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Exploring the Localization of Transportation Planning: Essays on research and policy implications from shifting goals in transportation planning

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UNIVERSITY OF CALIFORNIA

Los Angeles

Exploring the Localization of Transportation Planning: Essays on research and

policy implications from shifting goals in transportation planning

A dissertation submitted in partial satisfaction of the requirements for the degree

of Doctor of Philosophy in Urban Planning

By

David Andrew King

2009

The dissertation of David Andrew King is approved.

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For Megan and Boden

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ABSTRACT OF THE DISSERTATION

Exploring the Localization of Transportation Planning:

Essays on research and policy implications from shifting goals

in transportation planning

by

David Andrew King

Doctor of Philosophy in Urban Planning

University of California, Los Angeles, 2009

Professor Donald C. Shoup, Chair

Transportation planning has long focused on large scale projects using a civil engineering approach of maximizing throughput and minimizing interactions with the surrounding environment. Such efforts greatly increased the overall mobility and accessibility of individuals within and across

metropolitan regions, but it is clear that in the future such enormous initiatives are unrealistic due to political, financial, spatial and social concerns. The field of transportation planning is shifting away from this old model of planning towards one where transportation systems are considered part of the overall quality of life of communities.

This dissertation explores how local transportation planning is adapting to these changing dynamics of transportation planning through three essays. The first considers how cities are already planning for transportation through their general plans without strong mandates from regional governments. The second essay estimates the spatial variation in commute mode choice in order to show the complexity of travel due to geographic factors of infrastructure provision and land uses. The final essay discusses what flexible localized transportation policies look like, using cruising for parking as an example. Ultimately this research highlights a way forward for transportation planning as a quality-of-life issue, traditionally the purview of local governments.

1.   Introduction

Congestion, air quality and energy consumption are critical issues for transportation and land use planners. The challenges presented by these issues are changing the nature of transportation planning away from traffic engineering towards planning for access and quality-of-life (Banister 2005, 2008; Handy 2008; Straatemeier 2008). Since congestion, air quality and energy consumption are externalities that impose costs across municipal borders, many scholars promote a turn to regional governance of planning transportation networks and complimentary land uses (Calthorpe 1993; Calthorpe and Fulton 2001; Orfield 1997; Rusk 1999; Downs 1994).

Regionalism is institutionally problematic for planning quality-of-life issues, which are traditionally and legally planned by city government, largely because of the health, safety and welfare basis for zoning.   Yet the role of city planning in addressing transportation externalities is underrepresented in the literature. This thesis presents three essays that help fill this gap by 1) examining the process of planning for accessibility, 2) estimating the spatial variations of travel within a metro area and 3) measuring the excess travel caused by cruising for parking.   These essays provide insight in to the policies that reflect the growing concern for congestion, energy consumption, air

pollution and accessibility. In addition, methodological contributions for collecting and analyzing travel data are made.

This thesis is organized into five parts. This introduction explores the literature about the changing nature of transportation planning and provides a theoretical approach to localized transportation and land use planning. The three empirical essays that follow examine specific aspects of localized transportation planning and personal travel. A short conclusion ties together the themes of the dissertation and suggests extensions of this research.

1.1 *Exploring the changing priorities of transportation and land use planning*

Transportation planning has long been dominated by "predict and build" models administered by civil engineers. These models treat roads as linkages within systems where throughput should be optimized. These road networks offer benefits and costs measured on a regional scale, such as goods movement, mobility and wasted productivity caused by congestion. This approach is effective for implementing large scale major infrastructure projects (such as the Interstate Highway System), but personal travel is far more complex than these models accurately portray. Travel patterns and behaviors are affected by individual and household characteristics in conjunction with available destination opportunities, and aggregating the outcomes cloaks most of the variation that exists among travelers. The challenge to transportation and land

use researchers is how to conceptualize transportation planning in a way that addresses the complex factors of travel behavior, accessibility and environmentally sound transportation as a quality-of-life issue.

British scholar David Metz outlines the limits of transport policy for solving metropolitan problems (2002). He argues that future demand for mobility cannot be adequately met through construction of new infrastructure alone. This is largely because any gains would be quickly offset as people change their travel routes through induced demand for linkages (for a full discussion of induced demand and accessibility see Thill and Kim (2005)). Metz views mobility as a good that individuals seek to maximize. This notion is supported in part by research that identifies a positive utility of travel (Mokhtarian and Salomon 2001). To Metz, mobility is strictly a spatial phenomenon. He builds his evidence of increased spatial mobility within a time constraint on the work of Zahavi (1978), who posited that individuals have a fixed travel time budget of about an hour per day. From Metz's perspective any transportation improvements that increase the speed of travel will result in greater distances traveled, hence maximized mobility, within the constraint of an individual's travel time budget. This approach conforms with the conventional civil engineering model of transportation planning priorities to increase speed and flow.

Metz's position highlights three areas of concern for the future of transportation planning, all of which have strong connections to land use planning and quality-of-life concerns. The first area is the environmental impact of transportation systems through burning fuel, polluting the air, causing unwanted noise and poisoning groundwater through road runoff. The second area is the impact on the built environment of densely packed streets, especially those filled with high speed vehicles. The third area concerns population and economic growth. As populations grow and income increases, more cars lead to greater levels of congestion, driver frustration and unpredictability of travel times. Environmental concerns can be often mitigated through technological advances, though the appropriate role of local, state and federal governments towards encouraging technological adoption and innovation is poorly theorized and understood. However, the impact of transportation systems on the built environment and on population and economic growth point to the need for flexible local, state and federal polices, and this is the direction integrated transportation and land use planning is heading.

Shifting goals in transportation planning have elevated the importance of new tools and measures to plan for and evaluate transportation systems (Hall 1991; Handy 2008; Meyer 2000). One new tool planners use is accessibility. Accessibility is an important measure that provides a meaningful lens with which to measure the benefits of the transportation system to individuals. At its

core, accessibility refers to the cost of travel to destinations. More broadly, accessibility measures the abilities of people to reach meaningful opportunities for employment, services, shopping and recreation within their time and money budget. Access is determined by travel mode, distance, income, origin and destination locations and network connectivity, among other factors. More importantly to this research, accessibility is a function of spatial and governance scales as well, where travel sheds and network externalities affect the overall access to destinations.

Geographic scale is important for public policy as urban structure is no longer primarily dependent on radial transportation connections with the central city for employment opportunities. Metropolitan regions are polycentric systems of employment and activity centers located at various nodes on the overall transportation network (Anas 1999; Giuliano 1995). So long as people have access to the road or transit network they have access to multiple centers of employment or activities. Yet demographic changes have altered the importance of employment as a sole factor for deciding where to live. Two-income households are prevalent and job switching is more frequent than changing homes. These factors mean that households rarely locate to minimize multiple commutes simultaneously. What occurs is a compromise where non-work activities gain importance in the household's decisions compared to non-work travel.

Income has also risen dramatically over the past few decades, leading to more resources available to spend on more leisure (including family) goods. As this consumption has increased non-work travel has grown as an overall share of travel, where around 80 percent of all travel is now non-work related. The increased share of discretionary travel makes travel patterns more complex. This presents a challenge for researchers and planners as it seems we know less now about why people travel than we once did. I say this only somewhat facetiously. It may be that we are only discovering how little we knew then, and this is certainly grounded in the truth, but there are fewer indications of travel as strictly a derived demand than was once supposed by transport modelers. Ultimately what these changes mean are that transportation planners have to consider many more factors than generally featured in conventional models when confronting the role of transport for environmental quality, energy consumption, social equity and technological adoption.

Regional approaches to planning focuses on normative arguments for a correct form of growth through higher densities, transit oriented development, lots and lots of parking and countless other ideas. But urban growth may not actually have a "natural" or normal state that can be dictated; instead urban growth is a process that reacts and adapts to conditions set through regulations, taxes, preferences and economic activities. Through this way of thinking, planners and policy makers should focus on the incremental improvements of

the existing environment to achieve broad welfare improvements. Incremental planning cannot easily (or even likely) be accomplished at the regional scale due to political constraints, legal challenges over the rights to regulate land uses, the lack of understanding how people actually interact with their cities and the capital intensive nature of large public works projects.

Incremental planning is adaptable to competing forces of urbanization. What is occurring in metro areas is simultaneous growth and decline rather than uniform change in the same direction (Torrens 2008). Not all areas within a metro region are sprawling, and access to employment centers is no longer a problem limited to central cities. Instead of the monocentric "tentpole" model of urban form, where the older central business district is the dominant employment and transportation destination, there are many small poles. However, there are also many pits where there economic activity is stagnant or declining and feature fewer trips than predicted based on a metropolitan average. Such finely scaled differences raise concerns for regional governance, especially considering the current institutions.

None of this is to say that regional planning should be ignored. In contrast, there are policies where regional planning agencies are much better suited for efficient intervention. The main point is that there are many instances where regional governance will fail to be flexible enough to adjust to community goals, public participation requirements and heterogeneous public

goods bundles. Local level planning compliments existing plans while not precluding future cooperation. All the while welfare improving policies are enacted in non-zero sum ways. For example, this means that when one community or city improves their parking policies it does not diminish the quality of life in other areas. It likely improves the overall quality of life in the surrounding communities through better traffic flow, cleaner air and examples of better policies.

Fragmented governance creates a market for public services and policy bundles, which also occurs in transportation planning (Wachs 2000) and is important for fostering innovative policies. Such policy markets tend to create a broader selection of polices as each community tailors to their own needs and be more ambitious because of the greater homogeneity of small groups. A series of localized policies will certainly have some failures, but the extent of the policy damage will be limited because of the small size of the community. There is no guarantee that regional or other higher level policies will be any more effective for improving overall social welfare, but any mistakes will cause widespread damage.

1.2 *Accessibility as a tool for transportation planning analysis*

Access is an important concept for understanding social and environmental equity as well as economic activity and land values. Yet accessibility as an analytical tool for planners is fraught with methodological

challenges. One of the major issues researchers face is how to deal with the appropriate scale of access. Most analyses examine access as a distance measure, for instance by measuring the number of grocery stores within a certain distance (Handy and Clifton 2001). More recent explorations have looked at accessibility as a space-time phenomenon (Kwan and Weber 2008). The purported advantage of conceptualized access in space-time is that the geographic scale of access is accounted for in the analysis. Yet Kwan and Weber ultimately find that their methodological advances do not improve the overall understanding of travel patterns. They do, however, argue that accessibility is scale invariant. They conclude from this that localized improvements to access, such as New Urbanism, are unlikely to be successful.

The suggestion that access is scale invariant and thus localized solutions are unlikely to be successful is problematic and one that this dissertation directly challenges. The complexity of travel leads to problems of scale, such that accessible scales are dependent on mode, road facilities, network connectivity and congestion effects. It is precisely because of the scale invariance that localized transportation planning is likely to be so effective. For instance, the systems that are currently in place were designed with the region in mind. Kwan and Weber argue that this is the appropriate level of planning and investment. Others argue that regional accessibility needs to be maintained in order to preserve vital central cities (Bertolini 2005).

Data limitations and theoretical constraints are challenges to overcome to further our understanding of accessibility and the influence of the built environment on travel. One persistent concern in travel behavior research is endogenous factors in the models. Because of the non-experimental structure of these urban form effect studies, self-selection bias is problematic. To avoid such bias, interregional comparisons are favored, such as estimating the travel behavior differences between Boston and Atlanta caused by city form (Bento et al. 2005; Levine 2006; Levine and Frank 2007). While this makes sense in that people are far more mobile within metro areas than between metro areas, focusing on the region misses the complexity of communities.

Here is an example of the limitations of using regions as the area of study for transportation and land use planning. In a widely cited study on sprawl in US cities, Reid Ewing et al. generate a ranking index of sprawl that characterizes features of four categories (Ewing, Pendall, and Chen 2005). These ranks are applied to Metropolitan Statistical Areas (MSAs) and the MSAs are scored as sprawling or compact. While useful from a descriptive stance, their policy recommendations do not follow their analysis in a way that guides policy intervention. By their own admission each metro area has concentrated areas and sprawling areas, but their regional analysis suggests to them that local and sub-local policies need to be adopted. For instance, their first recommendation is to reinvest in neglected communities and provide more

housing opportunities. Yet they do not identify neglected communities, which are not included as part of their sprawl measure. Providing more housing opportunities is admirable, but as a policy recommendation to combat sprawl it is meaningless. Without a better understanding of intraregional spatial patterns of sprawl, urban form and transportation networks it is impossible to state that housing is underprovided. After all, the main critique of sprawl is that too much housing is being built in the wrong place. If there was no housing expansion there would not be sprawl by definition.

Moving away from a regionalist ideal to a local perspective, there are strong institutional factors that point to localism as the preferred policy arena. First, city governments hold the land use authority to influence development. In addition, cities are taking on more of the burden for financing road infrastructure and implementing policy innovations. Second, and most importantly, nodal improvements such as transit oriented development or parking improvement districts will need to be incrementally adopted across a region. Due to institutional, political and practical considerations a blanket regional policy of nodal improvements will simply not happen. One challenge of incremental deployment is how to maintain political support until the positive returns to scale from network effects of the policy act as an incentive for other communities to adopt the policies.

1.3 *Rational planning, localism and regional constraints*

One of the main pillars of support for regional planning is to improve transportation performance through land use planning (Calthorpe 1993; Calthorpe and Fulton 2001; Downs 2004). Performance measures of regional governance are improvements in the jobs-housing balance, development of transit-oriented development and neo-traditional development, and improvements in the related concepts of accessibility and mobility in order to minimize social and economic isolation. Policies to achieve these goals include aim to increase densities through rezoning, divert some financial resources from freeway construction to transit improvements, and encourage development of social services, employment opportunities and retail mixes in areas well served by alternative transportation modes from the automobile. These goals and policies all fall into the notion of "smart growth," which is commonly seen as a regional issue.

Researchers Ming Yin and Jian Sun looked at the effectiveness of growth management programs in the 1990s and found that at the state level there was no discernable effect from anti-sprawl or smart growth measures on population density and land use mixing (2007). While this result is not necessarily surprising, it is the authors' conclusion that deserves scrutiny as their policy recommendations are indicative of the problem with calls for increased regionalism. The authors use their findings that there is little difference between

metro areas with strong top down growth programs and those without such requirements to argue that there should be even stronger top down planning. While their ultimate goal of policies for more livable metro areas is commendable, there is no support for strong hierarchal governance from their analysis. A lack of evidence to support the effectiveness of growth management at the metro level suggests nothing except that perhaps growth management at the metropolitan level is ineffective.

Planning at local and sub-local scales as complements to regional coordination on some issues is also a reaction to the failures of the rational planning paradigm. Rational planning by impartial experts was favored by early regional governance such as the Twin Cities Metropolitan Council and, as an earlier example, the Port Authority of New York. These regional institutions not only used a rational planning model to guide their proposals but they had strong support of the local business community to garner political authority. Business leaders supported regional governance because they viewed the economic growth and success of their metropolitan areas as dependent on such institutions (Doig 2001).

One of the main challenges to increased regionalism comes from within the planning field. This is the shift away from rational planning towards a fractured planning approach. The dominant planning paradigm for transportation and land use planning has its roots in communicative action,

where public participation and transparency are critical and necessary for development (Handy 2008; Straatemeier 2008; Willson 2001).

Public participation and communicative action gives tremendous power to small groups who bother to show up and be heard. These constraints favor localized policies and bring to question the democratic value of regional government. With the exception of Portland Metro U.S. regional governments are not filled with elected representatives. Filling regional government with appointed rather than elected officials fits nicely with the expert expectations of good and efficient governance, but augers for a move away from the traditional democratic processes of the United States (Doig 2001).

Critiques of regional planning argue that long range transportation planning limits the flexibility required for reacting to the needs of future generations (Gifford 2003). A recent paper by Randall O'Toole argues that long range planning is inflexible and based on uncertain forecasts (2008). Worse yet, he argues, metropolitan plans are not cost effective and focus on behavioral changes. Metropolitan economies are based on "safe, efficient transportation systems" (p.24) and future plans should focus on short term issues and user fees. O'Toole reaches these conclusions while ignoring the role of traditional, long range planning in creating the safe and efficient system he praises.

1.4 *Rethinking transport efficiency*

As the process and institutions of transportation planning have evolved over the past few decades, planning goals have diverged. There are broadly two sets of priorities: economic and environmental (Bertolini, le Clercq, and Straatemeier 2008). The traditional role of transport has been to facilitate economic activities and growth. Much of the theoretical support for predict and provide argues for efficient use of facilities and locational decisions. Environmental concerns are relatively recent so far as importance. While smog and other air pollution were major problems in the 1950s and 60s, it was not until the 1970s when meaningful changes were made in fuel and other regulatory controls.

While the switch to unleaded fuel and catalytic converters represented victories for environmental concerns, the economic considerations of the oil embargo of 1973 was as great a factor in vehicle and regulatory changes. As the price of gas skyrocketed, small cars and engines were cheaper to buy and maintain. The shift to smaller cars allowed for the introduction of lower performance engines and fuel without consumer pushback. What this suggests is that while environmental concerns are important, they do not have a historical record of being a primary driver of transportation changes. The primary driver is economics of both the users and producers.

Within transportation policy there is recognition that traffic congestion a chronic problem (that reflects economic vitality) that needs to be managed. In addition, environmental concerns are important to the scale and institutional aspects of developing policies. These two broad areas of transportation planning lead policy makers and frame the policy options designed to improve city life.

At the same time these two broad concerns are rising to the forefront of urban policy, there is tremendous concern over urban sprawl and other measure of living, sustainable communities. But within metro areas sprawl-type measures are not equally distributed. Urban regions are simultaneously getting denser and spreading out. For any other measure of sprawl the same effects are seen. Access is no different, where regional accessibility is increasing due to economic growth and some communities are realizing gains in accessibility by mode or destination based on changes at their location. Other communities are losing accessibility because of diverted transit resources, changes in employment or the built environment.

The tools of transportation planners have not adjusted to the changes in transportation planning goals. While the issues of congestion and environmental costs directly associated with the transportation sector have become preeminent transportation concerns, the regional transportation planning process is still mired with primary concern for efficiency (Handy 2008). While efficiency is

still important, the primary means of achieving it are to build more and bigger roads and certain transit modes, namely light rail systems.

1.5 *Involving the public and governance scale*

One of the unintended outcomes of the environmental movement in the early 1970s was that the public developed the power to veto projects on environmental grounds (Heller 2008). This shift has improved planning in some cases but harmed it in other by increases the costs of development. In any event, from these environmental roots the public is required to participate in planning for development. As such, planning is a participatory process that involves public officials, professional planners and the public. The necessary inclusion of the public in decisions about infrastructure and private development was a result of a breakdown of the expert paradigm of planning that dominated the immediate post war period. Communities were outraged that they were left out of the process and were being told, in effect, that they did not know what was best for them. Making matters worse, the development of freeways, urban renewal and other interventions left communities decimated, dispersed or disenfranchised. Part of the challenge of regional governance is how to incorporate public participation into the institutional structure.

This challenge of involvement is trickier than simply holding public meetings or having elected representation. For instance, only the Portland Metro government has actual elected representation. In the Twin Cities, the

Metropolitan Council has appointed members who hold all the voting authority though each district is also represented by an elected shadow representative who holds no power. Another major problem within regions is in the rent seeking behavior of local officials that diminishes efficient governance. Within regions cities are likely to complain, sometimes rightly, that investments are distributed unequally. Often in the case of transportation decisions, these distributions result in over-investment in some areas and under-investment in others compared to optimal levels.

Recent research has explored the problems of regional governance by looking at the role of communities in the decision making process. One study argues that the lack of concern for place-space differences leads to underestimating the role of communities in local governance and distorts the expectation of appropriate scales and authority of democratic metropolitan governance (Raco and Flint 2001). The scale of governance is an important issue in light of regional institutions. Scale refers to the breadth of democratic involvement. Scale is a complementary term to scope of governance, which describes the reach of authority of public intervention. For instance, a neighborhood council and a city government are two different scales of government. Building infrastructure is part of the scope of governance. Freeways are not local in scope, but streets and parking are. The distinction between scale and scope are critical for resolving many tensions within the

planning process. Because of the mismatch at a regional level between the scale and scope of policy process and ensuing intervention, inefficient distribution and unnecessary conflict is the likely outcome.

While regional approaches suffer from mismatch problems, the literature is not clear on definitions of localized planning areas, either. One problem in advocating neighborhood planning is defining what a neighborhood is. This is an important piece of understanding the complexity of travel patterns and the role of self-selection to local areas (Guo and Bhat 2007). As cities and regions try to plan for communities that promote less driving, greater walkability and enhanced travel choices, they do so without knowing whether any changes in travel behavior are related to the new characteristics of their environment or if those who live in such areas do so because they prefer to. The self-selection problem is a perfect example of the pitfalls of not including geographic factors in travel behavior analysis. Much analysis is undertaken with global models that seek to determine the socio-economic factors that determine travel choices. Income is closely aligned with the amount of travel one undertakes, for instance. Terms like sprawl, suburbanization or density suggest that these are well-defined, uniform characteristics with consistent definitions in the literature. Yet the specific meanings of these terms are subject of substantial debate. Each of these terms has broad implications but localized effects. As regions grow, parts of the areas are densifying and becoming less auto-centric while others don't.

