A COMPREHENSIVE APPROACH TO MODELING

TRANSIT-BASED ACCESSIBILITY

THESIS

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Jessica N. Mefford, B.S.

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CHAPTER I

INTRODUCTION

The twentieth century witnessed the beginning of a new age of modern transportation; no longer was mass transportation the primary means of travel in and around metropolitan areas (Yago 1983). Prior to the mid-twentieth century, urban development favored cohesive communities joined by mass transit networks, where individuals could move freely, and journeys to work, recreation, and shopping were of human-scale proportions (Cervero 1998). The proliferation of the automobile in the mid-twentieth century United States spurred an age of low-density development, aptly termed *sprawl*, whereby intraurban travel began to take on new patterns of longer, more frequent trips. The decreasing price of automobiles through assembly-line mass production early in the twentieth century soon made them a common feature in the American household after World War I. Eventually the private automobile, rather than mass transit became the mode of choice for the American public, and in the last quarter of the twentieth century, suburb-to-suburb replaced suburb-to-city center as the predominant flow of intraurban trips (Pas 1995). This structural transition was accompanied by a new suite of problems, largely precipitated by the use of private automobiles. In the 1970s, increasing energy prices and a growing awareness of the insufficiency of domestic petroleum resources (see Kain and Fauth 1977) captured the interest of policymakers seeking ways of decreasing air pollution and dependence on foreign petroleum resources. Automobile ownership, particularly in low density suburbs, quickly emerged as a major source of excessive vehicle emissions that contributed to growing air quality problems as well as increased energy consumption.

In addition to environmental costs, high incidence of automobile ownership also produces significant social costs. Low-density development and private automobile use negatively impacts quality of life. Time spent traveling from low-density suburbs has been estimated as being as much as twice the time spent traveling by those living in high-density areas (Kain and Fauth 1977). Excessive time spent traveling robs individuals of time spent enjoying other activities, which has implications for personal development. Recent work has attempted to quantify the amount of commuting that occurs in excess of what existing urban structure mandates; the additional time spent commuting is labeled *excess commuting* (Horner 2002).

These and other problems brought on by automobile dependence hinder societal goals of sustainability (Hanson 1995). At its most basic level, sustainability mandates that any economic or social development should improve, at least not harm, the environment (Newman and Kenworthy 1996). Numerous researchers have explored the relationship between transportation and sustainability, and many have concluded that decreased dependence on private auto as the primary mode of travel is perhaps the only way to effectively mitigate the negative impacts produced by automobile use (Campbell 1996; Bernick and Cervero 1997; Kain and Fauth 1977; Murray 2001).

Mass transit is potentially an option for reducing urban congestion; however transit is frequently not a competitive means of travel. Numerous conflicting objectives including diversion of funding sources to new road and highway development, and low-density development have made public transportation often difficult to use; the result is low transit utilization; associated problems include decreased quality of life, air pollution, congestion, and limited mobility (Newman and Kenworthy 1996).

The success of transit systems as efficient modes of transportation for their patrons is determined largely by the *accessibility* of that system. Accessibility is a term used to describe the ease with which certain activities can be reached from a particular location using the transportation system (Handy and Niemeier 1997; Kwan 1999; O'Sullivan, Morrison, and Shearer 2000). An accessible transportation system achieves the objective of transporting individuals to their desired destination in an *efficient* manner. To capture efficiency, transportation accessibility is thus determined by a spatial perspective, incorporating the spatial distribution of destinations, their desirability, and the ease with which individuals can reach those destinations (Hanson 1995; Handy and Niemeier 1997).

Measures of accessibility often involve travel cost and attributes of destinations (Handy and Niemeier 1997), which are characterized by their attractiveness, frequently represented as the total number of destinations of a given type, such as those offering employment opportunities. Accessibility to retail locations is one common example where measures of attractiveness might include total retail floor space or retail employment (Hanson 1995). Perhaps the most conventional destination type used in accessibility measures is employment. Some have explored the relationship between accessibility and journeys to work, or commutes (Levinson 1998), as commutes are one of the most basic forms of travel (Hanson 1995). All types of accessibility measures typically characterize destinations by attributes designed to meet the objectives of that which is being measured (Handy and Niemeier 1997). Examples of destination characteristics might include total employment, total residences, or retail floor space.

Few studies exploring the accessibility of mass transit systems from a spatial perspective effectively consider one very important aspect of transit accessibility. This neglected facet of accessibility is the transit planning process, which ultimately shapes the accessibility of a transit system. Most empirical research addressing mass transit planning emphasizes the spatial arrangement of transit services (O'Sullivan, Morrison, and Shearer 2000; Murray 2001; Murray and Wu 2003). Such studies adequately address the physical accessibility of transportation systems; however this approach is not wholly successful in *explaining* spatial patterns of accessibility. The concept of accessibility encompasses both the ability of individuals to move to their desired destinations, and the perceived effectiveness of that transportation system, as interpreted by its users (Murray 2001). These perceptions encompass social issues including race, gender, and socioeconomic status. As such, existing spatial research neglects the *institutional perceptions* associated with the accessibility of transportation systems.

Social Equity

Regarding how institutions perceive their public, a discussion of *social equity* and its relationship to transportation is necessary (Yago 1983). Social equity, in the context of transportation, describes the relationships among people and transportation (Cervero 1998). This is an extremely important value for estimating the success of transportation systems. Individuals traditionally characterized by social exclusion, including the poor, the elderly, and single mothers (Miller 2004) frequently do not have access to private automobiles, and thus face being effectively being cut off from society, unable to reach employment, health care, and other activities vital to economic and personal well-being.

To promote social equity in transportation, there is a need to extend the current body of knowledge regarding how transportation systems and transit systems in particular, serve specific social groups. Comparing the accessibility provided between different social groups is useful in detecting disparities in transportation service provision. To this end, the objective of the present study is to explore multiple dimensions of accessibility across social groups, including planning institution perceptions and disparities in service across the same service area. This will provide a more comprehensive view of accessibility, incorporating *spatial* and *social* perspectives of accessibility.

CHAPTER II

STATEMENT OF THE PROBLEM

Purpose

As the nature of mobility in urban environs changes, so must the questions asked by geographers and other spatial scientists. Among these questions, issues of accessibility and equity merit further exploration. Changes that affect the manner in which transportation systems serve the public must be scrutinized to ensure that such developments are not serving only certain groups, at the cost of marginalizing others. Further, mass transit in particular should continue to be at the forefront of transportation research. Even as transit ridership decreases, its importance is perhaps increasing as society continues to become aware of the negative implications of alternative modes of transportation.

Accessibility largely determines transit patronage; only if accessibility provision is maximized, will transit then be utilized more fully. The central purpose of this work is to further our understanding of transit accessibility, how it is related to social groups, and how institutional perceptions shape accessibility.

Significance of Study

This study contributes to the existing body of research that addresses accessibility, mass transit, and social equity. Some of the planned contributions are methodological; others are substantive. From a methodological standpoint, this study is significant because it incorporates multiple perspectives of the same issue; transit accessibility via spatial analysis and qualitative methods. The use of mixed research methods is valuable because it allows greater breadth in the research questions, including some questions that could not be answered using only one method. A qualitative analysis of transit planning does not capture information on transit patronage levels, or even demographics of transit users; instead qualitative methods allow the researcher to glean information regarding the "conflicts beneath the surface" (Hay 2000), that otherwise go undetected.

Regarding the modeling approach, accessibility, as it is explored in this study, is stratified across several social groups. In spite of the availability of data sets that facilitate the exploration of accessibility across social groups, this has rarely been undertaken. Instead, most existing accessibility analyses focus on only one or two attributes, such as gender (Kwan 199). Recently, the incorporation of multiple axis of dissimilarity was identified as an important area of accessibility research that needs to be addressed (Kwan, Murray, O'Kelly, and Tiefelsdorf 2003); this work attempts to address that need.

Substantively, this study explores specific aspects of transit accessibility that largely determine both ridership levels and the provision of mobility to potentially disadvantaged social groups. The potential exists to deny certain groups accessibility by virtue of their lack of financial resources, public involvement, or minority status, and as a result inhibit their economic and social vitality. To ensure that accessibility is adequate for all social groups, especially to critical activities such as employment, research that explores the relationships between transportation systems and their users is sorely needed.

Theoretical Framework

Mass transit planning, although it occurs at many different levels, each with its own suite of objectives, ultimately determines the placement of transit routes and their associated stops (Gray and Hoel 1979). Transit planners make decisions governing transit service in consideration of the *perceived* geographic and socioeconomic characteristics of service areas. Studies that explore accessibility should not neglect this vital element of transit service provision. A more comprehensive understanding of the perceptions and policies underlying the transit planning process would assist in developing a framework for interpreting the results of *spatial* analyses of transit accessibility. To explore these perceptions which are manifested in transit planning institutions, we should incorporate a sociological perspective.

This study seeks to add an additional layer of interpretation to spatial patterns of accessibility by incorporating a quantitative model of transit accessibility with a qualitative assessment of transit service provision from the perspective of transit planners. The following sections introduce multiple approaches used to arrive at a more comprehensive view of accessibility. The existing literature which has identified several means of characterizing accessibility, will be reviewed in the next chapter; however, much of that work neglects to *explain* spatial patterns of accessibility. The present effort incorporates a qualitative analysis to address that void.

The existing qualitative literature establishes a definitive role for qualitative research in transportation. The theories and questions described in the following empirical examples, as well as others, serve as a framework for designing the qualitative portion of this study, and interpreting those results. This study incorporates a *triangulation* of methods, using a qualitative analysis of transit planning to interpret results from a spatial analysis of transit accessibility (Gaber and Gaber 1999; Gaber and Gaber 2002; Simmonds, Bierhanzl, Campbell, and Queeley 2003). Triangulation involves the incorporation of multiple research methods, designed to offer different, yet complementary views, of the same topic. Results of one method are typically compared to results of another method to facilitate interpretation. The triangulation of multiple research methods is occurring more frequently in many disciplines; Geography is not an exception. Research using mixed methods can address questions that only one research method could not fully answer.

The objective of the qualitative portion of this study is to explain accessibility patterns by gaining a holistic perspective of the influence of the perceptions of individual transit planners on transit service. To generate this perspective, in-depth interviews with transit planners and communications specialists are the chosen means of data collection. Interviews are a fundamental method of collecting sociological data; they allow the researcher to interact directly with the subject, which facilitates more extensive investigations of the research questions than some other methods, such as a survey, could offer (England 1993).

At the onset of the qualitative portion of this study, research questions were developed to satisfy the studies' objectives and guide the development of interview questions. The research questions are designed to form a contextual, holistic conception of the influence of transit planners' perception of the physical and social environments' relationship to mass transportation. To this end, the first research question is, "What are the perceptions of the individual transit planner regarding mass transportation?"

Research exploring the relationships between the sociological characteristics of transit patrons and transit service (Gaber and Gaber 1999; Kwan 1999; Gaber and Gaber 2002) suggests that certain social groups are disadvantaged in terms of their access to transportation. In the United States, mass transportation is commonly thought of as being a social service designed for those without access to private automobiles, particularly persons of color. The concept of a disadvantaged social class presents the potential for relationships characterized by power structure and subordination. This knowledge precipitated the second research question, "What are the perceived characteristics of transit patrons from the perspective of transportation planners?"

Numerous conflicting theories of urban structure have arisen in attempt to characterize the postindustrial city (Camagni, Gibelli, and Rigamonti 2002; Palen 2002). Given that there are distinct spatial patterns encompassing both land use and socioeconomic characteristics of cities, the third research question attempts to reveal the interaction between urban structure and transit service. Specifically, the third research question is "What are the distinctions, if any, between transit services in different sectors of the urban area?"

The GIS modeling analysis of accessibility is designed to detect differences, if any exist, in the accessibility achieved by different social groups. To effectively compare accessibility across groups, only one activity type, employment, is used to characterize the attractiveness of locations. Employment is vital to economic and personal fulfillment; in addition, it is one of the most basic travel purposes (Hanson 1995). The spatial data used in the modeling analysis, discussed in a later chapter, is based only on journeys to work, thereby prohibiting other activity types from being included in this analysis.

Accessibility to employment is further stratified between worker groups, including race/ethnicity, industry, and socioeconomic status. Worker groups were chosen for this analysis based on socioeconomic status, as it relates to the study objectives. Accordingly, the selected groups include minorities, non-minorities, professionals, service workers, and people living below poverty. To adequately compare accessibility across social groups, we must certainly compare the accessibility afforded between racial groups, holding all other worker characteristics constant. To capture economic status, the most appropriate attributes available, industry, are included. The purpose of this inclusion is to determine if accessibility varies between job type, and implicitly, income level. The anticipated model results will thus reflect the qualitative research questions, enabling a thorough analysis of accessibility.

