ABSTRACT

ACCESSIBILITY IN METROPOLITAN TRANSPORTATION PLANNING: VISUALIZING A GIS-BASED MEASURE FOR COLLABORATIVE PLANNING

by
Aditi Sarkar

Passed by the US Congress in 1995, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), requires Metropolitan Planning Organizations (MPOs) to further the trend of collaboration by employing visualization techniques for Transportation Improvement Programs (TIPs). In the first part of this two-part research, three New Jersey MPOs are investigated to understand how accessibility is considered by their organizations, how TIPs are evaluated, and how collaborative planning and visualization techniques are used to evaluate TIPs. In the second part of this study, a small segment of a MPO's jurisdiction is selected to develop a visualization of the change in accessibility brought about by a TIP.

Suitability analysis, a method commonly used for collaborative decision making in land use planning, is employed to develop the accessibility measure from service areas generated by ArcGIS Network Analyst. Service area values are calculated by a gravity-type model that decay inversely to network distance and network time and are dependent on the travel mode desires of the residents of the region. The resultant accessibility raster, a product of collaborative planning, is dependent on the physical characteristics of the region and the people residing there. This accessibility raster is used to visualize change in accessibility before and after a TIP. Zonal statistics may be applied on this raster to evaluate environmental justice concerns by MPOs.

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To

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and in the memory of

মেজদামামা

(To my parents and my aunt and uncle)

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

The Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 and the Transportation Equity Act for the 21st century (TEA-21) in 1998 mandated that transportation planning consider intermodality and engage the public in collaborative planning. The most recent transportation bill -- Safe, Accountable, Flexible, Efficient Transportation Equity Act for (SAFETEA-LU) -- passed in 2005, additionally requires Metropolitan Planning Organizations (MPOs) to enhance this trend by employing visualization techniques to depict metropolitan transportation plans to help people understand proposed transportation improvement programs (TIPs). Because the mandates are recent, both collaborative planning and visualization are in their infancy and because the choice of TIPs are buried in complex processes and calculations, unique to each urban region, the reasons for selecting TIPs are little understood by the tax-paying citizens who fund them.

Transportation improvement programs are usually built with a promise to increase accessibility. How this pledge is actually carried out by transportation planners is unknown. In contrast, academic studies of the measurement of accessibility form a large body of literature that has evolved ever since the first proposal to measure accessibility was published by Hansen in 1959. How many of these well-developed measurement methods are actually used by practitioners to make transportation planning decisions is not known. More fundamentally, it is unknown whether accessibility concepts are considered at all, either explicitly or implicitly, by transportation planning organizations.

In an era when citizens are demanding increased transparency, it is also not known if collaborative planning methods and visualization techniques, as required by SAFETEA-LU, are used to enhance these attempts.

This dissertation is an attempt to first, to comprehensively understand how accessibility is considered by MPOs and second, to build a tool for metropolitan transportation planners to measure accessibility that can be used in collaborative planning to visualize the difference in accessibility before and after a transportation improvement program is built.

1.2 Usage of the Term Accessibility

Access to goods and services is one of the primary factors in economic and social development in the past century. Yet the term "accessibility" is difficult to define and measure. One of the first persons to operationalize accessibility, Hansen, defined it as "the potential for opportunities for [economic and social] interaction" (Hansen, 1959, p. 73). Subsequent definitions developed Hansen's initial concept but to this day Hansen remains the starting point for most research on accessibility, including this one.

In common parlance accessibility is used in several ways. It is used to refer to the ability of disabled people to reach certain places; the ease of finding web sites on the Internet; and the quality of certain services that have organizational or linguistic options catering to particular communities. In this dissertation the term accessibility is used, as it is in transportation planning, to refer to the access of goods and services.

It is important at this point to differentiate between the terms accessibility and mobility as these two terms, frequently and inappropriately, are used interchangeably. In the context of transportation planning Handy (2005a) defines mobility as "the potential for movement, the ability to get from one place to another, an ability to move around" (p. 132) and accessibility as "an ability to get what one needs, if necessary by getting to the places where those needs are met" (p. 132). Movement and speed, which are essential parts of the concept of mobility, are absent from the concept of accessibility. An example of this would be a neighborhood like the Greenwich Village in New York City described by Jane Jacobs, in her book *The Death and Life of Great American Cities* (1962), where people have high accessibility to all goods and services to meet their essential needs in conditions of low mobility. Mobility in Greenwich Village is low as it is not possible to move at high speeds through its narrow streets and heavily used sidewalks. It is thus possible, to have high accessibility with low mobility; however high mobility does increase accessibility.

The difference between accessibility and mobility has been explained by several authors (Bertolini, le Clercq, & Kapoen, 2005; Handy, 1994; Helling, 1998). They have all called for a shift of focus from mobility to accessibility in planning and for the development of a measure of accessibility that can be used by planners.

1.3 Transportation Planning in the United States

To find out if and how accessibility is considered in transportation planning in the United States, one must first understand the structures within which transportation planning decisions are made in this country.

1.3.1 Transportation Statutes, Regulations and Guidance

Urban transportation planning is conducted by state and local agencies under the purview of the federal government. The federal government's role is to formulate national transportation policies, set design standards for construction, provide financial and technical assistance and conduct research.

Transportation planning statutes have fundamentally changed the focus and the hierarchy of responsibilities in transportation planning. The first change was a move away from the single focus on highway construction, and the automobile as the primary mode of transportation, to planning methods that would consider intermodal travel. ISTEA promoted “transportation systems that maximize mobility” and “a planning process which produced investment decisions that result in safe and efficient mobility and accessibility” (FHWA, 1995, p. 7).

The second major change was to devolve local transportation decision making to Metropolitan Planning Organizations (MPOs) (Schear, 1997). Until the 1980s local agencies, other than the state department of transportations (DOTs), played minor roles in the planning of transport (Weiner, 1997). The Intermodal Surface Transportation Efficiency Act (ISTEA), passed in 1990 changed transportation planning in major ways. MPOs now had the key role of defining the region’s transportation vision by selecting the right transportation projects that would balance transportation needs with acceptable level of air quality (Lyons, 1994).

The statues of the 1990s, for the first time, focused on the clients of transportation planning. ISTEA required “a proactive and inclusive public involvement process” (FHWA, 1995, p. 7). The Transportation Efficiency Act of the 21st century (TEA-21) passed in 1998 required demystifying the transportation decision-making process for non-professionals and reiterated the importance of including the public in a collaborative planning process. Safe, Accountable, Flexible, Efficient Transportation Equity Act: A

Legacy for Users (SAFETEA-LU), passed in 2005, reaffirmed what TEA-21 had legislated in this regard.

Other than changing focus and hierarchy, transportation planning statutes have laid out several important regulations that have MPOs rethink the process in which they conduct their planning efforts. SAFETEA-LU required transportation plans to be in electronic format to the maximum extent practicable and to provide "visualization techniques to describe metropolitan transportation plans and TIPs" (FHWA, 2005, p. 110). Regulations also required MPOs to seek out and consider in particular "the needs of those traditionally underserved by existing transportation systems, such as low income and minority households which may face challenges accessing employment and other amenities" (FHWA, 2005, p. 106).

Title VI of the Civil Rights Act of 1964 and Executive Order 12898 requires that the "traditionally underserved" not bear "disproportionate share of the negative environmental consequences resulting from…execution of federal…programs and policies" (Congress, 1994). Implementing orders from the US Department of Transportation (USDOT, 1997) and subsequently by the Federal Highway Authority (FHWA) and the Federal Transit Authority (FTA) (jointly known as "the federal agencies") explicitly enunciated that the President's order was to be applied to every stage of transportation planning (FHWA, 1998).

1.3.2 The Metropolitan Planning Organization and TIP

The Federal Highway Act of 1958 required all urbanized areas, with populations greater than 50,000, to have a body of locally-elected officials form a Metropolitan Planning Organization (MPO) (USDOT, 1958). At least 75 percent of the people of urban areas that have more than 50,000 people must be represented via their local governments in a MPO. Some MPOs, for this reason, need to straddle more than one state.