Guo and Bhat (2007) conceive of neighborhood units as "network bands" in order to use a sliding definition of neighborhoods for analytical purposes. They analyze a travel behavior survey using multinomial logit models to determine the spatial extent of their study areas. This allows them to make claims about the spatial extent of individual travel pattern. Their work is an important contribution to understanding individual travel behavior, but ultimately says little about the governance of transportation and land use.

1.6 *Conclusion*

Sprawling American metropolises are blamed for many ills including auto dependence, traffic congestion, air pollution, wasteful energy consumption and inefficient land development. Over the past few decades, many efforts to create policies that limit or reverse these ills have been successful, including transit oriented development, growth boundaries, zoning changes and other "smart growth" type approaches. As the connection between transportation and land use planning has received greater attention, as has research and planning efforts that specifically identify accessibility and mobility as promising avenues for improving problems. While auto-dominated metro areas offer high levels of regional mobility, there are costs of auto travel that limit the accessibility of destinations. Improving accessibility is a prominent concern of many public officials and planners from all levels of government. Yet efforts to strengthen accessibility planning are hindered by institutional and legal obstacles to

integrated transportation and land use planning. The following chapters explore how accessibility is incorporated into the planning process and introduce new techniques for improving planners' research.

2. Assessing the coordination of local and regional long range transportation planning

2.1 *Abstract*

The structural changes in transportation planning due to environmental, financial and operational challenges receives substantial attention in the literature (Arnott, Rave, and Schöb 2005; Banister 2008; Bertolini, le Clercq, and Straatemeier 2008; Garrison and Levinson 2006; Handy 2008; Wachs 2003). The traditional model of regional planning for transportation infrastructure is proving inadequate for dealing with shifting goals away from capital intensive infrastructure towards improved management of the existing system. This analysis contributes to the discussion on the future of transportation planning by exploring institutional differences between regional and local planning efforts and questions the necessity of regional requirements for accessibility planning. Using content analysis of local and regional plans, I examine how local planning efforts are complements to and substitutes for regional and state planning efforts. The analysis suggests that cities are better situated legally and institutionally to address many of the challenges facing transportation planning than regional planning organizations, and municipalities go above and beyond the requirements set forth through MPO or statewide mandates. These results suggest that the role of the state is overestimated in

metropolitan planning and that local governments are equipped to deal with the challenges of metropolitan growth.

2.2 *Shifting goals and institutions for transportation planning*

Since the passage of ISTEA in 1991 federal transportation funding legislation has encouraged greater emphasis on accessibility and mobility planning by increasing the flexibility of funding (Handy 2002). State governments follow this lead and often require comprehensive planning by cities, but the enforcement of planning guidelines tends to be inconsistent (Ben-Zadok and Gale 2001; Burby and May 1997; Chapin 2007). At a regional level, accessibility and mobility are included in planning efforts but regional authorities rarely have the political or legal authority to enforce transportation and land use plans (Freilich and White 1994). Taking into account state and regional planning efforts, local city officials are resistant to mandates that are perceived to be "life style" oriented policies but are generally supportive of "systems maintenance" in the form of infrastructure investment (Kanarek and Baldassare 1996). Life style policies go beyond infrastructure construction and maintenance (which are conventional transportation planning concerns) by addressing land use or police matters.

Local resistance to state mandates aimed at land use and police powers gets to the heart of the complexity of planning for transportation as strictly a mobility enhancing endeavor. Accessibility as a planning goal has strong land

use and development components through the inclusion of destinations in the calculus of accessibility. Yet cities are eager to protect their interests in economic development and zoning decisions (Peterson 1981) as they compete for residents and businesses with other cities within their metro areas (Schneider 1989). This disposition of cities potentially dilutes their incentives for cooperating with state and regional planning goals.

Though ISTEA represented a shift in focus, federal transportation funding has long encouraged regional plans. In 1962 the federal government required that money for transport projects were subject to the "3 Cs" of "coordinated, cooperative, and comprehensive" planning framework (Weiner 1999). This framework spurred the creation of metropolitan planning organizations (MPOs) which were supported by subsequent federal and state funding requirements (Giuliano 2004). Though MPOs were ostensibly in charge of regional transportation planning, most had little actual authority to carry out their plans because they lacked regulatory power or financial control. Many states resisted ceding traditional state authority to MPOs, and cities were even less willing to give up control over land use issues.

Greater emphasis on comprehensive planning for social and environmental impacts was included in ISTEA legislation in 1991 (Slater and Linton 1995; Handy 2002). This shift toward flexibility and comprehensive planning is more of an incremental shift in policy rather than a new approach to

transportation planning (Giuliano 2004; Gifford 2003; Handy 2002). The largest part of the new flexibility was that federal funding regulations increased local contributions to transportation infrastructure investment (in particular the share of the federal subsidy that can be allocated to rail or other transit) and increased their interest in the effects of transportation investments. The interest in the cities' systems required that transportation investments and planning be analyzed by their effects on central cities' development, tax bases, employment and mobility, energy and the environment (Weiner 1999; Kaiser, Godschalk, and Chapin 1995).

Even though ISTEA was not a revolutionary planning package, it has increased the credibility of MPOs. The flexibility allowed under federal authorizations has prompted state and metropolitan agencies to promote enhanced accessibility and mobility, often through increased transit and infrastructure investment and suggested land use improvements (such as development around transit stations). Yet the tools available for accessibility planning through federal funding mechanisms are limited by the land use planning component of accessibility. More importantly, as cities are already planning for transportation and land use improvements it is unclear if a strong federal, state or regional role in necessary.

2.3 *Planning for access*

Planners and public officials argue that accessibility should be improved for many reasons. Most commonly accessibility is discussed in terms of proximity or ease of access to jobs. Such measures have been discussed at length in the literature about jobs-housing balance (Cervero 1989, 1996; Giuliano 1992; Levine 1998; Schneider 1989). Yet accessibility varies by mode, trip purpose and geographic scale, which has led to calls for greater transit accessibility through denser residential development, mixed-use, neo-traditional and transit-oriented development (Calthorpe and Fulton 2001; Ewing 1997). Transit accessibility and overall accessibility are not synonymous, however, and require different measures to understand how successfully accessible areas are.

Accessibility-enhancing strategies typically focus on land use and transportation planning at a neighborhood scale, such as by encouraging Transit Oriented Development (TOD). As such, city and community plans have potential to positively affect accessibility through local control of land use and zoning. These local plans, however, are increasingly subject to coordination requirements from metropolitan or state planning agencies. Additionally, local land use development is subject to private investment constraints that metropolitan and state planning efforts are not. Through the analysis of general and local area plans from two metropolitan areas this paper examines how

accessibility is defined and encouraged by different levels of government within a region.

Accessibility is most evident at a local or sub-local level to the people who live, work and play in the community. Areas with high levels of access are expected to generate and attract more travel than those that have lower levels of access. These localized differences are major issues for neighborhoods because of congestion effects, economic vitality or public safety. Metropolitans regions, by contrast, are necessarily balanced between origins and destinations (Levine 1998). Because every neighborhood has its own characteristics, accessibility is valued differently in every community (Filion and McSpurren 2007). Some communities value transit, some desire access to shopping or retail, and some prefer isolation.

At a federal level the U.S. Department of Transportation has advocated for increased mobility as a strategic goal (Handy 2002) in addition to the increased flexibility in funding. But large federal subsidies almost always result in large scale transportation infrastructure projects rather than neighborhood level planning efforts. Some common examples are light rail systems as new transit capital investment and new road construction to service expanding metropolises. These types of investments focus on mobility enhancing strategies. Such investment increases the ability of people to move about the

area, but offer limited benefits for, and may possibly harm, accessibility-enhancing measures.

Handy (2002) explains the difference between accessibility-enhancing and mobility-enhancing strategies. Mobility Strategies to improve local accessibility include land use policies such as New Urbanist developments, TOD and prescriptive retail uses. Other strategies for accessibility are street oriented and target connectivity within the transportation grid. These types of policies potentially contrast with mobility enhancements of road construction, transit expansion and Intelligent Transportation Systems (ITS) applications. Specifically, these accessibility enhancing strategies are local in nature. Only cities have the ability to regulate land use as an accessibility improvement, but they are unlikely to implement such regional mobility enhancing strategies because the benefits will be dispersed throughout the region and/or the costs will be borne by the local communities through increased traffic.

Transportation planners define mobility as the ability for movement, but do not consider where people are going. Accessibility considers the ability of people to reach the destinations that are important to them for work or leisure activities within their budget constraints of time or money (Krizek and Levinson 2008). The primary difference between the two concepts is that accessibility includes a cost function of travel to a specific location or for a specific opportunity (El-Geneidy and Levinson 2006; Handy 2002). Though these terms

have distinct and specific differences in many cases accessibility is used only in tandem with mobility. This suggests that planners are either unable or uninterested in differentiating between the two goals. Such a lack of clarity potentially reflects a city's inclusion of language from regional, state or federal plans. In the plans where the terms are accurately defined it may reflect a meaningful attempt to increase the overall quality and effectiveness of the planning document. Since the quality of plans affects their influence (Berke and French 1994; Berke et al. 1996), it is important to better understand how these concepts are used within and across jurisdictions.

2.4 *Quality of plans*

High quality plans share three primary attributes: factual bases, clearly articulated goals and appropriately directed policies (Kaiser, Godschalk, and Chapin 1995; Burby and May 1997). The factual bases of a general plan describe the social, economic and environmental conditions that exist in the city (or region). Theses bases provide the context for the vision or goals set forth in the general plan, and lead to documents that are more frequently used by planners, elected officials and developers (Pitkin 1992).

The language used with planning documents is an important determinant of plan quality. Terms such as "should" or "encourage" are used to qualify policy goals as desirable but not required. Instances where plans use terms such as "will" or "shall" or "must" indicate action-oriented policies for inclusion in

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development. The use of directed, action-oriented language over guidelines

results in development proposals that are more consistent with the intent of the

plans (Fishman 1978). For instance, the city of Burbank's General Plan Land

Use Element contains the following language:

Any project undertaken by the City is subject to environmental review under the

California Environmental Quality Act (CEQA). This includes private development

projects, development projects carried out by the City, and the adoption of planning

regulations such as the General Plan and Zoning

Ordinance. All projects must be analyzed to determine whether they have the

potential to cause any significant environmental impacts, including but not limited to

traffic, noise, and air quality. (City of Burbank , 117)

The language in the Burbank plan requires compliance with California

state mandates for air quality assurance, and should result in development that is

consistent with state pollution targets. Because accessibility levels are poorly

defined at the state and regional level compared with air quality, it is expected

that cities' general plans are less likely to feature clear, action-oriented language

on land use issues and more likely to offer guiding language.

Policy goals within a planning document should be realistic and

attainable by the municipality for a high-quality document. An important aspect

of appropriately directed policies is to limit the scope of the plan to the authority

maintained by the planning institution. Returning to the main concern of this

paper, who plans accessibility is not obviously answered because high levels of

government do not have power over land use controls. Similarly, cities rarely have authority over regional transportation programs such as transit. The City of Minneapolis explained the how the city's goals affect the internal process of planning:

The City's vision for its future can also be described in terms of the eight goals adopted by our Mayor and City Council Members and incorporated into the work of city departments. The adopted City Goals are an important tool that has both informed The Minneapolis Plan process and will continue to be used in planning and decision making in the future (City of Minneapolis 2000, 1.i.1).

Yet the city included a specific goal that addresses public transportation, which is not part of the city's authority:

Goal 5: Improve public transportation to get people to jobs, school and fun.(City of Minneapolis 2000, 1.i.3)

While the City of Minneapolis has a legitimate interest in improved public transit, it has no real power to do much. Minneapolis addressed this concern with language stating that they will work with Metro Transit (which is operated by the Metropolitan Council) on transit improvements.

Beyond the qualities just discussed, effective plans must strive for three types of consistency in order to be effective (Burby and May 1997). First, plans must be vertically consistent, which means that local plans must match regional, state and federal plans for intent and process. Secondly, plans must try to be

horizontally consistent by aligning across municipalities within a region. This is trickiest in fragmented regions as cities must coordinate their plans with those of other cities (Filion and McSpurren 2007). Attempting to maintain horizontal consistency opens up the possibility of cities opting out of balanced growth allowing them to selectively plan for growth at the expense of the surrounding communities. Thirdly, plans must be internally consistent. This refers to planning goals must be in line with existing land use regulations, namely the zoning code. Even though internal consistency is conceivably the purview of one municipality and should be relatively easy to achieve, this is not the case.

2.5 *Case selection*

Two cases are considered to explore the issues of planning for accessibility. The regions were selected based on a strong history of state planning mandates in the case of California and a strong regional government in the Twin Cities of Minnesota. California requires that its cities draw up and adopt general plans that include seven elements: land use, circulation, housing, conservation, open space, noise and safety. However, the state does not require that cities regularly update their entire plans which leaves open the possibility of piecing together general plans over the course of many years or decades. The state does warn against such an approach on the basis of maintaining internal consistency (Rivasplata and McKenzie 1998).

In the Twin Cities, the Metropolitan Council is the regional planning organization. The Minnesota legislature passed the Metropolitan Land Planning Act in 1976, which required all cities within the Twin Cities region to develop comprehensive plans subject to review by the Met Council. This act was designed to ensure horizontal consistency across cities in the region. More recently, cities in the region are required to update their general plans every ten years. As a result of this, the plans from cities in Minnesota tended to be more recent than the plans from California cities, though cities in California did update bits and pieces of their plans.

The total number of cities within each region made it prohibitive to review all plans, so the sample was limited to cities in Los Angeles and Hennepin Counties, the largest counties in each region. Both Los Angles and Hennepin Counties represent about 40 percent of the total population of their respective regions. Within each county, cities were selected for inclusion in the analysis based on a few factors, including population and the availability of their general plan. Only cities with populations over 30,000 were considered. This constraint is justified on three assumptions. First, larger cities are more likely to have larger planning staffs and offer easier access to their planning documents. Second, this eliminates bedroom communities and small towns, which might not have any interest in accessibility within their city. Third, and directly related to the second assumption, is that larger cities are expected to have greater need for

comprehensive planning and have the potential to capture any benefits associated with improved accessibility through economic development or new residents.

Access to planning documents was the final consideration. Cities in the early stages of revising their entire general (or comprehensive) plans were eliminated, though cities that had an updated draft after public review were included as these plans were only waiting for city approval. Other cities did not have drafts available at any location except City Hall, where the public was welcome to read through the document. Cities that did not make drafts readily available were not pursued in this sample. The remaining drafts were collected in electronic form in order to expedite the coding process.

2.6 *Methodology*

State, regional and city planning documents were examined to test for the reach and effort of transportation planning. State and regional plans were examined for key concepts and terminology that is expected to show up in municipal general plans. The analysis focuses on the overall quality of plans at the local level in order to better gauge the influence that state and regional planning efforts have on cities.

Each local and regional plan was analyzed for inclusion of "accessibility" and "mobility" in addition to specific policy goals. In the case of the regional plans adopted by the Southern California Association of

Governments (SCAG) and the Met Council, accessibility and mobility were used in each and clearly defined as separate goals. This is not surprising as the regional plans are transportation plans that help guide infrastructure investment and development. In addition, at a regional level accessibility and mobility are more similar than at a local level. Regional accessibility tends to follow regional mobility, but accessibility at this level loses some influence because few people require high levels of accessibility throughout a region. At a regional level the balance between travelers and destinations tends to even out.

General plans from the two regional governments in the sample and a selection of cities from the largest county in each region were analyzed by coding each plan based on how each policy (variable) was addressed. The coding system was based on previous content analyses developed by Berke et al.(1996), Berke and Conroy (2000) and Brody et al. (2006). The plans were coded on a scale of 0, 1 or 2 depending on the presence of a particular policy and whether it was encouraged or required.

The plans were searched electronically for key words and phrases, and then all instances of hits were reviewed in the context of the document. Multiple versions of words were searched, such as "access" and "accessibility." In the Met Council's plan "land access" was used in place of "accessibility" and this language was reflected in the general plans of the cities. In all cases, most instances of "accessibility" were directed at Americans with Disabilities Act

(ADA) compliance. Plans that had no instances of the words being sought for each policy category were scored 0. Plans earned a 1 if the policy was mentioned but not defined, elaborated on or required. A score of 2 indicated a policy that was discussed at length, mentioned frequently as an action item or something to improve, or if the policy was required.

There were seven categories of policies (explained below) coded for each regional and local plan. Accessibility-enhancing plan quality was determined for each city and region using an adaptation of Brody et al's (2006) model used for calculating sprawl-reduction techniques. This index was calculated by normalizing the summed policy scores for each city and multiplying the result by 10 in order to place each city's index on a 10 point scale. The equation is listed below, where *A* is the accessibility index for each jurisdiction, *I* is the sum of policy score and *m* is the number of indicators for each city or region *j*.

$$A_j = \frac{10}{2m_j} \sum_{i=1}^{m_j} I_i \tag{1}$$

While the empirical measures of accessibility receive substantial attention in the literature, planning policies to address accessibility concerns are less succinct in their definitions. The seven categories of accessibility policies were developed from the literature on what inputs are part of accessibility

enhancing strategies (Handy 2001, 2002; Ryan and McNally 1995; Vuchic 1999; Dittmar and Ohland 2004).

2.7 *Accessibility versus mobility*

Like many planning terms, accessibility and mobility are bandied about as though their meaning is obvious. In truth, these are two terms that usually suffer from vague definitions even though technical definitions exist. Of course, there isn't complete agreement in the field about the technical meanings, either, and often the two terms are used simultaneously in planning documents. An example of the confusing usage in planning documents is cited by Handy from the Chicago area transportation plan (CATS) of 2002 :"…an integrated and coordinated transportation system that maximizes accessibility and includes a variety of mobility options," (2002, p. 7)

Handy (2002) offers a concise review of the terms and meanings. Mobility is defined as the *potential* for movement. Most transportation planning in the U.S. has focused on mobility measures. This is evident in the road system, which supplies tremendous opportunities to get to and from just about anywhere as long as one has a car. Level-of-service measures are all indicators of mobility, such as volume-to-capacity ratios (Handy 2002). These ratios indicate the ease of movement and as travel slows or speeds up, mobility decreases or increases.

Accessibility is a much trickier term to define, and suffers from more confusion about its meaning. One of the earliest contributions to the literature about accessibility was by Hansen, who defined accessibility as the potential for *interaction* (Hansen 1959). This means that measures of accessibility include an impedance, or cost, factor. The cost of travel is affected by the number of destinations available as more opportunities mean more choices for travel, each with a different cost structure (Handy and Niemeier 1997). Handy and Niemeier discuss three measures of accessibility: a gravity measure, based on the gravity model; a cumulative-opportunity measure of accessibility, which posits that choice is an important factor of accessibility and more choices generally mean greater accessibility; and a behavioral measure, which aims to predict the choices travelers make based on the utility of any given trip.

The relationship between mobility and accessibility is confusing. The potential for movement is obviously affected by the cost of travel because costs affect the ease of moving around. Mobility-enhancing policies tend to also improve accessibility because more destinations are easier to reach. But good mobility can exist with poor accessibility, and visa versa (Handy 2002). In the case of a congested neighborhood, there is poor mobility due to the congestion limiting the potential for travel, but if there are many opportunities within walking distance, accessibility is still good. Alternately, rural or exurban areas, with many uncongested roads has good mobility, but with few opportunities

these areas have poor accessibility. As such, "good mobility is neither a sufficient nor a necessary condition for good accessibility" (2002, p.5). In the Accessibility Index constructed here accessibility is included as a specific measure within the index because the term has a specific meaning. Taken together the accessibility indicators detailed below serve to improve the quality-of-life for the cities by reducing the cost of alternate modes of travel or rearranging the built environment to maximize interactions.

2.8 *Accessibility indicators*

The indicators used for content analysis are designed to measure strategies and techniques that planners use to increase connectivity within their cities. Each indicator represents a different conceptual approach and set of tools for planners, though the concepts may seem to overlap at times. The delineations among all policies was made based on specific instances in the literature where each policy was treated as a specific approach to enhanced overall accessibility, not limited to a particular mode. Below the distinctions between four of the indicators are discussed. These indicators are often used interchangeably or as similar concepts. For this research they are used to determine the level of detail provided in general plans.

New Urbanism

New Urbanism is a well defined approach to planning that goes beyond issues of connectivity. As a set of policy goals, New Urbanist plans aim to

rescale neighborhoods by emphasizing the design of the built environment.

New Urbanists argue that traffic congestion is the result of sprawling, low density development coupled with inefficient street designs and layouts. In addition to traffic congestion, New Urbanism seeks to rectify social isolation and other problems associated with city form.

In this analysis new urbanism is treated as a distinct policy set because of the efforts of new urbanism proponents including Calthorpe and Fulton (2001) and Duany et al.(2003). The Congress for the New Urbanism promotes new urbanism as a new way to conceptualize communities within and among metropolitan areas. In this sense it represents more of a set of guiding principles than specific tools to affect urban development. The content analysis of the general plans includes new urbanism to examine to what extent cities have embraced new urbanism as a planning ideal above and beyond any specific policy implications.