CHAPTER III

LITERATURE REVIEW

Geographic Information Systems for Transportation

Recent advances in computer technology and the availability of spatial data have increased the role of GIS in transportation research and planning (Nyerges 1995; Goodchild 2000; Thill 2000; Kim and Kwan 2003). Geographic information systems for transportation (GIS-T) have evolved into an important application of GIS. The functions of GIS-T are as diverse as the scope of transportation; they include capabilities for infrastructure planning, design and management, configuring complex logistic systems, and public transit planning and operations (Miller and Shaw 2001). The nature of geographic information systems, with their abilities to store, analyze, and manipulate spatial data make them ideal for transportation data storage and analysis (Thill 2000).

In recent years there have been marked advances in the use of GIS-T in nearly all transportation arenas including management, planning, and research. This widespread use has arisen out of advances in both the capabilities of commercial GIS and the availability of transportation data with a spatial component (Nyerges 1995; Thill 2000; Miller and Shaw 2001). In the United States, legislation including the Clean Air Act Amendments, the Transportation Equity Act for the 21st Century, the Americans with Disabilities Act and the Intermodal Surface Transportation Efficiency Act has encouraged collaboration between federal, state, and local governments in the development of spatial data (Nyerges 1995; Thill 2000).

In a review of the current challenges facing GIS and transportation, Goodchild (2000) cited a need for geographic information science to treat transportation events as dynamic activities. Goodchild characterizes this "behavioral view" of GIS-T as needing new representation methods beyond those that exist for navigation or display purposes. To that end, contemporary research has addressed spatial representation and behavioral modeling (Kwan 1999; O'Sullivan, Morrison, and Shearer 2000; Wang 2000; Casas 2003; Kwan, Murray, O'Kelly, and Tiefelsdorf 2003). Broadly, this work also attempts to address the need for enhanced applications of behavioral modeling through the development of accessibility indices stratified by several worker attributes within a single study area.

Spatial Interaction Modeling

Spatial interaction (SI) models are used in GIS to estimate probable interaction between geographic locations. Research involving spatial interaction is often applied to issues in policy and planning, particularly accessibility (Miller and Shaw 2001). Substantive applications of SI modeling include the evaluation of public transportation service, travel demand modeling, and the exploration of linkages between households and jobs, and provision of other social services including health care, childcare, and recreation (Fotheringham and O'Kelly 1989; Kim and Kwan 2003; Kwan, Murray, O'Kelly, and Tiefelsdorf 2003).

The underlying form of urban systems is explicitly captured through SI models, which consider the factors that drive trip generation (from origins), destination attractiveness, and the cost of travel between the origins and destinations (Miller and Shaw 2001). These attributes of origins and destinations are used to help determine accessibility across transportation systems. The flexibility of SI models and the diversity of origin and destination attributes have facilitated the development of numerous means of characterizing accessibility (O'Kelly and Horner 2003).

Geographic Information Systems in Accessibility Modeling

GIS-T offers numerous advantages for the study of accessibility; increases in the availability of spatial data and GIS-T capabilities continue to make GIS modeling an effective means of analyzing accessibility (Kwan, Murray, O'Kelly, and Tiefelsdorf 2003). Previous limitations including the inability of many GISs to handle matrix data structures, and difficulties in calculating intrazonal distance values have since been remedied (Geertman and Van Eck 1995). The strengths of GIS-T for accessibility modeling include the ability to represent irregular shapes and patterns (often inherent in spatial data), and more importantly the ability to model topology.

Accessibility Modeling

Modern society has become increasingly complex, and so the importance of space, and peoples' opportunities to move within space, has emerged as an important question in various areas of scientific inquiry, including mathematics, operations research, and regional studies. There have been many approaches to characterizing movement through space; among them is the notion of mobility incorporating time as a third dimension. Hägerstrand (1970) established the critical role of regional science in analyzing movement within time and space. He observed that analyzing singular aspects of movement or places neglects other critical factors that determine the interaction between places, such as the unique character of places and individuals. Geography offers unique approaches to analyzing accessibility to opportunities that consider the character of the region, the places, individuals, and the means of travel between places. Accordingly, the current study adopts a theoretical and methodological framework grounded in the transport literature.

Several views of accessibility have evolved from recent literature (Handy and Niemeier 1997; Miller 1999); each has been defined and operationalized in different ways, depending on the context of the application (Kwan 1998). Regardless of the specific aspect of accessibility, each approach includes both transportation and personal activity elements, but they differ in the units of analysis and the degree to which they reflect travel behavior. One fundamental distinction should be made between types of accessibility measures; that is whether the measure is based on individuals, or places. It is important to distinguish between these types of accessibility, as they imply very different units of analysis and thus do not fulfill the same objectives (Kwan 1998).

Place-based accessibility characterizes locations, specifically how easily locations (and their activities) can be reached using a given transportation system from other places (O'Kelly and Horner 2003). This type of measure often involves aggregate data sets and is most appropriate for analyzing accessibility across an entire transportation system (Horner 2003). However, place-based measures are not appropriate for characterizing individual accessibility, as they assign the same level of accessibility to *all* individuals in the same place, or zone (Kwan and Weber 2003).

Gravity-based measures are perhaps the most common place-based accessibility measures. Such approaches compare travel costs with the attractiveness of destinations, and emphasize the role of potential activity in determining present accessibility (Taaffe, Gauthier, and O'Kelly 1996). Geertman and Van Eck (1995) provide an example of the application of gravity measures to determine aggregate accessibility. They propose integrating potential models, a derivative of the classical spatial interaction model (Taaffe, Gauthier, and O'Kelly 1996), with GIS to determine aggregate accessibility to central places in relation to some measure of attractiveness, in this case jobs or services. The results of this application are measures of potential interaction across a metropolitan area in The Netherlands.

A place-based measure would be most appropriate for producing indices useful for transit service evaluation and enhancement. Among the factors that govern the transit planning process, the *spatial* distribution of population, which cannot be separated from *place,* is perhaps most significant (Pas 1995). For this reason, the GIS analysis portion of this study will produce place-based indices of accessibility via the transit network.

Individual-level accessibility is derived directly from the space-time approach to accessibility, developed by Hägerstrand (1970). Individual approaches take into account both the accessibility offered by locations, and the space-time budgets of individuals. This is an important concept, because physical access does not denote accessibility if the travel time to access opportunities is not within individuals' given space-time constraints (O'Sullivan, Morrison, and Shearer 2000). This approach is more appropriate for characterizing the accessibility of a specific category of individuals; much of the recent empirical work employing individual accessibility has been focused on gender differences in accessibility, based on the assumption that space-time constraints differ between gender groups (Kwan 1999).

Kwan (1999) justifies the need for studies of accessibility at the individual level based on the notion that women's access to jobs and urban opportunities is determined more by their space-time constraints than by factors such as relative location to opportunities. To this end, she employs a dataset from travel-data diaries collected in Franklin County, Ohio. A GIS was used to operationalize space-time measures across the study area to compare the benefit the transportation system provided to women vs. men in this study. Her results indicate that women have lower levels of accessibility than men; however there is no difference in the types of opportunities reached within each groups' space-time budget. Reflecting on some of the differences in individual vs. place-based accessibility, Kwan's research questions were fundamentally different from that of Geertman and Van Eck (1995), who sought to determine aggregate accessibility across the transportation system in an entire metropolitan area.

Others have explored the effectiveness of transit systems using location models to analyze accessibility at the *route level* (Murray 2001, Murray and Wu 2003); these studies perceive transit service as having the dual objectives of maximizing coverage and minimizing service costs. These criteria are especially important, as transit planners must often choose between these components of accessibility when planning transit service (Kwan, Murray, O'Kelly, and Tiefelsdorf 2003). Murray and Wu (2003) use two spatial optimization models, a distance constrained *p*-median problem (DCPMP), and a route-directed distance constrained *p*-median problem (RD-DCPMP) to analyze route effectiveness. These models include a parameter that allows the user to trade off between physical access and geographic coverage; the second includes a constraint that allows route direction to be considered. Route direction is an important feature of transit systems, as many routes service two directions; however route direction is often neglected (Murray and Wu 2003) in GIS models. The accessibility models are applied to examine a transit route in Columbus, Ohio. The implementation of either model in transit planning would serve to increase service speed. This type of work is useful for evaluating the success of existing transit route configurations, and planning for future route service.

O'Sullivan, Morrison, and Shearer (2000) developed an integrative approach to modeling accessibility that incorporates some elements of both individual and aggregate accessibility. The objective of this study is to explore the capabilities of GIS for analyzing accessibility using this integrative framework. The authors develop a model of accessibility across a multi-modal transit system in Glasgow, Scotland. To account for individual aspects of accessibility, they developed *isochrones*, or lines of equal travel emanating from a given origin. The isochrones are designed to reflect the geographic area an individual can reach within a given time. They combine individual isochrones with isochrones that reflect the geographic area accessible from transit stops. This approach effectively models *where* people can travel from given origins, when alighting from given transit stops. This work demonstrates the capabilities of GIS for modeling accessibility across a complex transit network. Additionally, a contribution of this work is the integration of two elements of accessibility; space-time constraints and the use of pre-determined origins. This work does not attempt to characterize the *places* where individuals can reach using the transit network, nor does it effectively incorporate *individual* characteristics, which as others (Kwan 1998; Kwan 1999) have noted, largely determine the space-time budget.

The principle distinction between the above studies is the representational framework around which the specific methods are developed. Kwan, Murray, O'Kelly, and Tiefelsdorf (2003) recognized representation as one of the most important directions for the future of accessibility research. As such, research incorporating diverse representational frameworks is needed. By including attributes such as gender, income, and race, accessibility can be stratified across multiple socioeconomic groups. This is vital in studies of accessibility, as the literature in areas of inquiry including sociology and transportation, has indicated that access and accessibility vary between groups depending on their socioeconomic characteristics. The exploration of socioeconomic status and its relationship to accessibility is a relatively new research area that has yet to be fully considered.

Qualitative Analyses of Transportation Accessibility

Research addressing the *institutional* forces that shape transportation accessibility could be valuable in contributing to a more holistic understanding of accessibility. This approach would be useful in reconciling quantitative accessibility measures with the processes that create these patterns. Without an understanding of *why* spatial patterns of accessibility are created, it would be difficult to improve the current state of accessibility. Much of the empirical research on mass transportation has explored the relationship between social equity and mass transit from the perspective of transit users (Kain and

Fauth 1977; Kirby and Reno 1987). Research has also focused on assessing transit needs of individuals (Gaber and Gaber 1999; Gaber and Gaber 2002). This approach is effective in assessing transit accessibility for small groups; however it often neglects the processes that shape mass transit provision.

Complex interactions between the physical and cultural environments manipulate decisions governing mass transportation. The transit planning process is one that encompasses culture, urban structure, and the meanings that individuals attribute to those values through their daily interactions (Steiner 1978). Quantitative studies seeking to characterize transportation accessibility neglect to consider the complex interactions between transit patrons, transit planners, and local officials, which determine accessibility. This study proposes that a combination of qualitative methods and GIS analysis would be most appropriate for evaluating these processes. Qualitative methods are holistic in nature, and so may be more appropriate for understanding social or human questions. Some of the questions this study seeks to address include the perceptions of those involved in transit planning, and the affect of physical and social environments on the transit planning process. Because the context surrounding some of these questions must be included, qualitative research methods are used to answer them (Tickamyer 2000).

Some research considers individuals' desires for transportation service. Many such studies are qualitative in nature; however some involve the triangulation, or juxtaposition, of research methods including qualitative focus groups or interviews and quantitative surveys. One study conducted by Gaber and Gaber (1999) assessed, qualitatively, the needs for mass transportation as identified by citizens and transit users in several midsize Nebraska cities. They used mixed methods consisting of focus groups and surveys of transit users and local government officials to produce outcomes directly applicable to the lives of their subjects. Gaber and Gaber's results were useful for their respondents; however they are not widely applicable, and can not explain local deficiencies in transit service.

Similar studies such as that of Roson (2001) evaluate the determination of local transport services by employing econometric analyses, which are useful for evaluating the value of certain services to society by placing those services in the context of their relative cost. Roson's objective was to determine the role of socioeconomic variables in the public's willingness to pay for the subsidization of public transport service through municipal funds. Two main themes emerged from interview data collected from residents of two towns; demand for services was found to be relatively independent of the demand for transport capacity, and most respondents preferred to leave service unchanged for lack of leaving a different and better alternative available.