The structure of a MPO varies across the country; at a minimum it consists of a policy board and a technical advisory committee (TAC). The policy board, depending upon the regional makeup, consists of elected and appointed officials from the region, modal representatives, state agency officials, interest group representatives and tribal government representatives. The policy board is advised by a technical committee that includes planning and engineering staff from the region. Some MPOs have additional committees like citizen groups or other specialized panels for advising purposes. The TAC has primary responsibility for developing the tools of analysis for evaluating the transportation requirements of the region. Federal laws allow local MPOs to have the freedom to develop the tools that they desire and require no uniformity between MPOs. MPOs only need to follow mandates from federal agencies and the Long Range Plan (LRP) from their states. For this reason, each MPO has its own set of criteria, determined by its TAC and its policy board, for choosing, among the various infrastructure projects, the ones that would be on the TIP list.

A TIP consists of a list of projects and project segments that are approved for funding and are at the implementation stage. These projects have already gone through the scrutiny of the planning process by the state DOT and the TAC of the local MPO and have been considered to meet the transportation needs of the projected population of the region (NJDOT, et al., 2006). Larger TIPs usually undergo a public opinion process conducted by the MPO and scientific environmental impact studies (EIS) before they are finalized. All acronyms are listed in Appendix A.

1.3.3 The Urban Travel Demand Model

Historically, transportation needs of a region have been identified by focusing on the single issue of estimating vehicular travel demand. The process of identifying demand varies by region and has evolved both as a result of planning statutes, mentioned earlier, and through a better understanding of complexities of the effects of transportation planning. At the heart of this approach to transportation planning lays an elaborate four-step Urban Travel Demand Model (UTDM).

UTDMs determine the number of trips that will be generated from each Traffic Analysis Zone (TAZ), the way the trips will be distributed (i.e. origin and destination of the trips), the split between the available modes that travelers will make, and the specific routes that would be chosen by them (Hanson, 2004). A TAZ is a zone created for traffic analysis purposes only that demarcates areas which have people with similar travel habits. TAZs usually lie within larger census demarcations like census tracts so that they can draw population information from census sources.

Although running the UTDM still remains the staple transportation planning tool used by almost all transportation planning organizations, over time, the narrow focus on just estimating travel demand and increasing road capacity has widened to take into consideration the secondary effects that improved transportation facilities and increased travel demand generates, like change in land use, congestion, pollution, accidents, energy consumption, environmental impacts, economic impacts and impact on the quality and life of the communities affected by the change in transportation capacity. Consequently simple travel demand models have evolved into integrated land use travel demand models, that take into consideration one or more of the above mentioned concerns

(Wegener, 2004). Efforts to make UTDM comprehensive, for more than the past 35 years, has led to levels of complexity in its design that have rendered it incomprehensible to people outside the small world of travel demand modelers. In spite of this shortcoming, this cumbersome and expensive method to evaluate the needs of the future population remains the primary tool to determine the need and the efficacy of a TIP.

UTDMs consider accessibility, but these considerations are usually buried deep within the models in ways that are difficult for the ordinary public to understand; moreover each UTDM considers accessibility differently. The complexity involved in the use of UTDMs makes it a weak candidate for demystifying the transportation planning process – an essential requirement of a collaborative planning process (Bertolini, et al., 2005). UTDMs are therefore not considered in this study, which is aimed to measure accessibility in a collaborative planning process.

1.4 A Roadmap of this Dissertation

This dissertation is organized into six chapters. In Chapter Two a conceptual framework to comprehensively understand how accessibility is considered is introduced. This framework is used throughout this dissertation and is thus explained in details here. In this chapter the framework is used to review the literature on accessibility. A general review of the current practice of visualization in collaborative transportation planning, and a review of the small body of literature on accessibility considerations by MPOs brings the second chapter to a close.

Chapter Three poses the research questions and elaborates on the research method used in this study. This chapter ends with a discussion of the advantages and disadvantages of the method used.

Chapter Four details the information gathered from three MPO case studies. Each subsection is dedicated to a single case and follows the conceptual framework outlined in Chapter Two to understand how accessibility is considered by a MPO. Each subsection ends with a discussion on how TIPs are evaluated by the MPOs and how collaborative planning is undertaken by them.

Chapter Five summarizes the data gathered from the three case study MPOs. It compares the methods used by each in measuring accessibility in detail. Based on this analysis, a measure of accessibility appropriate for MPOs is developed in the following chapter.

Chapter Six details the development of a GIS-based tool to measure accessibility suitable for use by a MPO in a collaborative planning process. Because of the lengthy geoprocessing time taken, this tool is developed at three levels. All the levels use the same application and have the same level of functionality, but the amount of data that they handle varies. The first, or the "demo" level, handles the least amount of data and is the one that was sent out to the MPOs for feedback on the tool. The second, or the "dissertation" level, uses approximately half the total data and is used for analyzing accessibility in this study. The third, or the "desired" level of the tool, uses all the data pertaining to the tool. This chapter concludes with findings from the modeling study, feedback obtained on the tool from the MPOs and a discussion of the limitations of the tool developed.

The seventh, and concluding chapter, puts the study in perspective and suggests ways in which the new tool for measuring accessibility can be developed further.

CHAPTER 2

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

This chapter reviews the central concept of this dissertation - accessibility - as it appears in urban planning, engineering and quantitative geography literature. As the number and type of accessibility concepts is large and varied, a conceptual framework is built to review these concepts systematically and comprehensively. This conceptual framework is used throughout this dissertation, wherever it is required to comprehensively understand how accessibility is considered, in the following chapters. An overview of the current practice of visualization in collaborative transportation planning is provided along with the review of the small body of literature that exists on accessibility considerations by MPOs. A synthesis and analysis of the entire chapter is provided as a concluding overview.

2.1 Conceptual Framework for Considering Accessibility

A conceptual framework to categorize the various ways accessibility could be considered by an MPO is presented in Figure 2.1. If accessibility is not considered at all by a MPO, no further analysis is possible. If, however, accessibility is considered, it may be taken into account either implicitly or explicitly. Implicit consideration of accessibility could occur through the adoption of land use practices or through planning practices (like those that encourage intermodal transportation systems). An explicit consideration of accessibility, on the other hand, could be defining it and not measuring it or both defining and measuring it.

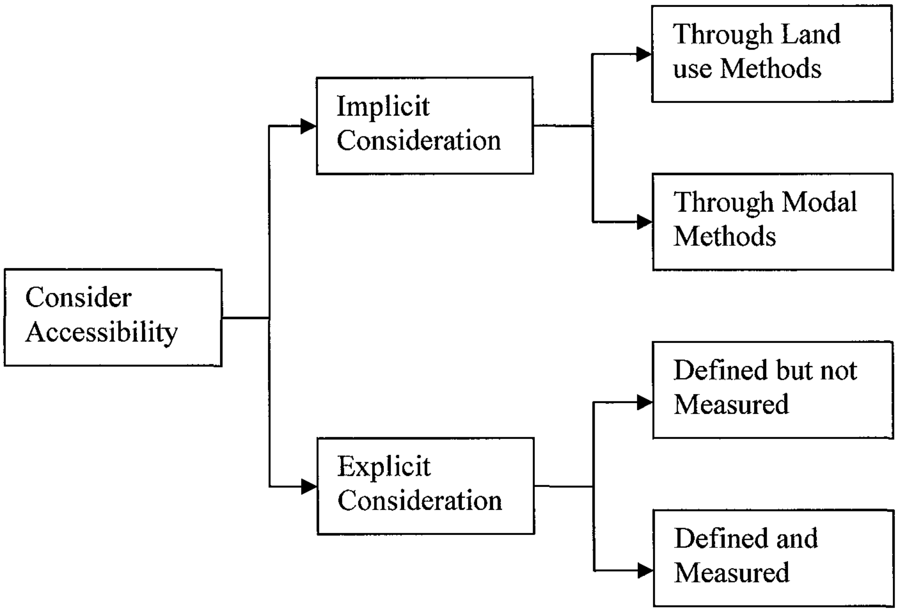

Figure 2.1 Conceptual framework for understanding how accessibility is considered.