Mixed-use Development

One common proposal for increasing accessibility is to promote mixed-use development. In this research, mixed-use was defined as residential and commercial uses in the same area. Some cities examined, such as Carson, California, promote commercial and industrial mixed uses as part of an economic development strategy. Since developments with no residential component do little to alter the current landscape, such policy goals were

omitted. In some cases mixed-use was something to promote in a neighborhood and in other cases it was something to promote for each development. Both approaches were treated equally.

Neo-traditional Development

Neo-traditional development, like New Urbanism, holds to a specific set of principles that proponents argue planners should use. Yet neo-traditional development does not feature the strong social component as a primary concern that is included in New Urbanism, and it is used more generically to refer to compact neighborhoods clustered around a small commercial area. Neo-traditional New Urbanist developments attempt to limit auto use by locating daily commercial needs near homes so that residents can walk or bike for their needs, and there is some evidence that this is the case (Nasar 2003). Because of their scale, however, and focus on individual neighborhoods as the unit of accessibility they may not be effective for increasing accessibility to jobs centers.

Transit Oriented Development

Transit Oriented Development goes further than neo-traditional development by focusing development around transit stations. This is a natural policy goal for accessibility enhancing strategies. Such development requires coordination with transit agencies about route locations and action on the zoning code to promote appropriate development. The inclusion of TOD along with

New Urbanism and Neo-traditional Development is to examine how fine tuned planning policies are in general plans. Plans that mention these approaches to similar concepts separately will score higher and be judged as plans of higher quality than those that use these terms generically or only as they are used in state or regional planning documents.

Jobs-housing balance

Many planners advocate for jobs-housing balance as a desirable planning goal (Cervero 1989, 1996). In theory, a community that has approximately the same number of jobs as workers can minimize the amount of overall travel. This is because long trips between cities will be replaced by short trips within cities, and these shorter trips are more easily served by transit and non-automotive modes. Cities can approach the jobs-housing balance by encouraging housing near employment or employment near housing. Measuring the effectiveness of jobs-housing balance as a broad planning goal is difficult. Not all jobs are share the same skill level, wage scale or specialization. Nevertheless, locating employment near residential developments increases employment accessibility, though not necessarily for all residents.

Congestion

Congestion imposes a cost on motorists through slower travel speeds and wasted time. As the cost of travel rises through gridlock, accessibility declines (Knaap and Song 2005). Congestion is also a visible cost of transportation that

regularly ranks as a top concern for people. High levels of congestion directly affect the perceived quality-of-life of cities and local governments have a wealth of alternatives available to address traffic concerns from street light synchronization to parking reform.

Pedestrian friendly

Pedestrian friendly development is popular in planning circles as a complement to neo-traditional and transit oriented development. In addition, pedestrian friendly planning encourages sidewalk activities, consolidated parking structures and greater potential for bicycling than auto oriented planning. By keeping the pedestrians in mind the planners are considering the human scale of the built environment and the quality-of-life issues that surround vibrant local areas.

2.9 *Plan Analysis and Discussion*

The results of the Accessibility Indexes calculated from the content analysis of the general plans are presented in Table 1. The index measures the relative importance of each of the criteria within the general plans, and is titled the Accessibility Index because each criterion reflects a particular cost of transportation and land use planning. The table also includes the results from each regional plan and an average score for each of the two counties included in the sample. From a regional perspective, both accessibility and mobility scored high in the SCAG and Met Council long range transportation plans. This is not

unexpected as accessibility should reflect mobility at the metropolitan scale. In this analysis, the regional transportation plan for Southern California scored higher than the plan for the Twin Cities (7.1 versus 5.0). The SCAG document used stronger language with some strategies such as jobs-housing balance and congestion mitigation.

Table 2.1: Accessibility index scores for select cities											
County	City	Population	Accessibility	Mobility	New Urbanism	Mixed-use	Neo-traditional development	Trasit oriented development	Jobs-housing balance	Congestion	Pedestrian friendly	Accessibility index
Los Angeles	Arcadia	53,054	1	1	0	1	0	0	0	1	1	2.1
	Burbank	100,316	1	2	2	2	0	2	2	2	2	8.6
	Carson	89,730	1	1	0	2	0	1	0	1	1	3.6
	Cerritos	51,488	0	1	0	1	0	0	2	1	2	4.3
	Gardena	57,746	0	1	0	2	0	0	0	1	2	3.6
	Lancaster	118,718	0	2	0	1	1	0	2	2	1	5
	Long Beach	461,522	1	1	0	2	0	0	0	0	1	2.1
	Los Angeles	3,694,820	2	2	0	2	0	2	0	2	2	5.7
	Pasadena	133,936	1	2	0	2	0	2	0	1	2	5
	Redondo	63,261	1	0	0	2	0	0	2	0	0	2.9
	SCAG		2	2	0	2	0	2	2	2	2	7.1
Los Angeles County average			0.8	1.3	0.2	1.7	0.1	0.7	0.8	1.1	1.4	4.3
Hennepin	Bloomington	85,172	2	2	0	2	0	2	0	2	2	5.7
	Brooklyn Park	67,388	2	2	0	2	1	2	0	2	2	6.4
	Eden Prairie	54,901	2	2	0	1	1	2	1	1	0	4.3
	Edina	47,425	1	0	0	1	0	0	0	1	0	1.4
	Maple Grove	50,365	0	0	0	2	1	0	0	1	0	2.9
	Minneapolis	382,747	2	2	0	2	2	1	0	1	2	5.7
	Minnetonka	551,102	1	0	0	1	1	0	0	1	2	3.6
	Plymouth	65,894	1	2	0	2	0	0	0	1	2	3.6
	Richfield	34,310	1	1	0	1	1	0	0	1	2	3.6
	Met Council		2	2	0	2	0	2	1	1	1	5
Hennepin County average			1.3	1.2	0	1.6	0.8	0.8	0.1	1.2	1.3	4.1

The stronger regional planning stance in California reflects the state mandates on air quality, pollution and other energy issues. California planning is subject to air quality guidelines and emphasize travel demand management techniques (Tietz, Silva, and Barbour 2001). Minnesota lacks the state requirements that support such metropolitan planning actions, though the state encourages metropolitan oversight. So while the regional plan appears stronger

in California than Minnesota, it is more accurately described as a reaction to state planning efforts rather than a strong regional presence. In the Twin Cities, however, the Met Council has greater freedom to plan.

The strategies employed by individual cities do not necessarily reflect the priorities identified in regional plans. In the case of New Urbanism, which was not discussed in regional plans at all, only one city mentioned it as a desirable planning strategy (Burbank, California). The inclusion of New Urbanism as a strategy is somewhat surprising as it is typically a collection of many different strategies rather than a comprehensive approach, though it seems that Burbank may use New Urbanism as a substitute for neo-traditional development. New Urbanism also contains a strong design component that many cities are reluctant to include in their general plans. It is not surprising to find that Burbank has the highest overall score on the accessibility index (8.6).

State mandates positively affected the inclusion of and language used for other strategies. Jobs-housing balance is of particular interest as it is specifically addressed in SCAG planning documents and reports (Armstrong and Sears 2001). The jobs-housing balance is an explicit goal of the regional planning agency, the state of California provided incentive grants aimed targeted to improving jobs-housing balance in 2001 and 2003 (Department of Housing and Community Development 2003). From these activities it is expected that language supporting jobs-housing balance is included in local plans. It is more

surprising that jobs-housing balance was included in the general plans of only four cities in the sample Los Angeles. Comparing this to cities in Hennepin County shows the complete absence of mentions of jobs-housing balance. In the Met Council planning documents, the phrase "connections" is used rather than jobs-housing balance. These are sufficiently different goals, as improving jobs access suggests transportation solutions in addition to any housing constructions. Jobs-housing balance makes more explicit claims to locate housing near employment centers.

The county averages for the accessibility indices are similar for Los Angeles and Hennepin, and in both cases the city averages are below the indices of the regional plans. The variation of the Los Angeles cities' indices is greater than that of the Hennepin County cities, likely from the wider range of ages of the plans. The Met Council requires that cities file a comprehensive plan at least once per decade, and this is enforced through transportation financing decisions. Neither the State of California nor SCAG has any requirements for how frequently the general plans must be updated, though the state has a consistency requirement that is loosely enforced. The low scoring Long Beach plan dates to 1989 with two subsequent revisions in the 1990s. The more recent plans, such as Burbank's 2006 plan, scored much higher. This is an unsurprising result considering the federal and state regulations that have been implemented over the past two decades and the increase in planning strategies designed

specifically to counteract the perceived problems of suburban sprawl including New Urbanism, Transit Oriented and Neo-traditional Development.

One concern with the accessibility index was that it potentially favors large cities that have greater incentives to internalize the benefits of accessibility. To test for this relationship, the Spearman's rank test was used between the cities' population and accessibility index. The coefficient established that there was no relationship between the two variables. This refutes the idea that population is a determining factor in accessibility planning. One likely explanation for the overall coverage of localized transportation planning is that cities of all sizes are confronted with transportation problems. Congestion, noise pollution and environmental concerns all affect the quality-of-life for residents, and cities will take steps to manage these problems without any type of hierarchal prodding. To maintain economic vitality, residential desirability and growing tax bases cities cannot wait for solutions to come from elsewhere. Part of the competition between cities will be based on access and high quality transportation services using existing infrastructure. New infrastructure potentially can reduce the desirability of communities because people do not want to live too close to busy freeways, freight corridors or noisy commuter rail.

2.10 *Measurement validity and directions for future research*

While content analysis is an established methodology within the literature, the technique is not without critics. Richard Norton argues that too many studies have focused solely on the communicative nature of planning documents without accounting for the clarity of the policy focus (2008). One of the troubles associated with this distinction is that communicative definitions are not easily tested for correlations or other measurement validity (Putt and Springer 1989). Furthermore, the weighting systems used for many indices are biased towards greater frequency of the search terms rather than the impact of them. In the case of accessibility, it may be mentioned many times throughout the plans, but without clear definitions and tasks it lacks the bite of a required development.

The analysis presented here addresses these concerns through the index created. Because accessibility and mobility are often poorly defined, this content analysis focused on how the language was used rather than the frequency of usage.

2.11 *Conclusion*

This research has examined how cities plan for accessibility planning and whether regional mandates can improve local efforts. The hypothesis tested was that planning efforts from federal, state and regional governments can influence local efforts. While this is undoubtedly true, municipalities

maintained a great deal of autonomy in how they planned for accessibility. This analysis does not clarify whether local plans simply mimic state and regional planning language rather than develop plans that best suit the cities' individual needs and goals. This conclusion is consistent with previous studies of planning for sustainability (Berke and Conroy 2000) and those that have looked at the role of state mandates for coordination (Berke and French 1994; Brody, Carrasco, and Highfield 2006).

Regardless of how general plans reflect city visions, the local plans reflect vertical consistency of planning language. Higher quality plans feature clearer language and commonly understood strategies. As such, higher quality plans are easier to follow and enforce (Burby and May 1997). The cities with plans that score highly on the accessibility index should see measurable improvements to accessibility (however defined) in the future.

Accessibility is of greater concern in municipalities' general plans in Hennepin County than in Los Angeles County cities according to the accessibility index demonstrated in this research. In this case, it does seem likely that the strength of the Met Council as a planning authority plus the relatively recent redrawing of the general plans had an effect on the terminology used in the documents. As noted previously, accessibility (and mobility) gained traction as planning goals with the revamping of federal transportation legislation in the early 1990s. From the local, regional and state plans examined

here, however, there is no reason to think that state mandates could not accomplish the same goals as regional ones.

The role of higher levels of government in influencing planning policies at the local level is important, but this research suggests that the state may be as effective as regional authorities for shaping policy. The isolation of jobs-housing balance as a California goal and the inclusion of accessibility as a concern in Hennepin County provide some evidence of this notion. What is unexplored in this paper is how effective the general plans are for guiding accessibility.

State and regional requirements for consistency may signal to local officials that specific words and phrases must be included in planning documents. Yet getting from a vision for a city expressed in a general plan to implementing zoning changes, new transportation systems and different mixes of land uses is challenging, to put it mildly. Even though the high scoring plans are expected to result in a larger share of development that adheres to local goals, there has been little research that examines the effectiveness of plans. Of the studies that are available, they generally support the idea that state planning efforts are effective at influencing development (Carruthers 2002; Talen 1996). This is a direction of future research that deserves attention.

What all of this says about planning for accessibility is that multiple layers of government can work together toward transportation and land use

goals. Local plans reflect the interests of regional and state bodies, but also reflect the interest of the local communities and often go farther in specifying desirable outcomes than state planning does. The plans examined here were not subject to strict language requirements, so the plans can be assumed to accurately reflect the interests of the cities generating them coercion in the form of funding contingencies.

Beyond the effectiveness of plans for promoting and guiding integrated transportation and land use developments, the growing influence of sub-local planning efforts should be explored on the overall performance of the transportation networks. Neighborhood planning carries substantial influence in development decisions. In particular neighborhood groups are able to organize against potential planning goals (such as large scale economic development or new road construction). Los Angeles and Minneapolis have tries to shift neighborhood planning towards active participation through the inclusion of local area plans as part of the municipal general plans. As accessibility is primarily something that people experience on a local level and affects residents' quality-of-life, neighborhood level planning for accessibility holds great promise as a strategy.

3. Estimating the spatial variability of commute mode choice using Geographically Weighted Regression

3.1 *Abstract*

Conventional travel behavior analysis uses socio-demographic factors to analyze personal travel choices. These studies often employ global regression techniques that estimate and display coefficients of the independent variable as uniformly distributed across the study area. These universal estimates are problematic because they mask the variation that occurs across localized areas. This essay contributes to the understanding of travel behavior by explicitly estimating the spatial distribution of travel patterns and common demographic determinants. To understand how socio-demographic factors that affect commute mode choices vary by neighborhood, geographically weighted regressions (GWR) and Geographic Information Systems (GIS) analyses are utilized using a U.S. Census-tract-level data set for the Twin Cities for the years 1990 and 2000. This analysis demonstrates that travel behavior varies substantially within cities and metropolitan regions controlling for socio-demographic factors and establishes geographically weighted regression as a useful contribution to travel behavior analysis. These results suggest that localized differences in land uses and transportation facilities can have an effect on travel choices. Planners and public officials can use these techniques to better

identify specific areas where policies that encourage travel mode shift are likely to have the greatest effect as well as to highlight potential travel determinants within the built environment that have been previously underestimated.

Evidence supporting non-stationarity of commute mode choice has implications for travel behavior analysis. Geographically weighted regression offers methodological improvements that partially resolve self-selection bias and modifiable areal unit problems. The analysis demonstrates that residential density has become a slightly stronger determinant of mode choice between 1990 and 2000 while employment in the central city has declined in importance. In addition, spatial non-stationarity of these factors has increased over time, meaning there is less geographic concentration evident in the data. This research provides tools for local officials and planners to target specific neighborhoods where transportation alternatives are likely to generate the largest improvements and improves the understanding of the role of geography in determining mode choice.

3.2 *Introduction*

As metropolitan regions have grown in land area and population, people traveled greater distances to reach their desired destinations. While no one disputes that a separation of land uses increases overall travel, there is still disagreement about how much travel is caused by such separation. The impact of land use and the built environment on travel behavior is also poorly

understood. This essay contributes to the understanding of land use impacts on transportation by explicitly estimating the spatial variability of commute mode choice using established demographic determinants. The existence of a significant spatial effect controlling for road density and demographic factors suggest that land uses affect travel choices, all else equal. To test this idea, the null hypothesis is that there is no variation across metro areas.

Most previous research on travel factors focuses on socio-demographic variables and neighborhood choice, but there are few studies that consider the effect these influences have across and within metropolitan areas. In part, the lack of spatial factors is due to problems associated with the aggregation of available data and methodological limitations from conventional linear regression modeling. This lack of geographic analysis is unsatisfying as transportation is obviously spatially oriented, and researchers should use methodologies that can specifically incorporate the impact of geography into their analyses. By focusing on the spatial heterogeneity of transportation within a metro area a clearer picture of how people interact with the transportation and land use systems will emerge.

Metropolitan growth coupled with private transportation (automobiles) has created more complex and dispersed travel patterns than radial cities feature. This complexity is not well understood, and the implications of this shift are only now being addressed in the literature (Batty 2005; Bertolini 2005; Torrens

2008). What is clear is that transportation should not be planned as a monolithic system but rather a complex network where the nodes, links and paths are all valued differently by users. This points directly to the need for flexible transportation planning, and I argue that flexibility is best achieved at a local or sub-local scale of governance. A critical aspect of this argument is that techniques are necessary to quantify and understand what is happening at the sub-local scale. GWR is a tool that assists researchers and policy makers in identifying the impacts of local characteristics.

Over the past few decades, metropolitan areas have been restructured from monocentric to polycentric forms. This has occurred for employment centers as well as non-work activities. As city form has changed, travel patterns have also changed. As travel is to a large degree a derived demand, the spatial distribution of destinations where people want to go has obvious implications for transportation networks. One major implication of new travel patterns is that as people locate closer to their desired discretionary destinations the number of trips made increases. This does not necessarily mean that the miles traveled increases. Instead, more short trips are likely to be made for discretionary travel because the cost of each trip declines (Boarnet and Crane 2001).

Local trips, such as those described above, are problematic for predict-and-build models of transport planning. One reason for this is local trips rarely wait for new infrastructure improvements as people tend to use the paths that are

available. As new paths are built the cost of travel to destinations served by the road are reduced, inducing new travel to those destinations but not necessarily new travel overall. This means that people travel locally with what they have, and expensive system expansion doesn't make sense financially to benefit only one community. For instance, the Westwood neighborhood in Los Angeles sits immediately to the south of the UCLA campus and suffers from heavy traffic congestion. There are many potential improvements that can be made that serve Westwood and reduce traffic congestion, such as pricing parking, developing a UCLA oriented transit system or building dedicated transit routes on Wilshire and Westwood Boulevards. All of these initiatives would help the local community but are unable to gain support due to the institutional structures of the broader (and traditional) transit and transportation agencies of the region and city.

Another issue confronting conventional transportation planning is that commute trips are the primary factor influencing transport models. Yet commute trips are only about 20 percent of overall trips and miles traveled (Pucher and Renne 2003). Though commute trips have declined in relative importance from an individual's perspective commuting is still the dominant focus of research for planning new facilities and investment (Meyer 2000). From a methodological perspective, improving our understanding how commute choices are made within the constraints of the transportation network and built

environment will improve transportation planning and also improve the models

and estimates when researchers turn their attention to non-work travel as the

main focus of transportation planning.

Local variation in trip making and mode choice has strong implications

for transportation planning as a quality-of-life concern and strengthens the case

for transportation planning at city and sub-local governmental scales. For

instance, some communities suffer from congestion or spillover traffic more

than others. In other cases dense communities may value reduced auto pollution

or quiet streets more than those that have ample parkland. What is clear is that

changes to the transportation system and built environment have primarily local

effects. These travel effects should be significant enough to be measured

through statistical analysis and many of the effects have network spillovers that

either positively (such as congestion reduction through parking policies) or

negatively (such as increased auto travel due to excessive parking requirements)

affect the entire network and region.

3.3 *Understanding destinations, congestion and transport networks*

The transportation network is comprised of many modes, nodes, links

and paths. Taken together, these parts of the system offer many choices for

where, when and how to travel, all at different costs. At any time on the

network there are links that are congested and some that are clear. This situation

is seemingly at odds with one of the strengths of networks, namely that

underutilized parts of the network can accommodate some of the demand from other parts in order to maintain a particular level of service. An example of network dynamics at work is the Internet, where bits of information are shuttled among routers and links, then reassembled at the final destination. Because the Internet is able to redirect traffic through many different nodes spread throughout the globe, the level of service across the entire web tends to remain high even during peak demand. Obviously, this is not the case with personal transportation.

Transportation networks have unique characteristics that help understand how travel varies across metropolitan areas and why localization of planning is relevant. First, there are clearly some nodes that are more desirable than others. This leads to tremendous traffic to a particular location, be it for work or recreation, and lower levels elsewhere, perhaps even sub-optimal amounts of travel. It follows from this that the value of transportation to drivers varies across space and mode, but such costs are not reflected in the provision of transportation facilities. The second issue of transport networks is one of substitutability. Travel paths and modes are often not substitutable, mostly because the origins and destination are fixed. While many economists argue that overall transportation costs have declined, in fact some of this decline has been transferred to individuals as part of their shopping, working and other

activities. In some highly desirable areas, the cost of personal travel has actually increased due to congestion, mismanaged parking and other factors.

Conventional travel behavior research offers little guidance for improving our understanding of how transportation network performance and access alters behavioral choices or how the built environment is adapted to network access rather than nodal improvements. One area where network access has tremendous importance is for commuting. Transit, for instance, tends to work well for a radially oriented city with a large employment center downtown, but it is a less viable alternative to driving otherwise. This is due to the lack of network connectivity of transit. To better plan for less auto dependence, travel behavior research needs to focus on the overall network connectivity. This is a critical area for future research, but first methodological tools must be developed. Geographically weighted regression (GWR) is a promising addition to the planner's toolbox for modeling how people actually use the transportation and land use networks.