Boschken (1998) is also an example of research examining economic the impact of development on transit policy outcomes. This paper probes the thesis that variance in economic development outcomes is partly determined by agencies that perceive their public to be anonymous and without involvement in the policy process. Boschken maintains that potential transit patrons who possess sufficient affluence do play a determining role in policy decisions regarding mass transportation. He examines this thesis within the context of the upper-middle-class, as he hypothesizes that individuals of lower socioeconomic status do not exert direct influence on transportation policy.

Boschken concludes that characteristics possessed by the upper-middle class are more significant in explaining differences in policy outcomes than previous work indicated.

CHAPTER IV

STUDY DESIGN

Overview

The literature reviewed here has contributed to existing applications and techniques of GIS in accessibility research. A parallel stream of work has addressed social issues in transportation, mobility, and public participation in transportation decision-making (Yago 1983; Hanson 1995). Although related, these two elements of accessibility have been undertaken separately. Currently GIS analyses of accessibility do not include means for incorporating perspectives of transit planners or other public officials. Future work in the area of accessibility research could explore relationships between physical accessibility, and the processes that determine accessibility.

In response to these needs, this work develops accessibility indices across a metropolitan area that measure the effectiveness of a transit system in the context of neighborhood characteristics. To fully consider both the physical and social elements of accessibility, a GIS analysis of accessibility and a qualitative analysis of the transit planning process that shapes accessibility are integrated to produce conclusions about the accessibility of a single transit system for its diverse users. The following sections further discuss the use of GIS in accessibility measurement and qualitative research methods to evaluate transportation service. The study area and data used in both elements of this study are introduced, followed by a detailed discussion of the methods used.

GIS Analysis

Accessibility indices are useful for travel demand modeling, forecasting, and the evaluation of existing transportation projects. In the literature, accessibility indices have been used to track changes in accessibility over time, characterize potential impacts of proposed transportation projects, and illustrate differences in various land use patterns, to name only a few (Bhat et al. 2000). A recent review conducted by Bhat et al. (2000) summarizes the objectives that must be considered prior to developing an accessibility index. They include identifying the degree and type of disagregation desired, deciding how to define origins and destinations, identifying measures of attractiveness, and determining impedance. This section outlines developing an accessibility index based on these parameters.

Most urban regions with existing public transit make substantial efforts to ensure that transit stops and routes are placed such that they effectively serve riders' origins and destinations (Murray 2001). However, transit systems that lack adequate investment tend to have more difficulty competing with automobile travel times, and as a result experience low utilization rates. Transit systems in suburban areas particularly experience low utilization rates due to relatively low population densities.

The effectiveness of a public transportation system is measured in the context of accessibility, which is a critical consideration in the provision of public transportation services (Murray 2001; Murray and Wu 2003). As discussed earlier, a substantial portion of the research addressing the accessibility of transportation systems focuses on the individual (Kwan 1999; Casas 2003; Weber 2003). This approach is valuable, however it is limited due the difficulty in conducting such an analysis, as disaggregate travel data is often expensive to produce (Miller 1999), and is only representative of a small fraction of the population. There is also difficulty in extrapolating measures of individual accessibility to a geographic area or population, as this would result in ecological fallacy.

Transit planners are responsible for producing transportation systems that effectively serve the entire population of their service area, and so their decisions would be better informed by aggregate measures of accessibility. Zonal-based accessibility measures depict spatial patterns in accessibility that, when subject to visual interpretation, can be used to identify areas of inadequate transit service.

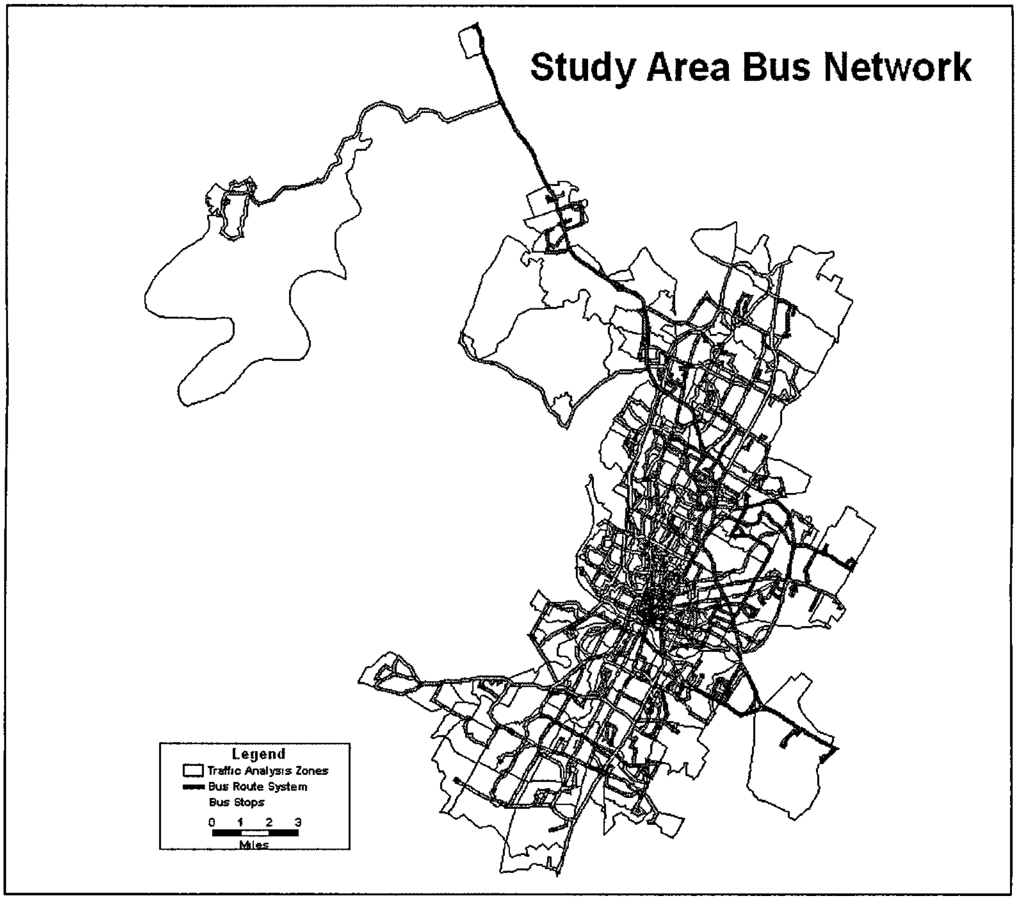
The accessibility index developed here is zonal-based, as opposed to indices based on individual travel patterns. The value of such an index is that measures of zonal-based accessibility can be used in developing a spatial conception of accessibility. Zonal-based accessibility measures are generated through the application of spatial interaction models and other techniques that capture accessibility across a transit network from origin zones to employment destinations.

Study Area and Data

For the purposes of the GIS analysis, detailed data on employment and residential locations are incorporated from the Census Transportation Planning Package (CTPP 2000). The CTPP is a large transportation dataset available for all major metropolitan areas of the US. The dataset is produced by the Bureau of Transportation Statistics (BTS) and is readily available to the public (Horner 2002). The CTPP contains detailed data on journeys to work, and is organized into three parts at multiple spatial resolutions. Part I contains detailed information on origins (home locations) including demographic information, mode of travel, travel time, etc. Destination data (workplace) is contained in Part II. Part III contains data on the flows (commutes) between origins and destinations. Data on residences is extracted from Part I, while Part II is used to glean employment totals by zone, disaggregated by worker type. The selected level of aggregation for the CTPP data is the traffic analysis zone (TAZ), as this is typically the most disaggregate unit for which aggregate transportation data is available (this is the case with the CTPP). The size of the TAZ is somewhat analogous to the census block group or tract; data aggregated to the TAZ is frequently used in studies of urban commuting and transportation (Horner 2002). This study incorporates the most recent CTPP data set available, from the 2000 Census. Several variables, representing axes of dissimilarity across worker groups, are the input into accessibility models. These variables include gender, race/ethnicity, industry, and income (see Appendix 1 for the CTPP description of these dimensions). These variables were chosen among several others because they are most useful in comparing accessibility across race and socioeconomic groups.

The study area is the transit service provider (TSP) service area of a mid-sized Texas city. The TSP provides bus transit service to the city and surrounding suburbs within its jurisdiction. Currently there are over 500 routes and nearly 4,000 stops in the TSP's service area. For purposes of this analysis, only TAZs that contained bus stops in 2003 are included, because zones not containing stops have no direct access to the transit system. This selection produces a study area where some TAZs are not contiguous with others. The reason for these "island" zones is that the bus routes serving the distant TAZs (i.e. express routes) do not have stops along each segment of the route, thus the route cannot be accessed from some zones, even though the routes pass through it. Data on 2003 route and stop locations were obtained from the TSP. US streets data (2000) enhanced by Caliper Corporation serve as the line layer underlying the transit network.

Fig. 1. TAZs, bus routes, and bus stops within the study area.



Models

The models applied to determine accessibility include derivatives of the gravity-based spatial interaction model as well as a cumulative opportunities model. Such approaches are especially useful in characterizing accessibility, because they allow the inclusion of urban structural elements (Shen 2000). Because this study seeks to measure only accessibility to employment, the *total number of jobs* in each zone represents the element of attractiveness in the urban landscape. The gravity model is perhaps the most widely used method of estimating interaction between zones, in this case interaction between TAZs via the transit network. The general gravity-based model formulation of accessibility is as follows:

$$A_j = \sum_{i=1}^{n} E_j f(C_{ij}) \qquad (1)$$

Where
A_j is accessibility at zone j,
E_j is total employment at zone i,
C_{ij} is travel cost between zones i and j via the transit network
f is a function of the expected interaction between i and j

To fulfill the objectives of this analysis, the general model has been modified to include an exponential function and several experimental β values. The function of β is to determine the effect of distance on accessibility values; relatively small β values lessen the effect of distance, while relatively large β values produce the opposite affect (O'Kelly and Horner 2003). This formulation is:

$$A_j = \sum_{i=1}^{n} E_i \exp(-\beta C_{ij}) \tag{2}$$

Where
A_j is accessibility at zone j,
E_i is total employment at zone i,
exp is the exponential function,
β is an experimental value, and
C_{ij} is travel time between zones i and j on the transit network

A power-based gravity model, similar to the exponential-base gravity model is also applied. This model (Equation 3) is the nearly the same as that in Equation 2, with the exception of the substitution of the power function for the exponential function. Similar to the exponential-based model, the power-based gravity model is a smoothing operation; however it does not have the ability to include self-potential (see O'Kelly and Horner 2003). This model is formulated as follows:

$$A_j = \sum_{i=1}^{n} E_i \, C_{ij}^{-p} \tag{3}$$

A_j is accessibility at zone j,
E_i is total employment at zone i,
C_{ij} is travel time between zones i and j on the transit network, raised to
p, which is an experimental value

In addition to exponential and power-based gravity models, a cumulative opportunities measure is applied to determine the number of opportunities, in this case jobs, available within a predetermined travel time. This measure is especially important because it places a constraint on which opportunities may be counted, not including those jobs that are beyond a reasonable travel distance. The exponential and power-based gravity models produce composite measures that are to some extent less interpretable than the values produced by the cumulative opportunities measure, which represents the total number of accessible jobs. The cumulative opportunities model is formulated as follows:

$$A_i^S = \sum_j E_j \qquad \forall j \in c_{ij} \leq S \tag{4}$$

Where
A_i is accessibility at zone i,
S is some pre-specified travel time,
E_j is employment at zone j, and
$\forall j \in c_{ij} \leq S$ ensures that destinations, j with travel time less than S are counted

The basic cumulative opportunities measure can be extended to control for the number of resident workers in each zone by dividing the cumulative opportunities available to the zone by total resident workers. The inclusion of resident workers produces a measure that more accurately captures *accessibility* to employment, controlling for the effects of zonal population.

$$A_i^S = \sum_j E_j / R_i \qquad \forall j \in c_{ij} \leq S \tag{5}$$

Where
A_i is accessibility at zone i,
S is some pre-specified travel time,
E_j is employment at zone j,
R_i is resident workers at zone i, and
$\forall j \in c_{ij} \leq S$ ensures that destinations, j with travel time less than S are counted

The accessibility models here are easily implemented in a GIS-T, in this case TransCAD version 4.5, for matrix multiplication. Travel cost, which is represented by an n^2 matrix and adjusted by the appropriate function, is multiplied by the $n \times 1$ vector of employment. The result of the application of the accessibility model to employment data is an $n \times 1$ matrix of accessibility values. This vector can be interpreted in raw format, or by converting the values to z scores, scaling all values by some constant, or some other standardization technique. Accessibility across the study area is mapped by joining the indices to the attribute table of the TAZs. The resultant maps spatially depict the accessibility of each zone; spatial patterns in accessibility are then subject to visual interpretation.