2.2 How Accessibility is Implicitly Considered

Land use planning in the United States, primarily pursued through comprehensive plans, master plans, subdivision ordinances, zoning statutes and other regulatory and proprietary actions of local governments, is carried out by local planners and elected officials with input from the public. Transportation planning, on the other hand (as indicated in the previous chapter), is primarily under the jurisdiction of the regional MPO and the state DOT. It is the MPO's responsibility to make sure that its own plans are in keeping with federal mandates and the state's LRP.

Land use planning and transportation planning are interdependent. The usual forms of growth, in the US, with their strict zoning codes and low dependence on transit, require people to travel long distances in automobiles to fulfill daily chores and consequently create road congestion (Handy, 2005b). As transportation improvements are built to alleviate congestion, new developments are encouraged because of increased road capacity. Transportation improvements thus induce demands on roads and once again create congestion. This unending cause and effect loop between new transportation facilities and new development is one of the most perplexing problems for MPOs. The first challenge that MPOs face is to break the dichotomy between transportation and land use planning by coordinating the two within its own jurisdiction. The second challenge is the coordination of land use planning and transportation planning across different jurisdictional boundaries and levels of government.

Accessibility enhancing (AE) planning methods try to approach both the problems together. Examples of AE strategies include, but are not restricted to, smart growth, new urbanism, transit oriented development and main street programs. Each of these AE strategies is a set of planning principles that is not necessarily unique; some of the principles is shared by more than one AE approach and vary from breaking down the strict zoning codes that separate land uses to introducing mass transit. AE methods are qualitative in nature and do not measure accessibility quantitatively; rather they use accessibility as a concept and a goal (Handy, 2004). This does not mean that the outcome of AE methods can not be measured; for that reason AE methods that implicitly consider accessibility have been included in this study. To clearly understand the methods used to enhance accessibility implicitly, the framework breaks down the integrated AE approach by it dichotomous goals: those that manipulate land use and those that encourage modal methods.

2.2.1 Land Use Methods

The lack of coordination between land use and transportation planning has promoted undesirable patterns of development like sprawl (Atash, 1996). Enhancing accessibility by land use planning methods includes strategies that use zoning ordinances and subdivision regulations. Zoning ordinances define the permitted uses of land, the nature of the buildings on it, and the density at which they can be placed. Subdivision regulations, on the other hand, spell out how the land can be divided for the "location, design and installation" of the supporting infrastructure (Hoch, Dalton, & So, 2000).

There are a number of land use planning methods that increase accessibility: strengthening the central and inner city, developing compact suburban centers, promoting mixed use development along metropolitan transit corridors. However varied these methods may be all of them exhibit the common characteristic of mimicking the qualities of an "urban village." These characteristics have been summarized as "mixed land use, with commercial offices and shops on main spine, surrounded by residential; high density so that everything within the village is within walking and cycling distance; a mixture of public and private housing with an emphasis on families; public spaces with strong design features; large degree of self-sufficiency for the community" (Roseland, 2005, pp. 139-140).

2.2.2 Modal Methods

The second method of accessibility enhancement is through design that encourages modes of travel other than the automobile. Since the passage of ISTEA, taking alternative modes into transportation planning into consideration has become mandatory: MPOs now need to incorporate the use of buses, light rail and bicycles as much as possible in their long range transportation plans. This is done in several ways including the construction of sidewalks and bike lanes in urban areas, trail programs in scenic areas, building bike and pedestrian bridges in high traffic areas, designating safe routes to local schools and building traffic calming measures that reduce negative effects of motor vehicle use (Roseland, 2005).

Increasing accessibility however “is more complex than simply pedestrianizing or transitizing the suburbs” (Ewing, Haliyur, & Page, 1994, p. 60). A study by Kyrgsman and Dijst (2001) conducted in the Netherlands looked into the most frequently occurring mode chain combinations, number of trips, trip duration, and mean trip length that people take and concludes that some very distinct personal characteristics are associated with multimodal travel. Murray (2003) points out the difficulties of calculating transit accessibility; in particular he shows how increasing the number of transit stops increases accessibility but at the same time decreases the perceived desirability of such service. More studies need to be done to understand the complexities of multimodal transportation.

2.3 How Accessibility is Explicitly Considered

Accessibility is considered to be a “slippery notion…one of those common terms that everyone uses until faced with the problem of defining and measuring it” (Baradaran & Ramjerdi, 2001; Church & Marston, 2003).

2.3.1 Accessibility Defined

Accessibility is defined variously in literature. Questions that come to mind when trying to define the word accessibility are “from what,” “to what” and “for whom” (Baradaran

& Ramjerdi, 2001). The answer to the first two parts, from and to what, lies in describing the characteristics of the built environment: distance between origin and destinations, types of services between origin and destination (e.g. lanes of highway, availability of bike lanes) and land use patterns (e.g. number of grocery stores within biking distance). These descriptions of the built environment are only the supply side of transportation planning. Indicators of fixed infrastructure characteristics turn a blind eye to the characteristics and behavior of the people which determine how the supply is used (which answers "for whom"). This dichotomy of spatial characteristics of infrastructure, that are fixed, and the characteristics of people, that are variable, gives rise to very distinct ways of defining accessibility.

Thakuriah's definition of accessibility as that which is "fundamentally concerned with the opportunity that an individual at a given location possesses to participate in a particular activity or set of activities" (Thakuriah, 2001, p. v) includes all the components of accessibility. It is however Geurs and Ritsema van Eck's (2001) definition that clearly identifies the four basic components of accessibility: (1) a transportation component that reflects the time and cost involved in traveling; (2) a land use component, that gives us the distribution of the supply side; (3) a temporal component that identifies the time limitations within which one operates; and (4) an individual component that reflects one's ability and needs. As an extension to this view, Geurs and Risema van Eck define accessibility to be "the extent to which the land use transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (combination of) transport mode(s)" (Geurs & Ritsema van Eck, 2001, p. 19).

2.3.2 Accessibility Defined and Measured

The bulk of the research on accessibility is about measuring it. Researchers have organized the literature on accessibility measures in various ways. Hanson (2004) groups accessibility measures by the characteristics of the infrastructure (of places) and by the behavior of the population (of people). Handy and Niemeier (Handy & Niemeier, 1997) classifies measures into isochrones, gravity-based measures and utility-based measures. In this study, accessibility measures are classified as those that are proximity-based, gravity-based, spatial opportunity-based, spatial choice-based, other economics-based and space-time-based. Each study is also categorized by how the following were taken into account when constructing the measure: scale (city, metropolitan or global); mode (if the mode of transportation was implicit or explicitly mentioned); interaction type (potential or actual and whether population data was aggregated or disaggregated); and whether GIS was used.

2.3.2.1 Proximity-Based Measures. Proximity-based measures are the simplest of all accessibility measures. Although it may be argued that proximity is an inherent characteristic of accessibility, and is a part of almost all measures, early measures tried to determine what constituted the proper estimate of distance and not much else. Garrison (1960) condensed the neighborhood to a point and used the straight line distance between points and graph theory techniques to figure out a measure of accessibility. Baxter and Lenzi (1975) considered people to be living in zones and took the centroids of these zones for their measure. Brans, Engelen and Hubert (1981) developed an aggregate measure as Garrison and Baxter and Lenzi did but, instead of straight lines, considered actual distance in a road network, creating one of the first rudimentary GIS-based accessibility measures.

A second set of proximity measures, sometimes referred to as topological measures, are concerned with the nature of connection between places. Ingram (1971) devised two important and distinct measures of accessibility by studying how places were linked to each other using two concepts: relative accessibility (the degree to which two places are connected), and integral accessibility (the degree of connection of a place with the entire network of places). Neither of these measures considers the mode of transport between places. As the name suggests, relative accessibility is at a smaller scale than integral accessibility.

All of the proximity-based measures mentioned above treat accessibility as a function of distance and do not take into consideration any variations in the population and are totally independent of the people involved. Table 2.1 summarizes the above mentioned distance-based measures by categories outlined in the previous section.