3.4 *Methodology and analytical contributions*

Studying accessibility within metro areas is well established in the literature (Kitamura et al. 1998; Handy 2002; Hansen 1959; Handy and Niemeier 1997; Handy 1992; Ryan and McNally 1995; El-Geneidy and Levinson 2006; Niemeier 1997; Levine 1998; Handy 1993). Conventional measures of accessibility are defined as a cost function of travel to various

destinations by mode. Yet transportation researchers and planners are not yet clear about how to incorporate accessibility into mainstream planning models (Handy 2002, 2008), nor is it clear how to apply travel behavior analysis to land use planning. Transportation plans are shifting away from large scale goals along the lines of the Interstate highway system (though the dollar amount may be enormous such as the case of new rail lines or subway investment) and towards planning investments that improve performance on a particular road or in a particular area.

The limits of conventional predict-and-build transportation planning are being challenged as traffic related problems are diminishing the quality-of-life in many cities (Banister 2008). Traffic congestion, air pollution, safety and accessibility are problems that local elected officials are expected to address and problems that cannot be left to state and federal governments alone. Personal travel costs, social isolation, transportation choices and access to destinations are now policy concerns for city planners and local officials because the current state of urban transportation system performance is hindering local quality-of-life and potentially harming those cities that suffer most. Conventional transportation planning, bred of engineering efficiency and geared towards capital intensive infrastructure projects, is often inadequate for dealing with transportation problems as quality-of-life issues. An additional extension of the problems stemming from transportation problems is that quality-of-life affects

the economic vitality of a community. The previous essay demonstrated how cities are adopting transportation planning goals that address many of these concerns.

A better understanding of how local travel choices vary within cities and metropolitan areas will shed light on the different types of transportation issues impact the quality-of-life for different communities, such as neighborhoods with poor access to jobs or districts with high amounts of congestion related to cruising for parking. Such local variations have not been explored in the literature. Research along these lines will help planners more effectively design and implement transportation. Better analysis can also suggest where land use effects are strongest for transportation interactions.

To these ends, this essay explores how local geographic factors affect commute choices through GWR on U.S. Census tract level data to measure the spatial heterogeneity of commuting mode choice. The analysis here demonstrates the degree of complexity and localism of transportation choices and introduces spatial factors into conventional models. In addition, the data set allows for analysis over time so the increasing complexity of travel behaviors is shown. The GWR demonstrates that socio-economic factors are inadequate as a complete explanation of commute mode choice, suggesting spatial differences, which could be attributed to the influence of the built environment or endogenous social factors. Together these analyses demonstrate the difficulty of

transportation planning for metropolitan areas and suggest the need for increased

localization of parts of the planning process rather than enhanced regionalism.

3.5 *Including spatial variability in mode choice modeling*

This essay focuses on two themes. The first is that conventional

travel mode choice models are limited in value because they fail to account for

spatial variations in the estimation results. Including spatial parameters helps

illuminate the potential effect of the built environment in a way that potentially

internalizes any self-selection bias that may be present in conventional models

by explicitly estimating localized variations. The second theme is that the

complexity of travel behavior influences at very local scales has been increasing

over time. This increased complexity has strong implications for local and

regional transportation planning and suggests that adaptable and flexible

approaches are required. The analysis presented here demonstrates the

heterogeneity of mode choice determinants resists a straightforward and cogent

metropolitan policy. In the light this complexity a series of localized policies

are an attractive approach to achieve meaningful changes for transportation

problems of traffic congestion, energy use and accessibility. This theme will be

explored in greater detail in the next section.

Travel choice modeling suffers from limitations that researchers have

tried many ways to improve upon. There are three main limitations which are

interrelated: 1) identifying the appropriate geographic scale of analysis, 2)

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overcoming data limitations due to aggregation and 3) ecological fallacy. Metropolitan policies and planning that are affected by these limitations include the continuing division of cities and suburbs in the literature even though most transportation and land use issues are present regardless of municipal status, poorly defined neighborhood boundaries (both geographic and institutional) and potential treatment bias from self-selection based on lifestyle preferences. Geographically weighted regression helps overcome these issues and offers at least a partial solution to future travel choice research.

3.6 *Methodology limitations and the appropriate scale of analysis*

The appropriate geographic scale for travel analysis has been discussed in the literature without resolution (Kwan and Weber 2008). Most studies of urban structure rely on data collected at the municipal level (Anas, Arnott, and Small 1998; Benguigui, Blumenfeld-Leiberthal, and Chzamanski 2006). While these studies offer a great deal of insight into the dynamics of metropolitan areas, they recognize the limitations of the scale of data. As metropolitan regions have become polycentric and the dominance of a central downtown has declined, so has the relevance of municipal borders for transportation policy analysis.

Another problem with studying spatial phenomena such as accessibility is that geographic scale is an integral characteristic of all phenomena. One common critique of social equity studies is that the data is often aggregated as a

level that is too large to accurately reflect social networks and neighborhoods (Omer 2006). This creates research results that smooth over meaningful differences. Another concern is that studies will mix and match data sets that have different scale or boundaries. What happens in these situations is that researchers estimate spatial (or social) distributions that are unique to the data they are using rather than reflecting the phenomenon they seek to illuminate.

Aggregated data is used not only for spatial equity research, but also for metropolitan development and travel patterns, in particular commuting patterns. In these cases, the constraints of aggregate data are clear. Because employment and other commercial nodes develop within and outside of central cities, studies that rely on the National Household Transportation Survey (NHTS) fail to pick up localized changes in travel behaviors that may have large impacts. Considering Los Angeles, it is possible to radically alter your travel routes, modes, times, distances, origins and destinations while remaining within the city borders. Such intracity activity will cloak the true travel within metro areas as the NHTS data set only allows for differentiation between central city, second city and suburban locales. Similar types of travel behaviors that occur within the central cities, second cities or suburbs will not be evident.

Data limitations are a large reason that zonal analysis has precedence over individual scales for travel survey research. One way around the limitations of aggregated data is obviously to use finer grained units of analysis.

Yet this is not as straightforward as it seems. Census data are available at a finer

scale but incomplete for transportation analysis. Transportation analysis zones

(TAZs) feature census data and travel patterns, but lack land use characteristics.

In addition, TAZs and census tracts often feature diversity of land uses and

populations that affect expected travel outcomes. For instance, a census tract is

too large to be walkable regardless of the walkability of streets within the tract.

In these instances a better measure needs to be utilized.

Though these problems are acknowledged in many studies, they are

rarely resolved. More often than not travel behavior research that examines

commuting uses data aggregated at the metropolitan, county or city level and

analyzed using OLS regressions (Gordon, Kumar, and Richardson 1989; Krizek

and Levinson 2008). These studies argue that commuting has spread along with

metropolitan growth and the commuting travel times are not fully explained by

metropolitan structure. Other commuting research estimated the expected

amount of commuting based on land use patterns aggregated at a traffic analysis

zonal level and found that land use patterns alone fail to account for the total

amount of observed commuting (Giuliano and Small 1993). Beyond limitations

from the scale of data aggregation, these studies do not address mode choice for

commuting. They are instructive of the general methodological constraints, and

are important contributions for refining economic models of urban form. They

also point to the need for additional models that specifically include spatial

variations as a parameter to be estimated in order to gain a fuller understanding of commuting behavior.

3.7 *Limits of conventional mode choice analysis*

Transportation research has helped push forward changes in the traditional transport planning model through insights about the (potential) role of the built environment (Banister 2005; Boarnet and Crane 2001; Boarnet and Sarmiento 1998; Calthorpe and Fulton 2001; Cervero and Kockelman 1997; Crane 1995; Ewing and Cervero 1998; Handy 2001, 2002; Khattak and Rodriguez 2005; Krizek 2003; Levine and Frank 2007; Shoup 2005). There are many studies that find no clear link between transportation and land uses, suggesting that land use in endogenous to travel patterns (Boarnet and Sarmiento 1996). Some of these insights include the role of street patterns and connectivity, the relative costs of travel across modes, and skewed urban form due to over-regulation or excessive parking requirements. In total, such studies have introduced localized (or spatial) variations into what was traditionally a spaceless field (Schheiner and Holz-Rau 2007).

Scheiner and Holz-Rau argue that the increased spatial precision in transportation research has been limited in value to the field due to factors hidden behind simply spatial explanations, such as residential self-selection (Boarnet and Crane 2001; Gordon and Richardson 1997; Levine 2006), or very low explanatory power (Kitamura, Mokhtarian, and Laidet 1997; Kitamura et al.

1998; McNally 2000; Mokhtarian and Salomon 2001). Taken together, these studies suggest that a scientific understanding of travel behavior and choices is elusive through conventional methodologies.

3.8 *Methodology*

Conventional OLS regressions are frequently used to assess the deterministic factors of travel behavior. Such analyses aim to improve the decision making process of planners and public officials, but they tend to suffer from a weakness of global estimation, where they treat the results as consistent across the metropolitan plane. This is problematic for policy discussions and harmful for assessing the needs of various communities with regions. While many authors have attempted to resolve the problem of localism through treating central cities as unique from suburbs, this no longer holds from a causality perspective or a planning perspective.

By employing geographically weighted regression techniques, a more nuanced explanation of transportation and land use can be developed that provides insights unavailable through conventional borders and global models. GWR estimates parameters at local scales. This is of particular importance for metropolitan policy analysis, where access to transportation links and opportunity centers directly affect the isolation or exclusion of individuals. In addition, standards determinants of travel choices such as income are not expected to remain constant over space. After all, if socio-demographic factors

were the only determinants of travel then future transportation policy should focus exclusively on those factors.

There are many reasons to include geography as a variable in transportation and land use analysis. The main reason to use GWR as an exploration device, at a minimum, is to address any variations due to random sampling across space (Brunsdon, Fotheringham, and Charlton 1998; Fotheringham, Charlton, and Brunsdon 1998). Another reason is that GWR helps to overcome the modifiable areal unit problem (MAUP) and ecological fallacy (and the inverse concept of atomistic fallacy). Lastly, spatial effects can help explain the effect of land uses (and the built environment generally) on transportation. By better understanding the complexity of localized transportation and land use differences policies and governance can be tailored to address localized needs. This shift has implications for planning, public finance, investment decisions and quality-of-life.

Ecological fallacy and MAUP are two related problems associated with spatial data analysis. The MAUP occurs when there is correlation between aggregated spatial data because of the boundaries drawn. The problem with the boundaries is they often have no relation to the phenomenon being explored, and the aggregated data can reflect the biases of the researcher (Openshaw 1983). The related concept of ecological fallacy is where the characteristics of a subset of the population are applied to the entire population included in aggregate data.

Potential solutions to these aggregation problems include including weighted samples from individual level data, redesign the boundaries or sample to maximize an expected effect and refitted a global model for local spatial regression. Working through these potential solutions is an important step in creating meaningful neighborhood and sub-local indicators that serve the needs of planning researchers. Since many urban policies are implemented spatially rather than through individuals it is critical that localized geographic effects are understood (Sawicki and Flynn 1996).

Geographically weighted regression has been recently used to extend understanding of many metropolitan phenomena. Many studies have begun to look at sprawl using these techniques (Fotheringham, Charlton, and Brunsdon 1998; Paez 2006; Torrens 2008). More specifically to transportation studies, localized differences in car ownership have been uncovered (Clark 2007). These studies have established GWR as an important methodological contribution to the study of complex urban interactions, yet there are scant examples that directly use these techniques for transportation and land use analysis.

By using GWR I also address the MAUP and ecological fallacy in a way that provides insight into how cities are organized and the effects of organization on individual behavior. However, this GWR is not intended to demonstrate the individual differences of travel behavior factors. Rather, the intent is to

highlight the complexity of metropolitan region in order to argue that regional governance will often be incapable of governing with the necessary flexibility for either managing the current transportation system or implementing policies largely aimed at quality-of-life issues. To this end I am interested in the differences attributable to space, not individuals. As such, in this essay I use a data set from Geolytics, Inc. comprised of U.S. Census data from 1980-2000. Geolytics normalized the data using 2000 Census tracts allowing for geographic analysis across time. This analysis makes multiple contributions to the literature, including the introduction of GWR to transportation and land use research and estimations of the increased complexity of metropolitan areas over time.

3.9 *Geographically weighted regression model*

Geographically weighted regression is an extension of ordinary least squares regression in that spatial distribution is added to the global model as an independent variable. This allows for parameter estimations at each point of each variable in the model in order to directly test the hypothesis that local parameter estimates exhibit spatial variations. By mapping the coefficients and residuals using GIS a detailed picture of the spatial variance is apparent and provides much richer detail than a global model. What this approach suggests is the role of space in addition to conventional techniques and fills in a substantial hole in previous studies.

The standard model for GWR is shown as equation (1). This model is an extension of OLS by including geographic locations for each data point. Each point is weighted using a bandwidth estimation drawn from kernel density estimates of the distance from each data point to all other points in the sample. The kernel bandwidth was estimated using a Gaussian function that weights each observed point against all other observed points using the Euclidian distance between them (Lloyd and Shuttleworth 2005), in the case of these data the centroids of census tracts. The bandwidth smoothes the data by weighting census tract closer to the census tract being estimated than those farther away (Holt and Lo 2008; Zhang, Gove, and Heath 2005).

$$y_i = \alpha_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i)x_{ik} + \varepsilon_i \qquad (1)$$

In equation (1), (u_i, v_i) indicates the coordinates of the ith point, and α_0 and β_k are continuous functions of (u, v) at point i (Fotheringham, Brunsdon, and Charlton 2002). This function includes the parameter estimates of the plane of each independent variable, resulting in estimates of the spatial variability of the data. This allows for the GWR model to accurately reflect neighborliness of data associations. Put another way, this means that the parameter estimates of each point account for the estimates of neighboring data.

One advantage of GWR is that it is possible to test the hypothesis that the coefficients of the OLS model are not randomly distributed across the study area. For transportation and land use research, this is a major concern that has

been largely ignored due to data and methodological limitations. Conventional studies have used global models that look at entire metropolitan regions (Newman and Kenworthy 1999; Newman and Kenworthy 1989) or crude breakdowns between cities and suburbs (Gordon, Kumar, and Richardson 1989). Alternately, many researchers have attempted to resolve the data limitations by looking at specific neighborhoods (Bagley and Mokhtarian 2002; Handy 1992, 2001; Khattak and Rodriguez 2005; Khattak, Virginie J. Amerlynck, and Quercia. 1999; Krizek 2003), but these studies may be limited by the problem of residential self-selection or systemic social isolation. In either case these studies only explore a subpopulation that may exhibit endogenous characteristics. Using GWR to analyze the entire metro area promises to avoid the endogeniety problems by including the entire sample population in the study. This can be used as either an exploratory analysis that facilitates future localized research or as a freestanding contribution that demonstrates the spatial component of travel behavior.

There are three characteristics of GWR that make it preferable as a model for testing transportation and land use interactions. These three factors are the result of being able to weight the data at various spatial points rather than compartmentalize the dataset (Nakaya 2001). First, the geographical scales do not need to be divided beforehand. This helps resolve the self-selection problem by including everyone in the sample universe. If the model is adequately

specified the variance in neighborhood preferences should be captured. Secondly, the functional form of local variations is estimated in the model so they are treated endogenously rather than exogenously. Lastly, through local kernel weighting GWR allows produces parameter estimates for mapping rather than generalized residual outputs.

Exploring local variations of interactions among designated variables should result is a model that better represents reality than global models that assume no variation (Fotheringham, Brunsdon, and Charlton 2002). Understanding the degree of variation across space provides insight into better model specification overall. For transportation mode choices, local variation is a critical factor in addresses transportation mismatch, jobs-housing balances and social isolation. In addition, social factors and networks may exist at local scales that affect travel decisions. Ultimately, as transportation and land use systems are inherently spatial in their form any analysis of the interaction of transportation and land use must account for these physical separations and differences.

The main challenge with using GWR is that while it is not especially computationally complex it is computationally demanding. The data in this study was limited to the Twin Cities metropolitan area for three main reasons. First, the study region had to be limited due to computing constraints. For each GWR run, the approximate computing time was between two and twelve hours,

depending on the software used and model validation specified. This constraint precludes analyzing a national sample on a desktop computer. Future research will take advantage of networked computers to overcome the processing limitations. Secondly, the Twin Cities has complementary travel behavior inventories that can be used to enhance this analysis. Lastly, the author's familiarity with the Twin Cities region aids in understanding what is causing the spatial variations. This insight will help form the basis of future research in different metro areas.

3.10 *Modeling commute mode choice*

In this research I test two hypotheses using GWR. First, I hypothesize socio-economic variables for determining commute mode choices exhibit spatial statistically significant non-stationarity. This hypothesis challenges conventional OLS results and suggests that analyzing the geographic variability of mode choice can inform policies that are more targeted at specific areas that offer potential benefits. One policy implication of this hypothesis is that variations in the built environment help explain mode choice and overall accessibility. Such variations point to the need for flexible transportation policies that accommodate localized differences and suggest that accessibility is a major determinant of mode choice.

The second hypothesis is that travel choices have changed over time. This hypothesis suggests that the overall environment for travel has grown more

complex and that travel choices are not static. Through this test I gauge the increased or decreased magnitude of the socio-economic and spatial effects for the years 1990 and 2000.

Geographically weighted regression was conducted on Census data from the years 1990 and 2000 using a U.S. Census data set normalized to the 2000 Census tract borders by the Geolytics Company. This data source provides a unique opportunity to estimate how U.S. metropolitan areas have spatially changed over time. This is a particularly important contribution as previous studies of the interaction between transportation choices and land use have been limited by data constraints to global regression estimates, where socio-economic variables are assumed constant across an area.

In order to test the usefulness of GWR as a research tool I will examine the spatial variability of driving to work. This is a useful travel choice to model spatially as the literature is rich with studies of socio-economic factors or of specific neighborhoods as explanatory variables for commute mode choice. When previous studies have explored geographic differences in commute behavior the analysis has been largely limited to a central city-suburban division (Gordon, Kumar, and Richardson 1989). Yet as metropolitan areas have grown the central city has become less dominant relative to the surrounding areas, and large variations in employment densities exist within cities, as well. The use of GWR in this context provides evidence that the differences between central

cities and suburbs is not as great as generally hypothesized in the literature and that localized differences in travel choices controlling for socio-economic variables are an important piece of the transportation and land use connection.

The GWR model was run in multiple forms on two different software platforms. The first sessions were calculated using Stata 9.0 with an .ado file added for the purpose of performing GWR. These calculations were conducted on a parsed set of data by census year. While this software seemingly worked well, there were a few troubling aspects. The first difficulty was is the amount of time the program required for processing the regression. While this may sound like a spilled milk situation, the specified models generally ran for about six hours and occupied the entire capacity of the Pentium processor of the machine. The second difficulty was the opaque process of setting a bandwidth for weighting the data points. While users are able to specify their own bandwidth for weights, there were few clues as to how to estimate bandwidth using cross-validation through the Stata program. The bandwidth estimates using the program defaults returned substantially different estimates each time the model was run. In addition, the computational difficulty made fixing alternative bandwidths clunky, time consuming and hard to verify. The third major issue was that Stata lacks a direct output into a Geographic Information Systems package in order to map the results. In order to map the residuals, the data had to be transformed and joined with an existing ArcMap shapefile. While

this was merely an inconvenience, every data transformation (especially on large data sets) has the potential to introduce error into the results.

In order to solve these difficulties, a second software package was used for GWR. This software is GWR Version 3.0.18 and was developed by researchers at the University of Newcastle (Fotheringham, Brunsdon, and Charlton 2002). There are three main advantages to this software over Stata. First, the output is formatted in a file that can be directly used in ArcMap. This eliminates two transformations required from the data output from Stata and thus two points where potential errors can be introduced. The second advantage is that the GWR software allows for more precision in estimating the kernel bandwidth for weighting the regression. Lastly, the GWR software is substantially faster than Stata, saving approximately four hours on each regression run.

The explanatory variables are well established as important in previous studies for determining commuting mode choice. The independent variables include the employment rate for the tract (share of adult population working) and the share of workers employed in the central city. Central city employment is likely to be better served by transit than non-central city employment because the Twin Cities transit system is radially organized. Other explanatory variables are income, which is widely viewed as a leading predictor of car use (Pucher and Renne 2003) and the length of the respondent's commute, where longer

commutes are expected to correlate with greater rates of driving. College

education is included as a predictor of higher income employment and a greater

likelihood of driving to work because of less sensitivity to the costs of driving.

Lastly, two measures of density are considered: household and population,

which are taken as predictors of transit use (Meyer and Gomez-Ibanez 1981;

Newman and Kenworthy 1999; Newman and Kenworthy 1989). While none of

these variables represent a contribution to the literature, they have been largely

considered through global regression models or on geographic scales that mask

the complexity of travel decisions and the potential effects of the built

environment (Brunsdon, Fotheringham, and Charlton 1998; Fotheringham,

Charlton, and Brunsdon 1998; Torrens 2008).

The following variables from each Census tract were considered for the

regression models and which were then trimmed for parsimony using post test

techniques:

"hhden"=Total number of households divided by the land area.

"den"=Population divided by land area.

"emr"=Employment rate of all adults in tract.

"emrcc"=Employment rate of adults who work in the central city.

"inc"=Income coded by $5,000 increments.

"white"=Percent of population that is white in tract.

"own"=Percent of households who own their home.

"college"=Percent of adults with college degrees.

