Household Number of Cars	-0.0114		1.8	1.9	1.6
Active Traveler	0.0086		25%	23%	31%
Ln (City Hall Distance Deviation)	0.0729		-0.08	-0.02	0.10
Years of Education	0.1603		12.5	11.8	12.7
Employed or in School	0.2142		58%	40%	63%

The correlations between the quality scale and other key travel or demographic variables are relatively small. However, some of the correlations stand out as representing potential, if relatively minor, sources of drawing skill bias. Most notably, years of education and status of being employed or in school are positively correlated with drawing quality. Thus, education and employment status may contribute to drawing skill, either due to innate ability or training. However, in the context of this analysis, the most important biases would be those between drawing quality and travel mode or between drawing quality and other types of spatial knowledge. In those cases, no substantial correlation is observable. Being an active traveler is nearly completely uncorrelated with drawing quality, and the measure of inaccuracy of respondents' City Hall distance estimate is only slightly correlated with drawing quality, with a counterintuitive *positive* correlation at that.

The table also compares the means of these key variables among categories defined by respondents either having no valid map, or being at the low (1 to 5) or high (6 to 10) of the drawing quality scale. Though the number of individuals who did not provide a valid "home to survey site" map is relatively high at nearly half of all respondents, the travel and demographic characteristics of those without maps are not substantially different from those who did provide valid maps. In fact, they show evidence of being better educated than the map drawers and having particularly accurate City Hall distance estimates. This suggests that their reasons for not drawing a map are not likely to be due to poor drawing ability.

Overall, the low correlation between drawing quality and other variables, as well as the similar characteristics of respondents who did and did not draw maps, indicates that there is likely to be little bias due to drawing ability in the sketch map analysis. Potential bias may lie in the relationship between drawing quality and education or employment status. However, those variables are controls, rather than the focus, of the analysis of travel behavior and spatial knowledge. In the analysis that follows, where this bias may be of concern, it is noted and explored.

7.2.2 Sketch Map Inventories

In addition to qualitative evaluation of the sketch maps, the maps can be analyzed quantitatively in terms of their elemental composition, or "construction." The framework for evaluating the sketch maps is based on the spatial learning process discussed in the literature review. Because individuals generally proceed from landmark to route knowledge in their spatially cognitive development (Montello 1997), sketch maps can be evaluated for their relative reliance on landmarks and routes. To compare landmark and route usage across individuals and their diverse maps requires a consistent method for inventorying the elements. I established a comprehensive set of categories by which each element that appears on a map can be catalogued. In order to promote accuracy in the inventory, initial element counts for each map were conducted independently by two research assistants. Following their assessment, as lead researcher I reviewed and selected a final value for any instances of discrepancies between the two initial values.

All sketch maps were evaluated across the following categories:

- Landmarks (text or icon)
- Route segments (line or text)
- Choice points (intersection or icon)
- Map keys (north arrow, legend, etc.)

Landmarks include real elements within the built environment that are not part of the transportation network, but represent waypoints along the route. Landmarks can either be drawn as iconic images or labeled as text. Route segments are elements of the transportation network itself, whether drawn as a line segment or labeled as text (e.g. "116th Street"). Choice points are waypoints along a route where a change in direction, mode, or vehicle is made. Thus, they could be an intersection for a driver or walker, or a transfer for a transit user. In the context of a sketch map, choice points are locations where the respondent is consciously indicating the complexity in the route. Finally, map keys comprise the remainder of the sketch, those elements used to situate the viewer such as a north arrow or legend, rather than illustrate the path itself.

Table 7.2 shows the average counts for each element across the four sketch maps: (1) South Los Angeles "home to survey site," (2) South Los Angeles "survey site to Los Angeles City Hall," (3) UCLA "home to survey site," and (4) UCLA "survey site to Santa Monica Pier." Despite the different samples and mapping tasks, the ratio between landmarks and route segments for each map is roughly balanced, with only the "home to survey site" maps for UCLA showing a relatively higher number of landmarks. For all maps, there is roughly half the number of choice points as route segments. Exceedingly few respondents used map keys in their drawings though map keys were somewhat more common at UCLA than in South LA. For all categories, “home to survey site” maps have more elements than “survey site to LACH/SMP” maps, and UCLA maps have more elements than South Los Angeles maps.

TABLE 7.2 Mean Element Counts for Sketch Maps				
	South LA		*UCLA*	
Elements	*Home to Survey Site (N=136)*	*Survey Site to LACH (N=111)*	*Home to Survey Site (N=176)*	*Survey Site to SMP (N=171)*
Landmarks	3.46	3.02	5.19	3.53
Route Segments	3.45	3.05	4.20	3.44
Choice Points	1.79	1.61	2.05	1.73
Map Keys	0.02	0.03	0.11	0.11
TOTAL	8.72	7.71	11.55	8.81

LACH = Los Angeles City Hall; SMP = Santa Monica Pier

7.3 Analysis and Results

The sketch maps are the most complex cognitive mapping products derived from the Cognitive Mapping and Travel Behavior Survey. However, the mapping tasks were not meant to be difficult for respondents, linking as they did familiar locations and landmarks. Instead, the maps are opportunities to observe how individuals build their spatial knowledge from basic elements. The analysis of the sketch maps examines how those elements vary among groups defined by their mode of travel. I hypothesize that the cognitive maps of active travelers will vary from those of passive travelers, cognitive travel style being defined in the same way as in Chapter 6. The more limited experience of passive travelers will result in a greater reliance on landmarks as opposed to knowledge of the streets themselves.

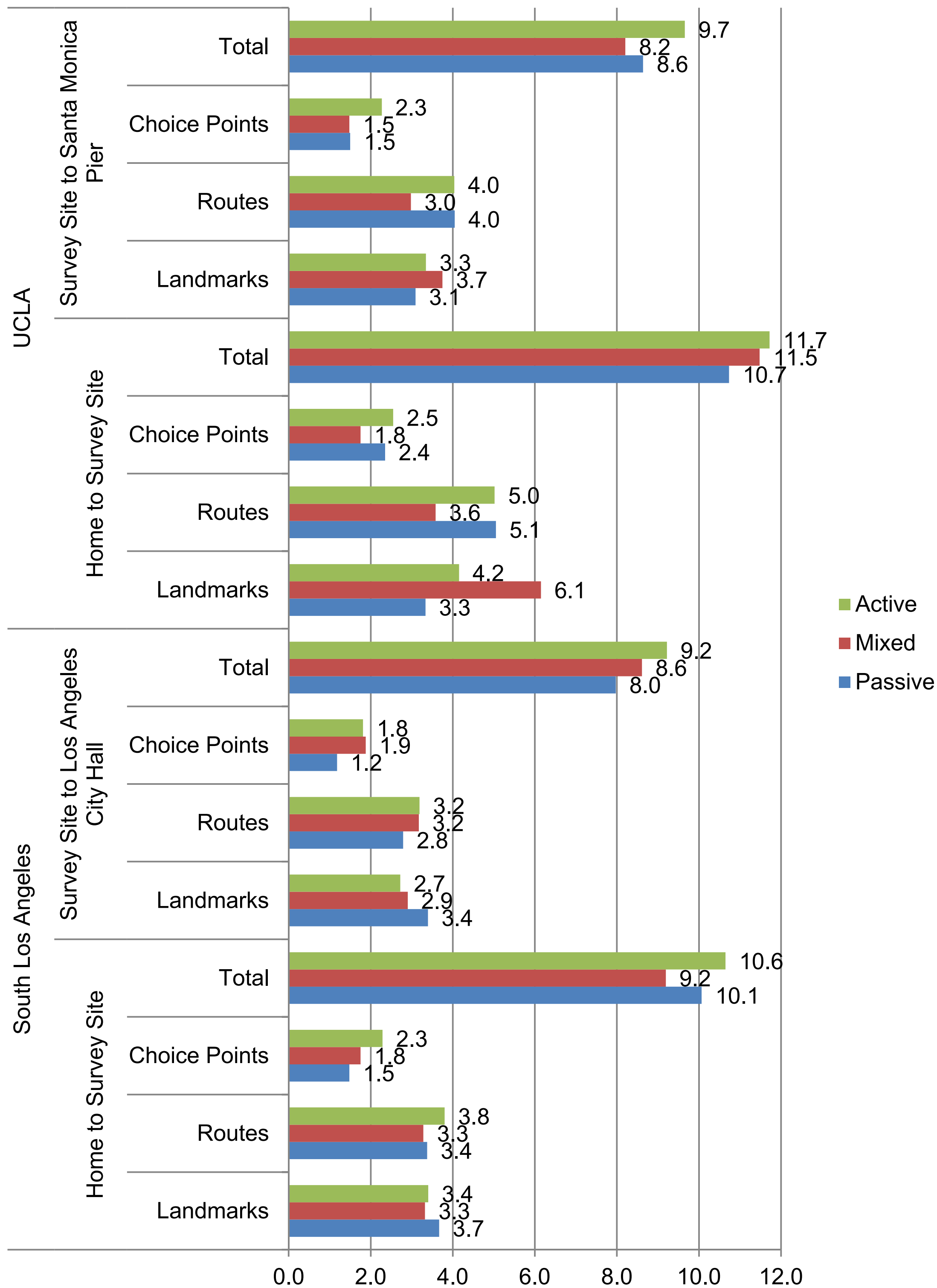
7.3.1 Ratios of Landmarks and Routes

As shown in Table 7.2, I inventoried the sketch maps by their component parts: landmarks, routes, choice points, and map keys. Counts of these elements can be compared across element categories by cognitive travel style. Cognitive travel style can be active, mixed, or passive. Active travelers are those who reported travelling exclusively by the cognitively active modes of auto driving or walking, passive travelers reported travelling exclusively by the cognitive passive modes of transit or auto passenger, and mixed travelers used a combination of active and passive modes.

Figure 7.5 illustrates the differences in map elements among travelers defined by cognitive travel style. Note that "map key" elements are not included, considering the very low number of respondents in any category who drew them. In terms of total elements used, the differences are not substantial, though active travelers consistently have higher numbers of elements than passive travelers. In South Los Angeles, passive travelers used more landmarks than active travelers. However, at UCLA the mixed travel group employs landmarks the most. For routes and choice points, South Los Angeles and UCLA again exhibit different patterns. In South Los Angeles, active respondents consistently used more routes or choice points than passive travelers, with mixed travelers not exhibiting a clear relationship to the other modes. At UCLA, mixed travelers used notably fewer routes and choice points than either active or passive travelers.