Table 2.1 Summary of Proximity-Based Accessibility Measures

Measure of	Measure Type	Authors	Measure detail	Scale	Mode	Interaction type	Study type
I	Proximity-Based-Distance	Baxter and Lenzi (1975)	Straight line distance between centroids of zones	C	X	L, T	X
		Brans, Engelen and Hubert (1981)	Shortest distance via modified network	C, M	X	L, T	Y
		Garrison (1960)	Straight line distance, graph-theoretical network analysis	C	X	L, T	X
	Proximity-Based-Topology	Ingram (1971)	Relative accessibility-degree to which two places are connected	C	X	L,T	X
		Ingram (1971)	Integral accessibility-degree of interconnection for a point with whole network	C, M, G	X	L, T	X

Key:

A= Actual Interaction	L=Potential	V=Individual
C=City	M=Metropolitan	X=No
G=Global	O=People	Y= Yes
I= Infrastructure	T=Aggregated	YE/I=Yes explicit/implicit

2.3.2.2 Gravity-Based Measures. Hansen's classic paper was not only one of the first to operationalize accessibility, it also implied that people, along with distance, are an integral part of accessibility. Hansen considered accessibility as "the potential for opportunities for [economic and social] interaction" (1959, p. 73). To operationalize this general definition Hansen suggested a more specific definition of accessibility as "a measurement of the spatial distribution of activities about a point, adjusted for the ability and the desire of people or firms to overcome spatial separation" (p. 73) and developed a gravity model. Transportation planners and other researchers have developed gravity models based on Newton's gravitational laws. These models aggregate human travel behavior to follow gravitational properties where attraction is directly proportional to population size and decays as an exponent of distance. Attractiveness is not measured by surveying but rather through surrogates like size or variety of opportunity (e.g. square foot of retail stores) and physical distance.

Ingram explores variations of the exponent of the gravity model in both straight line and Manhattan distances to measure accessibility and concludes that "it may be sufficient to use straight line rather than rectangular distances" (1971, p. 107) for the examples that he uses. A number of transportation studies, including the Erie Transportation Study and the Puget Sound Transportation Agency Study, have used the denominator of the gravity model to evaluate accessibility (Niemeier, 1997). Handy (1993) also applied an exponential form of the denominator of the gravity model in an evaluation of the differences between local and regional accessibility.

Gravity models have several criticisms. The model is constructed of measures of attraction and distance each of which can be represented in different ways (Thomas & Huggett, 1980). Gravity measures have an underlying assumption that elements of the physical environment affect all human beings equally. Also, personal ability, mode of transportation and time constraints felt by individuals are not in any way included in gravity measures. Gravity models are also sensitive to the modifiable area unit problem (MAUP) where the level of aggregation affects the value of any measurement made using the model.

A summary of gravity-based measures is shown in Table 2.2.

Table 2.2 Summary of Gravity-Based Measures of Accessibility

Measure of	Measure Type	Authors	Measure detail	Scale	Mode	Interaction type	GIS
I	Gravity-based	Handy (1993)	Exponential denominator	C	X	L, T	X
		Hansen (1959)	Inv. To size of activity area	C, M	X	L,T	X
		Ingram (1971)	Straight line and Manhattan distance-based	C	X	L,T	X

Key:

A= Actual Interaction	L=Potential	V=Individual
C=City	M=Metropolitan	X=No
G=Global	O=People	Y= Yes
I= Infrastructure	T=Aggregated	YE/I=Yes explicit/implicit

2.3.2.3 Spatial Opportunity-Based Measures. By far the most numerous of all accessibility measures are those that are based on opportunities available to people within a certain distance or a certain period of time. The summations of opportunities used in both spatial opportunity measure, and the denominator of the gravity model have some fundamental problems. First, both lack a direct relationship between individual choice and accessibility. Second, both gravity measures and spatial opportunity measures aggregate people which has MAUP implications. Finally, the magnitude of the measure of accessibility that is obtained by using gravity measures and spatial opportunity measures is ambiguous. Spatial opportunity measures, however, are easy to understand and calculate. They are also less demanding on data requirements and can be on a map using simple tools. A summary of relevant spatial opportunity measures developed are listed in Table 2.3.

Table 2.3 Summary of Spatial Opportunity-Based Measures Accessibility

Measure of	Measure Type	Authors	Measure detail	Scale	Mode	Interaction type	GIS
O	Spatial Opportunity – number of facilities within given distance from point of origin	Arentze (1994)	Multipurpose/ multi stop travel in agglomeration of facilities	C	X	L, T	Y
		Breheney (1978), Koenig (1980)	Weighted sum of facilities	C, M	X	L, T	X
		Craig (1978)	Accessibility to road network, services, regional activities using suitability	C, M, G	YI	L, T	X
		Dalvi and Martin (1976)	Attractiveness of opportunities	C, M	YI	L, T	X
		Handy and Niemeier (1997)	Number of shops within certain time	C	YI	L, V	Y
		O'Sullivan, Morrison and Shearer (2000)	Isochones for public transport	C	YN		Y
		Shen (2002)	Number of jobs from home	C	YI	L, V	Y
		Small (1992)	Attractiveness weighed by impedance	C	YI	L, T	X
		Thompson (2001)	Total number of jobs by transit	C	YN	L, T	X
		Wachs and Kumagai (1973), Cerney (1973), Shen (1998)	Cumulative opportunity, Isochrone (number of opportunities within certain time)	C	YI	L, T	X

Key:

A= Actual Interaction	L=Potential	V=Individual
C=City	M=Metropolitan	X=No
G=Global	O=People	Y= Yes
I= Infrastructure	T=Aggregated	YE/I=Yes explicit/implicit

2.3.2.4 Spatial Choice-Based Measures. Spatial choice measures are essentially utility-based indicators that have their roots in travel demand modeling. These measures consider choices from a "group of alternatives" that individuals have in making travel decisions. As individuals have incomplete information, a "random" component is introduced, so the measures are also called random utility models. Unlike the simple gravity measures, where all individuals in a particular zone experience the same amount of accessibility, regardless of how they perceive the choices that they have, spatial choice considers each person individually.

Ben-Akiva and Lerman (1979) were two of the first researchers to measure accessibility in a manner similar to how economists view choices that people make in buying goods. To continue the economic analogy, Ben-Akiva and Lerman put monetary values to each set of choices a person makes and then evaluated the "cost" incurred by individuals in order to compare them.

Spatial choice/utility-based measures have worked very well with theories of travel behavior but these measures are data intensive and require data that is not easily available. The requirement for large amount of data also translates into long computing time and higher computing power requirements than those required by the measures of accessibility mentioned so far. Another problem with the spatial choice measures, and most other economic measures, is that they assume that all individuals have the same discrimination capability at all times irrespective of factors like socio-economic status and other factors that affect choice. In spite of these drawbacks, spatial choice measures are innovative for being the first of the disaggregated, individual behavior-based measures of accessibility.

Koenig (1980) took the innovative concept of spatial choice measures, introduced a probability density function of gross utility and created a practical tool for comparing job accessibility in two road investment cases for both individuals and aggregated levels of population. A summary of some of the key research work done on spatial choice measures is shown in Table 2.4.

Table 2.4 Summary of Spatial Choice-based Measures of Accessibility

Measure of	Measure Type	Authors	Measure detail	Spatial scale	Mode	Interaction type	GIS
O	Spatial Choice	Ben-Akiva and Lerman (1979)	Random utility - individual's travel decision process viewed as set of alternatives w/random components for non-predictable factors	C	YI	L, T	X
		Koenig (1980)	Random utility with particular probability distributions	C	YI	L, V	Y

Key:

A= Actual Interaction	L=Potential	V=Individual
C=City	M=Metropolitan	X=No
G=Global	O=People	Y= Yes
I= Infrastructure	T=Aggregated	YE/I=Yes explicit/implicit

2.3.2.5 Other Economics-Based Measures. Burns (1979) explored the role of accessibility in making spatial choices but more importantly he was one of the first researchers to use monetary values to quantify ease of travel. Burns' measure however lacks the sophistication of Ben-Akiva's measure. A travel cost approach has also been used by Breheny (1978) and Guy (1977) to measure accessibility to retail markets and the performance of transportation infrastructures.

Current, Revelle and Cohon (1987) developed an algorithm to be used by transportation network designers for locating infrastructure elements such that the cost incurred to build the element and the cost incurred by the infrastructure users to access the elements is optimized. Other economics-based measures include Forkenbrock and Weisbrod's (2001) measure that takes into account vehicle operating costs, environmental costs and safety costs. These measures are easy to understand and calculate and are not data intensive.