"shortco"=Percent of workers with commute less than 20 minutes.

"medcom"=Percent of workers with commute between 20-40 minutes.

"longcom"=Percent of workers with commute greater than 40 minutes.

'workcc"=Percent of households who work in central city.

The independent variables were converted to ratios for inclusion into the model allow for comparisons across census tracts. Each tract in this instance is considered a neighborhood. Using tracts as neighborhoods has been addressed as problematic in previous studies (Guo and Bhat 2007), but this is often due to data limitations in conventional OLS regressions. Other studies using GWR have suggested the tract level analysis is appropriate for spatial analysis (Clark 2007; Holt and Lo 2008). As the intent of this research is to explore the spatial differences of travel behavior, tracts are a near optimal aggregation of individual data. This complements the idea that neighborhoods are not fixed in their definitions and the geographic scale of a neighborhood varies with the attributes being explored (Clark 2007; Galster 2001; Holt and Lo 2008; Suttles 1972; Lin and Long 2008).

There are two features of GWR worthy of note with regard to model specification. First, dummy variables are not used as would be the convention for conventional OLS. This is because the coefficients will vary across space rendering dummy variables unnecessary and the dummy coefficients would be

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meaningless. Second, GWR is appropriate for large datasets. This feature makes it ideal for metropolitan study but it would not necessarily be an appropriate technique for local areas or neighborhoods.

The model is constructed to explain the likelihood of driving to work from each Census tract controlling for the following factors, plus the spatial relation to all other Census tract centroids. They are household density, distance from the central business district, income, education, car ownership, employment location, home ownership and race. Density and distance are commonly used in OLS regressions to measure urban growth but tend to be problematic because of spatial autocorrelation (Torrens 2008). This problem is overcome with GWR (Fotheringham, Brunsdon, and Charlton 2002). In this case distance to the CBD is included because of the expectation the transit service is greatest at the center of the region and transit use should reflect this. Employment location is a similar case, where those who work in the central city should have more choices for travel because of the increased transit service. Income is strongly correlated with increased auto travel for all trip purposes. Education and racial variables are included in addition to income in order to capture additional variation of other social factors not reflected by household income.

The regression model was constructed first using all variables, then tested for multi-collinearity using the variable independence function (VIF).

This technique tests for independence of each factor. The variables that scored lower than 10 were maintained in the GWR models, as per convention. Tables 3.1 and 3.2 show the results of the global OLS regression for 1990-2000. The dependent variable is the percentage of workers who commute by car in each tract. For the explanatory variables, the coefficients are generally of the magnitude and in the direction expected and the models each have high explanatory power (r-sq=.7). However, there are shifts over time in the magnitude of the effects. For instance, the coefficient for working in the central city decreased from -.13 to -.17 during the period 1990-2000. This means that people who work in the central city are less likely to drive to work in the year 2000 than they were in 1990. This shift occurred while the overall likelihood of driving to work increased, as seen by the change in the intercept. Since the central cities are well served by transit it is not surprising that there was a decline in the coefficients for those independent variables. There were also some investments in new suburban commuter transit service that potentially shifted some drivers to transit in areas that previously had few travel options. But overall without knowing where these changes occurred it is difficult to design efficient and effective policies.

What is interesting about this table is what is statistically significant in the global model. The importance of income as an explanatory factor has declined during the same period and is clearly not significant in the later period.

This reflects the ubiquity of auto ownership regardless of income as well as the nature of the transportation-land use system, which favors cars and driving through excessive parking supply, low levels of congestion and lots of high service roads. This is not an unexpected result as car ownership and use increased in the study period (this trend was not limited to the Twin Cities) for all demographic categories, including lower income levels. It is likely that income was less of a factor for owning car in 2000 than in 1990. In all years distance to the CDB as measured by time spent commuting had no discernable effect on the share of commuters who drove to work.

Table 3.1: Global regression coefficients influencing auto commute 2000			
Parameter	Estimate	Standard Error	t score
Intercept	0.7300	0.0222	32.9274
Household density	-0.3391	0.0463	-7.3193
Employment rate	0.2026	0.0342	5.9248
Income	-0.0018	0.0027	-0.6692
White	0.0880	0.0201	4.3807
Own home	0.1448	0.0155	9.3432
College degree	-0.0887	0.0265	-3.3447
Long commute	-0.1679	0.0381	-4.4088
Work in Central City	-0.1658	0.0128	-12.9600

Table 3.2: Global regression coefficients influencing auto commute 1990			
Parameter	Estimate	Standard Error	t score
Intercept	0.5507	0.0233	23.6254
Household density	-0.3676	0.0465	-7.9068
Employment rate	0.3432	0.0314	10.9431
Income	0.0049	0.0028	1.7596
White	0.0872	0.0228	3.8268
Own home	0.1764	0.0161	10.9896
College degree	-0.1074	0.0301	-3.5636
Long commute	-0.1226	0.0433	-2.8305
Work in Central City	-0.1279	0.0126	-10.1729

The elasticities to the mean for the variables in the OLS regression were calculated to more simply show the effect each independent variable has on the likelihood of driving to work. These results are displayed in Table 3.3. These estimated elasticities are interpreted the change in likelihood of driving to work from a one percent change in the independent variable. Using long commute as an example, a one percent increase in the share of residents that have a long

commute increases decreases the share of residents who drive to work by .02 in

the year 2000. This is a small effect, but the relationship is statistically

significant and the effect nearly doubled in the decade studied.

Table 3.3: Elasticties to the mean for global coefficients of independent variables determining auto commute		
Parameter	1990	2000
Household density	-0.025	-0.024
Employment rate	0.258	0.151
Income	0.039	-0.020
White	0.091	0.084
Own home	0.135	0.115
College degree	-0.032	-0.033
Long commute	-0.011	-0.020
Work in Central City	-0.083	-0.082

Table 3.4 shows the p-values of the tests for non-stationarity from the

GWR model for the years 1990 and 2000. Non-stationarity is the spatial

variation of the coefficients. The p-values are interpreted in the same way as

conventional regression analyses, where the p-value indicates a level of

confidence that an effect is present. In the case of GWR the statistical

significance is that there is detectable and real variation across space. These

findings confirm the hypothesis that the independent variables affecting

commute mode choice generally demonstrate significant spatial variation. The

independent variables that do not feature statistically significant non-stationarity

at the 99 percent level are income, home ownership, employment rate and

education. This means that the estimated coefficients of these explanatory variables do not vary across the metropolitan area and exhibit no statistically significant non-stationarity. In addition to the spatial significance, the changes over time are worth noting but without mapping the parameter estimates we cannot see if the spatial variation has diminished.

Table 3.4: Test of spatial non-stationarity for
variables regressed on auto commute, 1990 and 2000

Parameter	P-value	
	1990	2000
Intercept	0.0000	0.0000
Household density	0.0000	0.0000
Employment rate	0.0000	0.0200
Income	0.0700	0.5700
White	0.0000	0.0000
Own home	0.0000	0.0400
College degree	0.0000	0.0500
Long commute	0.0100	0.0000
Work in Central City	0.0000	0.0000

The GWR models were tested for improvement over conventional OLS using ANOVA as described by Fotheringham et al (2002). These results are shown in Table 3.5 for the years 1990 and 2000. The sum of squares, which measure the variance from the mean for each set of estimates, declined from the OLS to GWR models, suggesting an improvement in fit. The high F-score confirms that the GWR model is an improvement over the global model. The

addition of spatial variation provides a better overall fit for estimating of

commute mode choice within the specified model.

Table 3.5: ANOVA test for GWR improvement over OLS, 1990-2000

	SS	DF	MS	F
1990				
OLS Residuals	2.8	9		
GWR Improvement	0.9	38.48	0.023	
GWR Residuals	1.9	677.52	0.003	8.29
2000				
OLS Residuals	2.7	9		
GWR Improvement	1.3	81.79	0.016	
GWR Residuals	1.4	634.21	0.002	7.37

The residuals of the GWR model were mapped using ArcMap GIS

shown below in Figures 3.1 through 3.8. The Geolytics data were geocoded and

matched with U.S. Census Tiger files, then converted to shapefiles. The data

from these shapefiles was then imported into Stata statistical software in order

to perform the GWR calculations. These results were then joined with the

original shapefiles in order to display the data. The results are mapped with

gradated colors to show where the strongest effects occur. The light blue and

pink colors are the parameter estimates that are in the highest quartile (blue) and

lowest quartile (pink). The dark blue and red show the locations where the

parameters are greater than one standard deviation above (blue) or below (red)

the mean. This convention is useful for understanding the true extent of the

variation and identifying the locations that are of particular interest

(Fotheringham, Brunsdon, and Charlton 2002).

Since the maps of spatial variation at the census tract level are visually

complex it is difficult to grasp the variation that occurs due to non-stationarity of

parameters. As such, Tables 3.6 and 3.7 summarize the parameters for 1990 and

2000 using the upper and lower quintiles plus the median. These estimates

demonstrate the difference in the middle 50 percent of the distributions and are

useful for examining the general shifts rather than any unusual changes. The

independent variables with detectable effects are marked as statistically

significant. Those that are significant at the 99% confidence level also featured

the strongest parameter effects at the minimum and maximum values.

To assess the degree of non-stationarity, the quartile data for selected

variables are mapped (Figures 3.1 through 3.8) with the standard deviation of

their parameter estimates. This is a useful comparison for understanding the

spread of the estimates. The quartiles indicate the grouping of all estimates, and

the standard deviations demonstrate the spread of the estimates. These results

can be compared to the parameter estimates at one standard deviation above and

below the mean, which include over two-thirds of the results. When the

quartiles exceed the standard deviation, there is significant non-stationarity

because over 50 percent of the distribution is more than one standard deviation

from the mean. The variables that showed this in these models are working is

central city, household density and commute length.

Table 3.6: Parameter summaries for determinants of auto commute 1990

	1990		
	Lower Quartile	Median	Upper Quartile
Intercept	0.5474	0.5610	0.5805
Household density	-0.3435	-0.3039	-0.2682
Employment rate	0.3505	0.4253	0.4579
Income	0.0044	0.0069	0.0088
White	0.0030	0.0259	0.0688
Own home	0.1647	0.2123	0.2353
College degree	-0.1717	-0.1456	-0.1010
Long commute	-0.4717	-0.4209	-0.3110
Work in Central City	-0.1683	-0.1604	-0.1473

Table 3.7: Parameter summaries for determinants of auto commute 2000

	2000		
	Lower Quartile	Median	Upper Quartile
Intercept	0.6880	0.7167	0.7681
Household density	-0.3177	-0.2856	-0.2719
Employment rate	0.2351	0.3108	0.3535
Income	-0.0042	-0.0009	0.0053
White	-0.0086	0.0089	0.0369
Own home	0.0956	0.1656	0.2012
College degree	-0.1343	-0.0803	-0.0265
Long commute	-0.5176	-0.3781	-0.2066
Work in Central City	-0.2154	-0.1872	-0.1668

Figures 3.1 and 3.2 are maps that show the spatial variability that

working in the central city has on the choice of driving to work. This

relationship has the strongest effect of all independent variables tested in these models. The results from the year 2000 suggest that more people are driving to work even if they work in the central city. This result suggests that new transit investment and other policy interventions to improve travel choices during the 1990s were largely ineffective for reducing the amount of auto commuting. However, even these observations vary by the sector of the metro area.

The people in the northwest corner of the region were far less likely to drive to work if they worked in the central city in 1990 than in the year 2000. In the southwest corner of the region, the opposite effect is seen, where much of the area turns from dark blue in 1990, indicating deviation from the mean greater than one standard deviation, to white, suggesting non-remarkable differences from the parameter's metro average, and pink, which suggests that there are some areas in the southwest part of the area that are more likely to find alternate ways to commute than driving. This sub-regional shift is likely due to 1990s expansion of private transit service connecting the southwestern suburbs with downtown. Alternately, the northeastern part of the region was better served with improved freeway access into downtown during this period. But for the region overall there was an increase in driving to work based on working in the central city. Conventional OLS models would miss the sub-regional changes from transit and freeway expansion. The ability to test the relationships locally

points to a much more nuanced understanding of mode choice than previously

discussed in the literature.

Figure 3.1: Parameter estimates of working in central city on auto commute by quartile and standard deviation, Twin Cities 2000

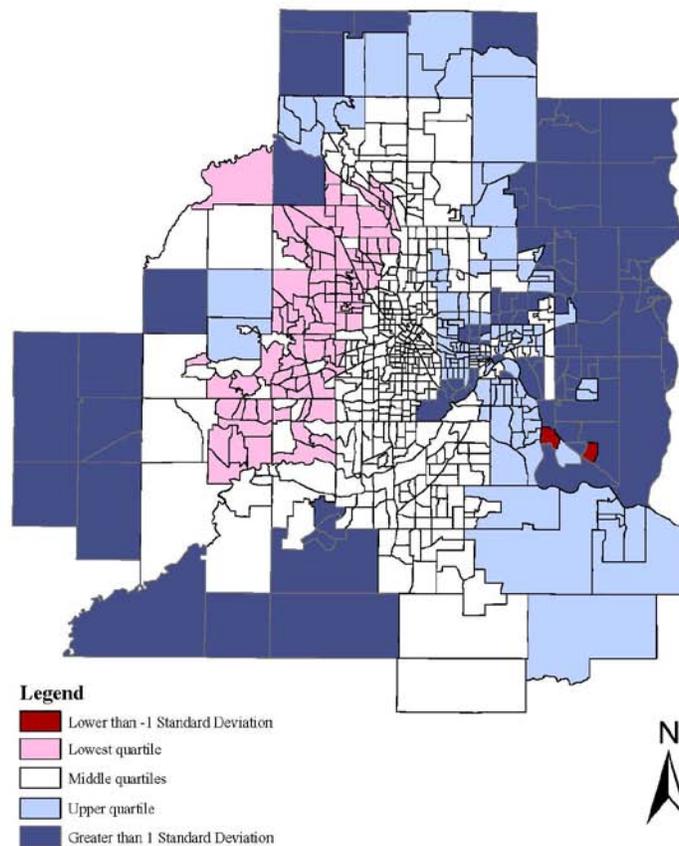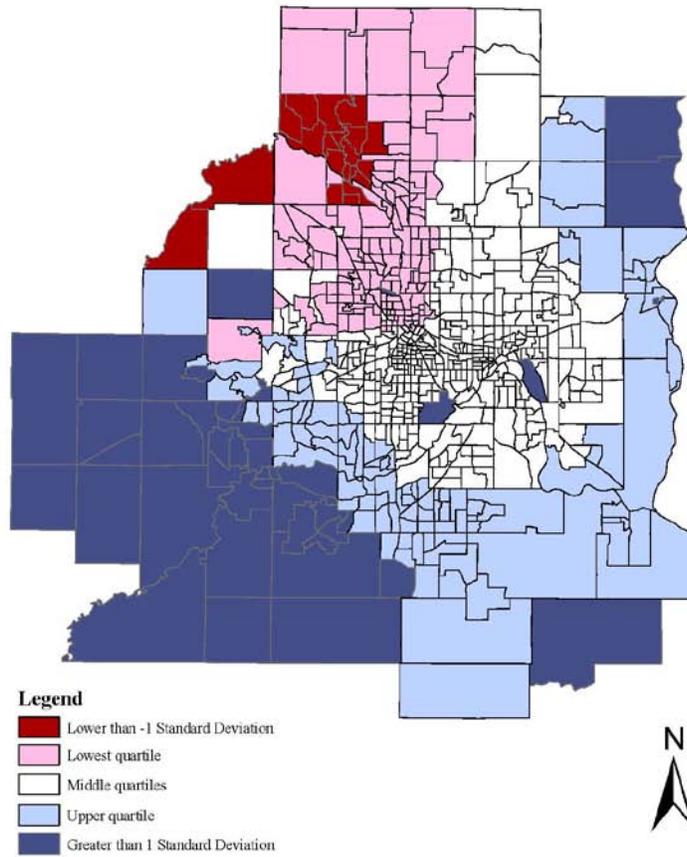Figure 3.2: Parameter estimates of working in central city on auto commute by quartile
and standard deviation, Twin Cities 1990

Legend
■ Lower than -1 Standard Deviation
■ Lowest quartile
□ Middle quartiles
■ Upper quartile
■ Greater than 1 Standard Deviation

Figures 3.3 and 3.4 show the parameter estimates from household

densities in each census tract for 1990 and 2000. What is striking about these

maps is that the effect of density is not as strong in 2000 as in 1990. Rather than

the surprisingly distributed density estimates in 1990, where the western (mostly

light and dark blue) part of the metro area was less likely to drive to work based

on density than the eastern (mostly light and dark red) part, the distribution in

2000 adheres much more to expectations. In 2000, the central part of the metro

area is light blue, suggesting that people here are more likely to not drive to

work. This effect is not evident in 1990. Also shown in 2000, as you move

towards the periphery of the region lower densities have a stronger effect on the

choice to drive to work as these households have few transportation options

available other than driving. These are areas not served by transit and spatially

separated from employment centers so walking or bicycling is difficult. One

phenomenon that is occurring but not reflected in the maps is that many of these

commute trips are suburb to suburb. In these cases the incentive to drive is

driven as much by the availability of cheap and easy parking as it is by available

transit service.

Figures 3.5 and 3.6 are shown to demonstrate parameters that do not vary

spatially. Here the income variable is used. What is clear from the two maps is

that the effect of income decreased to almost nothing between 1990 and 2000.

Where in 1990 (Figure 3.6) the central area of the region was less likely to drive

to work than the out parts of the region, the differences have all but disappeared

by 2000 (Figure 3.5). These results are consistent with the notion that driving to

work increased overall during the study period and the relative stationarity of the

parameters is expected. In this case, it is clear that there is little to no racial

differences in determining mode choice for commuting. This can be explained

not just through the overall increase in driving to work but also the increasing

racial heterogeneity of the region and increased spread of jobs away from the

central city.

Figure 3.3: Parameter estimates of household density on auto
commute by quartile and standard deviation, Twin Cities 2000

Legend

■ Lower than -1 Standard Deviation
■ Lowest quartile
□ Middle quartiles
■ Upper quartile
■ Greater than 1 Standard Deviation

N
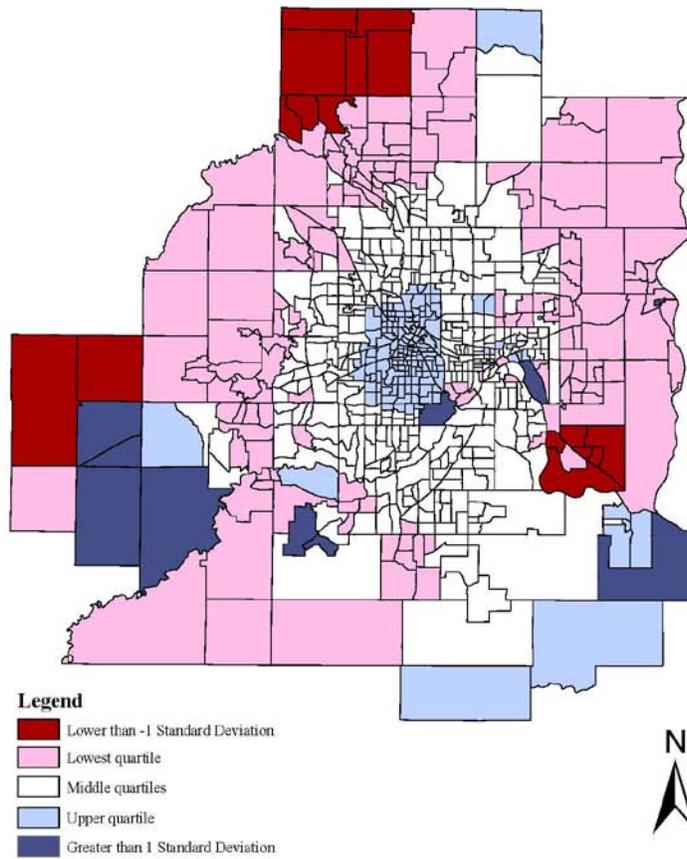
Figure 3.4: Parameter estimates of household density on auto commute
by quartile and standard deviation, Twin Cities 1990

Legend

- Lower than -1 Standard Deviation
- Lowest quartile
- Middle quartiles
- Upper quartile
- Greater than 1 Standard Deviation

N

Figure 3.5: Parameter estiamtes of percent white on auto commute
by quartile and standard deviation, Twin Cities 2000

Legend

- ■ Lower than -1 Standard Deviation
- ■ Lowest quartile
- □ Middle quartiles
- ■ Upper quartile
- ■ Greater than 1 Standard Deviation

N

Figure 3.6: Parameter estimates of percent white on auto commute
by quartile and standard deviation, Twin Cities 1990

Legend

- ■ Lower than -1 Standard Deviation
- ■ Lowest quartile
- □ Middle quartiles
- ■ Upper quartile
- ■ Greater than 1 Standard Deviation

N

The last two maps show the parameter estimates for long commutes determining commute choice to work. Here the increased complexity of travel choices is stark. The 1990 map (Figure 3.8) is recognizable as a monocentric city where the likelihood of driving increases with commute time. These effects are so pronounced they could be used as a textbook complementary example of how urban economics explains metropolitan structure. However, by 2000 the moderate effects were largely gone and pockets of long commutes determining mode choice are shown. The degree to which commute length is unrelated to mode choice in 2000 likely indicates increased decentralization of employment during the 1990s. The areas in red shown in Figure 3.7 are areas that are not well served by the Interstate system in the Twin Cities.