While the raw element counts show some difference between the cognitive travel styles, they do not directly address the hypothesis that one type of element dominates the other in actively- and passively-formed cognitive maps. Rather than look at absolute numbers, the ratio of landmark elements to either routes or choice points would more closely address the conceptual hypothesis of landmark dominance for passive travelers. A ratio measure is advantageous also because it is a unitless measure, meaning it is comparable across maps regardless of the actual physical distance covered. A sketch map covering a long distance may use higher numbers of landmarks and routes or choice points, relative to a map of a short distance. However, with a ratio, relatively high or low element counts in both the numerator and denominator should cancel

FIGURE 7.5 Map Elements by Cognitive Travel Style



out, and thus maps covering varying distances should be comparable, all other factors being equal.

Choice points and routes cover roughly the same conceptual ground of greater cognitive map refinement. The major difference in the choice point and route counts as inventoried for this analysis is that the count of choice points is limited to those moments along the sketched path where some directional or modal change is being made, while the count of route segments can include not just the segments along the path from origin to destination but also contextual route segments (such as cross streets). Thus, the route segment counts may contain, in part, some elements that almost serve a "landmark-like" function in the cognitive map.

Figures 7.6 and 7.7 depict the differences between active, mixed, and passive travelers for two ratio measures, "landmarks over route segments" and "landmarks over choice points," respectively. By directly comparing landmarks to a form of route knowledge, clear patterns emerge. However, these patterns are significantly different in South Los Angeles and at UCLA. Figure 7.6 illustrates variations using the landmarks to route segments ratio. The South Los Angeles "survey site to LA City Hall" map is the only map to exhibit a clear positive relationship between passive travel and relative use of landmarks in the sketch. The "home to survey site" map for the same sample shows marginally higher use of landmarks by passive travelers, but the mixed category uses landmarks least. For UCLA, the relationship is particularly divergent from the hypothesis, with the mixed group showing far higher use of landmarks relative to route segments than either fully active or passive travelers, and the active group actually shows somewhat higher reliance on landmarks than the passive group.

FIGURE 7.6 Ratio of Landmark to Route Segment Elements

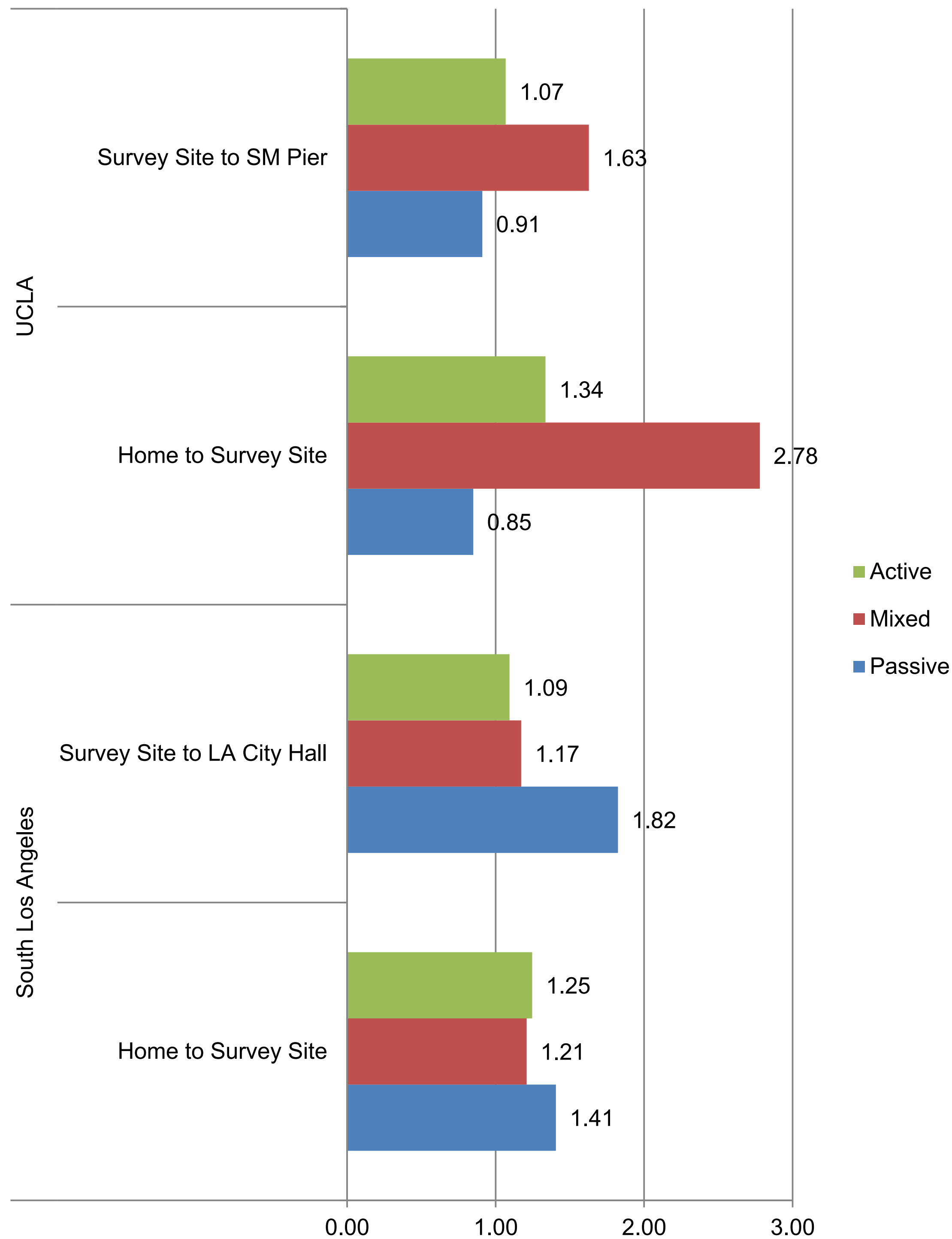


FIGURE 7.7 Ratio of Landmark to Choice Point Elements

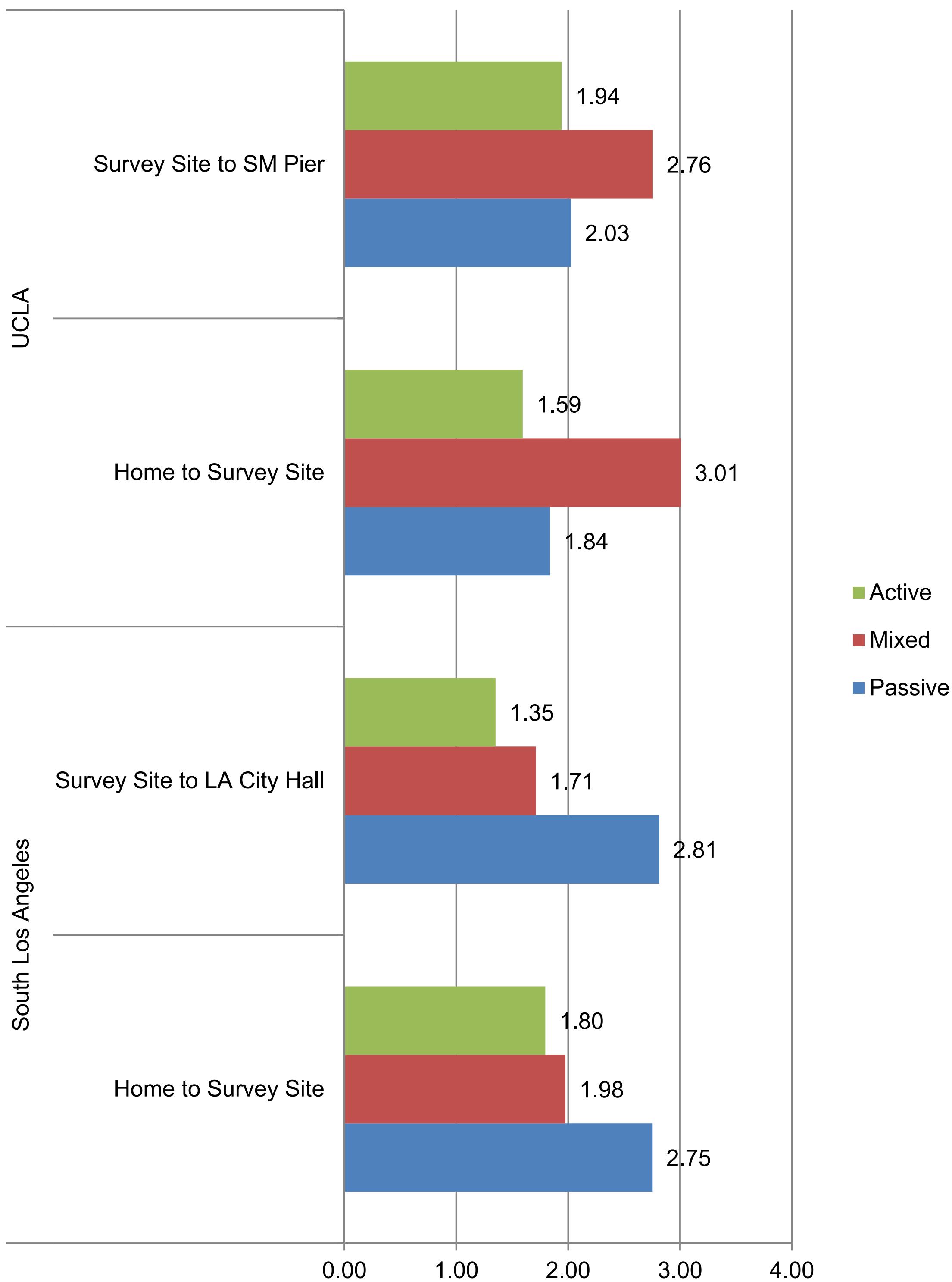


Figure 7.7 illustrates the ratio of landmarks to *choice points*, rather than route segments. I argue this is a more valid measurement of the relative dependence on landmarks, because choice points, as inventoried in this study, relate only to the route itself and the respondent's conscious expression of its complexity. The route segment count, on the other hand, may include road segments used in "landmark-like" context, rather than as integral parts of the path between origin and destination. Indeed, for the South Los Angeles sample, the differences between travel modes become very clear and consistent with the landmarks to choice points ratio. Passive travelers utilized landmarks in their maps far more than others. The ratio consistently increases from active to mixed to passive travelers.

At UCLA, however, the situation is quite different from that in South Los Angeles. Looking again at Figure 7.7 for UCLA and excluding the mixed travelers, passive travelers do appear to rely marginally more on landmarks than active travelers. However, reliance on landmarks among active and passive travelers is dwarfed by the use of landmarks among mixed mode travelers. This trend is inconsistent with the hypothesis, but still quite distinct and uniform across the two UCLA sketch maps. The trend at UCLA suggests that the "mixed" mode group may have distinctive characteristics that significantly affect cognitive map development beyond their travel experience.