Economics-based measures have MAUP implications and do not consider variation in the quality of locations and ignore behavioral aspects of individuals. How different individuals value time is also not considered by this group of measures. Individual socio-economic circumstances that determine how people make decisions are also absent from measures that are based on economics. A summary of economics-based measures other than spatial choice measures is shown in Table 2.5.

Table 2.5 Summary of Other Economics-Based Measures of Accessibility

Measure of	Measure Type	Author	Measure detail	Spatial scale	Mode	Interaction type	GIS
O	Economics	Burns (1979)	Space-time autonomy	C, M, G	YE	A, V	X
		Breheney (1978),	Weighted sum of facilities	C, M	X	L, T	X
		Current, Revelle, Cohon (1987)	Minimization of both path (median distance) and travel time	C, M	YI	L, T	X
		Forkenbrock and Weisbrod (2001)	Cost of travel along with 3 other factors	C, M	Y	L	X
		Guy (1977)	Cost of traveling to supply, impedance	C, M	YI	L, T	**X**
		Leonardi (1981)	Consumer surplus or net benefit as decreasing function of travel costs	C, M	YI	L, T	**X**

Key:

A= Actual Interaction	L=Potential	V=Individual
C=City	M=Metropolitan	X=No
G=Global	O=People	Y= Yes
I= Infrastructure	T=Aggregated	YE/I=Yes explicit/implicit

2.3.2.6 Space-Time Measures. Most accessibility measures mentioned so far consider people in an aggregate manner that do not allow for individual variations in the behavioral constraints they face. Space-time, the final class of measures, overcomes these limitations by using actual travel and activity patterns of individuals and their personal characteristics to measure accessibility. Based on Hagerstrand's (1970) work, this class of measures considers both the time and space constraints that individuals face on a daily basis in trying to reach opportunities or potential opportunities.

Torsten Hagerstrand first introduced the concept of time in the study of human activities in 1963 through "space-time prisms" that he drew of individuals (Newsome, Walcott, & Smith, 1998). The space-time prisms identify all locations in space and time that can be reached by an individual depending on the environmental and social conditions of the person. The prism is refined by the time constraints in the person's personal life, like mandatory activities, and the travel velocities of the transportation modes that are available to that person. Though this system is powerful, it does not recognize the varying attractiveness of places, individual motivational factors, intentions or experiences that play a part in a person's mind when choosing an activity. Rather, it emphasizes the constraints that are imposed on a person's daily activity and defines the physical limit to the accessibility field of the person for whatever personal reasons the individual decides to follow his/her path (Golledge & Stimson, 1997).

Space-time analysis can be conducted at several levels. At the individual level, space-time analysis takes into consideration the fact that one's surroundings has a role on individual accessibility and that the choices made by one person may constrain the choices available to some others (Weber, 2001). At the station level (places where people meet as a result of different tasks and projects) events that can take place are defined by an activity area called the potential path area (PPA). When an entire population of individuals, bounded by space and time, is studied, the characteristics of the population, like age and gender, determine the dynamics of the group's space time prism (Kim, 2005; Kwan, 1999).

Space-time prisms were operationalized in a GIS by defining PPAs as feasible transportation routes between activity nodes. This made it possible to visualize accessibility in a transportation network and identify variations in accessibility for the first time (Miller, 2004). Calculating the network equilibrium condition from this view point brought into question the four step travel demand models. Forecasting travel demand, using a variety of complex four step models, has been the basis of all transportation planning in the United States since the 1950s (Miller, Kriger & Hunt, 1998).

Lenntorp (1976) developed a set of alternative sample paths that a person could take, given the individual's activity and space-time constraints, to calculate the number of feasible paths between origins and destinations. Lentorp considered the feasible activity schedules generated by the program to be a measure of accessibility. Other researchers have employed modified space-time prisms to indicate individual accessibility based on various travel speeds, multistop trip chaining, and changes in activity schedules (Arentze, et al., 1994; Pendyala, Yamamoto, & Kitamura, 2002; Wu, 2003).

Consideration of the temporal dimension of human activity and individual time constraints was a new step in measuring accessibility. Miller (2000) summarizes the disadvantages of these measures and derives new measures by combining the space-time and the utility-based models into a composite model. Miller adopts Weibull's (1976) axiomatic approach as a starting point and calls these models space-time accessibility measures (STAMs), which are based on the assumption of uniform travel speed. STAMs are based on the utility of performing a series of discretionary activities (e.g., shopping, visiting), given the mandatory activities (e.g., work). Individual STAMs (Miller and Wu, 2000) have gained increased popularity in the late 1990s and early 2000 partly due to GIS developments that include programming facilities and techniques for visualizing individual behavior.

The major problems with space-time measures are that they depend on large amounts of information about completed activities and trips at the individual level (Kwan, 1998; Pirie, 1978). These activity trips (also called travel diaries) need to be diligently filled out for every activity that participants undertake when they are outside their homes whatever the time may be. The tediousness of recording this data, upon which the entire measure rests and which has to be carried out by respondents, requires a considerable period of time, sometimes leads to gaps or erroneous data. GPS in car diaries have helped to make digital travel diaries more accurate and complete. Another drawback of space-time measures is that they are best applied retrospectively (Pirie, 1978). Otherwise this measure, gives the most accurate measure of accessibility.

It is to be noted is that all people-based measures, including space-time measures, consider constant speed for all movement. This static model of accessibility has been improved upon in a space-time measure of accessibility by Wu and Miller (2001) and by Weber and Kwan (2002) who propose dynamic models that take into consideration variable speed and travel times of individual but, as mentioned earlier, their methods rely excessively on the accuracy of data keeping from a large population over a long period of time. A summary of space-time measures is shown in Table 2.6.

Table 2.6 Summary of Space-Time-Based Measures of Accessibility

Measure of	Measure Type	Authors	Measure detail	Spatial scale	Mode	Interaction type	GIS
O	Space-Time	Berglund (2001)	Path-based measure with zonal weights	C	YI	A, V	Y
		Dong (2006)	Activity-based	C, M	YE	A, V	Y
		Harris (2001)	Competitive accessibility between opportunities	C	YI	L, V	X
		Miller (2004)	Urban activity prisms	C, M	YE	A, V	Y
		Weber and Kwan (2002)	Variable travel time	C	YE	A, V	Y
		Wu and Miller (2001)	Considers time variation in network	C, M	YE	A, V	Y

Key:

A= Actual Interaction	L=Potential	V=Individual
C=City	M=Metropolitan	X=No
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I= Infrastructure	T=Aggregated	YE/I=Yes explicit/implicit

2.4 GIS-based Measures of Accessibility in Transportation Planning

Compared to the considerable body of research on accessibility measures since 1959, a small, relatively recent, literature exists on how transportation planners use the accessibility measures with GIS; understandably so as GIS is a recent development.

In the recent past, three GIS-based analytical tools have been developed for transportation planners to measure accessibility. Studying a large MPO in an equity framework, Klein (2007) measures the degree of influence a TIP project has on the population that lives around it. He uses cluster analysis and a gravity-based measure of accessibility to determine a value for the distribution of the impact of the TIP on minority population groups. The British Department of Transportation uses ACCESSION

(Citilabs, 2007) a software program for measuring access to basic needs, via a multimodal network. As ACCESSION is the product of a private corporation and no published literature could be found on it, information about how it works exactly could not be obtained. Vandenbulcke et al (2009) have developed a GIS-based tool, that they have used in Belgium, for measuring accessibility to transportation centers and transportation nodes by car during peak and off-peak hours.

2.5 Visualization

Visualization refers to computer graphic techniques and interactive visual displays. The first subsection below gives an overview of the use of visualization in transportation planning and the second subsection gives an overview of GIS-based measures of accessibility that have a visualization component.

2.5.1 Visualization in Transportation Planning

US transportation legislation of the 1990s made public participation a critical factor in the TIP selection process. Since then, transportation projects can no longer be justified on merits decided upon by esoteric travel models alone but have to take into account the opinions of people who will be affected by the proposed projects. SAFETEA-LU, passed in 2005, strengthened this process by requiring the inclusion of visualization techniques in public/stakeholder interactions. It has been established that providing "maps and other spatial and non-spatial information in graphical form enhances the...understanding of decision scenarios" (Yamada & Thill, 2003, p. 378). Decision scenarios arise in collaborative planning processes.