Geographically weighted regression offers an improved methodology to understanding travel behavior over conventional OLS regression models. The regression models discussed here reveal more subtle and localized differences in commute mode choice than conventional estimation techniques. In addition, GWR offers a better model than simply conducting a regression at each census tract and presenting those data. The GWR improvement is largely the result of the weighting function that accounts for neighboring effects. Catching the interactions with neighboring areas shows where the relationships are strongest relative to all other areas. If these maps depicted the estimates from 690 separate regressions (one for each tract in the study) rather than the GWR

estimates there would be no better understanding of the magnitude of the

parameters than from a conventional global model, and the estimates would be

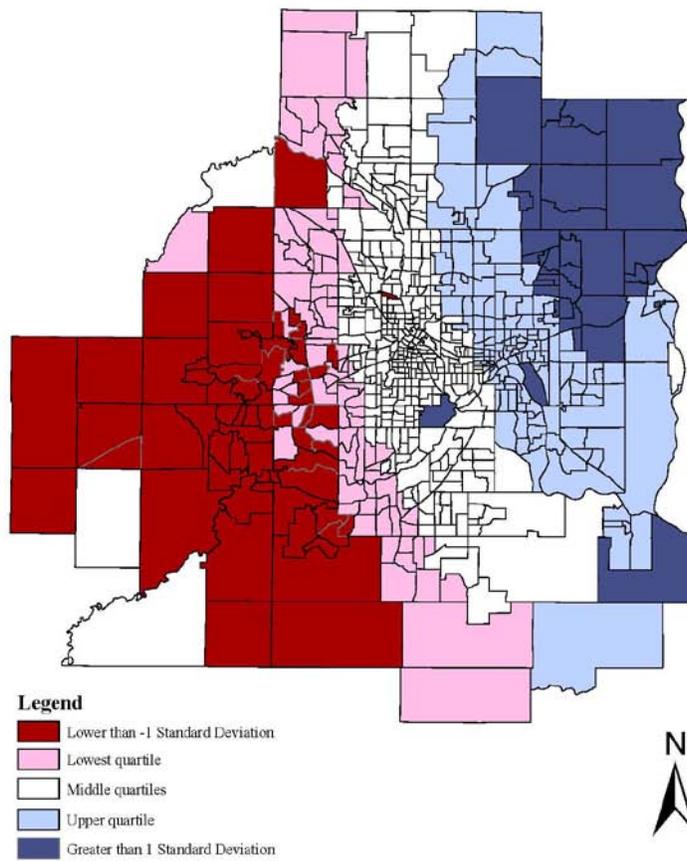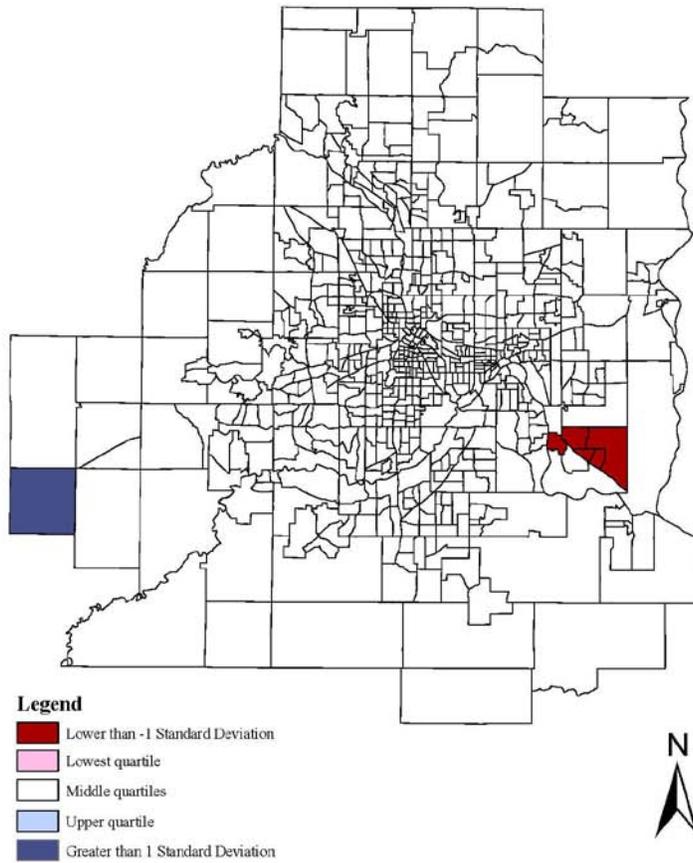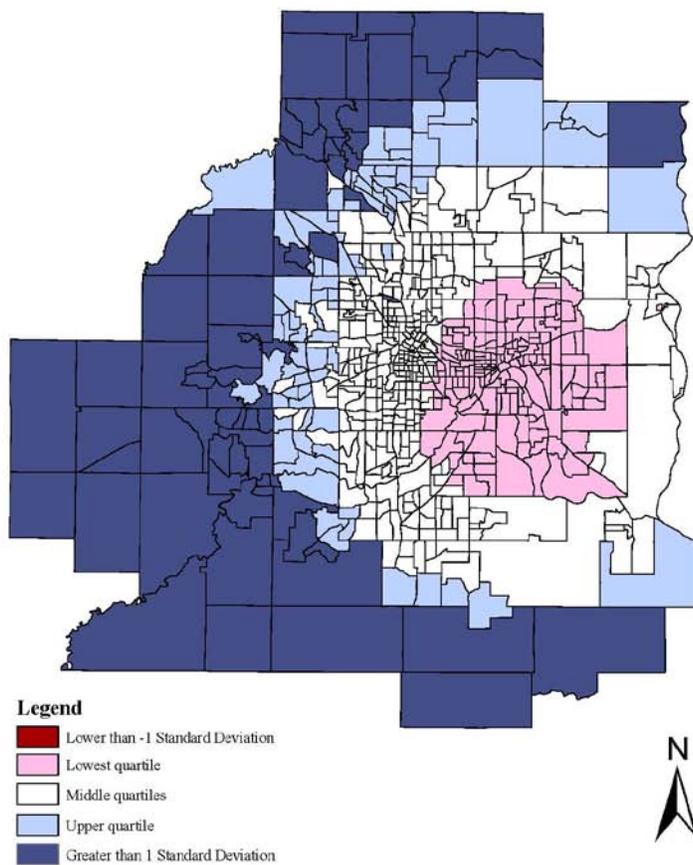plagued by MAUP and ecological fallacy. These issues are resolved through the

use of GWR.

Figure 3.7: Parameter estiamtes of long commute on auto commute
by quartile and standard deviation, Twin Cities 2000

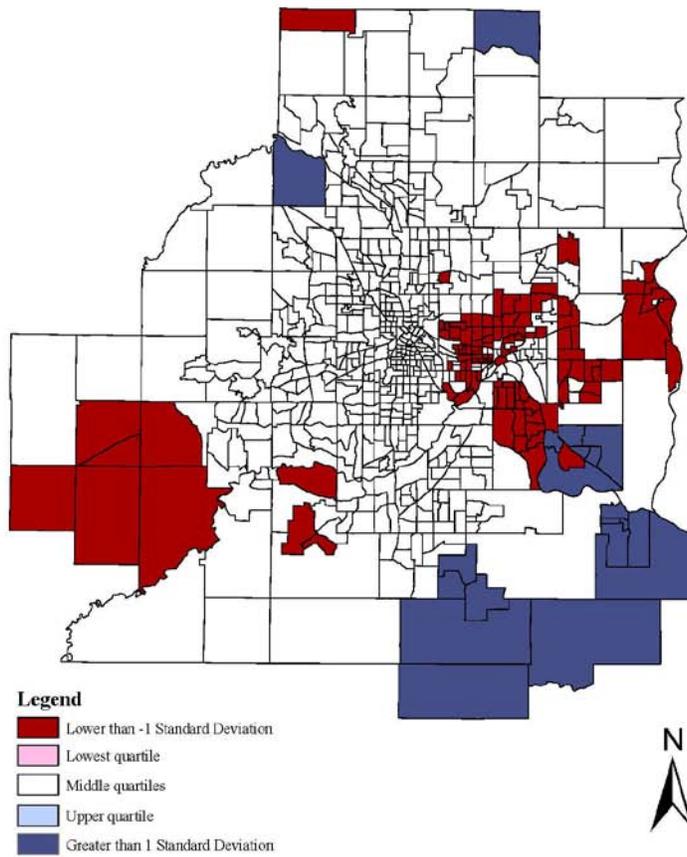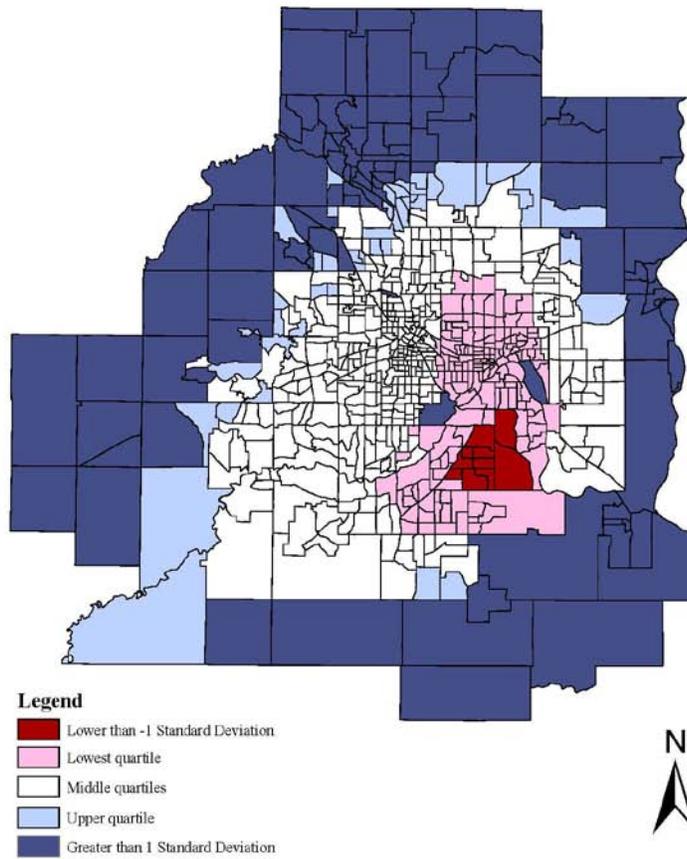Figure 3.8: Parameter estimates of long commute on auto commute
by quartile and standard deviation, Twin Cities 1990

Legend
- Lower than -1 Standard Deviation
- Lowest quartile
- Middle quartiles
- Upper quartile
- Greater than 1 Standard Deviation

N

3.11 *Discussion*

The analysis presented here confirms the hypotheses that auto use exhibits significant spatial variation controlling for socio-economic factors. This analysis extends this observation by demonstrating that there are some localized differences in the growth or decline of auto commuting rates. The 1990 maps clearly demonstrate greater monocentricity of metropolitan structure than shown in the maps using 2000 parameters. Housing and employment expansion during the 1990s helped diminish the dominance of downtown. These changes in commute patterns are partially explained by the facts that the city of Minneapolis gained some population in absolute terms during this decade while the share of regional employment located in the Minneapolis CBD declined from around 11 percent to about nine percent of the total. These results confirm the hypothesis that the spread of metropolitan areas is increasing the complexity of travel patterns. In addition, the spread of employment away from the CBD greatly complicates transit service enhancements as travel to and from the center is relatively less important. The largest gains from introducing new commute choices and price incentives on driving potentially will come from changing traveler's choices in the suburbs.

The spatial variability of commute mode choice has not been previously explored as an important issue within transportation planning. As densities,

employment locations and other factors change the available choices that individuals have for work travel transportation planners need to account for these localized effects. An improved understanding of local conditions and behaviors through GWR can inform the planning process and improve targeted investment in new facilities and services.

The use of GWR addresses the MAUP by adjusting the travel analysis to account for scale effects. As the GWR coefficients are an improvement to the OLS results, the exploration of spatial variation at a neighborhood scale improves the output of the model over municipal level analysis. Aggregated data is challenging for social scientists as it tends to smooth over differences that are important to the researcher. For instance, just about any desired outcome in correlation coefficients can be estimated by altering the scale of analysis. This was shown by Openshaw and Taylor in their work on voter behavior (1979).

The preferred solution to the MAUP is to perform analysis at the most disaggregated scale available through the data (Fotheringham and Wong 1991). This technique does not fully resolve the issue of sensitivity, but a theoretically sound research design can overcome sub-optimal data aggregation. In the case of travel choices, Census tracts are adequate theoretically and in practice. Tract level analysis is well established in the literature, and though there are limitations due to scale, tracts are generally considered adequate substitutes for neighborhoods. To help estimate what, if any, effect residential location

selection has on commute mode choice census tracts are potentially the best choice largely because the available data are standardized geographically.

3.12 *Conclusion*

These GWR results suggest that intracity differences in commuting choices are not explained by socio-economic factors alone. The influences of travel mode choice vary over space, and this suggests that there is a role for the built environment as an important piece of transportation decision making. The results showed here also call into question the accuracy of global regression models for modeling metropolitan commuting choices because of the spatial variation in transportation choices. GWR has the potential to greatly improve researchers' understanding of how people make travel choices and what types of built environments influence travel behavior.

This paper introduced GWR as a useful methodological tool for exploring the relationship between transportation and land use. Important future directions for research are to revise existing travel behavior analyses using GWR and other spatial extensions. Such research would greatly enhance our understanding of how space affects transport. More directly, the results here point to the need to explore census tracts for similarities that may be hidden within the spatial variations. Geographically weighted regression can be used as a powerful exploratory toll to delineate neighborhoods that exhibit similar travel choices.

This analysis presented here will be extended by tested the predictive power of GWR analysis for indentifying traditional neighborhoods with design features planners advocate for in order to reduce auto dependence. A metropolitan analysis should highlight specific communities where desirable features match the expected travel outcomes. Another extension is to further resolve the MAUP by weighting the zonal data with individual microdata in order to test the sensitivity of the spatial relationships, which is a technique suggested by Steel and Holt (Steel and Holt 1996). Individual level microdata, when available for the same phenomena studied with GWR though not necessarily from the same location, can be combined with aggregated data at a tract level to produce estimates of disaggregated phenomenon. Such an analysis is useful for estimating continuous variability across all space in the study area. These techniques may prove useful for exploring the self-selection bias of individuals into neighborhoods that match their travel preferences by tested for travel behavior outcomes at all locations rather than only locations where a specific outcome is expected.

Lastly, GWR is an analytic tool that accounts for problems associated with spatial auto-correlation (Fotheringham, Brunsdon, and Charlton 2002). This is a major advantage for GWR as a method for examining social behaviors that exhibit spatial variation. Conventional methods for addressing spatial autoregressive errors tend to underestimate the error terms of the regression

model, which is problematic for inferring the magnitude and direction of the relationship under study. Geographically weighted regression clarifies these relationships by modeling each error term as a spatial component. This allows for more accurate inference.

Geographically weighted regression is a novel addition to transportation research as a tool to examine urban structure, travel choices and potential land use implications. This essay used the technique to show that commute mode choice has spatial characteristics that are not apparent from conventional models. As transportation data is available at finer scales than previously considered, new techniques offer improvements in rigorous analysis, and GWR should be part of a researcher's toolkit.

4. Cruising for parking: the environmental and congestion effects of local transportation planning

4.1 *Abstract*

Previous essays in this dissertation explored how cities are integrating transportation and land use planning and the spatial variation of mode choice within metro areas. This essay looks at the phenomenon of cruising for parking as an example of localized transportation issues. Localized transportation policies are a required part of a larger bundle of planning efforts that complement and enhance regional, state and federal efforts. Economist Anthony Downs advocates for multiple solutions simultaneously, including localized efforts, as success by a hundred small cuts (Downs 2004).

In busy areas where curb spaces are underpriced drivers have a strong incentive to drive around searching for an empty parking spot. Such cruising behavior creates the perception of a parking shortage, but typically what seems to be a shortage is simply a misallocation of valuable resources, namely parking spaces. Unfortunately the effects of mispriced parking spaces are neither simple nor benign. Cruising for parking is excess travel that occurs only after drivers have reached their destination. This travel causes congestion, pollutes the air, diminishes pedestrian safety and wastes energy. Nearly all benefits from cheap curb parking are captured privately by the drivers at great costs to the public. This essay demonstrates a novel method for measuring cruising and estimates the environmental costs directly caused by cruising. This methodology validates

previous research and the results presented suggest that the private gains from cruising are dwarfed by the public costs.

4.2 *Introduction*

Transportation planning is undergoing a transition from a largely engineering exercise charged with improving traffic flows to a practice that includes environmental and land use concerns. The transportation sector is the second largest producer of carbon dioxide after electricity generation and the largest consumer of oil. Personal transportation is a substantial factor in overall pollution and energy consumption, and as journey to work trips have become a smaller share of overall travel discretionary travel creates a majority of the costs. A substantial portion of the costs from discretionary driving trips is cruising for cheap (or free) curb parking rather than parking off-street. The direct costs from cruising include congestion, air pollution, reduced pedestrian safety and wasted energy. Simply by eliminating cruising for parking many environmental and traffic improvements can be achieved.

Excess travel directly caused by mispriced curb spaces is an unintended consequence of misallocating a valuable resource. The misallocation is manifest in two ways. First, the demand for street spaces outstrips the available supply within a reasonable distance of drivers' destinations. Obviously, if drivers were willing to drive far enough away from their destination they would eventually find an available space. But drivers likely try to minimize their walking distance

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by limiting their cruising search to nearby blocks to where they ultimately want to go. Second, costly off-street spaces are often underutilized. Even though most off-street spaces in the United States are free (and required by local zoning codes), drivers still cruise for curb spaces. The result is that businesses pay for expensive and empty off-street parking while valuable yet underpriced street spaces have a queue waiting for turnover. This is a lose-lose situation.

Urban economists have recently begun to build models to explain cruising behavior (Arnott, Rave, and Schöb 2005; Calthrop, Proost, and van Dender 2000; Young 2000; Albert and Mahalel 2006; Button 2006; Shoup 2005). These studies are a welcome addition to an underserved literature. Many studies tend to reach the conclusion that cruising is inefficient and should be eliminated by minimizing the price differential between curb spaces and off-street spaces. Calthrop and Proost (2006) provide an example of this through their work. Their model suggests that the optimal meter charge is the marginal cost of increasing the off-street parking supply. This means that the optimal meter price is equal to the off-street price if the off-street supply exhibits constant returns to scale. This relationship between the prices of on-street and off-street parking is simple to grasp and potentially viable as public policy, but it isn't clear that the differential between curb and lot parking is the only factor affecting the choice to cruise. As noted in the previous paragraph, most off-street parking in the U.S. is free but underutilized. Drivers search for on-street

parking for a variety of reasons beyond price including perceived safety, lack of information about the off-street alternatives and proximity to their final destinations.

Local businesses and residents are often skeptical of raising the price of parking as they tend to view parking as a good in short supply rather than a good that is poorly allocated. This is not altogether wrong, but parking is only in short supply when the price is too low relative to demand. Fortunately these concerns can be satisfied and ultimately parking management can be used as a tool for local public finance. Greg Marsden (2006) reviewed previous studies of parking restraint policies and their effect on the economic vitality of communities. He finds that the available evidence does not reach a clear conclusion about the impact of parking restraint policies on local economic activity. He concedes that while this conclusion suggests that parking may not be as dominant a determinant for trip choices as previously assumed, the effect of parking prices on competition across retail districts may be underestimated and deserves further study.

David Hensher and Jenny King (2001) surveyed drivers in Sydney about their parking choices. Using a nested logit model to estimate price elasticities for various parking locations in and around the Central Business District (CBD), they found that there are certainly effects from price sensitivity; some drivers will switch parking locations or switch travel modes, but there was little

evidence to support the idea that fewer trips were taken into the CBD overall. Economic theory shows that as the price of travel goes up the amount of travel will decline, but perhaps parking charges can simply reduce wasteful travel rather than entire trips.

There are a few examples of communities using parking meter price increases to improve the safety and ambiance of a neighborhood. In Old Town Pasadena just east of Los Angeles parking meters were installed with the condition that the revenue collected would be used to fix and maintain clean sidewalks, plant trees and finance other local public goods. The program was an overwhelming success for the economic vitality and growth of the neighborhood, and Old Town Pasadena enjoyed the most robust sales tax growth of all commercial districts in the city (Shoup 2005). While in this instance meter revenue was used to improve the neighborhood, the low price of the meters and increased popularity of the area has likely led to an increase in cruising.

Other communities are pursuing parking policies that are designed to eliminate or greatly minimize cruising. Redwood City, California passed an ordinance that establishes an 85 percent occupancy rate as city policy. The city will measure traffic and raise or lower prices incrementally in order to maintain their desired rate. Washington, D.C. has established parking districts near their new baseball stadium, and San Francisco is exploring the idea of performance

parking. These examples are too young (or still in the exploration stage) to provide evidence of their effectiveness, but they do point to the universal problem of cruising for parking.