To obtain impedance, in this case travel time over the transit network, a transit network generated from the original route and stop location data in TransCAD served as the input to accessibility models. The underlying arcs for line and route system layers are taken from TIGER line files, which form a more complete network than the original route location data.

For the purposes of this study, TAZs are assumed analogous to neighborhoods. Trips ending and beginning within each neighborhood, or TAZ, are modeled such that they end at a TAZ centroid. The aggregation of travel data to zone centroids is a process common to zonal-based GIS analysis (Horner 2002). Data on trip destinations are connected to the transit network by means of connecting TAZ centroids to the nearest bus stop. The access links from TAZ centroids to bus stops are Euclidian distances between the two points, and are assigned a walking speed, as physical access to bus stops is typically gained by walking (Murray and Wu 2003).

Once data on origins and destinations are connected to the transit network, a shortest path algorithm imbedded in TransCAD is used to create a cost matrix between zones via the transit network, using travel time as impedance. The desired output from the generation of the transit network is a single n^2 matrix containing travel time between all zones in the study area that are connected via the transit network.

Qualitative Analysis

The unit of analysis in the qualitative phase of this study is the individual interviewee. It should be noted that spatial and social patterns are evident that are potentially widely applicable; however no attempt is made to extrapolate these findings to society as a whole. The study area is the same for both the modeling and qualitative aspects of this study. Although decision-making and physical planning for mass transit occurs at several levels including federal, state, and local agencies, only those individuals employed directly by the local transit service provider, the TSP, are involved. This agency is responsible for the physical planning of transit service, the operation of service, community outreach and marketing, and the generation of operating funds. A sample of individuals from both the planning and communications departments was chosen based on their professional positions and demographic characteristics.

Each of six interviews was conducted in the individual's office or a nearby conference room during normal business hours. The interviews were typically 1-1.5 hours in length. Each interview was audio tape-recorded and transcribed. The individuals signed a written consent form before beginning the interview stating their knowledge of the recording process and their agreement to participate in this study. During the interviews, respondents were asked a series of questions based on the preliminary research questions (the reader is referred to Appendix 2: Interview Guide). Each interview loosely followed the interview guide. Follow-up questions were determined in part by the respondents' answer to each question in the interview guide. This 'probing' technique is commonly used in qualitative methods.

The interview guide (Appendix 2) was organized into four themes, including three research questions and a concluding theme. The first theme addressed the individuals' perception of mass transit in several contexts, beginning with the universal value of mass transportation, and gradually becoming more specific to address the specialized roles of transit. The second theme was "the transit patron in your city". The purpose of this unit is to elicit the interviewees' perception of the racial, socioeconomic, and employment status of their patrons. A second purpose was to surmise the interviewees' perception of their patrons' dependence on their service. The third section was designed to identify the role of urban structure in the provision of transit service. Interview questions specifically inquired about variances in service between segments of the city. This section also included a question about the marketing techniques and audiences the agency typically considered.

The interview transcripts were reviewed and coded. Initial codes were assigned to transcript excerpts that related to any of several themes including race and ethnicity, socioeconomic status, categorizing transit patrons, urban structure, and public participation. With each subsequent review, transcript excerpts were further coded to associate similar responses, and eventually groups of responses were analyzed in the context of the research questions. Some themes emerged independent of the research questions; in such cases relevant themes and theories were identified from the literature following data collection.

Limitations

There are several limitations to the methods introduced above. Beginning with the GIS analysis of accessibility, the measures developed are sensitive to the level of aggregation of the dataset. As previous researchers have noted (Horner and Murray 2002), spatial scale can have significant effects upon model results. The effect of scale is inherent in any aggregate analysis of accessibility. An attempt is made to mitigate these effects by using data aggregated to the smallest spatial unit for which the CTPP (2000) is available, the TAZ. Secondly, by using aggregate data, an assumption is made that all workers are distributed evenly within the TAZ, which is certainly not the case. Again, this type of error is inherent in using aggregate data.

The desired temporal period for the travel time measures developed in this study is the morning peak travel period (indicated by the fare schedule as 7-9am). During this time it is reasonable to assume that many links in the transit network are congested. The available data on the transit routes and underlying arcs is insufficient for accurately modeling congested travel time. A traffic assignment cannot be performed using the available data, as link capacity and flows are unknown. To account for this error, the wait time between services during the morning peak period is incorporated in the measure of travel time. It is reasonable to assume that wait time (as described in the fare books) reflects typical morning congestion on each route.

The CTPP data used in this study are preliminary (2000); this data was used because it is the most recent dataset available, and choosing a more complete product would require using 1990 CTPP data residence and workplace data, which far outdates the transit routes, stops, and streets. One potential problem with preliminary data is that some fields might not be complete; where this is the case those fields can not be used. In the accessibility maps, zones where data is not available are filled with diagonal lines. These TAZs might be missing residential or employment data, or those zones did not contain both residences and jobs of that particular type, in which case this is not an error in the dataset.

There are potential limitations with respect to the qualitative analysis that are inherent in any study employing qualitative research methods. Unlike quantitative methods, qualitative methods often require the researcher to employ inductive logic, as the data are frequently unexpected, given that they are dependent on the responses of individuals (Esterberg 2002). This is not to imply that qualitative research methods are without scientific basis. Qualitative analysis actually moves between deduction and induction, as the researcher interacts with the subjects and the data. Reflection is an important aspect of data analysis. The nature of qualitative methods makes them subject to the personal biases and experiences of the researcher. It is perhaps most difficult to address this potential for error during the data analysis, at which time the researcher often finds him or herself reflecting on personal beliefs and biases. To ensure that the data collected in this study was analyzed accurately, themes are first identified and reference made to previous empirical studies. These themes are then interpreted using relationships defined in previous studies and sociological theory.

CHAPTER V

RESULTS OF ANALYSIS

Overview

This section presents the results of the qualitative analysis of the transit planning process and the GIS analysis of accessibility. The results of the qualitative analysis are presented categorically, based on related responses that emerged throughout the interviews. Each theme is introduced and discussed, and excerpts from the interview transcripts are offered that are particularly exemplary of each theme. Following the qualitative results, model outputs are introduced. This section includes maps containing accessibility indices and conclusions from the qualitative analysis are offered in the interpretation of spatial patterns of accessibility.

Qualitative Themes

Classifying Audiences

Several categories of findings emerged from the data, some of which were expected given the research questions, however others emerged independent of prior expectations. The first of the findings was somewhat expected, given traditional conceptualizations of mass transportation, and given that the first segment of questions addressed the interviewees' perceptions of mass transportation. Each of the six interviewees indicated that, from their experience, transit planning is conducted in consideration of two separate and distinct groups, which are those people who are absolutely or mostly dependent on mass transit for mobility, and those who have the option of using a private automobile, but at least some of the time, choose to use mass transportation. The respondents all expressed this perception, however at varying degrees. One individual clearly identified this relationship:

> "You can break down your market into two distinct groups… the transit dependent… and the choice riders are the other group. In my definition a choice rider is someone who has a car available to make a trip but either because it's more convenient or they save money, or because they don't like the hassle of driving."

The two distinct roles and audiences for mass transit can be accounted for by two social theories. The notion of mass transportation as a social service provided by some level of government to aid those in need of assistance arises out of *welfarism*, which is characterized by the adoption of Keynsian-style economic policies and programs (Bailey 2001). In the United States, welfarism was dominant largely during the post-World War II era of economic restructuring. Although the United States is currently in a post-welfarist era, as many welfarist programs have been since eliminated or reduced, many of the welfarist theories and some programs remain in place. The interviewees typically characterized those riders who are transit dependent as unfortunate individuals who rely on the services of the agency:

> "…we've developed routes that specifically cater to areas where we have impoverished slums, areas where people are just trying to get to the grocery store or some medical facilities and we develop service that travels a lot into these major points that people need to get to. So there's a role for that and a large need."

The above quote illustrates the respondent's perception that the role of certain transit routes is to provide transportation to disadvantaged patrons with access to essential services including healthcare and shopping. Another interviewee noted the importance of transit service in providing intangible value to transit dependent users:

> "And in that sense it's a social service function that not everyone's able to buy a car, not everyone's physically able to drive a car, and it gives those people a chance at mobility for things in their personal life, for work, for medical appointments, and any of the other things they need to do to function as a person in society."

Transit as a choice was presented very differently from transit as a social service. In this sense, the choice that people made and the options they chose to forgo were the emphasis in transit service. Many econometric analyses of travel patterns (Roson 2001) incorporate *rational choice theory* which attempts to explain individuals' impetus for decision-making. Interviewees emphasized that in the interest of 'choice riders'; mass transportation is competing with the benefits offered by the private automobile:

> "People who traditionally use the express service… it's a combination of the cost of parking downtown and the desire to help things and, their own self-help, or they want to be a little more at leisure."

While describing the socioeconomic characteristics of their patrons, several respondents separated transit dependent riders and choice riders. Choice riders were frequently described as being of higher income levels, and holding professional positions:

> "And, generally our choice rider here in (city) is going to be of a moderate to higher income level, probably well educated, being in an office-type job, and most of them commuting into the downtown area."

Other respondents indicated that that non-transit dependent people perceive themselves as unlike transit dependent bus riders, and as a result do not consider themselves as someone who might use bus service:

> "There is a perception that if you are a white collar and you have a perception that bus is not for you because you don't associate yourself with those kinds of people who might use the bus, that's why we are trying to offer services like light rail..."

This pattern of two disconnect audiences, each with different transportation needs, would likely manifest itself in the GIS accessibility analyses. Because transit planning is conducted in consideration of two different groups, it is reasonable to assume that the service provided to these groups is not dissimilar. This theme can effectively be examined using the available CTPP data, as transit dependent riders can be distinguished from choice riders on the basis of income and occupation or industry.

Voices of Patrons

As the literature suggests (Boschken 1998; Gaber and Gaber 1999; Gaber and Gaber 2002) private citizens often have an active voice in the provision of transportation services. The data indicate that the two groups mentioned in the previous section differ greatly in terms of their influence on transit provision. Boschken (1998) suggests that the upper-middle-class have a privileged role in society, and by virtue of their education and economic affluence, their voices are more readily heard. This theme was mentioned repeatedly in the data. Although most interviewees reported serving larger numbers of the transit-dependent riders, their accounts of direct interaction with patrons voicing their concerns nearly always involved choice riders. This reflects the 'digital divide' of the information age (Kenyon, Lyons, and Rafferty 2002). Most contacts with patrons described in the data consist of electronic communication, which many transit dependent riders are unable to access. Several themes were mentioned as the possible causes of this divide including a lack of access to technology, too little time on the part of the transit dependent riders to interact with public policy, lack of information received by transit dependent riders, and a sense of powerlessness. The interpretation of this theme is the theory of indirect social influence postulated by Boschken (1998), which holds that certain social groups, in the case of his study the upper-middle-class, exert an indirect and significant influence on policy outcomes by virtue of their affluence. The 'choice' riders in this study area exert this indirect social influence through their interactions with representatives of the TSP. These interactions often take the form of requests for additional service or criticisms of existing service:

> "We have customer service and public hearings, we listen to people to see what they need."

> "People who have access to cars, Internet, can voice their opinion much more frequently and easily, and a lot of transit dependent riders, and unfortunately I'm making a generalization, but a lot of them don't have computers, they work, it's hard for them to voice their opinion at public meetings because it's hard for them to get there."

Several interviewees indicated that both groups (transit dependent and choice riders) have distinct objectives regarding transit service in their neighborhoods. These functions conflict because they are competing for the same set of scarce resources including funding, time, and attention. This conflict is especially significant because one group is perceived to have less of a voice in the political process:

> "...but the thing is, a lot of transit riders don't read the paper, I'm making generalizations, but there's some truth. It's really hard to get them involved in the planning process so as a planner you do your best to hear them and at least study demographic patterns and movement patterns and any kind of patterns to find those pockets of people who may not be voicing their opinions, and make sure that they're served somehow."

A third audience also influences the transit planning process, the potential riders, who do not currently use the service. It should be noted that potential riders are actually potential choice riders; they are not dependent on mass transit. Planners often consider these individuals most in marketing campaigns and drives designed to increase ridership, this focus often contributes to the competing voices of the transit planning audience:

> "...we have people that are our potential riders that we have to think about, you know, how can we get those people on too?"

> "It seems that a lot of our funding is a little flashy, and is directed primarily toward students and things like airport routes, and our late night routes in the entertainment district."