Table 7.3 explores the demography of cognitive travel groups for variables that may themselves influence knowledge of the built environment. At UCLA, the mixed travelers are the youngest, (relatively) least educated, have spent the least amount of time in their current neighborhood, and have the highest proportion of students. In fact, half of the mixed travelers have spent a year or less in their current neighborhood. This suggests that, at UCLA, the mixed group is more dominated by undergraduate students. Undergraduates mostly live in dormitories or close to campus, thus walking (active mode) to school but taking transit (passive mode) to get off campus. Thus, for UCLA the possible differences in cognitive map construction due to travel mode appear to be swamped by other experiential factors, namely undergraduates' life in the dorms and relative lack of local knowledge.

TABLE 7.3 Knowledge and Life Experience of the Cognitive Travel Groups

UCLA				
	Age	Years in Neighborhood	% Student	Years of Education
Passive	29.3	5.8	67%	15.9
Mixed	25.4	3.5	79%	15.1
Active	26.7	4.5	71%	16.2
South Los Angeles				
	Age	Years in Neighborhood	% Student	Years of Education
Passive	34.0	11.5	31%	12.0
Mixed	37.7	11.6	14%	12.3
Active	34.3	13.8	24%	13.2

7.3.2 Comparing the Sketch Maps to Cognitive Mapping Exercises

The analysis of sketch map elements suggests that the construction of individuals' cognitive maps does vary by travel experience, though other factors may also influence the components of the maps. Before delving deeper into the factors that shape the cognitive map, the results from the sketch maps analysis can be compared to the results from other exercises in the Cognitive Mapping and Travel Behavior Survey. Multi-method approaches to cognitive mapping research are a powerful way of reinforcing the internal validity of findings (Liben, Patterson et al. 1981; Kitchin 1996). Particularly due to the threat from drawing ability error, any support for the patterns observed in the sketch maps from non-sketch methods would be particularly prized.

Beyond the cognitive map accuracy measures explored in Chapter 6, respondents were also asked to complete the simple task of describing where they lived and worked (see

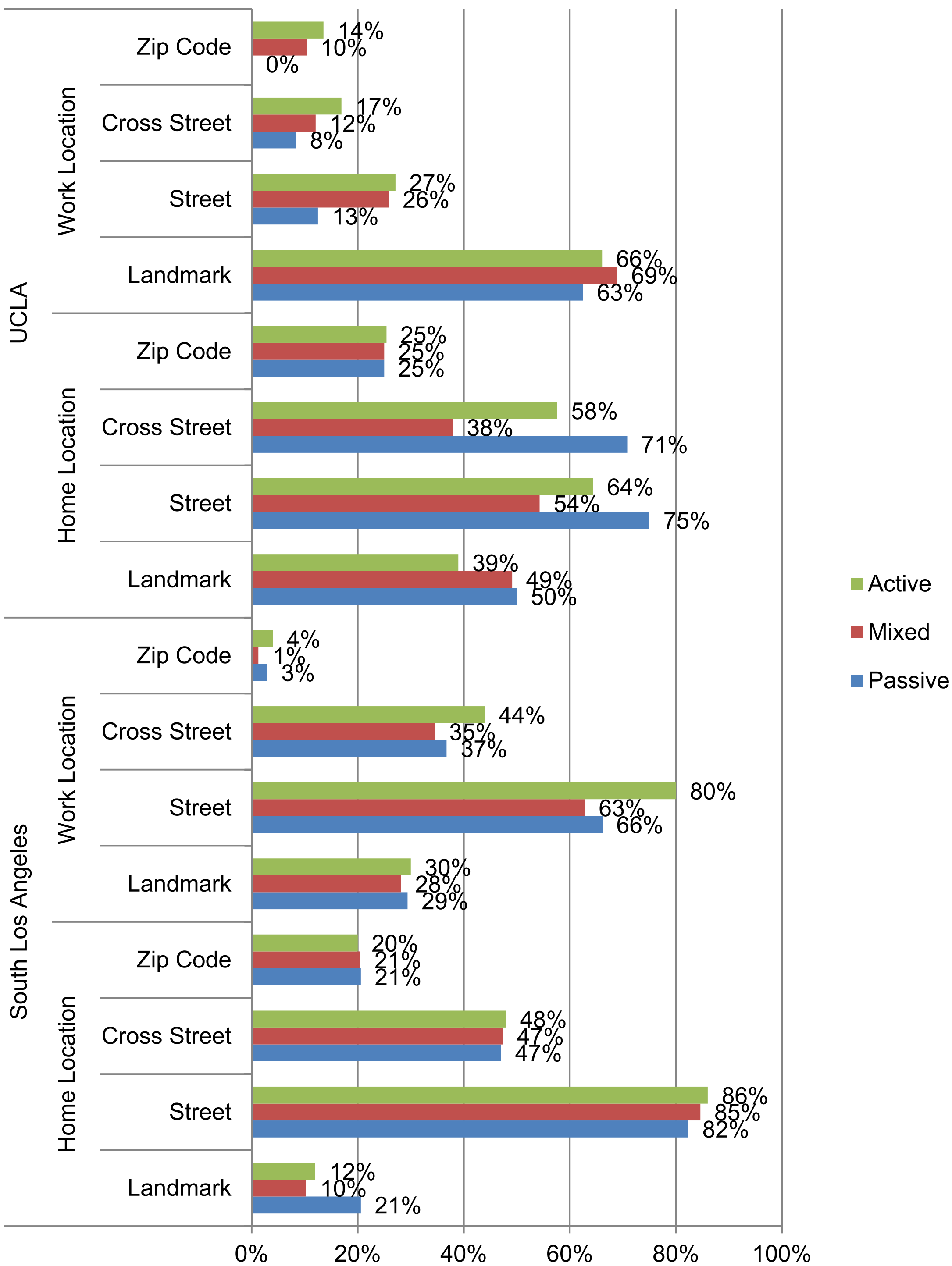
Appendices A and B). Respondents were asked, "Could you tell us some identifying feature of your neighborhood: your street name, cross streets, another landmark or feature, or your zip code?" A similar question was asked for workplace. Thus respondents were given an open ended opportunity to locate themselves using either landmarks, elements of the transportation network, or a zip code.

Figure 7.8 illustrates the how the elements used to describe home and work/school locations vary by cognitive travel style. Several patterns among survey locations and map types stand are evident, notwithstanding cognitive travel style. UCLA respondents tend to utilize landmarks to describe locations far more than the South Los Angeles sample. This finding highlights the critical importance of urban form in any cognitive map exercises. UCLA is a campus, and thus potentially more likely to be understood in terms of its buildings than its route network, where most of the walking paths are unnamed. South Los Angeles, on the other hand, is embedded in the Los Angeles street grid.

Both at UCLA and in South Los Angeles, respondents relied more on landmarks and made less use of streets and cross-streets to describe their work location. It is possible that respondents are relatively less familiar with their work locales, and thus must rely more on landmarks to describe those locations. This explanation would fit a developmental theory of spatial learning, where individuals' spatial knowledge would be most developed near their home location and degrade in areas they spend less time exploring.

Beyond the overall trends, some differences are evident among the groups defined by cognitive travel style. In South Los Angeles, passive and active travelers describe home and work locations in different ways. For home locations, passive travelers rely on landmarks doubly as much as active travelers. Streets, cross-streets, and zip codes, however, are fairly

FIGURE 7.8 Elements Used to Describe Home and Work Locations, % of Respondents by Cognitive Travel Group



similarly used among groups. For work locations, active travelers are able to name streets and cross-streets at a higher rate than passive travelers. Landmarks and zip codes, however, are equivalently used among the groups for work. In South Los Angeles, the mixed group shows an intriguing pattern, mimicking active travelers on the home-location exercise and mimicking passive travelers on the work-location exercise. It is quite possible that “mixed” travelers walk near home but use transit to go to work, explaining their similarity to active travelers near home and passive travelers at work.

At UCLA, the results are more complex. For the home-location exercise, mixed travelers use streets and cross-streets the least to describe their home location, consistent with the results seen with the sketch maps. For the work-location exercise, the pattern is more surprising. Mixed travelers do not stand out the same way. Instead, much like in South Los Angeles, no substantial difference in use of landmarks is evident between the groups, but active travelers name streets and cross-streets for the work-location exercise more often than the other groups. Mixed travelers occupy the middle position between active and passive travelers, as would be expected. Importantly, for the UCLA sample the work (or school) location was a given – UCLA – as the survey was taken during working hours on campus. Here, active and passive travelers made differing use of streets and cross-streets to describe their location while work location was held constant as UCLA. This indicates that the nature of the built environment, while important, is not the only factor controlling how people describe their location.

The exploration of the elements used to verbally describe home and work/school locations underscores that modal differences in the use of basic elements to process space extend beyond the sketch maps. Overall, landmarks play a larger role for passive travelers near home, while streets and cross-streets are more apparent to active travelers near work. The patterns of the UCLA home-location exercise reinforce the relationships seen in the two UCLA sketch maps, with the mixed group being most landmark-reliant. The UCLA work-location exercise did not repeat this pattern of mixed travelers being the most landmark reliant, but it did show that even when location is held constant (UCLA as work/school), active and passive travelers differ in how they describe locations, along lines that match the spatial learning framework.

7.3.3 Controlling for Other Factors

Experience of the built environment through travel, measured by the cognitive travel style variable, is of course not the only factor that may influence how cognitive maps are constructed. As the descriptive statistics above demonstrate, possible non-travel related factors may include time living in the local area, education, and employment or students status. In addition, other demographic factors such as sex, age, or ethnicity may influence the construction of the cognitive map, as they have been found to influence its dimensions and accuracy (Maurer and Baxter 1972; McGuiness and Sparks 1983; Banerjee and Baer 1984; Dabbs Jr, Chang et al. 1998). The relationship between cognitive map and travel behavior measures in this chapter can be examined for significance using multiple regression, employing additional data collected in the Cognitive Mapping and Travel Survey as controls.

Based on the results in the sections above, the ratio of landmark elements to choice points in the sketch maps stands out as the clearest representation of difference in how an individual's cognitive map is constructed. In addition, this ratio possesses a clear relationship to cognitive travel style, even if that relationship varies substantially between South Los Angeles and UCLA. The ratio is a continuous variable, roughly normally distributed, making ordinary least squares

(OLS) regression an appropriate method for controlling for other factors. The OLS model has the same basic formulation as those in Chapters 5 and 6.