4.3 *Fiscal equivalence, Occam's Razor and efficient transportation planning*

Better management of on-street parking is a task that can help explain fiscal equivalence and governance efficiency. Mancur Olsen defined fiscal equivalence in terms of matching governance scale between those paying and those receiving benefits (Olson 1969). While Olsen did not make the case for fiscal equivalence in terms of minimizing externalities, in the case of local control over parking policy negative spillovers can be diminished and local services improved. A similar idea exists as "Occam's Razor," which states that "one should not increase, beyond what is necessary, the number of entities required to explain anything" (Wassermann 1997). While Occam's Razor refers to the parsimony of explanation and does not address money concerns specifically, the parallels between these two concepts illuminate the benefits of localized parking management.

Large cities such as Los Angeles feature complex bureaucracies that routinely mismanage tasks as seemingly mundane as parking policies. They do this to the detriment of the city and neighborhoods. One of the reasons that cities do not manage their parking systems to eliminate congestion and cruising is that parking meters and tickets tend to be revenue generators, and the monies

collected disappear into the mysterious city budgets. Niskanen argued that bureaucrats will work to expand their reach and power at the expense of efficiency (1971). This observation holds for local transportation agencies that manage parking, where the revenue generated from parking is substantial and the easiest way to increase collections is to increase enforcement rather than raise parking prices. Such increases in bureaucracy for parking management violate both fiscal equivalence and Occam's Razor.

The principles of fiscal equivalence are not met by the mismatch between the revenue collected from meters and enforcement to those paying and receiving benefits. In effect drivers feel cheated because they think they have to pay (however little) for an inferior good (in these cases too few cheap parking spaces). Local businesses feel their clients are being harassed by enforcement and there is nowhere for their clients to park. And the city feels no responsibility to use the money collected to improve the communities where it was generated. No entity feels that parking meter or collection revenue improves their well-being.

As cities centrally manage parking and use the revenues from meters and enforcement to finance general fund expenditures the match between those who pay for the services and those who receive the benefits diverge. Worse yet, the residents and businesses in the areas where parking is underpriced pay dearly through increased congestion, reduced safety, increased air and noise pollution

and the reduced attractiveness of the community because of a perceived parking shortage. In fact, the overall shortage is illusory, but there is certainly a shortage of extremely valuable, desirable and extremely cheap curb spaces.

Occam's Razor is relevant as central mismanagement of scarce parking resources increases the number of parties involved in trying to solve localized traffic problems and economic vitality. This results in a diluted power structure, which in turn leads to poor planning and decision making. This is similar to the anti-commons, where fragmented ownership causes gridlock. In the case of parking there is no gridlock except on the streets clogged with cars cruising around for an empty space. Curb parking is a good that can be easily managed at the neighborhood level. Once meters are purchased and installed there is little reason to expect benefits from economies of scale. In neighborhoods with active Business Improvement Districts (BIDs) or Home Owners Associations (HOAs) the potential for accountability and effective monitoring exists. By managing parking prices and enforcement at such small scales these microgovernments can raise revenue to improve their streetscape and economic vitality, reduce congestion from cruising and improve health and safety. These effects will have positive spillover to neighboring communities, yet these benefits are locked up in centralized bureaucracies and gridlock caused by too many claims on localized policies.

4.4 *Cruising and excess travel*

The existence of cruising is readily accepted; after all nearly everyone who has driven a car has cruised at some point. But the amount of travel and the environmental costs of cruising are much more difficult to quantify, which makes understanding the problems caused by cruising hard to explain. Donald Shoup collected the results of many earlier studies of cruising dating back to the 1920s (Shoup 2005). What he found was that cruising is pervasive regardless of the location of the study or the methodology used to collect the data. Table 4.1 is adapted from his work and it shows the share of traffic cruising and the amount of time spent cruising reported in each study.

There are two main points to take away from the previous studies of cruising. First, the share of traffic cruising varies widely, which partially reflects exogenous factors to the overall traffic flow such as overall car use and the popularity of the destinations in the study areas. Second, the durability of search times stands out. The average search times established in previous research falls between seven and eight minutes, which is about a minute longer than the median search time. Twelve of the 15 studies feature cruising times within one standard
deviation of the mean, suggesting that the average search times are bunched together and fall within the expected time it takes to circle a block.

The right hand column of table 1 shows the methodology used to collect the data for the studies. Nearly all studies used one of three methods to collect their data: personal observation, park-and-visit trips (by car or bicycle) or driver surveys. One survey tracked 800 vehicles with video equipment. The most popular data collection methods have both strengths and weaknesses, however, and will be discussed individually.

Table 4.1: Cruising studies and data collection methodologies

Year	City	Share of traffic cruising	Average search time	Data collection methodology
		%	(minutes)	
1927	Detroit	19		Personal observation
1927	Detroit	34		Personal observation
1933	Washington		8.0	Park-and-visit
1960	New Haven	17		Driver survey
1965	London		6.1	Park-and-visit
1965	London		3.5	Park-and-visit
1965	London		3.6	Park-and-visit
1977	Freiburg	74	6.0	Vehicle tracking
1984	Los Angeles		3.3	Park-and-visit
1984	Jerusalem		9.0	Driver survey
1985	Cambridge	30	11.5	Park-and-visit
1993	Cape Town		12.2	Driver survey
1993	New York	8	7.9	Driver survey
1993	New York		10.2	Driver survey
1993	New York		13.9	Driver survey
1997	San Fransisco		6.5	Personal observation
2001	Sydney		6.5	Driver survey
2007	Brooklyn	28		Driver survey
2007	Brooklyn	45		Driver survey
2008	Manhattan		3.8	Driver survey

Source: Shoup (2005), Transportation Alternatives (2008)

Park-and-visit strategies were the most common data collection method.
These approaches involve using a car or a bicycle in the traffic lane adjacent to
the parking lane to determine the distance traveled in order to find a parking
space. While using a bike for this task seems preferable to using a car because a
driver is unlikely to think that the cyclist is competing for a parking space, there
are limitations to this method. Bicycles affect traffic flow and driver behavior in

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ways that may not be apparent to the cyclist (Jia et al. 2008). These changes in driver behavior may alter the routes some drivers take to cruise for parking. If a driver is searching for parking and sees a cyclist turn right, the driver may be more inclined to continue straight, for instance. This introduces bias to the sample that would go undetected.

Using a car to cruise for parking introduces obvious bias in that the research vehicle will be seen as a potential competitor for a parking space. This certainly has the potential to alter other drivers' search behavior and may make it less likely that an actual cruiser would go down one street or another. These biases introduced into the sample are likely to cause over or under estimations of traffic flow and parking availability, thus affecting the overall estimates of cruising. Another limitation of park-and visit searches is the beginning of the search may bias the results by underreporting the actual amount of cruising. The 2008 study of the Upper West Side of Manhattan by Transportation Alternatives measured cruising distance from the front door of the final destination (2008). Their results do not capture whatever cruising occurred before the driver reached the destination. This raises a question of when does a cruiser become a cruiser. If the researchers for Transportation Alternatives had to travel an average of four-tenths of a mile to find a space after they have reached the front door, others who are heading to the Upper West Side for a visit may have started searching for parking (and changing their route accordingly) before they arrived.

In this instance the four-tenths of a mile is the lower bound estimate of distance cruising in the area. Any time spent cruising earlier must be added to this total.

Personal observations are also a popular method of collecting data, but observation bias poses a problem. The observers may miscount vehicles or, more likely, unable to observe the full extent of the road. Generally these observations are focused on the cars traveling around. The early studies in Detroit relied on counting how many times an individual car passed a checkpoint. Such a strategy focuses on vehicles, which is valuable, but the main question being explored in this research is what happens to the parking spaces. The behavior and travel patterns of the drivers searching are dependent on the condition of the existing spaces. For this reason it is a better strategy to collect data by observing the metered spaces themselves rather than individual cars.

Driver surveys allow for some additional data to be collected, but there are potential drawbacks to this method. One is a bias towards those who found a parking space and are willing to answer the survey. Such intercept surveys are valuable for gathering data while it is fresh in the respondents mind (unlike a conventional travel survey that asks an individual to recall all of their trips over the past day or week), but the results are certainly biased towards those who successfully parked. Without matching these survey results to traffic counts and parking events an incomplete picture of the problem is painted.

These methods used and described in the literature all provide useful insight into the enormous impact of cruising for parking. Yet each method carries its own bias and limitation, and importantly they tend to focus on the changes to drivers from a perceived lack of parking. This research presented here in a new study of Westwood Village improves on the previous methodologies by using video observation of a fixed set of parking spaces. This methodology promises an easier and quicker way to estimate the amount of traffic cruising for parking than previous approaches. Here the focus is how the spaces are used rather than the behavior of drivers. From the data collected estimates of how underpriced metered parking increases overall travel and cruising are presented.

4.5 *Case Selection*

Cruising for parking is a phenomenon that occurs anywhere people are looking for a place to park. The difficulty is deciding where to collect data on traffic and parking in order to draw generalizable conclusions about the overall impact of cruising. For this research Westwood Village was chosen as the study area because of the previous study of the village (Shoup 2005), the village's rich retail mix and the proximity to the UCLA campus (Figure 4.1). By returning to the location of a previous study, the durability of earlier cruising estimates can be calculated.

If cruising is measured along side streets where all traffic is local, the share of overall traffic that is cruising is likely to be overestimated. This is because such streets serve primarily those trips that originate or terminate at or near the street. The share of local traffic that is cruising is important to know, but this share needs to be considered in the context of overall travel. If only local trips are harmed by the congestion caused by cruising, for instance, the externalities of cruising are limited to that neighborhood. This internalization underestimates the total damage caused by cruising.

By measuring cruising on a thoroughfare that features both local and through traffic, the effects of cruising on those who are passing through can be considered. This is an important distinction for traffic flow and network effects to the system, which in turn have policy implications for governance and management of the meters. If traffic is impeded in a way that diminishes network performance outside of the commercial district where cruising is occurring, then the rationale for intervention includes a much broader coalition of political actors than if the congestion effects are limited to a local area.

The study area was a line of seven metered parking spaces mid-block on a busy street from mid-morning to mid-afternoon. Gayley Avenue is a street with a mix of small retail businesses including a coffee shop, copy store and independent sporting goods stores. In addition to the smaller retail establishments there is a Whole Foods grocery store with its own off-street

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parking on one side of the road. The overall mix of businesses attracts many

shoppers and offers a mix of quick service (such as the coffee shop) and longer

service (such as the sit down restaurants). In addition, there is ample

opportunity to combine trips by parking once. These characteristics suggest that

drivers will place a premium on convenience to their destinations.

Figure 4.1: Westwood Village
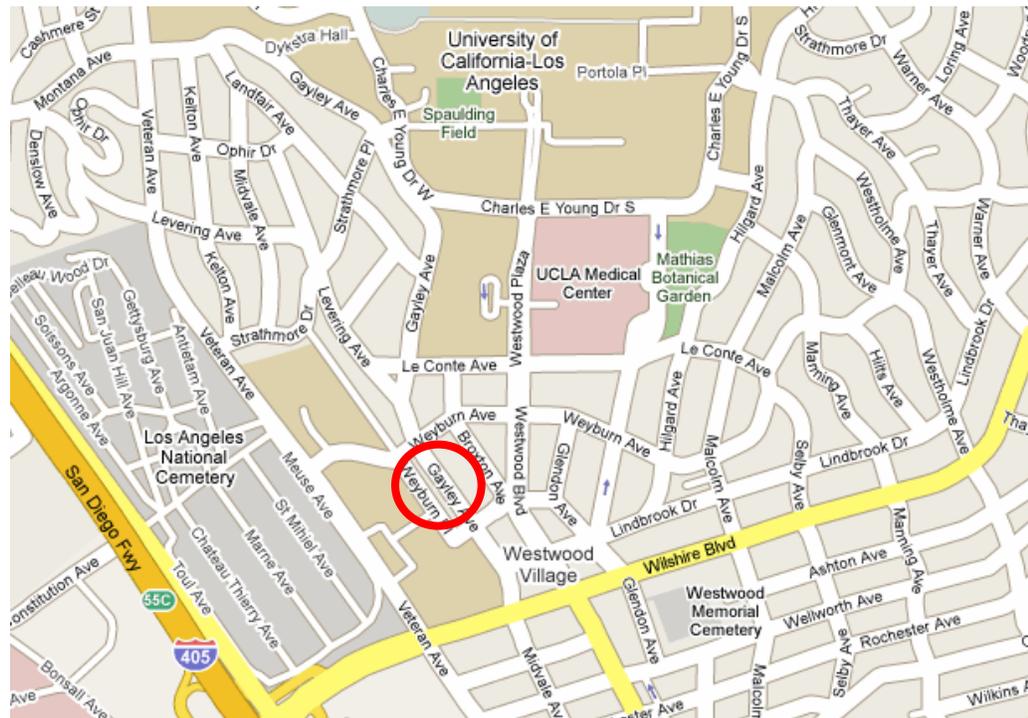
Source: Google Maps

The meter spaces cost $.50 per hour during the study period and were

enforced from 10 am until 6 pm. One block east of Gayley Avenue on Broxton

Avenue there is a municipal parking structure that offers two hours of free

parking. This structure is rarely if ever filled to capacity, and had ample empty

spaces on the study days. The availability of free parking with no cruising one

block from the observation point suggests that the price differential between

curb and off street spaces is not the primary incentive to cruise. Many of the

businesses along the study corridor also have limited parking in the alley

(generally a space or two). This available parking allows drivers searching for a

space an alternative to parking at a meter and should lead some drivers to

abandon their cruise before they find a curb space. Due to limitations of the data

collection these drivers are not counted, nor are the drivers who decide to forgo

their trip altogether because they could not find a parking space.

4.6 *Methodology*

To collect the data for this analysis, this research used a video camera to

record a row of seven mid-block parking spaces during mid-day hours over a

typical week. The study area selected was a section of Gayley Avenue that

features two traffic lanes and two parking lanes in each direction. The

advantage of counting traffic on a busy multilane road rather than a two lane

road is that the share of traffic cruising can be estimated as a share of total traffic

including those vehicles that are passing through the neighborhood. This allows

for some inference of the overall congestion effects of cruising for parking.

There are multiple advantages to fixed-location video observation over

participant cruising or personal observation. The most obvious advantage is that

the traffic data can be validated more easily than through participant

observation. Unlike personal observation, the video recordings are screened multiple times for different data and double checked for observation errors. This allows for a richer and more accurate data set. The other main advantage is the observations do not interfere in any way with traffic flow or cruising behavior. While researchers on bicycles are not necessarily competing with auto traffic for parking spaces, drivers do behave differently in the presence of bikes than they do otherwise. Video observation eliminates this endogeneity problem.

The video was analyzed by the following process. The spaces were recorded as full or empty at the beginning of the day at 9:30 am. This time was chosen to capture space occupancy before the meters were enforced at 10 am. At any time a space was vacated, the time of day was recorded and the amount of traffic that passed in each lane was counted. The traffic that was driving on the opposite side of the road was not counted.

Figures 4.2 through 4.5 are still images from the video recording. In Figure 4.2 all seven spaces are visible, and the second space is unoccupied. In order to use the space as a viable source of data the full space had to be visible and the make, model and color of the car had to be identifiable in the video. The still images lose a bit of the quality of the video image, but the cars are easily identifiable in all seven spaces. Figure 4.3 shows all seven spaces occupied, and a Mercedes at the bottom of the frame turning into the free parking attached to the Whole Foods grocery store.

In Figure 4.4, there is a silver Ford Escape waiting for a black Honda Accord to leave, and in Figure 4.5 the Ford is parked in the space that just emptied. This is a situation where the cruising affects traffic flow because the cruiser is blocking one lane of traffic rather than driving along. The way this situation was treated in the data collection was that once the Ford stopped in the traffic lane the traffic count passing through the study area was restarted. In other words, since the Ford was going to wait for the space in front of it to open, the space was treated as occupied an d the traffic count was restarted from the time the Ford stopped. If the Ford had decided to continue to cruise because the Honda driver was taking too long to leave, the traffic count was tallied as though the Ford had never stopped.

Figure 4.2: A view of the study area with an open space

Figure 4.3: A view from the study area with all spaces full

The data recorded for each parking event (defined as any time a car left or
arrived at a space) was the total traffic by lane, the time of day and the amount
of time the space was empty or occupied. From these data the average turnover,
traffic flow and cars driving past each empty space are determined. The share of
traffic cruising is assumed to be stable for each time period and throughout the
neighborhood. Estimating the share of traffic cruising was done by counting the
number of cars that drove past each available (empty) space until a car parked.
For instance, if a space was available and three cars drove past before the fourth

car took it, 25 percent of the traffic in the lane is assumed to be cruising. If nine

cars passed before the tenth took it, then ten percent of traffic is cruising. In this

way each parking space takes a sample of the traffic flow. Using this sampling

technique for the data, a Poisson process is used to estimate the likelihood of

any space being available at particular times.

Figure 4.4: Silver Ford Escape cruising for parking
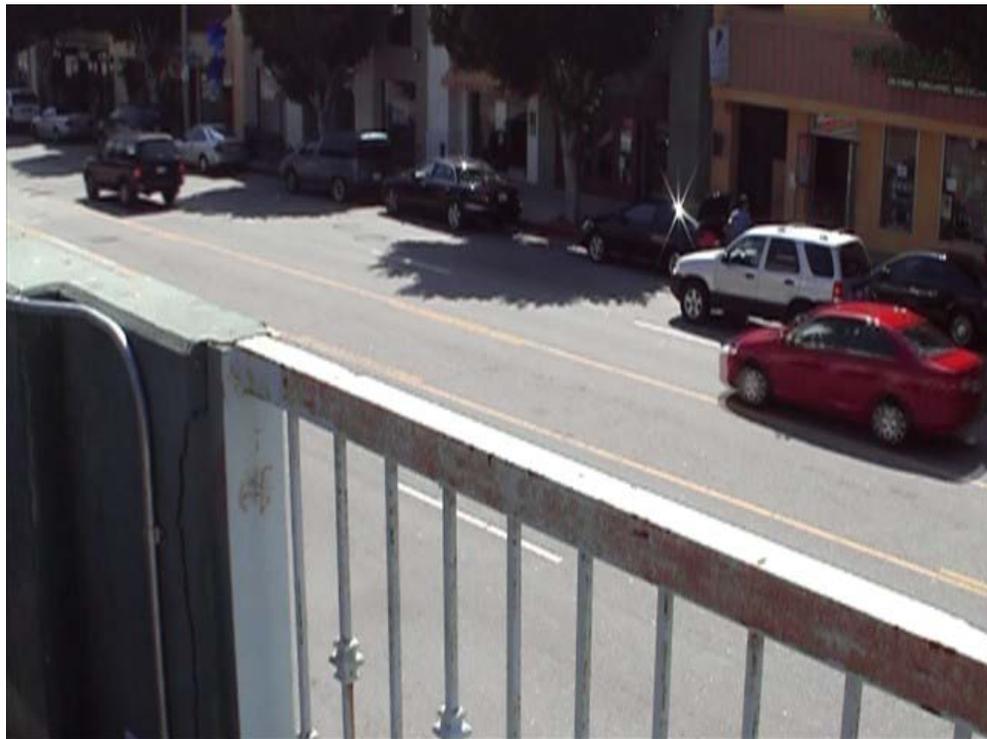

Table 4.2 shows the characteristics of cruising for mid-day parking

during a typical week in Westwood. The data were collected during the first

week of February, 2008. During all days the weather was clear and there were

no holidays, UCLA events or other factors that might unusually influence travel

in the Village. The totals for traffic and parking events are displayed by each

hour they were collected. The parking lane traffic was the traffic that was in the lane immediately adjacent to the line of parked cars. The data demonstrates that the share of traffic cruising increases based on time of day rather than of the amount of total traffic. Even though the turnover of spaces increased during the period 11am – 2pm and overall levels of traffic remained relatively flat, the share of traffic cruising increased from a low of slightly less than four percent to a high of about 20 percent. This means at the peak cruising period at lunchtime one of every five cars in the study area was cruising for parking, wasting time, energy and congesting the roads. Proper pricing at peak hours could reduce as much as 20 percent of the total vehicle travel.