Current transportation visualizations are primarily of two types. The first type borrows technology from the rapidly evolving video gaming industry to construct high resolution 3D images of proposed TIPs in virtual reality that show the community how a project would look like (Hickson, 2007; Rhyne, Manore, & Hughes, 2008; Walker, 2007). High resolution images are also used to visualize the image of a project at various stages of construction using recent research on visual perception (Garrick, Miniutti, Westa, Luo, & Bishop, 2005; Liapi, 2003). Visualization of this nature is a very useful tool, if used from the early stages of the project, for correcting design flaws and getting design input from the community (Henry, 2005).

The second type of visualization in transportation planning involves the construction of traffic simulation models (Kitamura, 2004; Landers, 2008). Although these can show anticipated improvement of traffic flow due to a proposed project and falls partially in the category of visualization of operational performance of a TIP, simulations do not involve any input from the public and do not, in way, embody the community's desires and requirements; they are dependent solely on the information that the transportation modeler sets up for the simulation.

Research indicates that structured public involvement increases user satisfaction, both at the process and the outcome stage and when planned carefully with visualization is an effective tool. Components required in the planning include electronic scoring, incorporating iterative public involvement before finalizing design and ensuring that the chosen public involvement process is compatible with the technologies used (Bailey, Brumm, & Grossardt, 2002).

2.5.2 Visualization of Accessibility

Visualization of accessibility is not new. Miller and Wu (2000) map accessibility for STAMs using their own software while Kwan (2000, 2004b) maps possible space time paths of individuals (particularly on women) in three dimensions. Liu and Zhu (2004a, 2004b) map accessibility by tessellating an urban region into hexagons, and use travel time and cost of travel as impedances along the shortest path in a network. The authors use a origin-destination matrix, for each mode of travel but do not consider different modes together.

2.6 Collaborative Transportation Planning

Though ISTEA and TEA-21 emphasize public involvement there appears to be no research on collaborative planning in tranportation. Collaborative planning though is a mature field in urban planning. Also, public participation geographical information system (PPGIS) is a well developed and well-recognized field within GIS that particularly studies participation issues. Unfortunately this knowledge had not been transferred to transportation planning.

2.7 Notes Literature Reviewed

Transportation projects have several outcomes. Determining which of these outcomes best measure a TIP's value is beyond the scope of this dissertation. It is a personal determination of this author that one way to evaluate a proposed TIP is to understand the increase of accessibility that a TIP provides. Large sums of funding come to MPOs from the federal government, state government, local governments and public private partnerships and are in the hands of a small number of members of the MPO board who decide on the region's TIPs. The MPO board members depend on members of TAC for the technical assessment of the TIPs. Whether TACs consider accessibility at all can only be determined by interviewing them. If they do consider accessibility, it is important to understand if the measure of accessibility they use is a valid measure. If TACs do not consider accessibility, then knowing the literature well helps us to build a measure of accessibility.

It is important to include the entire evolution of the measures of accessibility until now as each of the researchers who worked towards measuring accessibility incorporated important concepts that need to be considered if one is building a measure, as is the aim in this study. For example distance-based measures like Current, Revelle and Cohon's (1987) algorithm for optimizing cost or Dalvi's (1979) concept of weighing spatial opportunity by their attractiveness, are concepts in the accessibility measuring evolution that are quite removed from the conception of STAMS, the measures developed most recently. The older measures however incorporate fundamental conceptions of accessibility that can be quite easily expressed in GIS and hold a promise for being a part of any new GIS-based measure of accessibility.

There are very few studies on MPOs themselves. Sanchez and Wolf (2005) review large MPOs on several factors: their efforts to achieve equity in planning outcomes; their efforts to reach out to the public via citizen participation plans; and the extent to which MPO boards reflect the communities that they represent.

There are two important points to note in the measure of accessibility and their visualization. First, the notion of considering the transportation mode is new in accessibility measures. With the exception of space-time measures and some spatial opportunity measures, none of the measures mention the mode of travel. A single mode of transportation is assumed in most of the measures. Second, visualizations of accessibility developed so far are deterministic and are developed with no input from the public and hence are not appropriate for collaborative planning.

CHAPTER 3

RESEARCH DESIGN

The research for this project was conducted in two parts. In Part 1 three MPOs were selected and data about these MPOs was collected to be used in Part 2. In Part 2, an area was selected from one of the MPOs jurisdiction; data on this area was collected and with this data a GIS-based tool for measuring accessibility was developed. This chapter details this sequential exploratory mixed method research for this "developmental" study (Brannen, 2008; Creswell, Clark, & Garrett, 2008). The previous chapter talked about the measures of accessibility that are considered in literature. It gave a comprehensive list of measures and then synthesized and analyzed the measures. The following chapter details the data collected for the first part of the research.

3.1 Part 1: Collecting Data from MPOs

As outlined in the Introduction, transportation planning takes place in the US under stringent statues, regulations, and guidance. These requirements are general principles that need to be followed by the MPOs. It is left to the discretion of individual MPOs as to how these principles are to be followed. The result is that MPOs use a variety of methods to meet the federal requirements. During the first part of the research three MPOs were studied to find out how they consider accessibility and how they conduct collaborative planning in their efforts to meet federal regulations.

3.1.1 Research Questions

As accessibility can be considered in various ways, the research questions follow the conceptual framework that was laid out in Chapter Two, Figure 2.1 to sort the accessibility literature (to take into account both the implicit and explicit considerations). The only information known about how the MPOs consider accessibility are the statues, regulations and guidelines they are required to follow. The decisions made by the MPOs about accessibility resulting from these requirements are not under the control of anyone but the MPOs themselves. As requirements imposed on MPOs by external agencies change over time, MPOs evolve in their own chosen ways to adapt to these requirements. The research questions, in the first part of this inquiry pertain to the current state of planning:

At the current time do MPOs consider accessibility in making decisions about regional transportation?

a) If it so, how is it considered?

b) If accessibility is defined, how is it defined?

c) If accessibility is measured, how is it measured?

d) Is the measurement conveyed to the public in a collaborative planning process?

e) If accessibility is conveyed, how is it conveyed?

3.1.2 Research Method

The first part of this study required finding out whether MPOs consider accessibility and how they disseminate this information. The lack of information on this matter, as evidenced in the literature review, calls for an exploratory study. The research method for the first part of the study is thus a case study. Yin suggests a case study form of research when questions ask how things are done about a contemporary set of events, over which the investigator has little or no control (2003).

3.1.3 Selection of Cases

The purpose of the first part of the study is to identify the ways in which accessibility is considered by the MPOs. The unit of analysis is thus the MPO. This permits the understanding of differences between MPOs in regard to their consideration of accessibility. This unit of analysis is appropriate as this study does not intend to look into "how" accessibility considerations are determined within a MPO; that would call for a smaller unit of analysis. The MPO is also the appropriate unit because the use of a larger unit of analysis, like a state, would drown out the variation of accessibility considerations of the various MPOs within a state's boundaries.

The MPOs selected for this research are the three MPOs of the State of New Jersey. The northern most MPO, NJTPA (North Jersey Transportation Planning Authority), is an integral part of the NYMTC (New York Metropolitan Transportation Council) which provides transportation planning for the northern counties of the State of New Jersey and the southern counties of New York State. DVRPC (Delaware Valley Regional Planning Commission), lying to the west of the state, provides transportation planning to the western, and central counties of New Jersey. DVRPC straddles both New Jersey and the eastern counties of Pennsylvania. SJTPO (The South Jersey Transportation Planning Organization) provides transportation planning of the southern counties of the State of New Jersey.

In 2008 there were approximately 400 MPOs in the US (Plumeau, 2007). The political boundaries of the US 48 contiguous states metropolitan planning organizations are shown in Figure 3.1. A comparison of these MPOs in terms of their size, economic capability and technical expertise were not available either from AMPO, a nonprofit organization serves the needs of a MPO or from the Transportation Research Board (TRB). It is thus difficult to claim that the three MPOs chosen for this research form a representative sample of all MPOs.