Table 7.4 contains the OLS regression results for four models, two each for South Los Angeles and UCLA. Note that the models were executed with robust standard errors to address concerns of mild heteroscedasticity observed during the model building process. In practice, the use of robust errors did not substantially change the results or findings of significance. Conceptually, the two sketch maps drawn by each respondent were treated as separate measures of a single phenomenon: the construction of the cognitive map. Therefore, the measures were combined in a straightforward manner, taking the mean of the ratios of landmarks to choice points for the two sketch map exercises.

TABLE 7.4 Sketch Map Elements Regression - OLS Regression with Robust Errors

Dependent Variable:
Mean Ratio of Landmarks to Choice Points for "Home to Survey Site" and "Survey Site to LACH/SMP" Maps

	Model 1 S. Los Angeles		*Model 2 S. Los Angeles*		*Model 3 UCLA*		*Model 4 UCLA*	
Independent Variables	*Beta*	*Sig.*	*Beta*	*Sig.*	*Beta*	*Sig.*	*Beta*	*Sig.*
Mixed Travel Style (vs. Passive)	-0.453	0.038	-0.402	0.036	0.233	0.111	0.230	0.099
Active Travel Style (vs. Passive)	-0.569	0.012	-0.513	0.009	-0.127	0.311	-0.125	0.309
Years in Neighborhood	0.195	0.122	0.201	0.090	-0.116	0.120	-0.132	0.058
Education in Years	0.015	0.902			-0.012	0.886		
Female	-0.101	0.365			-0.004	0.968		
African American	0.010	0.947			-0.123	0.048	-0.124	0.002
Employment Status	-0.072	0.579			0.008	0.944		
Student Status	-0.078	0.596			0.026	0.797		
Age	-0.165	0.149	-0.147	0.187	-0.025	0.827		
Constant	.	0.027	.	0.000	.	0.035	.	0.000
N	65		67		107		108	
F	1.90		2.95		3.65		7.30	
Prob > F	0.0709		0.0271		0.0006		0.0000	
R-squared	0.2511		0.2171		0.1633		0.1572	

LACH = Los Angeles City Hall; SMP = Santa Monica Pier

The cognitive travel style measure is included as a set of dummy variables comparing mixed and active travelers to the base case of passive travelers. Years spent in the neighborhood captures the degree to which the cognitive map may have developed over time. Education in years could potentially capture either learned or innate skills in processing the environment, as well as overall socioeconomic status as a proxy for income. Sex (female or not) is frequently a significant factor in cognitive research, with researchers often finding that women have less accurate or more truncated cognitive maps (Golledge and Stimson 1997). Being African American is another potentially important demographic factor, linked in the literature with limited mobility and a lack of opportunity, and the only racial/ethnic variable available from the Cognitive Mapping and Travel Survey (Kain 1968; Holzer 1991). Employment and student status may be indicators of experience with the built environment, and age, like years in the neighborhood, may shape the cognitive map.

Models 1 (S. Los Angeles) and 3 (UCLA) include a broad set of variables, while Models 2 (S. Los Angeles) and 4 (UCLA) include a parsimonious set of the most significant variables. Only a few variables are significant across all of the models. The small N, particularly for the South Los Angeles sample, likely contributes to the lack of significance in the results. However, the cognitive travel style variables do exhibit significance beyond the 0.10 level in each of the models aside from UCLA_1, indicating that they do have an abiding relationship with cognitive map construction. In South Los Angeles, mixed and active travelers both have significantly lower landmark to choice point ratios than passive travelers. Oddly, given the literature cited previously on individual development of cognitive maps over time, years spent in the neighborhood, significant at the 0.10 level, is *positively* related to landmark dependence. This result is unexpected, as time spent in the neighborhood should, conceptually, lead to a more developed cognitive map. However, the time spent in the neighborhood may capture other demographic effects, such as socioeconomic status or even cultural effects that are not otherwise captured in the model.

In the UCLA models, the most significant effect is for African-American respondents. African Americans, in this sample, exhibit a reduced reliance on landmarks compared to the rest of the UCLA sample. In the UCLA context, this is very likely to be due to the fact that African Americans on the UCLA campus are largely local staff who live off campus and therefore may have more developed cognitive maps of the region. The student population at UCLA, on the other hand, is almost exclusively non-African American, only 4% African American in 2011 (UCLA Office of Analysis and Information 2012). The cognitive travel style variable in the model behaves as it did in the descriptive tables, with mixed travelers still significantly more dependent on landmarks in their cognitive maps than passive travelers. Active travelers show no significant difference from passive travelers. Finally, at UCLA the “years in the neighborhood” variable is significantly negatively related to the ratio, indicating that those who have lived in their neighborhoods longer are less reliant on landmarks, as spatial learning theory would suggest.

Overall, the models explain a moderate amount of variation in the landmarks to choice points ratio, with an R-squared of 0.217 for Model 2 (S. Los Angeles) and 0.157 for Model 4 (UCLA). The models overall are significant, though the variable-heavy yet low-N Model 1 is only significant at the 0.07 level.[18] Despite the caveats, the models highlight some important findings. Standard socioeconomic factors such as sex, race/ethnicity, and education do not

[18] I ran diagnostics on Model 2 (South Los Angeles), the model with the most explanatory power. Despite the small N and limited set of available data, residual plots showed no major deviations from homoscedasticity or normality. In addition, no multicollinearity was detected in a variance-inflance-factor test. As discussed in Chapter 6, however, the observations are likely not independent of one another, spatially or otherwise.

negate the relationship observed between cognitive travel style and the construction of the cognitive map. This result suggests that some of the findings of previous planning and design researchers that attribute differences in accessibility to socioeconomic factors may in fact be caused specifically by differing travel experiences.

Time spent in the neighborhood does not always improve the cognitive map, and can even be associated with a less developed cognitive map, at least in the case of South Los Angeles. Finally, much of the variation in the ratio of landmarks to choice points remains unexplained by this model. Certainly, more refined measures of travel and spatial knowledge, collected from a larger population, may enhance the model and its results. However, it may also be that factors unaddressed by the Cognitive Mapping and Travel Survey, such as personality and culture are needed to successfully explain the construction of the cognitive map.

7.3.4 Looking at Space and Place

As with any aspect of cognitive mapping research, location matters. The fact that landmark counts are higher on average at UCLA than in South Los Angeles is likely due in no small part to the fundamentally different urban forms of the two areas, and the different experiences that arise from navigating through a campus versus navigating through the Los Angeles street grid. Similarly, travel mode will be correlated with spatial location, as some parts of the city have better transit access than others. Such differences may operate at a variety of scales, from regional to the neighborhood or even block level. This section explores how space and place may influence the results seen so far in this chapter.

The relationship of the UCLA sample to its built environment is fairly distinctive in the contemporary urban context. The majority of respondents were students, most of whom live in the dorms on campus or in nearby apartments. Their daily experience of travel is therefore going to be shaped by the pathways and distinctive buildings of a college campus (see Figure 4.5). In this case reliance on landmarks, while indicative of a more rudimentary form of spatial knowledge, may also be the most appropriate and effective response to life on campus.

While the cognitive maps of the UCLA respondents are clearly linked with place, the linkages between place and the South Los Angeles sample are less obvious. Figure 7.9 highlights the residential locations for the set of respondents (N=149) for which enough data were provided in the survey to determine residential location to the precision of a neighborhood block. Residences are not surprisingly clustered around the South Los Angeles survey site near the crossing of the Blue and Green light rail lines, but the distribution extends several kilometers beyond. In general, this area is part of the urban grid of the southern Los Angeles Basin, an extensive area of single-family homes, moderate-density apartments, neighborhood shops and strip malls, and industrial development. However, it may be that the construction of cognitive maps does in fact vary spatially across this mythically "undifferentiated" swath of Los Angeles.

TABLE 7.5 Spatial Autocorrelation (Moran's I)

Variable	*Index*	*Zscore*	*Pvalue*
"Survey Site to LA City Hall" Ratio	-0.151	-0.447	0.655
African American	-0.128	-0.808	0.419
Active Travelers	-0.042	-0.233	0.815
Education in Years	0.006	0.097	0.923
Age	0.113	0.794	0.427
Map Quality	0.191	1.311	0.190
"Home to Survey Site" Ratio	0.311	1.162	0.245
Years in Neighborhood	0.329	2.193	0.028

The variables included in the analysis can be tested for spatial dependence using the Moran's I measure of spatial autocorrelation. This measure can help assess if the dependent or independent variables examined for South Los Angeles vary significantly over space. Table 7.5 includes the Moran's I measure and significance tests for a range of variables.