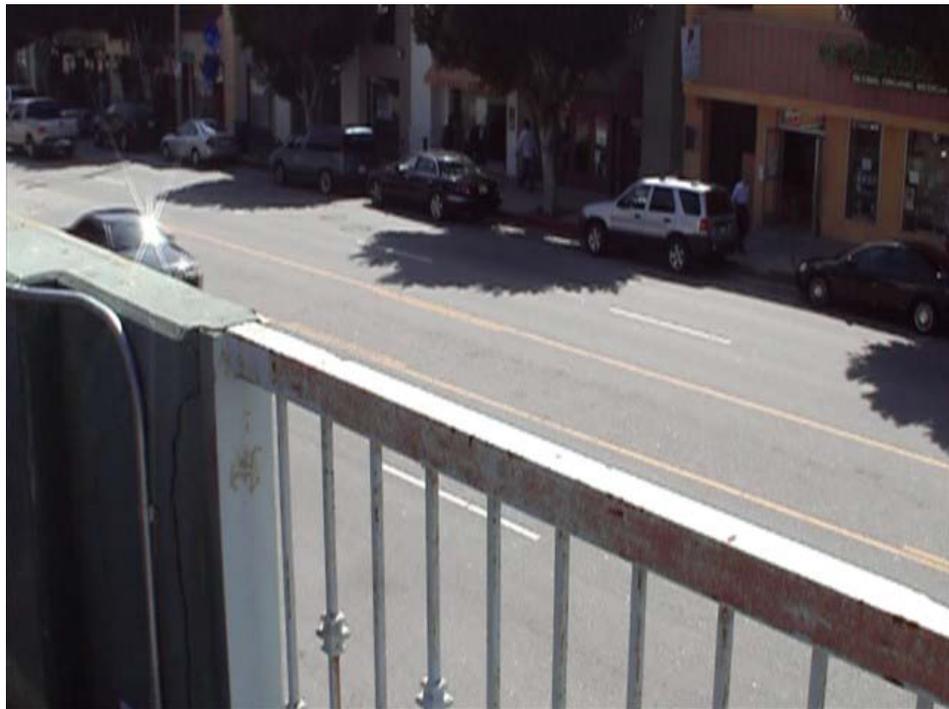Figure 4.5: Silver Ford Escape rewarded for cruising

Table 4.2: Mid-day curb parking in Westwood Village

	Total traffic	Parking events	Parking lane traffic	Average cars past available space	Share Cruising	Harmonic mean of cars past available spaces
Before 10am	983	10	273	27.3	3.7%	5.2
10am-11am	1605	16	278	17.4	5.8%	5.8
11am-12pm	1542	20	104	5.2	19.2%	1.9
12pm-1pm	1901	21	142	6.8	14.8%	1.9
1pm-2pm	1733	28	362	12.9	7.7%	2.0
Totals	7764	95	1159	12.2	8.2%	

Poisson processes are often used for traffic modeling and frequently taught using a "car-parking problem" (Lakshmikantham and Trigiante 2002; Bartlett 1974). Curb parking is a natural for a Poisson distribution because of the independence of each parking event. The availability of an open space is assumed independent of the availability of other spaces, as is the likelihood of a car approaching. Most importantly, space availability and cars cruising are independent of each other and all other available spaces or traffic. Another characteristic of the Poisson distribution that is meaningful for this analysis is that the mean of the phenomenon being estimated is equal to the variance. This feature allows probability estimates from individual occurrences (such as the availability of a parking space).

Lastly, a Poisson distribution is particularly well suited to fit the observed data because the time is not a major influence on the model. In

essence, each vacancy is randomly distributed and each space has an equal chance of being occupied at any given moment. As such, the traffic flow passing a vacant space is also randomly distributed and is sampled. Each vacancy collects data about all drivers who pass by since they either take the space and park or they don't. Though simple, this sampling technique conveys a great deal of information about the flow and intention of traffic and allows for conventional statistical analysis.

Useful estimates of the average time each space remains vacant with regard to traffic are challenging to calculate. While each the time each space remains vacant is a straightforward calculation, the traffic flow affected by stop lights and obstructions (including other cruisers). This means that the traffic flow passing vacant spaces is not randomly distributed over time or space. Rather, traffic is controlled by stoplights and the volumes vary by time of day among other exogenous factors. For instance, if a space opens up during peak cruising periods the first car is likely to take the space. The first car may be first in line at a stop light and by obeying the law will take two or three minutes to get to the space. Conversely, the first car may be driving through the intersection on a green light, and the empty space will be filled immediately. In both cases the first car took the space, and the traffic flow was the same. Yet the time the space was available differed widely. By only looking at the average time the space was available it seems that there This limits useable data

collected to the traffic sample passing by empty spaces, as previously noted, but the results can be generalized to the overall volume of traffic on the road.

The Poisson distribution was estimated from the conventional model (1).

$$f(k; \lambda) = \frac{\lambda^k e^{-\lambda}}{k!},$$ (1)

Where k is the number of occurrences of a parking event, in this case the probability that at least one of the observed spaces will be vacant at any time, and λ is the expected number of occurrences in an hour. This model is used to show the probability of a parking space being available in Westwood Village by using the data collected through observation. From these estimates the expected travel required to be assured of a parking space is calculated. The Poisson distribution compliments the expected travel estimated through observed cruising and suggest that this is a valid method for quickly determining the amount of traffic cruising in any given neighborhood.

The estimates from the Poisson calculations suggest that a car entering Westwood during a typical weekday would have less than a one percent probability of finding the first space they sought being vacant. These calculations can be extended to estimate the amount of travel caused by cruising. One feature of the Poisson analysis is that each space is estimated individually, so the occupancy of one parking space does not affect the potential occupancy of another space. In essence each space has an equal chance of being vacant. From these assumptions, the Poisson distribution predicts that a car will have to

travel around a maximum of 150 spaces in order to increase the chance of passing an empty space to 100 percent. Most drivers will have to cruise less to find a space, but 150 spaces is the upper bound of expected cruising distance. Some fortunate drivers will find a space right away, and some may actually end up cruising more than this. On average, however, if every driver that enters Westwood Village cruises until they find a street space they will pass about 150 spaces.

This sounds like an absurd amount of cruising, but it represents about four trips around a block that has 10 spaces per block face, which is not unusual. Assuming that circling a block covers about one-half mile, four trips around the block results in upwards of two miles of travel for each car to find a parking space. That's two extra miles for each car traveling to the area to park, which results in thousands of excess miles traveled each day. These amounts of cruising are consistent with the previous studies cited in Table 4.1, though the methodology is substantially different.

The Poisson estimates are a useful way to quickly analyze the amount of cruising, but they need to be validated as a robust technique. In order to accomplish this original data are used to estimate the share of traffic cruising through alternative techniques. Table 4.3 shows the probabilities of finding a vacant space and the associated time costs of cruising for each driver. The probability is shown in Column (1). The probability of an empty space being

available is calculated using the average amount of time each space is empty per hour. The results suggest that the probability of finding a vacant space quickly varies substantially during the day. This variance is related to more frequent turnover of spaces rather than marked changed in the total amount of traffic passing.

Table 4.3: Probabilities and time costs of cruising for parking per metered space

	Probability of empty space one first block	Times around block to be assured of space	Maximum estimated travel from cruising (miles)	Maximum estimated travel from cruising (minutes)	Time cost of cruising per vehicle
Before 10am	39%	2.6	1.17	3.18	$ 0.64
10am-11am	33%	3.3	1.52	4.13	$ 0.83
11am-12pm	29%	9.1	4.13	11.27	$ 2.25
12pm-1pm	22%	7.7	3.50	9.54	$ 1.91
1pm-2pm	2%	6.7	3.03	8.26	$ 1.65
Totals			13.3	36.4	$ 7.28

The noon hours are when cruising has the highest cost and the most excess travel is generated. Lunchtime errands and dining are certainly the leading reasons that this is the case. Returning to the data presented in Table 4.1, these hours (11am-1pm) also have the most turnover and the least amount of parking lane traffic, yet the rate of cruising is much higher than at other times. This strongly suggests that availability of parking spaces in not enough to diminish the amount of cruising. These hours have more opportunities for parking (about 20 spaces turnover per hour) and no discernable change in the total amount of traffic, yet cruising dramatically increases. An additional element of the data is that the amount of traffic in the parking lanes drops by

well over half. This drop in traffic in the lanes where cruising is likely to occur

points to congestion effects that cause drivers to shift away from their preferred

lane of traffic into one that has more cars total but fewer cars searching slowly

for a parking space. The end result is that the two lanes of traffic do not carry

equal numbers of vehicles, and the cruising lane operates substantially below

capacity.

The estimates daily time costs of cruising per hour for all parking spaces

in Westwood Village are shown in Table 4.4. These calculations assume that

cruising as a function of each parking space is evenly distributed across all

parking spaces in Westwood Village. These estimates were calculated using the

figures from Table 1and assuming they held constant for all meters in

Westwood, then the neighborhood wide cruising numbers were then multiplied

by the corresponding numbers in Table 4.3.

Table 4.4: Time costs for cruising in Westwood Village per day

	Totals for all traffic in Westwood (miles)	Totals for all traffic (hours)	Total time cost	
Before 10am	93	4.2	$	50.86
10am-11am	121	5.5	$	66.12
11am-12pm	331	15.0	$	180.32
12pm-1pm	280	12.7	$	152.57
1pm-2pm	242	11.0	$	132.23
Totals	1,067	48.5	$	582.10

Though the assumptions for all traffic in Westwood may not hold in all

cases, these results are useful for seeing the magnitude of the problems

associated with cruising. As Table 4.4 shows time wasted per meter, these amounts can be compared to the cost of each meter per hour. During peak cruising hours, the 470

$ .50 per hour meters cause over $150 per hour in wasted time spent looking for parking. Obviously if the price of parking was increased the demand curve would shift, so it is not correct to say that the price per meter per hour should be $150. Rather, as raising the meter rates will reduce the number of curb spaces more drivers will forego cruising and opt for off street parking. Sensitivity to this substitution is likely high in Westwood Village as there is a municipal parking structure that offers two hours of free parking. The structure is currently underused and was less than half filled on the days the cruising was observed.

4.7 *Discussion*

The rate of cruising for overall traffic was estimated for Westwood Village using observed traffic between 9:30 am and 2 pm along Gayley Aveune. These estimates confirm previous studies of cruising suggesting that not only is cruising a real phenomenon but there may be a natural limit to how long people are willing to cruise. Such a limit would conform with other research that has established the existence of a travel time budget (Zahavi 1978; Metz 2005). If cruising is included as part of the travel time budget for individuals, the elimination of cruising through higher meter prices may induce some drivers to actually drive to a farther destination rather than park off street since the travel

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time saved from not cruising would still be spent on driving. But many trips will continue to be made, just without the wasteful cruising once the driver has reached their destination.

The observed and estimated cruising present problems for the actual management of curb spaces. It is not enough to simply raise the cost of curb spaces and forget about it. Nor is it adequate to base dynamic pricing on the flow of traffic on the roads. As the data shows, cruising is largely independent of the amount of traffic. The amount of cruising results more from the activities in the area. Because of these temporal differences any pricing program that adjusts the price of parking to achieve an 85 percent occupancy rate will be inefficient if the price is not adjusted by time of day (there were also differences observed by day of week but those were much smaller than the differences by hour). If the price is set to work best at lunch time it may discourage trips at times when there is less demand for parking. Conversely if the price is set to manage demand in the middle of the afternoon it will be too low to send the proper signals to drivers at lunchtime.

The impact of dynamic pricing on drivers' decisions to make the trip at all is not well understood in the literature. Some authors suggest that a lack of information about the cost of parking may diminish the overall attractiveness of the area as drivers worry that it will cost them a week's salary to park. There are many services attempting to address these concerns by offering online

information about the cost and availability of parking spaces, often sent directly to a cell phone in real time. More likely, however, is that dynamic pricing will encourage travelers by guaranteeing that they will always have a place to park very close to where they want to go. This has been suggested by Shoup (2005) and others.

Due to decades of enforcing minimum parking requirements, most areas have lots of off-street parking available. These spaces should be used more effectively by renting the spaces to drivers who are priced off of the street by higher curb prices. Ideally, off-street parking facilities will shift towards drivers who are staying longer in the area. Street spaces will be used mostly by short term parkers. This arrangement is consistent with gaining the support of local businesses. Those businesses that depend on many small sales, such as a coffee shop or take out restaurant, stand to benefit most from high meters prices because their customers will always be able to park nearby.

To gain political support for dynamic meter pricing, the revenue can be used to fund the local Business Improvement District (BID) or, in a residential community near a commercial center, fund a local Homeowners Association, repair sidewalks, provide security or other services. Such strategies can legitimize a potentially unpopular shift towards dynamic pricing for parking meters. Most drivers who park away from home traveled from a separate neighborhood to get to their destination. These drivers are voters and potential

opponents to any type of parking reform. By introducing parking reform at a city rather than neighborhood scale, planners and officials are opening up the process to rent seeking (Shoup 2005) or diluting the policies due to political compromise, which is seen in efforts to install congestion pricing (Isaksson and Richardson 2008) or ramp meters (Levinson and Zhang 2006). Rent seeking and compromised policies are the expected results of transportation pricing where the benefits are ambiguous. Limiting parking meter pricing management to local areas preserves the benefits to those who will notice and care, such as the use of revenue to enhance the pedestrian experience or less congestion on the roads.

If alternatives to driving are inadequate, there remains the possibility that overall traffic to the area will decrease. For example, in central London retail business declined about eight percent after the cordon charge was installed in 2003 (Quddus, Carmel, and Bell 2007). While eight percent is substantial, the auto traffic declined over twenty percent. This suggests that most of the travel that was removed from the roads due to the tolls was simply displaced to other modes. In addition, the London study placed a high weight on sales from large department stores. Larger stores are more dependent on shoppers from a larger area than smaller stores are. It is likely that dynamic meter pricing will help preserve or create a "Main Street" feel of small shops that cater to a local population.

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Other external effects from cruising include air and noise pollution. The stop and go trolling for a parking space is especially inefficient for engines and creates tremendous amounts of carbon monoxide (CO) and particulate matter that hangs in the air. Researchers measured emissions in an urban parking garage and found estimated that for every one percent increase in vehicles there is about a .3% increase in CO emissions. Even worse for the pedestrian air quality is every one percent increase in vehicles increase polycyclic aromatic hydrocarbons (pPAH) just over one percent (Kim, Dominici, and Buckley 2007). These personal health risks are in addition to the wasted fuel, road wear and other environmental concerns. While much of the pollution can be eliminated by shifting to cleaner cars, cruising traffic will always pose safety concerns and congest the roads.

The availability of free off-street parking one block away from the study block suggests that the price differential between curb spaces and off-streets spaces is not the primary factor in deciding to cruise, as is theorized by Calthrop and Proost (2006). In the case of Westwood off-street spaces were cheaper and would save time. To remedy cruising the price of curb meters should be set to match the price of off-street parking plus the monetary value of the premium travelers place on street spaces. The premium value of curb spaces has not been explored and deserves further study. Business owners allude to the value of spaces immediately outside of their doors even though the spaces are rarely

vacant due to underpricing. If there is an unmeasured premium on proximity, the market clearing price of curb spaces may be substantially higher than off-street spaces. A positive feedback loop would occur where demand for curb spaces would increase because spaces are always available exactly where people want to go. Thus the optimal price of curb parking would greatly exceed the cost of off-street spaces because of an increase in the premium for proximity.   It is unlikely that the optimal price could be adequately modeled in advance as it would depend on the time of day, weather conditions, day of week and time of year, plus other exogenous factors such as the overall state of the economy. However, existing but not installed meter technology is capable of adjusting meter rates quickly to reflect demand, and additional technology can be used to alert drivers to the costs of parking via cell phone or email.

4.8 *Conclusion*

Cruising for parking is a behavior that congests traffic, reduces safety, wastes energy and pollutes the air. These negative outcomes are correctable by getting the pricing of curb meters right. Properly priced curb spaces accomplish many planning goals. First, market priced meter pricing minimizes congestion and excess travel. This outcome alone should be enough to garner support for high meter prices. Second, eliminating or flipping the price differential between curb and off street parking will create vacant spaces at the locations where they are most demanded. By having spaces available where drivers want to park

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commercial areas will likely become more vital even though the price of each

space is higher. The Westwood data shows that the parking spaces turn over

many times per hour, so even a dramatic increase in hourly parking rate will

only have a nominal effect on each driver. However, visitors to the area will

notice that there are always parking spaces available making it more likely that

they will travel there in the future. Of course the higher cost of parking should

discourage some trips all together, but parking is a small part of the overall cost

of driving. This is especially true when the activities are quick and frequent

such as stopping for a coffee or quick lunch.

One other direct benefit from increased parking rates is increased

parking meter revenue. This revenue can be used for improving the streetscape

by repairing sidewalks, planting trees or providing security. This was

successfully accomplished in Pasadena, California (Shoup 2005). But the use of

the revenue is also the key to gaining support for better parking management.

Most parking meter revenue goes into a city's general fund. In these situations

no one has any incentive to maximize the revenue or manage parking. The

bureaucratic response is for individual agencies to maximize their share of the

general revenues regardless of where they came from (Niskanen 1971). This

fails to incentivize any type of parking management within government and

reduces any interest in managing curb parking in the private sector. After all,

why would a business owner want to see parking charges raised if they don't

know where the money is going? At least when the meters are cheap the business perceives a benefit for their customers. Plus, when transportation planners see traffic congestion business owners see busy streets filled with potential clients. Never mind what they really see is just the same few clients circling around the block.

Resolving the problems of support for pricing curb parking will not be easy, but the benefits of smart pricing far outweigh the costs. Using the estimates provided here and previous studies, a strong argument can be made that cruising for parking is the single most wasteful part of personal transportation. Twenty percent or more of traffic is simply driving around after they have reached their destination! Considering that a typical urban car trip is less than five miles one way, a mile of cruising for parking represents about 20 percent of the total trip, as well. This behavior is not limited to Westwood, and there are certainly many areas where cruising is even worse. But wise communities, cities and neighborhoods can have the largest impact on overall urban travel compared with state, regional or federal projects simply by managing their parking supply.

5.   Conclusion: tying it all together

The notion that transportation is a local issue challenges conventional thinking about transportation. Economist Edward Glaeser (2007) argues that transportation and land use policies are better suited for regional governance jurisdictions have incentives to promote exclusionary policies that push undesirable development and traffic on their neighbors. While I agree that there are potential problems with exclusionary policies, I disagree that this points to a natural fit for regional governance. In particular, Glaeser does not differentiate between capital outlays to build new infrastructure and managing the existing system. The difference between construction and management is important for policy. For instance, many new local streets are built as private controlled access roadways as local governments require homeowners associations and planned communities to supply many of their own public services (Nelson 2005). In these communities the benefits of the roads are internalized without new costs to those outside the community. More generally, mature cities with built-out infrastructure and land uses are not going to build much new infrastructure because of political, financial and spatial constraints. Rather they are going to turn towards managing the roads that already exist. Such management is improvement by local knowledge.

One of the ways that local knowledge is critical for transportation management is that cities and neighborhoods can function as a laboratory of

techniques and mechanisms to solve problems. The essays in this dissertation point to the appropriateness of many policies. Returning to Anthony Downs' argument, transportation and land use systems can be improved by many small policies (or 'cuts' in his vernacular). There is no reason to believe, however, that a diverse collection of small scale polices cannot be implemented locally in order to achieve regional benefits.

Chapter 2 explored how cities are often ahead of regional planning with regard to many transportation issues. The analysis of planning documents demonstrates that many cities are planning for accessibility and environmental improvements above what is required by state or metropolitan mandates. This is a particularly interesting finding as the states and regions studied have a strong culture of planning. California has been a leader of environmentalism and the Twin Cities has seen the mission of the Metropolitan Council grow in the four decades since its creation from an institution in charge of sewers to one that actively manages metropolitan growth. Yet many cities in these study areas still used language and proposed action in excess of what the state or region requires. These cities view transportation as a quality-of-life issue that impacts their economy, environment and desirability. These efforts should be commended, but unfortunately most of the proposed planning goals ignore parking management.

Geographically weighted regression was used in chapter 3 to validate GWR as a useful methodology and to explore the spatial variation of commute mode choices. The variation of mode choice for commuting within metropolitan regions controlling for socio-economic factors is an important addition to our understanding of how people make travel choices. The methodological contributions suggest a way for planners to identify hot spots that deserve special policy consideration. More targeted transportation policies that account for local variations have the potential to improve the efficiency of transport infrastructure and investment.

Cruising for parking is an example of a lousy outcome due to mismatched incentives. Underpriced curb parking was shown to have a dramatic impact on excess travel, leading to polluted air, excess noise, reduced safety and wasted fuel. Drivers who cruise are simply acting rationally in response to price signals, but the individually rational action has substantial collective costs. Cities also face skewed incentives when it comes to managing curb parking through prices. Currently, most meter revenue goes into cities' general fund, where there is very little accountability for the meter revenue. Because parking is such a contentious issue, city officials are happy to maintain the status quo of cheap parking, which is a position that local businesses all too often support. Parking reform is unlikely to occur without more transparency of where the meter revenue is spent, and the money should be used in the community where it

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was generated in order to gain political support and fund valued community investments.

Ultimately, city regions are complex systems that are difficult to manage and no one type of governance or transportation policy will be adequate to address the environmental, social and accessibility problems that they face. Changing travel behavior and outcomes is extremely difficult through crude regulatory approaches, such as odd-numbered driving days or designating new one-way streets. Heavy handed regulations are likely to engender resentment and populist opposition plus they can result in inequitable outcomes and reduce accessibility for those who need it most.

An alternative to regulations is using prices to manage demand. Pricing transportation facilities as though they are scarce resources (which they are) is important, and some of the revenue generated can help mitigate some inequities through subsidies or lifeline payments. But to overcome the political obstacles to new transportation fees, the revenue needs to be used in a way that generates support. Getting the scale right for policy interventions is one way to focus the costs and benefits of new policies. City leaders are responsive to their constituents, and policies should be tailored to consider the intended outcomes of the intervention, such as reduced congestion, but also reflect the political realities of scale and scope for governmental interest. Accounting for localized

in transportation and land use systems helps move planning towards more

flexible and responsive systems and networks.

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