Boundaries of Metropolitan Planning Organizations in the United States

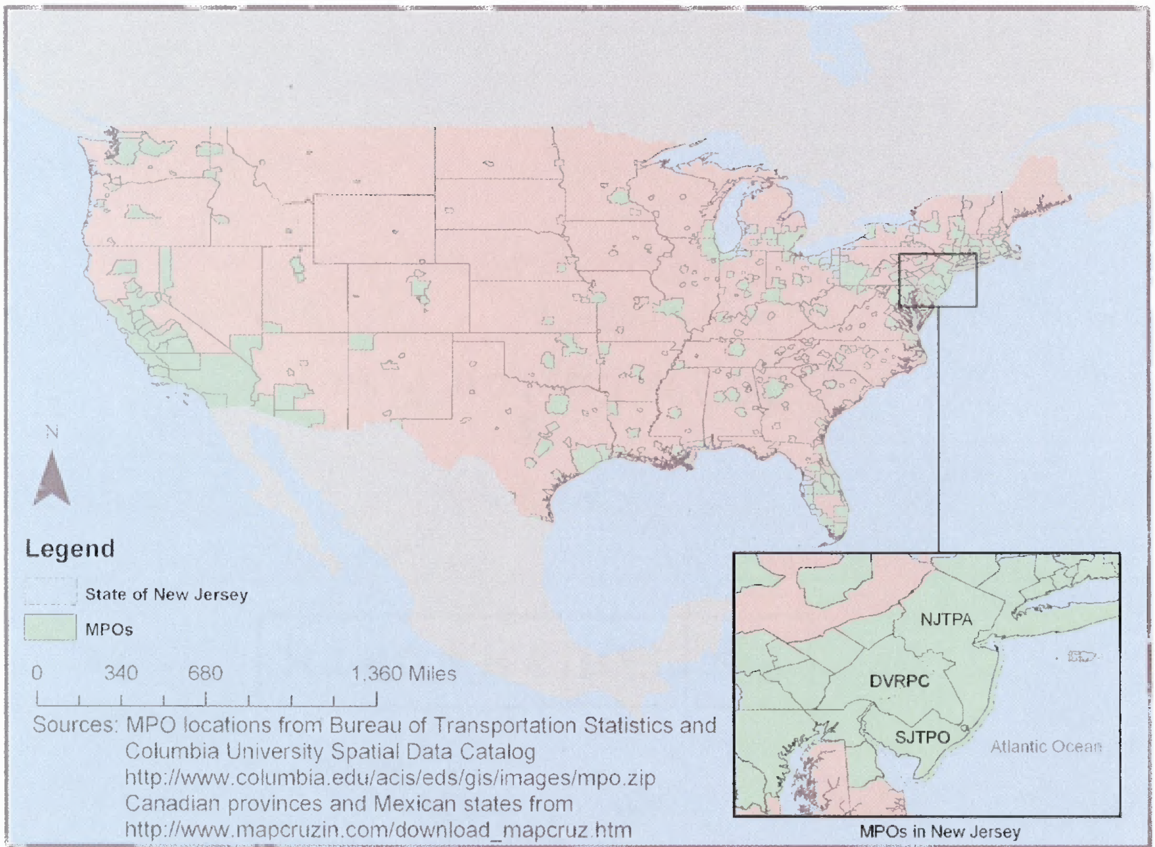

Figure 3.1 Political boundaries of US metropolitan planning organizations.

The NJTPA provides transportation planning services to one of the most dense and diverse metropolitan populations of the country. The region it serves has one of the most complex network of roads and transit facilities in the entire country. SJTPO provides transportation and other planning services to an area that has low population density and has large, environmentally sensitive areas and DVRPC provides transportation and other planning to an area that has high population densities with environmentally sensitive pockets and increasing interest in transit facilities. These three MPOs range from a dense multi-state urban to a mostly rural MPO may be considered as good representatives of MPOs of the Eastern seaboard. Short of picking all the MPOs in the US it would be impossible to figure out which MPOs would be representative cases as no information comparing them is available to the public. The choice of choosing three MPOs was determined by constraints of time and feasibility.

3.1.4 Data Collection and Analysis

The data collection from the MPOs started with gathering relevant information available on the website of each MPO. This was followed by interviews with one or more of the MPO's TAC staff depending on the number of staff members available. All interviews followed a fixed protocol. The first step was to obtain permission to interview the relevant MPO staff (Appendix B) and the second was getting permission for digitally recording the interview at the time the interview took place. The questionnaire (Appendix D) for each MPO was separated into four parts: the first part confirmed information obtained from the MPO's website; the second asked about how accessibility is considered by the MPO; the third asked how MPOs consider TIPs and the fourth asked about the MPO's collaborative planning process and the ways accessibility information is communicated to the public.

The data collected, both quantitative and qualitative in nature, was hand coded soon after the interviews into categories that were relevant for developing a tool for measuring accessibility, for the second part of the study. The coding followed the conceptual framework developed for the literature review (shown in Figure 2.1).

3.2 Part 2: Constructing a GIS-Based Measure

SAFTEA-LU clearly indicates that collaborative planning requires "visualization techniques to describe metropolitan transportation plans and TIPs" (FHWA, 2005, p. 110). In this, the second part of the research, a technique to visualize accessibility, before and after the construction of a TIP, is developed.

3.2.1 Research Questions

Building on the answers to the part of the research, the second part of the research asks the following questions:

What measure (or measures) of accessibility can be developed that would:

a) Be appropriate for the set of practices and conditions that an MPO uses in its collaborative planning process, if at all it has one.

b) Be developed from the data that a MPO possesses or has easy access to

c) Indicate via visualization differences in accessibility before and after the implementation of a transportation improvement project

3.2.2 Research Method

The questions for the second part of this research ask for the development of a measure of accessibility with certain conditions. The literature for this part, unlike the first part of the research, offers a large number of measures from which to select answers for this question. The selection of a measure of accessibility, as the subparts of the question reflects, is restricted by four conditions. These conditions were fully known only after relevant information from the first part of the research was collected.

The first subpart of the Part 2 research question pertains to the way MPOs carry out their collaborative planning process. The second subpart pertains to the data MPOs possess and the last subpart pertains to the product of a MPOs transportation planning process, a *transportation improvement* project. The answers to the first two subparts were obtained from the interviews conducted during Part 1 of this research.

The last part entails constructing a method using the data that a MPO possesses to evaluate the "difference in accessibility before and after the implementation of a transportation improvement project." Geographical Information System (GIS), "a sophisticated database management system designed for the acquisition, manipulation, visualization, management, and display of spatially referenced (or geographic) data" (Aldenderfer & Maschner, 1996, p. 4) becomes an appropriate choice for conducting second part of this research.

Analytical modeling lies at the core of GIS. Goodchild defines a model as "a computer program that takes a digital representation of one or more aspects of the real world and transforms them to create new representation" (2005, pp. 2-3). In this study spects of the "real world" that affect accessibility, as obtained from literature and the interviews with MPOs were modeled in GIS. The model, an accessibility measuring tool, can be used by MPOs to visually learn about changes in accessibility in a neighborhood resulting from a TIP project.

3.2.3 Case Selection

Atlantic City was selected as the area on which the tool was applied. It is a part of the SJTPO region and is its largest city. The primary reason for selecting Atlantic City was that, being on an island, it is very compact and together with some of its surrounding municipalities, it is an integrated economic and social unit. It is an ideal place to study as an independent unit as it has very little edge effect.

The unit of analysis in Part 1 of this study is the MPO, which is at a metropolitan region scale. The development of the tool is undertaken at the city-region scale, which forms a part of the metropolitan region. A discussion of how this change of scale is handled is discussed in a later chapter.

3.2.4 Data Collection

Although GIS is primarily a tool for quantitative analysis, recently qualitative data and analysis have been successfully modeled in GIS (Kwan, 2004a, 2006; McCray & Brais, 2007). However it is only spatial information (or spatiotemporal for dynamic analysis) that GIS is capable of handling.

GIS analysis starts with a conceptualization of the real world in a way that is conducive to yielding answers to the research question at hand. The first step is identification of relevant geographic entities and defining the relationships between them –also known as modeling. The second step involves making representational choices for the purposes of storing data in a computer. This includes the consideration of scale (or level of data aggregation) and the geometric class (like point, line or polygon) that would be appropriate for the representation. The third and final step of GIS data collection involves an understanding of the uncertainties and errors that affect the analysis (Haining, 2003).