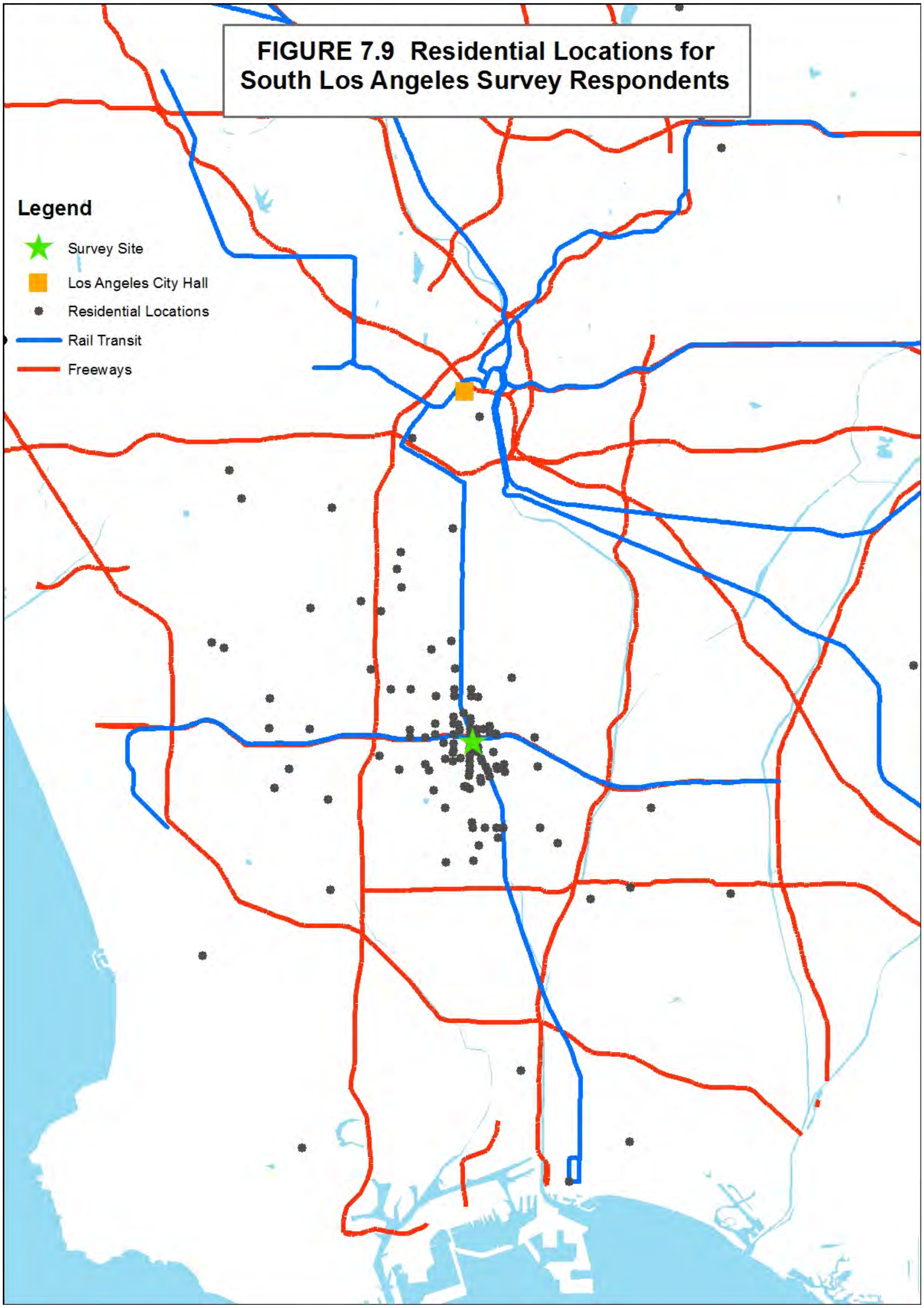


FIGURE 7.9 Residential Locations for South Los Angeles Survey Respondents
Legend
Survey Site
Los Angeles City Hall
Residential Locations
Rail Transit
Freeways

The values for most of the variables do not show a high degree of spatial dependence. Index values from 0 to 1 represent increasing clustering and values from 0 to -1 represent increasing dispersion.

Intriguingly, the only value to exhibit significant clustering is “years in the neighborhood.” This is noteworthy because for South Los Angeles, “years spent in the neighborhood” produced a counterintuitive and statistically significant result in the OLS regression. In the OLS regression, a longer time in the neighborhood was positively associated with reliance on landmarks, despite the fact that conceptually, spending more time in the neighborhood should reduce dependence on landmarks for navigation. Figure 7.10 shows an interpolated surface of respondents’ time spent in their neighborhood. The surface, validated by the significant Moran’s I result, shows that the neighborhood to the north of the survey site was represented by people who had spent a particularly long time in their neighborhood, up to 36 years in the sample.

This area, from Watts Towers northward toward the Vernon-Central neighborhood, is a center of African-American life and culture in Los Angeles (Local Initiatives Support Corporation 2012). Perhaps, in this case, years lived in the neighborhood for this population and place represents a different kind of knowledge of place that actually is not tied as much to navigation, but to the cultural value of specific, identifiable landmarks in the area. An in depth study of both the area and the people who live there would be needed to determine whether this hypothesized effect is real. However, the counterintuitive result in the OLS regression, combined with the significant clustering of values for “years spent in the neighborhood” does indicate that in South Los Angeles, as well as at UCLA, there is added complexity to the way in which cognitive maps are constructed that is not captured by the spatial learning model.

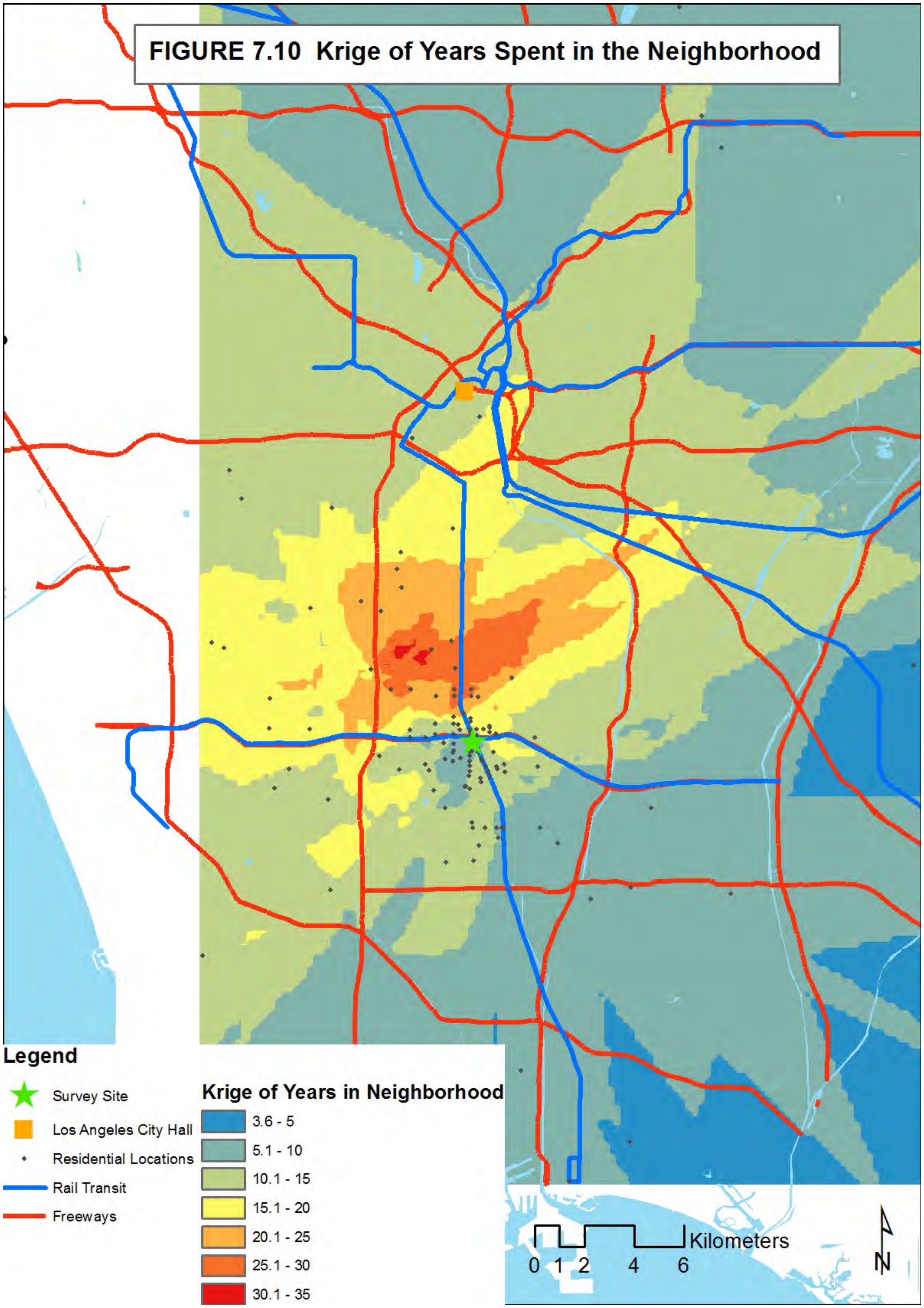


FIGURE 7.10 Krige of Years Spent in the Neighborhood
Legend
Survey Site
Los Angeles City Hall
Residential Locations
Rail Transit
Freeways
Krige of Years in Neighborhood
3.6 - 5
5.1 - 10
10.1 - 15
15.1 - 20
20.1 - 25
25.1 - 30
30.1 - 35
0 1 2 4 6
Kilometers
N

7.4 Conclusion

The exploration of how individuals construct their cognitive maps from basic elements has shown that experience of travel fundamentally shapes our personal cities and how we understand our urban environment. The patterns observed in South Los Angeles and at UCLA highlight that transportation mode is associated with relative reliance on landmarks within the cognitive map. This relationship, where passive travelers depend on landmarks more than active travelers to navigate the city, reinforces the power of spatial learning theory for understanding cognitive maps. The pattern was most clearly observed in South Los Angeles, through the descriptive analysis of the sketch maps, the comparison with verbal location descriptions, and the regression analysis. Notably, the effect stood out as significant despite the small sample size.

The findings from UCLA do not so clearly show the same relationship between cognitive travel style and reliance on landmarks. However, the reason that the "mixed" population stands out as reliant on landmarks at UCLA does not negate spatial learning theory. Instead, it suggests that the lack of local experience of the student population also engenders a reliance on landmarks similar to the effect seen due to travel mode in South Los Angeles. Importantly, even at UCLA, when asked to describe the location of their workplace or school (UCLA), the descriptors chosen did vary by cognitive travel style, with active travelers using streets and cross streets at a rate double that of passive travelers.

In this exploratory analysis of cognitive map construction, I acknowledge threats to both internal and external validity. The empirical models are limited by the nature of the Cognitive Mapping and Travel Behavior survey. The survey only included a limited set of cognitive and socio-demographic variables. A wider range of variables, particularly those that address issues of personality and culture would likely have improved the models' internal validity. Further, the small samples of people in two distinct neighborhoods, who themselves varied significantly from one another, suggest that more research would be necessary to improve claims of external validity. Despite these threats, the analysis shows powerful relationships between travel and the cognitive map, namely that passive travelers rely more on landmarks and active travelers have greater facility with the street network itself. These findings are reasonable within the conceptual framework and robust at least within the context of the local samples.

These findings are important, and worth further exploration, because the implications for transportation planning and urban design are compelling. If individuals who travel by passive modes tend to rely on landmarks to understand and navigate their space, then planners have two choices for addressing the resulting reduced accuracy and clarity in the cognitive map to assist way-finding. Planners can develop compensatory measures for passive travelers. Information technologies, for example, may be a way to supplement the cognitive maps of passive travelers without needing to "rebuild" passive travelers' maps with more complete route and survey knowledge. Beyond this sort of compensatory strategy, however, planners and designers can draw on these findings to embrace the importance of landmarks in the built environment. If passive travelers rely on landmarks to navigate, then perhaps the creation and maintenance of landmark-dense environments – like UCLA – could be a valid way of making the city more legible to all of its inhabitants.

Chapter 8

Conclusion

Throughout this dissertation, I have emphasized the experiential quality of urban activity and travel. The personal city is the repository for everything that an individual knows and thinks about the surrounding urban environment. I have shown that the personal city varies by socioeconomic status, by location, by means of travel, and even by the formal elements that comprise it. Collectively, these concepts and findings imply that there is more to individual accessibility than straightforward matching of needs, resources, and destinations across a neighborhood or an entire city. Instead, this calculus is modified by experience and available information, things that only develop over time and with the effort of travel and way-finding.