Service Variance

Classical sociological theory including Burgess' concentric zone theory of urban structure (Palen 2002) suggests that sociological characteristics vary throughout distinct zones of the urban environment. Empirical research (Bernick and Cervero 1997, Cervero 1998) further suggests that, to a degree, transit service reflects urban structure. This theory was the basis for the third research question. The data analysis indicates that transit service varies between different urban segments in ways including frequency of service, distance between stops, type of vehicle, price of service, and marketing strategies. The reasons for these differences are based on both the built and sociological environments. For example, smaller busses are often used in suburban neighborhoods because narrow streets prevent the passage of large busses that typically carry high passenger volumes:

> "We are constrained by a lot of street patterns; with smaller busses we have to operate those more frequently just to get people where they want to go."

> "On the commuter route, if it's the express route, then it's even quicker. If you have someone on a local fixed route with a lot of stops, then it's probably going to take the same amount of time."

Service frequency and route placement are highly correlated with land use. The most frequently cited variable for determining bus service is population density. These patterns reflect varying land uses, densities, and types of roads throughout the metropolitan area. However, there are variances in service that exist to accommodate the sociological characteristics of the patrons in that area:

> "We have commuters in the suburban area and they demand, and I mean that, they demand quite a bit. They want busses on time, they want clean vehicles, clean stops, clean everything. They want comfortable busses, comfortable seats. Every amenity we could possibly give them, they want more. They want it not to cost anything. They're very vocal about it. They get big busses with nice seats, they get things to keep them happy and keep them riding because they pay a higher fare, for nice busses with nice seats."

Each of the interviewees recognized that transit patrons in suburban areas demand higher levels of service, and so pay a higher fare. This also reinforces the first finding, that transit patrons may be grouped into two distinct categories.

Racial Paternalism

The literature suggests that minorities are considered vulnerable members of society, and are treated as such by agencies (Afshar-Mohajer 2002, Street 1996). In cases of racial paternalism, the dominant group is compelled to act as the provider for members of the subordinate group, thought to be unable to care for him or herself. Such a condition typically breeds an environment of subordination and resentment. The theory of racial paternalism was employed to analyze responses that indicated that the transit dependent, a group characterized largely as minorities, are socially inferior and so depend on advocacy from other groups.

> "I think the average person (who rides the bus) is probably a person of color, or an ethnic minority."

Racial paternalism was evident when respondents indicated that minorities often required more attention than other transit groups, or when minorities were characterized as disenfranchised members of society.

Accessibility Modeling Results

We now turn our attention to the results of the accessibility models. This analysis produced zonal-based indices that depict accessibility from residential locations to employment locations via the transit network. These indices represent, quantitatively, the accessibility of several socioeconomic groups. Each accessibility index quantifies the accessibility provided to resident workers of that zone to jobs filled by workers of their group, via the transit network. Further analysis allows comparison of accessibility between and within these groups.

Each type of measure introduced in the previous chapter was found to produce results facilitating varying levels of interpretability. Figures 2-4 depict accessibility for all worker groups to all jobs using three different, yet basic measures; one power-based gravity measure ($p = 2$), one exponential-based gravity measure ($\beta = 2$), and one cumulative opportunities measure ($S = 30$). Power-based gravity models (see Figure 2) do not typically include self-potential, and thus prohibit inclusion of employment opportunities that are likely accessible to resident workers within their home zone. As seen in Figure 2, the power-based gravity measure does not exhibit the same magnitude of accessibility near the urban core that is found in the exponential-based gravity model (see Figure 3); which does include self-potential. Of the two types of gravity measures, the exponential-based measure is more appropriate, given that the objectives of this study include modeling accessibility from all zones to all employment opportunities of a given type.

The two gravity models and the cumulative opportunities model (see Figure 4) produced spatial patterns of accessibility that reflect zones of high employment; this is evidenced by a pattern of high accessibility near the urban core, and progressively lower accessibility traveling outward from the core. This effect potentially limits the interpretability of maps using such measures, as it is difficult to distinguish between employment and accessibility effects. In addition, because the numeric values produced by the gravity models do not represent any specific unit, it would be meaningless to scale these values by the number of residences in each zone. Because of these limitations, cumulative opportunities measures, scaled by the number of residences of a given type in each zone, are the selected means of further accessibility analysis (see Figure 5). These measures reflect the total number of jobs accessible to each zone; this number can then be scaled by the number of residences of a given worker type in each zone by simply dividing the cumulative opportunities by the number of resident workers. The resultant measures are perhaps more appropriate for modeling accessibility to employment because they control for zonal population.

Fig. 2. Accessibility to all jobs using a power-based gravity model.

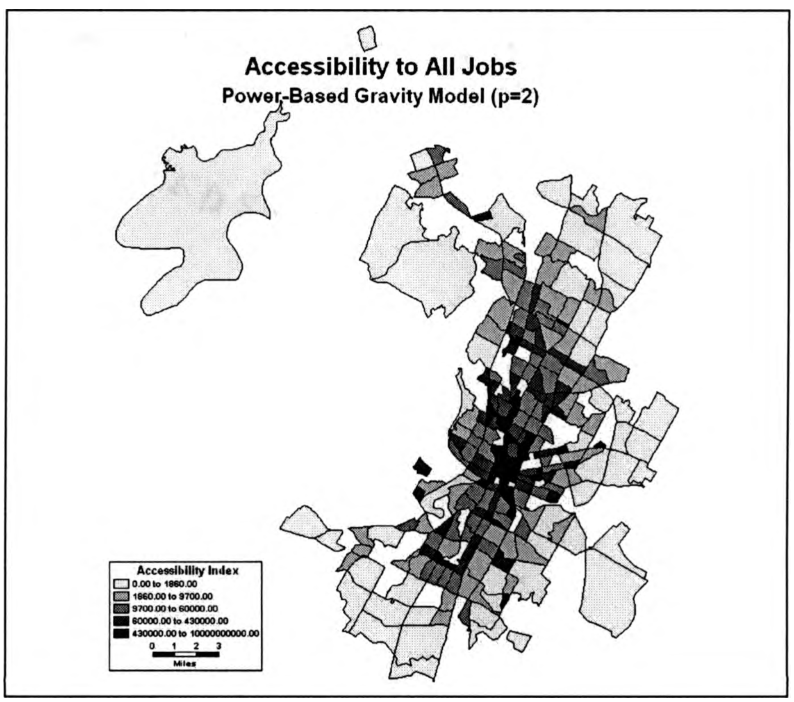


Fig. 3. Accessibility to all jobs using an exponential-based gravity model.

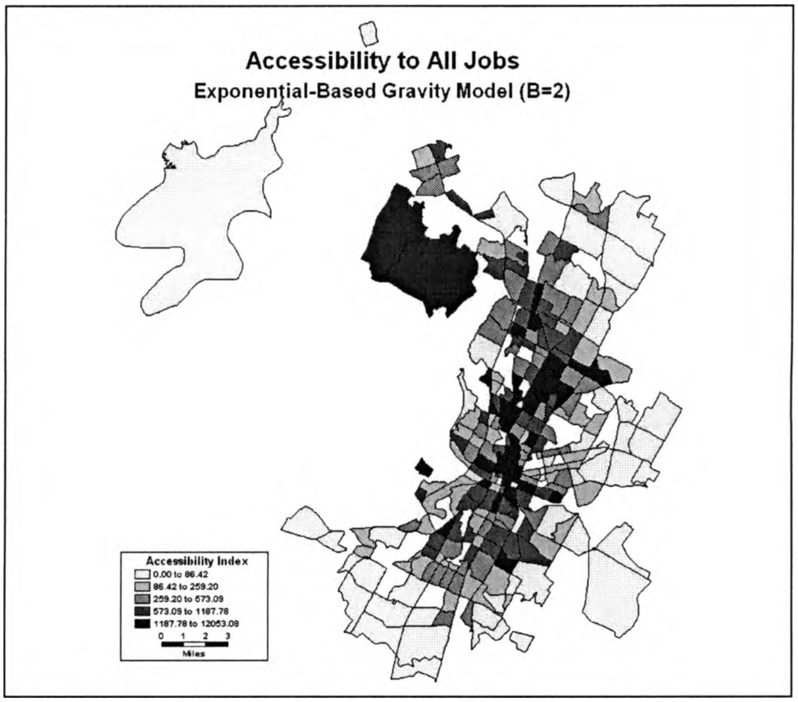


Fig. 4. Accessibility to all jobs using a cumulative opportunities measure.

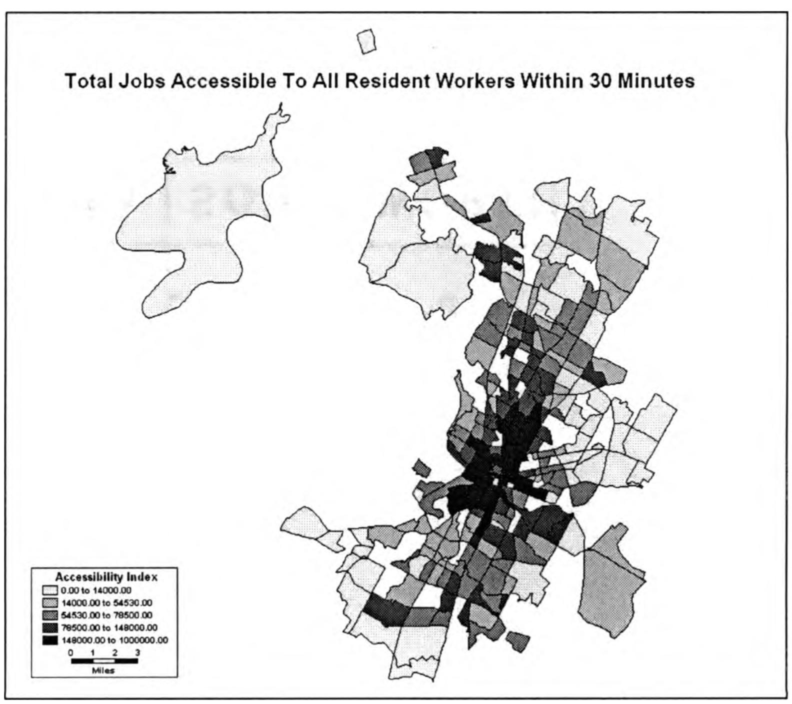
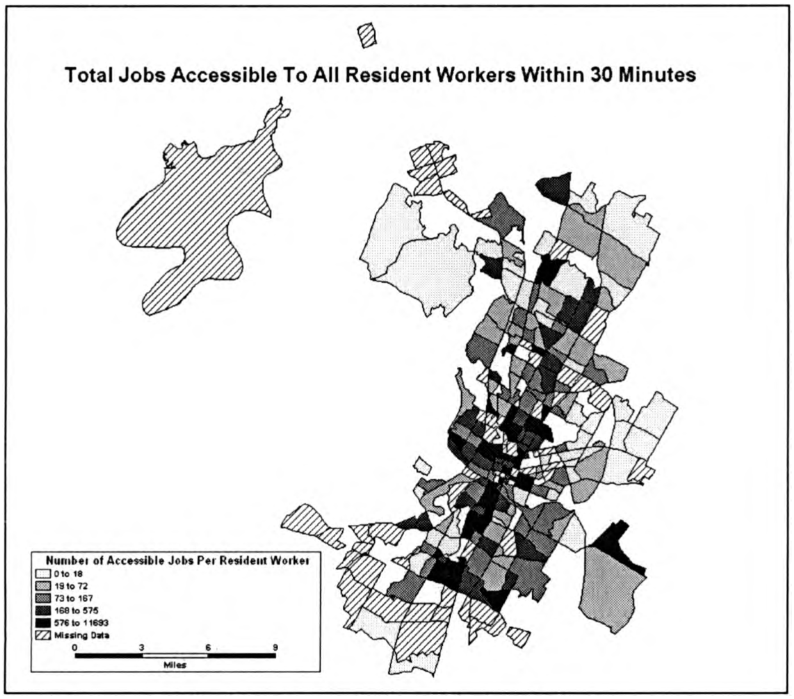


Fig. 5. Accessibility to all jobs using a cumulative opportunities measure scaled by residences.



To provide more relevance to cumulative opportunities model outputs, the maximum travel time to included employment opportunities was selected based on average transit travel times within the study area. From the 1990 CTPP (Part III), mean transit travel time for this city was found to be approximately thirty-two minutes. Because transit service has substantially increased since that time, a slightly lower travel time, thirty minutes, was chosen. Each of the subsequent analyses presented employs a cumulative opportunities measure, using a thirty minute travel time threshold.

The worker groups chosen for the present analysis include the three most populated race/ethnicity groups; they are non-Hispanic white, non-Hispanic black, and Hispanic white (or all Hispanic workers where Hispanic white is unavailable). Each of these groups is further stratified by industry for the purpose of comparing accessibility to different types of employment. Industry arguably plays a determining role in individuals' socioeconomic status, and is thus an appropriate attribute for this analysis. The selected industries are professional, retail, and entertainment. Significant differences in accessibility between professional and the latter two industry groups might indicate some disparity in accessibility provided to individuals of higher vs. lower socioeconomic status, respectively. A third attribute, poverty status, is included to capture the accessibility provided to workers who are likely to be transit dependent, by virtue of their economic status. Analysis of accessibility across several income levels is not possible due to data limitations.

To compare aggregate accessibility for each worker group across the entire study area, a weighted mean accessibility is calculated (see Table 1). Given a travel time threshold, the *weighted* mean accessibility represents the average employment opportunities available to a given worker group within the *entire* study area, controlling for the number of resident workers of that group. The weighted mean can be interpreted as the total number of potential jobs accessible per resident worker. This is the first point of discussion because the weighted mean identifies any large disparities in accessibility produced by the transit system overall.

Considering accessibility of the three primary race/ ethnicity groups to all types of jobs available to them, there is little difference in the accessibility provided to the two most populous groups, the non-Hispanic, white and Hispanic, white workers (97.22 and 93.42 accessible jobs per worker, respectively). The similarity in weighted mean accessibility provided to these two groups indicates that, on average across the entire system, there are not significant differences in accessibility. However, there is a large difference in accessibility between the two former groups and non-Hispanic, black workers (73.36 accessible jobs per worker). This suggests that, system-wide, non-Hispanic, black workers are provided far less accessibility than their counterparts. It is important to consider that in this study area, non-Hispanic, black workers are the lesser populated minority group (15,185 workers), while there are significantly more Hispanic, white workers (21,009 workers). It is possible that these two minority groups do not receive the same level of service. Particular attention will be paid to this group in subsequent analysis of spatial accessibility, and mean zonal accessibility.

In regard to industry type, sharp differences appear between industries within the same race/ ethnicity group. This is particularly interesting because it indicates that, holding race constant, workers of different industries and thus different socioeconomic status are not served in the same fashion by the transit network. Considering the three industry classes used in this analysis, it seems that the transit network would provide the greatest accessibility to workers in the retail or entertainment industry, as wages are typically lower than in the professional sectors, and these workers would be more in need of transit. However, the weighted mean accessibility for Hispanic, white professional workers, for example, is 116.05 employment opportunities per resident worker, and only 84.15 and 75.89 employment opportunities per retail and entertainment resident worker, respectively. This is point is counterintuitive, because as the qualitative analysis suggests, lower-income people are perceived to be more likely to use transit. Because of their potential propensity to be dependent on transit, it is reasonable to assume that workers in retail and entertainment industries would be provided greater accessibility than workers in professional industries, who are more apt to choose other modes of transportation. However, this is not the case. Professional workers have greater accessibility to employment, as evidenced by their higher number of accessible employment opportunities. Reflecting back on the qualitative analysis, interview respondents indicated that 'choice riders' have much greater influence on transit decisions than transit dependent riders. Professionals, as opposed to retail and entertainment workers, are more likely to have greater affluence. Professional workers thus possess the resources necessary to influence transit policy decisions, such as route and stop placement and service frequency. The result of diversions of service to accommodate 'choice riders' is that workers in other industries are provided lower levels of accessibility, even if they are more dependent on transit as their primary means of transportation.

Continuing with this theme, accessibility as experienced by workers living below the poverty level is also low relative to total accessibility. This perhaps suggests that workers living below the poverty level are not provided adequate accessibility to employment. Workers living below poverty are likely to be transit dependent because of their economic status; they are also less likely to participate in transit planning decisions, which appears to be evident in their level of accessibility. To further probe these preliminary findings, we can consider mean zonal accessibility and spatial patterns of accessibility (see Table 1). Mean zonal accessibility is calculated as the mean of all zonal accessibility indices (cumulative opportunities) for a particular worker group. In contrast with weighted mean accessibility, mean zonal accessibility simply averages the cumulative opportunities measure estimated for each zone, irrespective of its number of workers.

Table 1: Weighted Mean and Mean Accessibility to Employment

Worker Group	Employment Type	Cumulative Opportunities	Total Resident Workers	Weighted Mean	Mean
Non-Hispanic, White	All Available jobs	9,446,149	97,166	97.22	1124.04
Non-Hispanic, Black	All Available jobs	1,113,944	15,185	73.36	183 02
Hispanic, White	All Available jobs	1,962,777	21,009	93 42	250 21
Non-Hispanic, White	Professional Jobs	1,528,165	15,113	101.11	363.37
Non-Hispanic, Black	Professional Jobs	90,066	1,172	76 85	32.18
Hispanic, White	Professional Jobs	201,007	1,732	116 05	79.68
Non-Hispanic, White	Retail Jobs	1,392,567	10,974	126.90	294 52
Non-Hispanic, Black	Retail Jobs	126,576	1,508	83 94	59.76
Hispanic, White	Retail Jobs	180,847	2,149	84.15	72.11
Non-Hispanic, White	Entertainment Jobs	163,862	2,159	75.89	182.37
Non-Hispanic, Black	Entertainment Jobs	72,107	592	121 80	37 08
Hispanic, White	Entertainment Jobs	163,862	2,159	75 89	61.43
Non-Hispanic, White Below Poverty Level	All Available Jobs	526,973	7,083	74.39	160 61
Non-Hispanic, Black Below Poverty Level	All Available Jobs	100,373	1,247	80.49	36 60
All Hispanic Below Poverty Level	All Available Jobs	415,896	6,704	62 03	105.73

The inclusion of weighted mean accessibility and the interpretation of spatial patterns of accessibility allow a further level of analysis. Looking back to the accessibility of non-Hispanic, black workers, when the same race/ethnicity groups are stratified by industry, non-Hispanic black workers again have low accessibility in the professional and retail industries. Non-Hispanic, black workers emerge as having the highest accessibility in the entertainment industry, and the highest among workers living below the poverty level. These conflicting results might suggest that significant efforts are made to ensure that non-Hispanic, black workers of low incomes have adequate accessibility. When considering only weighted mean accessibility, non-Hispanic, black resident workers seem to experience a lower level of accessibility compared to other groups, however this is not consistent for all industries and socioeconomic status. When we consider mean accessibility, non-Hispanic, black workers experiences the lowest accessibility in each employment category. This finding strengthens the preliminary conclusion that this worker group is not provided the same level of accessibility as other race/ethnicity worker groups. The following maps allow us to consider the spatial distribution of the accessibility indices that produce the mean accessibility values.

Fig. 6. Non-Hispanic, black accessibility to professional jobs.

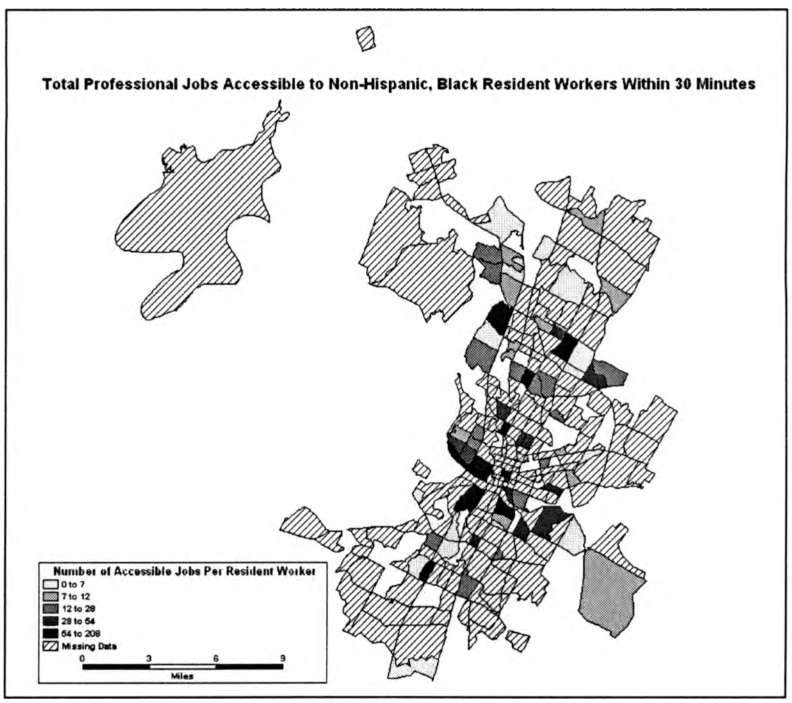
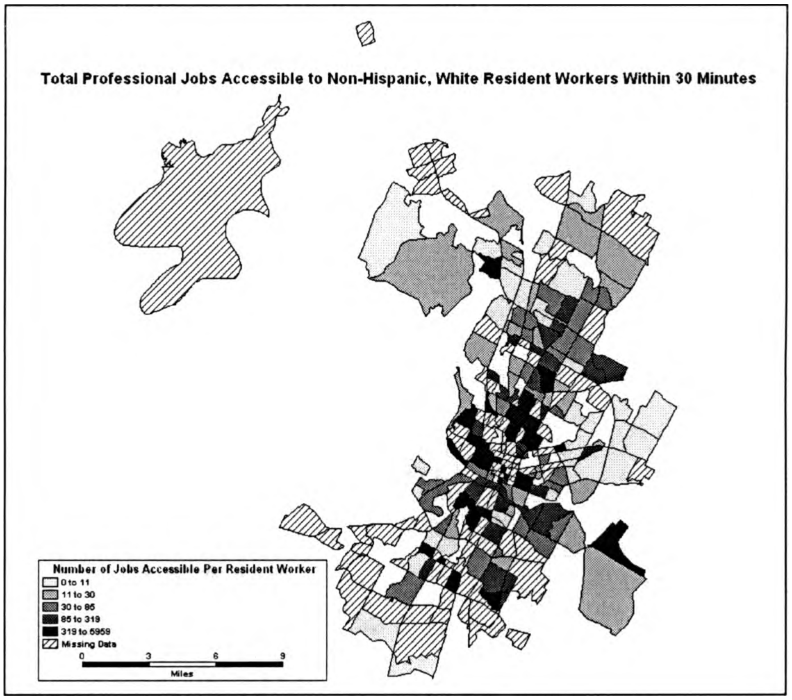


Fig. 7. Non-Hispanic, white accessibility to professional jobs



Non-Hispanic, white mean accessibility to professional jobs is 363.37 cumulative opportunities per resident worker, while that for non-Hispanic, black professional workers is 32.18. The spatial patterns of accessibility of these groups (Figures 6 and 7) are helpful in explaining this relatively large disparity. High areas of accessibility to professional jobs for non-Hispanic, white workers (Figure 7) are clustered about the urban core, along several linear paths which can be assumed to be routes that serve these workers' neighborhoods. By contrast, high accessibility for non-Hispanic, black workers is dispersed throughout the service area, with few significant clusters of high accessibility neighborhoods. This dispersed pattern suggests the lack of several routes traveling from non-Hispanic, black neighborhoods to high concentrations of professional jobs.

The primary difference between the weighted mean and mean accessibility is that mean accessibility reflects how the transit system serves *neighborhoods*, rather than the entire service area. Weighted mean accessibility will produce sharp contrasts only if an entire group is provided significantly more or less accessibility than another; the weighted mean thus produces a smoothing effect. In contrast, the mean accessibility index explicitly considers each neighborhood's accessibility score. As a result, neighborhoods experiencing extremely high or low accessibility for a given worker group will thus have significant influence on the mean accessibility.

Given the smoothing properties of weighted means, it is not surprising that the there is greater disparity among mean accessibility values, as opposed to weighted means. An interesting point to consider is that most groups have higher mean accessibility values than weighted mean accessibility, and only a few groups exhibit the opposite relationship. In each employment category, non-Hispanic, black workers have lower mean than weighted mean accessibility, and Hispanic workers also have lower mean accessibility in three of five employment categories. Conversely, non-Hispanic, white workers experienced higher mean than weighted mean accessibility in each category. The relatively low mean accessibility values for the minority groups indicate that there are a significant number of neighborhoods where these worker groups have low accessibility, these values cause the mean accessibility value to drop far below the system-wide weighted mean. The opposite effect occurs for non-Hispanic, white neighborhoods; higher mean accessibility values are driven by zones with relatively high accessibility. While non-Hispanic, white workers as a whole do not achieve far greater accessibility than their minority counterparts, it is evident that there are some neighborhoods where they receive relatively high levels of service, relative to system-wide levels.

This pattern of low minority mean accessibility and high non-minority mean accessibility is repeated throughout each group; one race/ethnicity group, non-Hispanic, white workers, emerged as having the greatest mean accessibility in each employment category, while Hispanic-white workers were second each time, and non-Hispanic, black workers always had lowest mean accessibility. The uniformity in this pattern is strong evidence that the transit network favors non-Hispanic, white neighborhoods significantly relative to minority neighborhoods.