This dissertation is a piece of a broader agenda to integrate the effects of information and cognition into transportation and urban planning research, in order to better understanding the nature of individual accessibility and to craft more effective policies and interventions. The findings in the three empirical analyses have implications for the contemporary practice of urban planning. As cities become increasingly large and complex, and as urban travel becomes about more than just going to work and back, I would argue that the personal city approach to accessibility will become increasingly relevant to planning and urban dwellers' daily lives.

8.1 Implications for Planning

The implications of these cognitive, experiential facets of urban life proceed directly from the findings of the empirical analyses. I discuss the implications of each analysis chapter in sequence.

8.1.1 *Activity Spaces and Individual Accessibility*

Chapter 5 explores the activity spaces of individuals in the Los Angeles region. One basic implication is revealed in the correlations among various activity measures, contained in Table 5.2. It shows that activity space measures such as minimum convex polygons and standard deviational ellipses are not entirely correlated with more traditional transportation measures, such as distance traveled, time traveled, and number of trips. If a well-defined activity space is a good measure of individual accessibility, as I, Kwan, and other scholars argue, then measures like vehicle miles traveled (VMT) may only be second-best measures for understanding the benefits individuals accrue from the transportation system. Certainly, VMT is an important measure in its own right, both in terms of understanding overall system usage and the sustainability of that system, but it may be less useful than other measures for understanding accessibility.

While distance traveled may not be the ideal measure of accessibility, we do know that planners continue to seek out ways of reducing overall travel, particularly by auto, as a part of the push to increase the sustainability of cities and the transportation system (Handy and Clifton 2001; Noland and Lem 2002). However, reducing auto travel, if implemented carelessly, risks reducing accessibility for marginalized populations. The models of activity space extent show that low-income individuals tend to have smaller activity spaces, but that neighborhood characteristics associated with poor local accessibility, such as low opportunity density, inflate activity spaces as residents of those areas are forced to travel out to engage in desired activities. Thus, limiting auto use, such as by wholesale increases in the cost of auto travel, is likely to disproportionately negatively impact those who already have constrained activity spaces but live in places with limited opportunities. This reinforces the findings of welfare-to-work research that auto availability may be beneficial in getting and holding a job (Blumenberg and Ong 2001; Ong and Miller 2005). Planners recommending policies that increase the price of auto travel should be especially sensitive to their impact on low-income, relatively isolated households.

Another major implication of the activity space analysis is the role of the built environment in shaping individual accessibility. The models show a large, significant negative relationship between activity space size and opportunity density. Interpreting opportunity density is not straightforward, but the measure most clearly captures the concept of activity agglomerations. Those who live near such agglomerations have less need to range widely for their opportunities. Importantly, opportunity density stands apart from population density in the analysis. It is not enough to simply have dense housing, but active clusters are requisite to reduce the size of activity spaces. This finding reinforces the value of agglomerations in cities not just for economic productivity but also, potentially, for reducing travel among those fortunate enough to live near them.

The geographically-weighted regression (GWR) results highlight something important for urban research. When allowed to vary spatially, factors influencing activity space size take on very different levels of importance from place to place and even, in some instances, reverse their effects. Taking the example of income, the GWR model assigned this factor a negative relationship with activity spaces in several ethnically defined neighborhoods, and a positive relationship elsewhere, as in the global model. This suggests that even something so fundamental as how wealth shapes our travel will vary from place to place and community to community. The GWR model underscores that universalizing urban behavioral models is difficult, as actual behavior is likely highly dependent on local factors that may be difficult to capture.

8.1.2 Travel Mode and Spatial Knowledge

Chapter 6 uses the Cognitive Mapping and Travel survey to explore how the experience of travel mode modifies knowledge of opportunities at local and regional scales. The differences in spatial knowledge by mode of travel, controlling for a range of demographic factors, show that how one travels has a significant effect on the extent and accuracy of the cognitive map. This finding, in a different way than findings from Chapter 5, highlights the potential hazard to an individual's accessibility embedded in greater reliance on public transit versus auto driving. Passive travelers appear to simply be less clear about the locations of opportunities in the city, and of how to get to them. Even if this result is not surprising in light of spatial learning theory, it underscores the importance of ensuring that those who do not have access to autos are given additional tools to maximize accessibility by other, more passive modes. Again, this echoes the findings of welfare-to-work research investigators that argue that reliable access to autos may be more beneficial for getting and keeping a job than access to the transit system (Blumenberg and Ong 2001; Ong and Miller 2005). This analysis lays down a cognitive, experiential foundation to explain, at least in part, why job seekers may be more successful with a car than with transit.

Regardless of the potential hazards to accessibility, planners are committed to increasing transit use in cities, the argument for which often revolving around long-term sustainability. Certainly, the multimodal, mixed-use vision of cities typically espoused by New Urbanists and other contemporary planners and designers includes a lot of walking, as well as transit use, and the findings here actually predict improved spatial knowledge with increased walking. However at the regional scale, driving would likely be replaced with transit, and therefore planners should consider ways to compensate for the reduced navigational burden, and consequent spatial learning deficit, of transit use. Today, it appears that information technologies may be a valuable solution to the problems of poor knowledge of the city (Moss and Townsend 2000). A transit pass coupled with a smartphone may be far more beneficial for individual accessibility than a transit pass alone. Efforts by transit agencies to provide more responsive data on transit systems, combined with the availability of opportunity search services such as Google, may eventually make transit more competitive with driving, regardless of cognitive map development.

8.1.3 Urban Form and Cognitive Maps

Chapter 7 explores the elements with which people build their cognitive maps. Here again, the experience of travel has an effect on how people think about the city. In line with spatial learning theory, passive travelers are more reliant on landmarks than those who travel actively. These findings extend research by Lynch (1960), Banerjee and Baer (1984), and Loukaitou-Sideris and Gilbert (2000) among others, showing that variations in cognitive maps are shaped in part by the nature of urban travel. If we hope to improve navigation and accessibility for individuals who rely on landmarks, the solution may involve information technologies, as discussed above. However, there may also be value in returning to some of the original precepts of city design, making cities more legible across long distances by deliberately filling cities with noteworthy landmarks using strategies not dissimilar from those of “New Urbanists” (Ewing and Handy 2009). If landmark-reliant passive travelers can get off of a subway, or out of a taxi, and see in each direction a set of landmarks that designates not just local but regional context, perhaps it will convey sense of comfort that facilitates further exploration and navigation, on foot. Clear landmarks make the danger of getting lost less worrisome, and may enable greater exploration, and more spatial learning, beyond transit nodes.

8.2 Contributions

This dissertation's contributions to transportation and urban planning research reside primarily in the integration of cognitive and developmental theory into accessibility research, and in findings that highlight how transportation systems and urban form may foster deeply embedded, rather than easily modified, travel and activity choices and patterns within cities. The complete city conceptual framework is synthetic, combining individual accessibility concepts with cognitive mapping and spatial learning theory. This approach is, to my knowledge, new in urban accessibility research. It is a complement to a more prevalent microeconomic theory of individual accessibility, described by Boarnet and Crane (2001). In this theory, individuals make activity and travel choices based on their currently available resources, constraints, and the utility of their destination. What this theory does not capture, however, is that no person has access to perfect information, and choice sets are constrained by familiarity and long-term patterns. These medium- and long-term effects can be explained in the cognitive, experiential personal city framework. This perspective on accessibility is distinctive and highlights the "stickiness" of behavior patterns as planners try to shift them.

The other significant contribution made in this dissertation is the relationship revealed between travel mode and knowledge of the city. Not only does travel mode affect the accuracy of the cognitive map, but the differences reach down to the basic elements with which people construct those cognitive maps. The research shows that passive and active travel does not just refer to levels of physical activity, but also mental activity. Much like physical activity, though, it appears that engaging in the mental exercises of navigation and way-finding results in "healthier" mental maps. This finding extends the work of Golledge and others in explaining the cognitive map as part of a development, experience-based learning process, and shows how this process is tied to individual accessibility. In addition to the potential accessibility consequences for current passive travelers such as transit users, this finding may have tremendous implications for people using information technologies to choose destinations and navigate in cities. The results from the study of travel mode are easily transferred to the growing research area of information technology use in cities.

Methodologically, I have sought to bring relatively well-established methods into planning research from other fields. Those methods facilitate examination of activity and travel behavior at the level of the individual, as well as the use of cognitive data, including activity space analysis and cognitive map analysis. Throughout the dissertation, I have attempted to address the issue of spatial dependence and autocorrelation among observations and variables. Using spatial statistical methods is becoming more common in many social sciences, though is still rarely seen in urban planning research. Geographically-weighted regression and spatial autocorrelation tests such as Moran's I do not just increase statistical validity of planning research, but also provide new avenues for understanding how individuals and urban processes array themselves throughout a city.

8.3 Future Research

This dissertation comprises a substantial research effort, but it alone does not represent the endpoint of my exploration of its topics. Rather, the personal city conceptual framework and its integration of individual accessibility with cognitive and experiential theories, methods, and data suggest a variety of problems for future research. Below I describe several avenues for future research in this area, guided by the findings of the dissertation. These topics extend the personal city to new areas of accessibility research, and also address some of the potential shortcomings and threats to validity that this dissertation does not itself address.

8.3.1 Information Technologies, Accessibility, and the Cognitive Map

As of March 2012, half of the mobile phones in the United States were "smartphones," portable devices with data and navigation services (Carmody 2012). The adoption not just of smartphones, but increased computing and internet usage at home, as well as the deployment of information technologies by cities and transportation providers has resulted in an explosion of urban-scaled data available to individuals, used as they make decisions about activities to engage in and how to get to them. If passive travel results in a less developed cognitive map, what happens when people are able to get their destination and route information from devices rather than their cognitive map? Does this form of passivity result in atrophied cognitive maps? Do they strengthen cognitive maps? Does it matter, when potentially superior information is available online or in a smartphone?

These questions highlight two potential hypotheses of information technologies' impact on the cognitive map and accessibility. First, information technologies make travelers more passive, stunting their cognitive maps. Second, information technologies replace cognitive maps and are potentially superior to them, increasing functional accessibility. Whether either, or both, of these hypotheses are true represents a major research effort. I have already begun exploration of these issues. My initial research findings show some evidence for information technologies, in this case cellphones, facilitating travel further from home than would otherwise be possible (Mondschein 2011). I am currently pursuing a more thorough investigation of these hypotheses, based on a refined survey of cognitive knowledge and information technology usage, and by mining the outputs of a variety of urban-scaled information services.

8.3.2 Enhanced Cognitive Survey

The cognitive survey used in this dissertation made it possible to analyze the surprising relationship between travel mode and the cognitive map. As noted in Chapters 6 and 7, however, the survey was exploratory, limited in both the number of questions asked of respondents and in its sample size. The findings with respect to the effect of travel mode on spatial knowledge have been echoed by other researchers, enhancing external validity (Chorus and Timmermans 2010). However, a new more refined survey of cognitive knowledge would help reinforce the differences ascribed to active and passive travelers and also extend findings to other aspects of the personal city. An enhanced survey would certainly ask respondents more cognitive questions than was possible in the first survey. In addition, the survey should grow from just asking about distances to include other types of cognitive information such as perceptions of safety, attachment, and belongingness. Finally, the survey should include a more through set of questions about socioeconomics and actual activity patterns, facilitating for the first time a comparison between an individual's cognitive map and their activity space.

8.3.3 Accessibility and Activity Spaces Analysis – GPS Tracking

The activity space analysis in Chapter 5 drew on a traditional regional travel survey. As discussed in that chapter, the single day's activity and travel data available from the survey only facilitated the development of relatively rudimentary activity spaces. More refined activity and travel data, such as what can be collected with GPS tracking over the course of a month or more, would allow a more refined personal activity space to be constructed. These data would highlight nuances in the activity space such as where activity is concentrated and relative "dead zones" within the border of the activity space. This could help clarify whether an individual's activities and travel are highly clustered, even in a large activity space, or whether they are well dispersed. Such patterns could indicate, for example, whether multimodal systems of transit and walking could potentially replace driving in a person's daily activities.

8.4 Making a More Complete Personal City

The idea that the city is something a person learns, with effort over time, is not commonly expressed in urban planning. However, inasmuch as planners can help people take advantage of the vast range of opportunities inside a city, that effort will only be as successful as each person's capacity to pick an activity and find her way to it. Planners spend their lives getting to know their cities, but we are, I believe, an exception. For some people, the city may only extend as far as their neighborhood, or even their block. Planning needs to better understand why some people will not go where others venture without difficulty. If we hope to improve access for all people, even those truly constrained by a lack of resources, prior experience, inadequate education, or just simply fear, we should consider how we might help people learn the city.

Beyond this primary concern with ensuring that all people are able to learn what's out there in the city, the personal city framework also asks, how much is enough? In the vast modern conurbations of millions of people and hundreds of square miles, is there any value in maximizing one's experience and knowledge of the city? The correlation between socioeconomic success and large activity spaces does suggest that there is either advantage or appeal in travelling and living out life on a vast scale. We need to understand better, as planners, what sorts of value – whether economic return, psychological well-being, or otherwise – people derive from this type of extensive activity, particularly as we seek to shift travel from autos to transit, and create land use patterns that cluster opportunities in smaller, denser configurations. Ultimately, and perhaps fortunately, no one's personal city can ever be truly complete, with all destinations learned and accessible. The wherewithal to explore, however, and to strive towards that completion, is something that planners should provide to all a city's residents, in their search for opportunity.

Appendix A

South Los Angeles Cognitive Survey Instrument

UCLA INSTITUTE OF TRANSPORTATION STUDIES
COMMUNITY TRAVEL SURVEY

We're students at UCLA. Would you be willing to take a quick survey about transportation?

[if they stop] Before we start, I need to make sure that you're 18 years old or older. Are you? ☐ *yes* ☐ *no* ***[if yes, then continue]***

We'll give you a $10.00 gift card to Starbucks to participate in our study. We're studying how adults in your neighborhood travel around and what they know about their neighborhood and the city. We'd like to ask you a few questions and have you sketch two quick maps.

Anything you say will be kept confidential; you don't have to answer any questions that you do not want; and you may stop at any time without consequence. If you have any questions about the research or your rights as a research subject, you can contact Andrew Mondschein at UCLA or the Office for Protection of Research Subjects. Here's the contact information. ***[hand out contact information sheet]***

Are you willing to participate? ***[if yes, continue]*** Great!

1. What neighborhood do you live in? You can also respond that your neighborhood doesn't have a name or that you don't know it's name.

   Name of neighborhood: ___________________

   ☐ *no name* ☐ *don't know*

2. For privacy reasons we don't need your address; but could you tell us some identifying feature of your neighborhood: your street name, cross streets, another landmark or feature, or your zip code?

   street: ________________________________
   cross-street: ___________________________
   landmark: _____________________________
   zip code: _______________________________
   other feature: ___________________________

3. For how many years or months have you lived in this neighborhood? ___________

4. Do you know how to drive? ☐ *yes* ☐ *no* *[note: ____________________]*

5. How many cars, trucks, or motorcycles are usually available for people to use in your household? __________

6. Do you have a car, truck, or motorcycle available to use when you want to go somewhere, even if you don't own a vehicle?

☐ always, ☐ usually, ☐ sometimes, or ☐ never

7. How did you travel here today? ***[check single best answer]***

☐ *public transit (bus, train, etc.)*

☐ *drove myself*

☐ *someone drove me (friend, relative, taxi, van, etc.)*

☐ *walked*

☐ *other ____________________ (incl. bike)*

8. Are you… ***[check all that apply]***

☐ employed? (Do you have a paid job?)

☐ looking for paid work?

☐ going to school?

☐ responsible for caring for other family members?

☐ doing something else these days that takes up most of your time? If so, what? ___________________________________

[In Question 9 below ask about the FIRST box checked above]

9. Where did you last **[go to work, look for work, go to school, care for family members, or do other]**? Again, we don't need the address but could you give us the street name, cross streets, landmark or other feature, or the zip code?

street: ________________________________

cross street: ___________________________

landmark: _____________________________

zip code: ______________________________

other feature: __________________________

10. On your most recent trip to **[go to work, look for work, go to school, care for others, or do other]**, how did you get there?

- ☐ *public transit (bus, train, etc.)*
- ☐ *drove myself*
- ☐ *someone drove me (friend, relative, taxi, van, etc.)*
- ☐ *walked*
- ☐ *other* ____________________ *(incl. bike)*

11. If you were going to travel from here to Los Angeles City Hall on a typical Wednesday morning, how would you get there?

- ☐ *public transit (bus, train, etc.)*
- ☐ *drive myself*
- ☐ *someone would drive me (friend, relative, taxi, van, etc.)*
- ☐ *walk*
- ☐ *other* ____________________ *(incl. bike)*

12. About how far away would you say LA's City Hall is from here? You can answer in miles or kilometers.

___________ *(miles/km)*

13. Now I'm going to list five pairs of landmarks, one pair at a time. For each pair, tell me which one you think is closest to this shopping center. Just give me your best guess, don't worry if you are not sure. If you have not heard of any of these landmarks or have no idea where they are, that's fine. ***[Put an X by the one listed as closest, or a ? by the pair if they don't know.]***

A) ___ Watts Towers, or
___ Compton City Hall

B) ___ CSU Dominguez Hills / Home Depot Center, or
___ Hollywood Park

C) ___ Crenshaw Shopping Center, or
___ South Bay Galleria

D) ___ Los Angeles City Hall, or
___ Long Beach City Hall

E) ___ Los Angeles Zoo, or
___ Santa Monica Pier

Just 5 more questions before we ask you to draw a couple of maps and give you your gift certificate:

14. What year were you born in? ___________________

15. What's your racial/ethnic background? ***[check all that apply]***

☐ *Latino/a* ☐ *Black/African American* ☐ *Asian/Pacific Islander*
☐ *White/Anglo* ☐ *Other* _______________

16. What country were you born in? ____________________

17. What was the highest grade you completed in school? __________________

Map 1 – TRAVELING TO THIS SHOPPING CENTER.
Next, we'd like you to draw two simple maps. In this first box, we'd like you to draw a map of the route that you took or would take to get from your house to this shopping mall. We've labeled the shopping center. First, mark the relative locations of this shopping center and your house on the map. Then label the parts of your route. You can include major streets, businesses, bus and light rail lines and stops, highways, or any landmarks that are important to you. Be as detailed as you can but don't worry if you're not good at drawing. That doesn't matter.

Map 2 – TRAVELING TO LA'S CITY HALL.
In this second box, we'd like you to draw a map of the route you would take to get from this shopping mall to City Hall in downtown Los Angeles. First mark the relative locations of this shopping center and City Hall. Then label the parts of your route. You can include major streets, businesses, bus lines and stops, highways, or any landmarks that are important to you. Again, be as detailed as you can but don't worry if you're not good at drawing. That doesn't matter.

18. Finally, I'd like to ask you how do you feel about transportation here in L.A.? What, if anything, would you do to improve it?

____

____

____

____

Concluding Script
That's it! Thanks so much for your time. Your answers will help us better understand how people get around in LA, where they go, and what transportation experts can do to make traveling easier for everyone. Here is your Starbucks gift card.

[If they have questions about who we are, or how they can learn more about our study, we can refer them to the ITS website (www.its.ucla.edu) if they have access to the web, or Andrew Mondschein at (310) 903-3278]

Surveyor completes:

Sex of Respondent: ☐ *Male* ☐ *Female*
Location: ________________ *Surveyor Initials:* ____________
Date: ___________________ *Time:* ______________________

MAP 1- Home to Shopping Center

- **Mark the relative locations of your house and the shopping center**
- **Include major streets, businesses, bus stops or any landmarks**
- **Be as detailed as you can but don’t worry if you are not good at drawing. Do the best that you can.**

MAP 2- Shopping Center to Los Angeles City Hall

- **Mark the relative locations of the shopping center and Los Angeles City Hall**
- **Include major streets, businesses, bus lines and stops, highways or any other landmarks**
- **Be as detailed as possible but do not worry if you are not a good drawer. Do the best that you can.**

Appendix B

UCLA Cognitive Survey Instrument

UCLA INSTITUTE OF TRANSPORTATION STUDIES
COMMUNITY TRAVEL SURVEY, UCLA

We're students at UCLA. Would you be willing to take a quick survey about transportation? We'll give you a $10.00 gift card to Starbucks to participate in our study.

[if they stop] We're studying how adults in your neighborhood travel around and what they know about their neighborhood and the city. We'd like to ask you a few questions and have you sketch two quick maps.

Anything you say will be kept confidential; you don't have to answer any questions that you do not want; and you may stop at any time without consequence. If you have any questions about the research or your rights as a research subject, you can contact Andrew Mondschein at UCLA or the Office for Protection of Research Subjects. Here's the contact information. ***[hand out contact information sheet]***

Again, it shouldn't take too long to take the survey, and for your time, we'll give you a $10.00 gift certificate to Starbucks. Are you willing to participate? ***[if yes]*** Great!