Between minority groups, the Hispanic, white worker group consistently emerges as having greater accessibility than the non-Hispanic, black worker group. To analyze accessibility between these groups, it is important to consider whether they share the same neighborhoods. To do so, we can examine the spatial patterns of these race/ethnicity groups within the same industry. Figures 8 and 9 depict the spatial accessibility of Hispanic, white and non-Hispanic, black entertainment workers.

Fig. 8. Hispanic, white accessibility to entertainment jobs

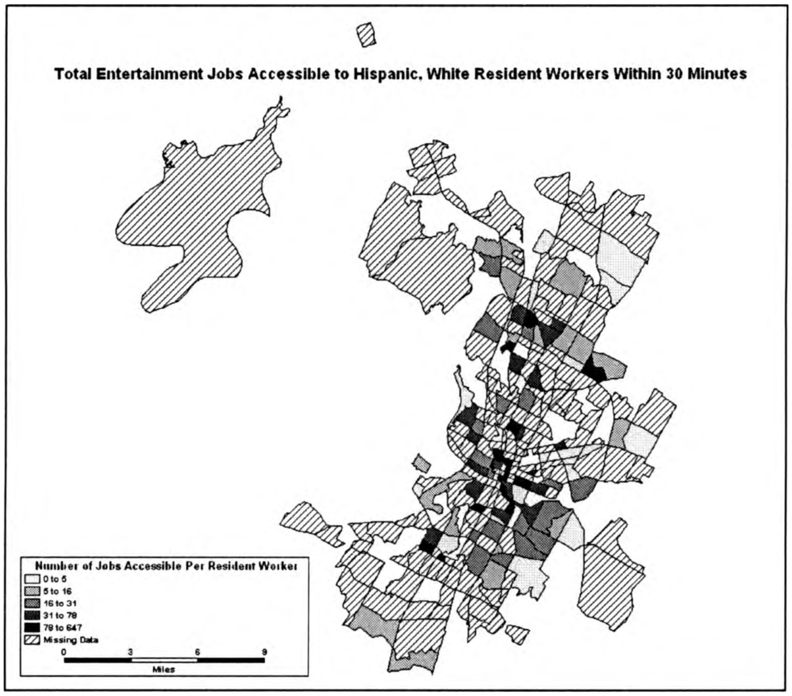
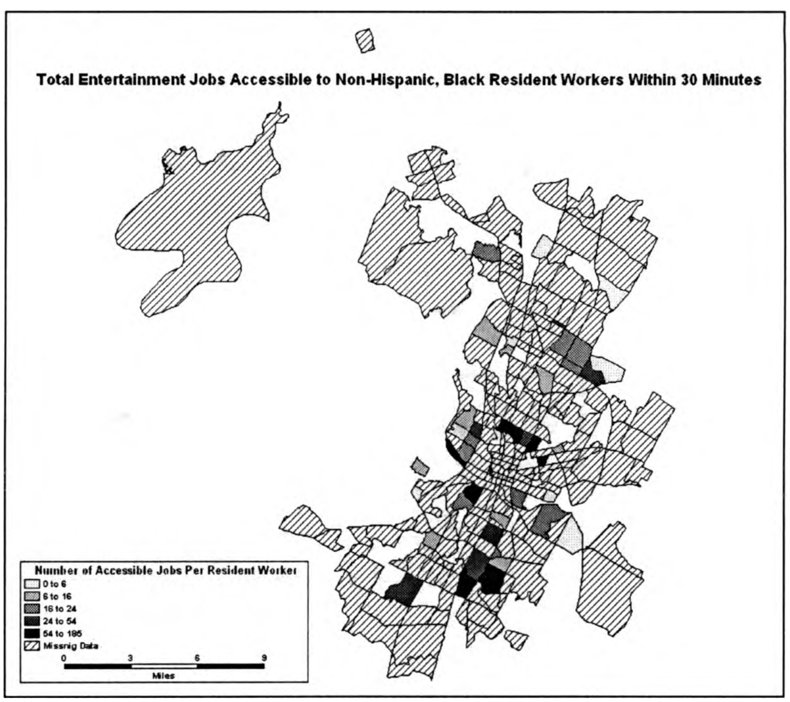


Fig. 9. Non-Hispanic, black accessibility to entertainment jobs



It is evident that these two minority groups do not share the same residential and employment neighborhoods, as their concentrations of high and low accessibility, even within the same industry, is not alike. Because the accessibility patterns of these two groups are dissimilar, we can conclude that underserved non-Hispanic, black and Hispanic neighborhoods are not duplicate low-service areas; rather both minority groups are separately underserved.

These accessibility models results are relevant to the purpose of this work because they identify observable disparities in accessibility, relative to the socioeconomic status of worker groups. Conclusions generated from these results relevant to the broader social issues will be discussed in the following chapter, as well as recommendations for improving disparities in accessibility. These conclusions will be followed by directions for future research.

CHAPTER VI

SUMMARY

Conclusions and Suggestions for Future Research

Following the qualitative analysis and the development of accessibility indices, the two data sets can be analyzed together. The methods offer very different perspectives; however they are a reflection of the same subject. The in-depth interviews produced several themes, as discussed in the previous chapter. These include the notion of two distinct ridership groups, transit dependent and choice riders. The two groups influence the transit planning process disproportionately; riders who choose to use mass transit also have the resources to influence transit planners far beyond the scope of transit dependent riders. Transit service varies between neighborhoods dependent on the socioeconomic characteristics of residents, the physical structure of the neighborhood, the length of the route, and the time of day. Finally, transit patrons perceive transit dependent riders as minorities who are in need of social service, in this case, transit access.

The GIS analysis of accessibility indicates that there is significant variation in accessibility between social groups, dependent on race, industry of employment, and even workers' socioeconomic status. Each of these findings is related to conclusions from the qualitative analysis of transit planning. The qualitative analysis facilitates the interpretation of model results, which would otherwise not be as meaningful.

Among the accessibility model results, perhaps the most apparent divergence in accessibility occurred between racial groups. In each of the industries included in this analysis, non-Hispanic, white workers had the greatest accessibility. Because accessibility to employment plays a vital role in economic and social prosperity, this fact is alarming. Minority workers face barriers to economic success in the form of discrimination in labor and housing markets; poor accessibility to opportunities exacerbates the likelihood that the will experience economic and social difficulties. This pattern of relatively low accessibility experienced by minority groups is contradictory to their needs, as revealed by the qualitative analysis. Interviewees indicated that they perceive minorities as those most likely to be dependent on transit for their mobility needs, and so it would seem that these groups would be afforded greater access than others. The accessibility indices indicate the contrary, that the weight of the resources is diverted to serve more affluent people.

Another significant finding from the qualitative analysis helps to explain the low accessibility achieved by minorities. Public participation in transit planning decisions was reported as occurring between transit planners and individuals of relatively high to moderate socioeconomic status. This suggests that minorities receive less attention during the transit planning process because their voices are not readily heard.

Considering the mean accessibility of all groups in the analysis, workers living below the poverty level had relatively low accessibility, which is surprising given that these workers are more likely to be dependent on mass transit than workers living above the poverty level. In the context of the qualitative results, it appears that the "choice riders", as opposed to the transit dependent, have greater accessibility. This reflects a persistent issue in mass transit planning, as transit systems are designed to fulfill the dual objective of reducing congestion and provide mobility to otherwise transportation disadvantaged individuals.

Given some recent literature on this subject (Handy, Weston, Song, and Lane 2002), it is not especially surprising that there is a significant lack of adequate public involvement in transit planning, especially where minorities and low-income people are concerned. In a recent analysis of the types of education transportation planners receive during their university education, Handy and others (2002) found that transportation planners ranked public involvement very high in the subjects not adequately covered during their education. The results of this study provide empirical evidence that there is an urgent need to improve communication between planners and public officials and socially disadvantaged people. Prior to this study, there have been few, if any empirical studies that explore the relationship between transit accessibility and socioeconomic status.

Several actions could be taken to improve equity in accessibility in this study area. First, the institution must recognize the inequity in service provided to minority vs. non-minority residents. Interview respondents suggested that there were no differences in service, and that ridership was largely representative of the population. This contradicts other responses indicating that transit dependent riders are predominantly minorities.

Second, further efforts must be made to involve minorities and low-income groups in the transit planning process. As the interviewees indicated, these people are difficult to reach via traditional means of public involvement, such as telephone, Internet, and public meetings. Their lesser role in public-participation decision making is evident in the lack of several efficient routes serving their neighborhoods. These changes are vital to the success of increasing accessibility in minority neighborhoods. Before specific routes can be assessed to determine optimal route and stop placement and service frequency, we should reflect back on the purpose of the system, and consider the unique character of the people it serves.

Data used in the GIS accessibility analysis are also designed to protect individual identities; in the case of the CTPP, data is aggregated to the traffic analysis zone so that individuals may not be identified, especially members of smaller groups such as minorities. This fact is somewhat limiting because it prohibits the incorporation of space-time budgets into the model, and does not allow consideration of multiple trip purposes. However, as established in previous chapters, it is valuable to model journeys to work only, as this is the most fundamental trip purpose. Some would argue that aggregate accessibility indices are not useful in modeling accessibility of population subgroups, due to the above mentioned limitations. The results of this study did find sharp differences in the accessibility provided to different socioeconomic groups including race/ ethnicity and industry. Further, these disparities in accessibility were readily interpreted using the findings of the qualitative analysis. These are important methodological findings; they indicate that aggregate measures are useful for modeling accessibility between specific population groups. This creates an abundance of opportunities for the study of accessibility because aggregate data, such as the CTPP, is readily available; individual-level data, however, is difficult to obtain and use.

The results of this study have limited application due the sensitivity of the qualitative data. To protect the identity of interview participants, the study area will remain anonymous. Each interviewee participated based on this assumption; had anonymity not been agreed upon the responses would likely have been less candid, and perhaps less telling about transit planners' perceptions of transit service in their area. Because the study area remains undisclosed, the results presented in this chapter should be used to further our broad understanding of the relationship between socioeconomic characteristics and accessibility, and the forces that help determine those relationships.

This work has attempted to contribute to the existing body of knowledge regarding differences in accessibility across social groups by developing zonal-based accessibility indices, stratified by several worker characteristics. This analysis was successful in identifying several variations in accessibility. Combined with a qualitative investigation of transit planning, the results clearly depict not just variance in accessibility, but socioeconomic characteristics that influence the level of accessibility available to groups. In addition, this work clearly demonstrates the utility of aggregate measures in the study of accessibility.

The integration of qualitative methods and GIS is a relatively new approach in the discipline of Geography. The addition of qualitative methods is not designed to replace GIS analysis; rather qualitative methods bring additional context to GIS models. The information gleaned during the qualitative portion of this study could not have been captured through a GIS model; however it is appropriate for interpreting the model results, and adding an additional layer of analysis. As our abilities to simulate real-world activities using GIS is enhanced, we must also continue to strengthen the rigor of GIS analysis results. One approach to this is the inclusion of other methods that capture the human behaviors and perceptions, which cannot be modeled using GIS. Within

Geography, we have reached a vantage point where the sophistication of GIS and quantitative methods allows us to reflect on the utility of these approaches. Now we can to consider other means of observation that potentially strengthen the geographic perspective, and diversify the questions geographers seek to explore. Mixed-method analysis will continue to appear in many disciplines, Geography included. This work strives to contribute to the relatively new body of knowledge integrating qualitative methods and GIS.

APPENDIX 1: 2000 CTPP DIMENSION SUMMARIES

Dimension Name: Race

Summary: The question on race was asked of all people. The concept of race, as used by the Census Bureau, reflects self-identification by people according to the race or races with which they most closely identify. These categories are socio-political constructs and should not be interpreted as being scientific or anthropological in nature. The race categories include both racial and national-origin groups.

Dimension Name: Hispanic

Summary: A self-designated classification for people whose origins are from Spain, the Spanish-speaking countries of Central or South America, the Caribbean, or those identifying themselves generally as Spanish, Spanish-American, etc. Origin can be viewed as ancestry, nationality, or country of birth of the person or person's parents or ancestors prior to their arrival in the United States.

Dimension Name: Sex

Summary: The data on sex was asked of all people. Individuals were asked to mark either "male" or "female" to indicate their sex. For most cases in which sex was not reported, it was determined from the person's given (i.e., first) name and household relationship. Otherwise, sex was imputed according to the relationship to the householder and the age of the person.

Dimension Name: Occupation

Summary: Occupation describes the kind of work a person does on the job. For employed people the data refer to the person's job during the reference week. For those who worked at two or more jobs, the data refer to the job at which the person worked the greatest number of hours. The occupational classification system used during Census 2000 consists of 509 specific occupational categories for employed people arranged into 23 major occupational groups. This classification was developed based on the Standard Occupational Classification (SOC) Manual: 2000.

Dimension Name: Industry

Summary: Information on industry relates to the kind of business conducted by a person's employing organization. For employed people the data refer to the person's job during the reference week. For those who worked at two or more jobs, the data refer to the job at which the person worked the greatest number of hours. The industry classification system used during Census 2000 was developed for the census and consists of 265 categories for employed people, classified into 14 major industry groups. The Census 2000 classification was developed from the 1997 North American Industry

Classification System (NAICS). Census data, which were collected from households, differ in detail and nature from those obtained from establishment surveys. Therefore, the census classification system, while defined in NAICS terms, cannot reflect the full detail in all categories.

Dimension Name: Poverty

Summary: The data on poverty status were derived from answers to the income questions. The Census Bureau uses the federal government's official poverty definition. Poverty status was determined for all people except institutionalized people, people in military group quarters, people in college dormitories, and unrelated individuals under 15 years old. These groups also were excluded from the numerator and denominator when calculating poverty rates. They are considered neither 'poor' nor 'nonpoor.'

To determine a person's poverty status, one compares the person's total family income with the poverty threshold appropriate for that person's family size and composition. If the total income of that person's family is less than the threshold appropriate for that family, then the person is considered poor, together with every member of his or her family. If a person is not living with anyone related by birth, marriage, or adoption, then the person's own income is compared with his or her poverty threshold.

Poverty status is not defined for households, only for families and unrelated individuals. Because some data users need poverty data at the household level, we provide tallies of households by the poverty status of the householder. In these matrices, the householder's poverty status is computed exactly the same way as described above. The householder is classified as poor when the total 1999 income of the householder's family is below appropriate poverty threshold. For nonfamily householders, their own income is compared with the appropriate threshold.

APPENDIX 2: INTERVIEW GUIDE

Introduction to the study and interview: I am interested in the mass-transit planning process including the experiences of those who plan physical routes and stops, and those who interact with the public and transit patrons in particular. I will explore how institutional beliefs, biases, and needs with respect to transit influence service provision, and ultimately mobility. The interview will consist of four modules of related questions as stated below.

I. Perceptions of Mass-Transit

A. How did you become interested in public transit?
B. Why do you believe transit is valuable?
C. What do you perceive the role of transit to be?
    a. What is the relationship between transit and congestion relief?
    b. What is the relationship between transit and the transportation disadvantaged?
    c. What is the relationship between transit and commuting?

II. The Transit Patron in Your City

A. How would you describe bus riders in this city? For example, what is their race/ethnicity, income, age, gender etc?
B. Do you feel that particular racial/ethnic groups ride the bus more than other social groups?
C. How often do you think most patrons ride the bus?
D. What are the destinations of most bus riders?
E. Where do you think most commuters that ride the bus are employed? Which industries employ most transit riders?
F. Why do you believe people ride the bus? Do you think most transit users have other transportation options?

III. Transit Service and Urban Structure

A. Does transit service vary, for instance frequency of service, distance between stops, type of vehicle, etc. between suburbs and the urban core, low-income neighborhoods, middle-class, and wealthy neighborhoods?
B. If so, why are there are variations in service between neighborhoods?
C. Who does your transportation agency try to target in their marketing campaigns?

IV. Conclusion

In a perfect world, what would you do to improve bus service provision and ultimately to increase mobility?

REFERENCES

Afshar-Mohajer, Ramin and Evelyn Sung. 2002. *The Stigma of Inclusion: Racial Paternalism/ Separatism in Higher Education.* Unpublished paper: New York Civil Rights Coalition.

Bailey, Stephen J. 2001. "Cities and Services: A Post-Welfarist Analysis" In *Handbook of Urban Studies*. Ronan Paddison, ed. London: Sage Publications.

Bernick, Michael and Robert Cervero. 1997. *Transit Villages in the 21st Century.* New York: McGraw-Hill.

Bhat, Chandra, Susan Handy, Kara Kockelman, Hani Mahmassani, Qinglin Chen, and Lisa Weston. 2000. *Development of an Urban Accessibility Index: Literature Review*. Austin, Texas: Texas Department of Transportation. 7-4938-I.

Boschken, Herman L. 1998. Upper-middle-class influence on developmental policy outcomes: the case of transit infrastructure. *Urban Studies* 35, no. 4: 627-47.

Bureau of Transportation Statistics. *The 2000 Census Transportation Planning Package.*

Camagni, Roberto, Maria Cristina Gibelli, and Paolo Rigamonti. 2002. Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion. *Ecological Economics* 40: 199-216.

Campbell, Scott. 1996. Green cities, growing cities, just cities? *Journal of the American Planning Association.* 62, no. 3: 296-312.

Casas, Irene. 2003. Evaluating the importance of accessibility to congestion response using a GIS-based travel simulator. *Journal of Geographical Systems* 5: 109-27.

Cervero, Robert. 1998. *The Transit Metropolis: A Global Inquiry*. Washington, D.C.: Island Press.

England, Kim V. 1993. Suburban pink collar ghettos: the spatial entrapment of women? *Annals of the Association of American Geographers* 83, no.2: 225-42.

Esterberg, Kristin G. 2001. *Qualitative Methods in Social Research*. Boston: McGraw Hill.

Fotheringham, A.S. and M.E. O'Kelly. 1989. *Spatial Interaction Models: Formulations and Applications*. Dordrecht: Kluwer Academic.

Gaber, Sharon Lord and John Gaber. 1999. Qualitative assessment of transit needs: the Nebraska case. *Journal of Urban Planning and Development* 125, no.2: 59-67.

Gaber, John and Sharon Gaber. 2002. Using focus and nominal group techniques for a better understandıng of the transit disadvantaged needs. *Transportation Planning and Technology* 25: 103-120.

Goodchild, Michael F. 2000. GIS and transportation: status and challenges. *GeoInformatica* 4, no.2: 127-39.

Geertman, Stan C.M. and Jan R. Ritsema Van Eck. 1995. GIS and models of accessibility potential: an application in planning. *International Journal of Geographical Information Systems* 9, no.1: 67-80.

Gray, George E. and Lester A. Hoel, ed. 1979. *Public Transportation: Planning, Operations, and Management*. Englewood Cliffs, New Jersey: Prentice-Hall.

Hägerstrand, Torsten. 1970. What about people in regional science? *Papers of the Regional Science Association* 24: 7-21.

Handy, S.L. and D.A. Niemeier. 1997. Measuring accessibility: an exploration of issues and alternatives. *Environment and Planning A*. 29: 1175-94.

_______., Lisa Weston, Jumin Song, and K. Maria D. Lane. 2002. Education of transportation planning professionals. *Transportation Research Record* 1812: 151-160.

Hanson, Susan ed. 1995. *The Geography of Urban Transportation*. New York: The Guilford Press.

Hay, Iain e. 2000. *Qualitative Research Methods in Human Geography*. London: Oxford University Press.

Horner, Mark W. 2002. Extensions to the concept of excess commuting. *Environment and Planning A* 34: 543-66.

_______. and Murray. 2002. Excess commuting and the modifiable areal unit problem. *Urban Studies* 39 no. 1: 131-9.

_______. 2003. Exploring metropolitan accessibility and urban structure. Paper forthcoming in *Urban Geography*.

Kain, John F. and Gary R. Fauth. 1977. *The Impact of Urban Development on Auto Ownership and Transit Use*. Urban Planning and Policy Analysis Admınistration Dıscussion Paper D77-18. Cambridge, MA: Harvard University Press.

Kenyon, Susan, Glenn Lyons, and Jackie Rafferty. 2002. Transport and social exclusion: Investigating the possibility of promoting inclusion through virtual mobility. *Journal of Transport Geography* 10: 207-19.

Kim, Hyun-Mi and Mei-Po Kwan. 2003. Space-time accessibility measures: a geocomputational algorithm with a focus on the feasible opportunity set and possible activity duration. *Journal of Geographical Systems* 5: 71-91.

Kirby, Ronald F. and Arlee T. Reno, ed. 1987. *The Nations Public Works: Report on Mass Transit*. The Urban Institute.

Kwan, Mei-Po. 1998. Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework. *Geographical Analysis* 30, no.3: 191-216.

_______. 1999. Gender and individual access to urban opportunities: a study using space-time measures. *Professional Geographer* 51, no.2: 210-27.

_______., Alan T. Murray, Morton E. O'Kelly, and Michael Tiefelsdorf. 2003. Recent advances in accessibility research: representation, methodology and applications. *Journal of Geographical Systems* 5: 129-38.

_______. and Joe Weber. 2003. Individual accessibility revisited: Implications for Geographical analysis in the twenty-first century. *Geographical Analysis* 35(4): 341-53.

Levinson, David M. 1998. Accessibility and the journey to work. *Journal of Transport Geography* 6, no.1: 11-21.

Miller, Harvey J. 1999. Measuring space-time accessibility benefits within transportation networks: basic theory and computational procedures. *Geographical Analysis* 31: 187-212.

_______. and Shih-Lung Shaw. 2001. *Geographic Information Systems for Transportation Principles and Applications*. Oxford University Press: Oxford.

_______., "Travel Chances and Social Exclusion," in *Moving Through Nets: The Social and Physical Aspects of Travel,* K.W. Axhausen, ed. Elsevier, forthcoming in 2004.

Murray, Alan T. 2001. Strategic analysis of transport coverage. *Socio-economic planning sciences*. 35: 175-88.

_______. 2003. Accessibility tradeoffs in public transit planning. *Journal of Geographical Systems* 5: 93-107.

_______. and Xiaolan Wu. 2003. Accessibility tradeoffs in public transit planning. *Journal of Geographical Systems* 5: 93-107.

Newman, Peter W.G. and Jeffrey R. Kenworthy. 1996. The land use-transport connection: An overview. *Land Use Policy* 13, no.1: 1-22.

Nyerges, Timothy L. 1995. "Geographic Information System Support for Urban/ Regional Transportation Analysis" in *The Geography of Urban Transportation.* London: The Guilford Press.

O'Kelly, Morton E. and Mark W. Horner. 2003. Aggregate accessibility to population at the county level, U.S. 1940-2000. *Journal of Geographical Systems* 5, no.1: 5-23.

O'Sullivan, David, Alastair Morrison and John Shearer. 2000. Using desktop GIS for the investigation of accessibility by public transport: an isochrone approach. *International Journal of Geographical Information Science* 14, no.1: 85-104.

Palen, J. John. 2002. *The Urban World. Sixth Edition.* Boston: McGraw Hill.

Pas, Eric I., "The Urban Transportation Planning Process," in *The Geography of Urban Transportation*, Susan Hanson, ed. New York: The Guilford Press, 1995.

Roson, Roberto. 2001. Assessing the option value of a publicly provided service: the case of local transport. *Urban Studies* 38, no.8: 1319-27.

Shen, Qing. 2000. Spatial and Social Dimensions of Commuting. *Journal of the American Planning Association* 66, no.1: 68-82.

Simmonds, Keith C., Edward Bierhanzl, Michael Campbell, and Gilbert Queeley. 2003. *An Examination of the Relationship Between Organizational Structure and Transit Performance.* Tallahassee, Florida: Florida Department of Transportation. BC 137-27.

Steiner, Henry Malcom. 1978. *Conflict in Urban Transportation.* D.C. Heath and Company.

Taafe, Edward J., Howard L. Gauthier, and Morton E. O'Kelly. 1996. *Geography of Transportation.* 2nd. ed. Upper Saddle River, NJ: Prentice Hall.

Tickamyer, Ann R. 2000. Space matters! Spatial inequality in future sociology. *Contemporary Sociology* 29, no.6: 805-14.

Thill, Jean-Claude. 2000. Geographic information systems for transportation in perspective. *Transportation Research Part C* 8: 3-12.

Wang, Fahui. 2000. Modeling commuting patterns in Chicago in a GIS environment: a job accessibility perspective. *Professional Geographer* 52, no.1: 120-33.

Weber, J. 2003. Individual accessibility and distance from major employment centers: an examination using space-time measures. *Journal of Geographical Systems* 5: 51-70.

Yago, Glenn. 1983. The sociology of transportation. *Annual Review of Sociology* 9: 171-90.

VITA

Jessica Nicole Mefford received the degree of Bachelor of Science with a major in Geography from Southern Illinois University-Edwardsville in May 2002. In August 2002 she entered the Graduate College of Texas State University-San Marcos.

Permanent Address: 15278 Roberts Lane
Dow, IL 62022

This thesis was typed by Jessica N. Mefford.