Since we're interested in the travel of adults, before we start, I need to make sure that you're 18 years old or older. Are you? ☐ *yes* ☐ *no* ***[if yes, then continue]***

1. Where do you live during the school year? ***[if students, it's OK if they say they live in either "the dorms" or Westwood]***

   Name of neighborhood: ___________________

   ☐ *No name* ☐ *don't know*

2. If you were telling someone where you lived what kinds of features would you use to describe your location? For privacy reasons we don't need your address; but could you give us your zip code, street, cross street, or another landmark or feature that identifies the location of your neighborhood?

   zip code: ______________________________
   street: ______________________________
   cross-street: __________________________
   landmark: ____________________________
   other feature: __________________________

3. For how many years or months have you lived in this neighborhood? ___________

4. Do you know how to drive? ☐ *yes* ☐ *no* *[note: ____________________]*

5. How many cars, trucks, or motorcycles are usually available for people to use in household? ***[Can clarify that means current residence, such as if they have a car they use in the dorms.]*** __________

6. Do you have a car, truck, or motorcycle available to use when you want to go somewhere, even if you don't own a vehicle?

   ☐ *always* ☐ *usually* ☐ *sometimes* ☐ *never*

7. How did you travel here today? (check single best answer)

   ☐ *bus/rail*
   ☐ *drove myself*
   ☐ *someone drove me (friend, relative, taxi, van, etc.)*
   ☐ *walked*
   ☐ *other ____________________ (incl. bike)*

8. Are you… ***[check all that apply]***

   ☐ employed? (Do you have a paid job?)

   ☐ looking for paid work?

   ☐ going to school?

   ☐ responsible for caring for other family members?

   ☐ doing something else these days that takes up most of your time? If so, what? ___________________________________

9. Where did you last [**work, go to school, look for work, or do other]**? Again, we don't need the address but could you give us the zip code, street, cross streets, landmark or other feature?

   zip code: _________________
   street: ________________________________
   cross street: __________________________
   landmark: ________________
   other feature: __________________________

10. The last time that you [**worked, went to school, looked for work, or did other**], how did you get there?

- ☐ *bus/rail*
- ☐ *drove myself*
- ☐ *someone drove me (friend, relative, taxi, van, etc.)*
- ☐ *walked*
- ☐ *other ____________________ (incl. bike)*

11. If you were going to travel to Santa Monica Pier, how would you get there?

- ☐ *bus, light rail*
- ☐ *drive myself*
- ☐ *someone would drive me (friend, relative, taxi, van, etc.)*
- ☐ *walk*
- ☐ *other ____________________ (incl. bike)*

12. About how far away would you say that Santa Monica Pier is from here?
______ (miles/km)

13. I have six pairs of locations that I am going to read aloud to you. For each pair just tell me which one you believe is closer to here. Just give us your best guess, don't worry if you are not sure. If you have not heard of any of these landmarks or have no idea where they are just let me know. ***[Put an X by the one listed as closest, or a ? by the pair if they don't know.]***

A) ___ Hammer Museum
___ Sculpture Garden

B) ___ Getty Center
___ Mormon Temple

C) ___ Grauman's Chinese Theater in Hollywood
___ Santa Monica Pier

D) ___ Downtown Los Angeles
___ LAX Airport

E) ___ Universal City Walk
___ Staples Center

F) ___ Home Depot Center
___ Rose Bowl

Just 4 more questions before we ask you to draw a couple of maps and give you your gift certificate:

14. In what year were you born? ___________________

15. What's your ethnic background? (check all that apply)

☐ *Latina/o* ☐ *Black/African American* ☐ *Asian/Pacific Islander*

☐ *White* ☐ *Other* _______________

16. In what country were you born? ____________________

17. What was the highest grade you completed in school? _______________

Map 1 – TRAVELING TO UCLA. Next, we'd like you to draw two simple maps. In this first box, we'd like you to draw a map of the route that you took or would take to get from your house to UCLA. Mark the approximate locations of your home and UCLA on the map. Then label the parts of your route. You can include major streets, businesses, bus and light rail lines and stops, highways, or any landmarks that are important to you. Be as detailed as you can but don't worry if you're not good at drawing. That doesn't matter.

Map 2 – TRAVELING TO SANTA MONICA PIER. In this second box, we'd like you to draw a map of the route you would take to get from UCLA to Santa Monica Pier. First, mark the approximate locations of UCLA and the pier. Then label the parts of your route. You can include major streets, businesses, bus lines and stops, highways, or any landmarks that are important to you. Again, be as detailed as you can but don't worry if you're not good at drawing. That doesn't matter.

Concluding Script: That's it! Thanks so much for your time. Your answers will help us better understand how people get around in LA, where they go, and what transportation experts can do to make traveling easier for everyone.

[If they have questions about who we are, or how they can learn more about our study, we can refer them to the ITS website (www.its.ucla.edu) if they have access to the web, or Andrew Mondschein at (310) 903-3278]

Surveyor completes:

Sex of Respondent: ☐ Male ☐ Female

Location: ________________ Surveyor Initials: ____________

Date: ___________________ Time: ______________________

MAP 1 - Home to UCLA

- **Mark the relative locations of your home and UCLA**
- **Include major streets, businesses, bus stops or any landmarks**
- **Be as detailed as you can but don't worry if you are not good at drawing. Do the best that you can.**

*** DRAW BELOW LINE ***

MAP 2 - UCLA to Santa Monica Pier

- **Mark the relative locations of UCLA and Santa Monica Pier**
- **Include major streets, businesses, bus lines and stops, highways or any other landmarks**
- **Be as detailed as possible but do not worry if you are not a good drawer. Do the best that you can.**

*** DRAW BELOW LINE ***

Appendix C

Correlation Table for All Model Variables

	Ln(SDE)	Ln(DT	# Trips	Vehicles / Person in Hhld.	% Walk Trips	% Social/Rec. Trips	% Hhld. Serving Trips	Income	Female	NH-White	Hispanic	African American	Asian-PI	Age	Age-SQ	Education	English Speaker	Professional	Service Worker	Manual Laborer	Dest. Density (SDE)	Pop. Density (SDE)	Emp. Density (SDE)	Homicide Rate -Local	School Scores - Local	Transit Share - Local
Ln(SDE)	1.00																									
Ln(DT)	0.83	1.00																								
# Trips	0.21	0.37	1.00																							
Vehicles / Person in Hhld.	0.10	0.10	0.05	1.00																						
% Walk Trips	-0.20	-0.16	0.05	-0.16	1.00																					
% Social/Rec. Trips	0.06	0.02	-0.12	0.00	-0.01	1.00																				
% Hhld. Serving Trips	-0.04	-0.00	0.13	0.06	0.01	-0.38	1.00																			
Income	0.17	0.16	0.11	0.24	-0.14	-0.05	0.07	1.00																		
Female	-0.06	-0.06	-0.02	-0.09	0.04	-0.03	0.08	-0.04	1.00																	
NH-White	0.04	0.06	0.08	0.28	-0.07	0.01	0.06	0.34	-0.02	1.00																
Hispanic	-0.06	-0.07	-0.10	-0.29	0.09	0.01	-0.11	-0.37	0.00	-0.67	1.00															
African American	0.02	-0.01	-0.03	-0.06	-0.02	0.00	0.02	-0.06	0.06	-0.33	-0.13	1.00														
Asian-PI	0.01	0.01	0.01	-0.02	-0.02	-0.04	0.05	0.01	0.00	-0.32	-0.12	-0.06	1.00													
Age	-0.02	-0.03	0.00	0.19	-0.01	0.00	0.08	0.13	-0.03	0.30	-0.25	-0.08	-0.08	1.00												
Age-SQ	-0.04	-0.05	-0.02	0.18	0.00	0.01	0.06	0.09	-0.04	0.28	-0.24	-0.07	-0.08	0.98	1.00											
Education	0.10	0.12	0.13	0.21	-0.09	-0.03	0.08	0.45	-0.05	0.32	-0.43	-0.03	0.10	0.16	0.12	1.00										
English Speaker	0.08	0.08	0.05	0.24	-0.10	-0.01	0.07	0.31	0.03	0.37	-0.51	0.08	-0.01	0.15	0.14	0.33	1.00									
Professional	0.12	0.13	0.09	0.09	-0.07	-0.07	0.02	0.33	-0.06	0.12	-0.17	0.01	0.05	-0.07	-0.11	0.35	0.15	1.00								
Service Worker	0.04	0.07	0.01	-0.02	0.00	0.01	-0.04	-0.05	0.01	-0.05	0.05	0.04	-0.02	-0.17	-0.18	-0.11	0.04	-0.41	1.00							
Manual Laborer	-0.04	-0.07	-0.06	-0.11	0.02	-0.02	-0.02	-0.22	-0.15	-0.20	0.28	-0.02	-0.06	-0.13	-0.12	-0.27	-0.33	-0.23	-0.16	1.00						
Dest. Density (SDE)	-0.46	-0.36	-0.03	-0.06	0.20	-0.04	0.01	-0.08	0.03	-0.02	0.02	-0.01	0.00	-0.08	-0.07	0.01	-0.07	-0.02	0.00	0.01	1.00					
Pop. Density (SDE)	-0.12	-0.09	-0.02	-0.10	0.09	-0.02	-0.04	-0.08	0.03	-0.09	0.08	0.03	0.00	-0.05	-0.05	-0.03	-0.09	0.00	-0.01	0.04	0.38	1.00				
Emp. Density (SDE)	-0.10	-0.08	-0.02	-0.05	0.03	-0.02	-0.02	-0.01	-0.02	0.01	-0.00	-0.01	-0.00	-0.02	-0.02	0.02	-0.02	0.03	-0.02	0.00	0.22	0.42	1.00			
Homicide Rate -Local	0.06	0.04	0.00	-0.02	0.01	0.01	0.00	-0.02	0.01	-0.03	0.03	0.02	-0.01	-0.04	-0.04	-0.04	-0.01	-0.02	0.02	-0.01	-0.04	-0.02	-0.01	1.00		
School Scores - Local	0.10	0.13	0.11	0.17	-0.08	0.00	0.05	0.40	-0.01	0.36	-0.38	-0.16	0.08	0.11	0.10	0.37	0.22	0.19	-0.05	-0.20	-0.03	-0.11	-0.04	-.04	1.00	
Transit Share - Local	-0.09	-0.10	-0.05	-0.22	0.20	-0.01	-0.05	-0.36	-0.01	-0.37	0.36	0.14	-0.01	-0.15	-0.13	-0.24	-0.30	-0.13	0.02	0.21	0.20	0.28	0.16	0.00	-0.56	1

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