The data collected thus largely depends upon the model that is conceptualized for measuring accessibility. The nature of the data depends on the scale at which the model is conceived. The scale in turn determines the geometric class of the dataset (for example at the scale of the city-region, Atlantic City is a set of lines of roads while at the scale of the metropolitan-region the same city is a point). Finally, easy availability of data (to the MPOs) is one of the limitations on the dataset that is expressed in the research question. Description of the data collected and the method of building the model is discussed in Chapter Six.

3.3 Inference Quality

There are several issues about the inferences made in sequential mixed method research, such as this study, which need to be assessed. The use of construct validity, internal (or content) validity, external (or criterion-related) validity and reliability are four tests that are well established for judging the quality of empirical social science research with a single research method (Creswell, 2008; Isaac & Michael, 1990; Yin, 2003). When a research uses mixed methods, three sets of standards are required; one for each of the methods and one the meta-interference that go across the two groups. Tashakkori and Teddlie argue for an "integrative framework" (2008, p. 102), to determine inference quality for mixed method research.

The two separate strands of this research, Part 1 and Part 2, need to be first tested individually and then through an integrative framework. Since there are no constructs and no causal inferences drawn in Part 1 of this research, the question about testing for construct validity, internal validity and external validity do not arise. The credibility and dependability of the data quality was confirmed by sending in the three parts of the case study chapter (Chapter Four) to the respective MPOs for their approval. Only one of the MPOs (NJTPA) replied mentioning that the method that they used for considering accessibility had evolved since the time of the interview (August 2007) and that this fact should be mentioned in the dissertation. It is assumed that since DVRPC and SJTPO did not reply, they did not have any concerns with the contents of Chapter Four that dealt with their respective organizations.

The reliability and validity of the data collected for Part2 of the research depends on the organizations from whom the GIS data was obtained. Street data, the primary base of the entire analysis, was based on data obtained from Navteq, a private street data collection firm. Navteq is currently one of the two leading companies in the field of street data information collection. Navteq is the process of continually updating their data and publishing a new version of their data every quarter. The accuracy of their data, primarily used in automobile GPS navigation systems, depends on the date the data was downloaded. For this research the data published for the fourth quarter update of 2008 was used.

The quality of the meta-inference requires data, results and interpretation of results to be appropriate and analytically adequate to the purpose of the research. The research was centered on developing a tool to measure accessibility that could be used by MPOs in their collaborative planning practice. Data to understand how accessibility was considered by MPOs was collected through case studies. This helped to develop the accessibility measuring tool that was suitable for the MPOs. A demonstration version of the tool was sent out to the MPOs to get a feedback about its appropriateness for its purpose and the comments received by the MPOs were recorded.

The conceptual framework based on which the research and analysis was carried out covers every aspect of accessibility that an organization could possibly consider. This framework to consider accessibility is the first of its kind. The literature on accessibility does not have a framework of this nature and thus there is no other reference to compare it to regarding its comprehensiveness or adequacy.

Interpretive rigor for this research pertains to the appropriateness of the use of suitability modeling. Suitability modeling was essentially used in this study to search for the boundaries of lands that have predetermined characteristics. In land use planning, examples of these characteristics are proximity to water bodies, slope of the land and type of zoning; corresponding examples in habitat modeling are the flora or fauna of the land, humidity and temperature characteristics. There is no logical difference in searching for boundaries of lands that have predetermined characteristics pertaining to accessibility to searching for lands that have predetermined characteristics pertaining to habitat or land use. Suitability modeling has thus been reinterpreted appropriately for a transportation planning problem.

Suitability modeling is a time tested method used for collaborative land use planning; it is deemed to be an appropriate modeling method for collaborative planning (Malczewski, 2004; Pettit & Pullar, 2004). Suitability modeling is dependent on adding cell values of raster data. Combining raster data mathematically "should only be done using interval or ratio data" (Carr & Zwick, 2007, p. 49). The values of the raster that are added in the model developed for this study is time and distance, both of which are ratio data and hence appropriate for raster addition. The adequacy of the suitability model is analyzed in Appendix M by comparing the variables considered in literature to those that are used in the tool developed. All measures of accessibility that appear in literature, unless conceptually different or violating requirements have been included in the tool developed; thus fulfilling the requirements of adequacy of the study.

3.4 Advantages and Disadvantages of Research Method used

The sequential mixed research method used in this study has several advantages and disadvantages. The primary advantage of a case study approach in the first part is that it involves interviewing relevant staff members of each planning organization, to gather information about an issue, like accessibility, that is implied on their websites but is not discussed explicitly. Open-ended questions based on the conceptual framework, illustrated in Figure 2.1, is the ideal instrument to understand of the implied concepts. The framework used for the questionnaire is the one developed for the literature review.

Multiple sources for the information collected for the case studies helped in the comprehensive construction of information for each MPO. This aspect of a case study approach was very appropriate for studying New Jersey MPOs as they have a large number of publications and a high turnover rate.

Cresswell et al (2008) point out certain methodological issues that arise in conducting mixed method research that has a sequential design, as in this study. The first of their issues is sampling. Because of its sequential nature, information from the first part of the research is used to conduct the second part. Problems may arise if the sample selection in the first part is not a representative set for the issue under study. This problem could be avoided by selecting a different set of participants for the follow up or by enlarging the quantitative follow-up by adding extra sample to confirm that the tool is valid. The second solution was used in this study; the Mid-Region Council of governments, New Mexico's largest MPO, was included in the follow-up interview over and above the three New Jersey MPOs.

The advantage of using a quantitative GIS-based method for developing the tool is that GIS produces user friendly interfaces to model complex understandings of the world. Calculating accessibility in a multimodal system of transportation is a complex process that can be achieved by setting up a "network dataset" that embodies all the properties of multimodality. It also supports access and inquiry to multiple types of data (that have been appropriately transformed) to be analyzed concurrently. This is needed as accessibility has been defined variously and the tool needs to be comprehensive and flexible enough to accommodate these definitions. The disadvantage of using GIS is that it is designed for spatial (and spatiotemporal) components of data only. Non-spatial components of accessibility (like safety) need spatial proxies (like number of accidents per segment of road) for GIS analysis.

The disadvantage of using a mixed method as in this study is that one part could be disproportionately be given more effort. In this study both the parts were given one year each. However approximately 80 percent of the time spent on the quantitative GIS aspect of the study was spent on preparing the data obtained and making it appropriate to the GIS software used.

CHAPTER 4

CASE STUDIES

This chapter describes the ways in which the three MPOs, selected in the Research Design chapter (Chapter Three) address accessibility in their transportation planning process. The first MPO, the smallest and southernmost of the three cases is the South Jersey Transportation Planning Organization (SJTPO). The second is the bi-state organization Delaware Valley Regional Planning Commission (DVRPC) and the third and final case is the North Jersey Transportation Planning Organization (NJTPA), the largest MPO of the state. Each case begins with a profile of the region; subsequent sections describe how accessibility is implicitly or explicitly considered, how TIPs are evaluated and the MPO public outreach program. The chapter following this (Chapter Five) evaluates and compares the three MPOs for each of the above mentioned categories.

4.1 Case 1: South Jersey Transportation Planning Organization

The South Jersey Transportation Planning Organization (SJTPO) has jurisdiction over the four southern New Jersey counties of Cumberland, Atlantic, Cape May and Salem. It covers 68 municipalities of 1,778 square miles, 274 square miles of which are in urbanized areas (places with population densities of at least 1,000 persons per square mile and a residential population of at least 50,000 persons) and urban clusters (densely settled territory with a total population of at least 2,500 but fewer than 50,000 persons) (Figure 4.1). SJTPO was formed in 1993, from three MPOs that existed in the major urbanized areas of the region but the new organization also incorporates areas that were previously not served by an MPO (USDOT, FHWA, & FTA, 1999). With the formation of SJTPO in 1993 every part of New Jersey came under the jurisdiction of an MPO; New Jersey is one of the few states in the country to have all counties included in a metropolitan region.

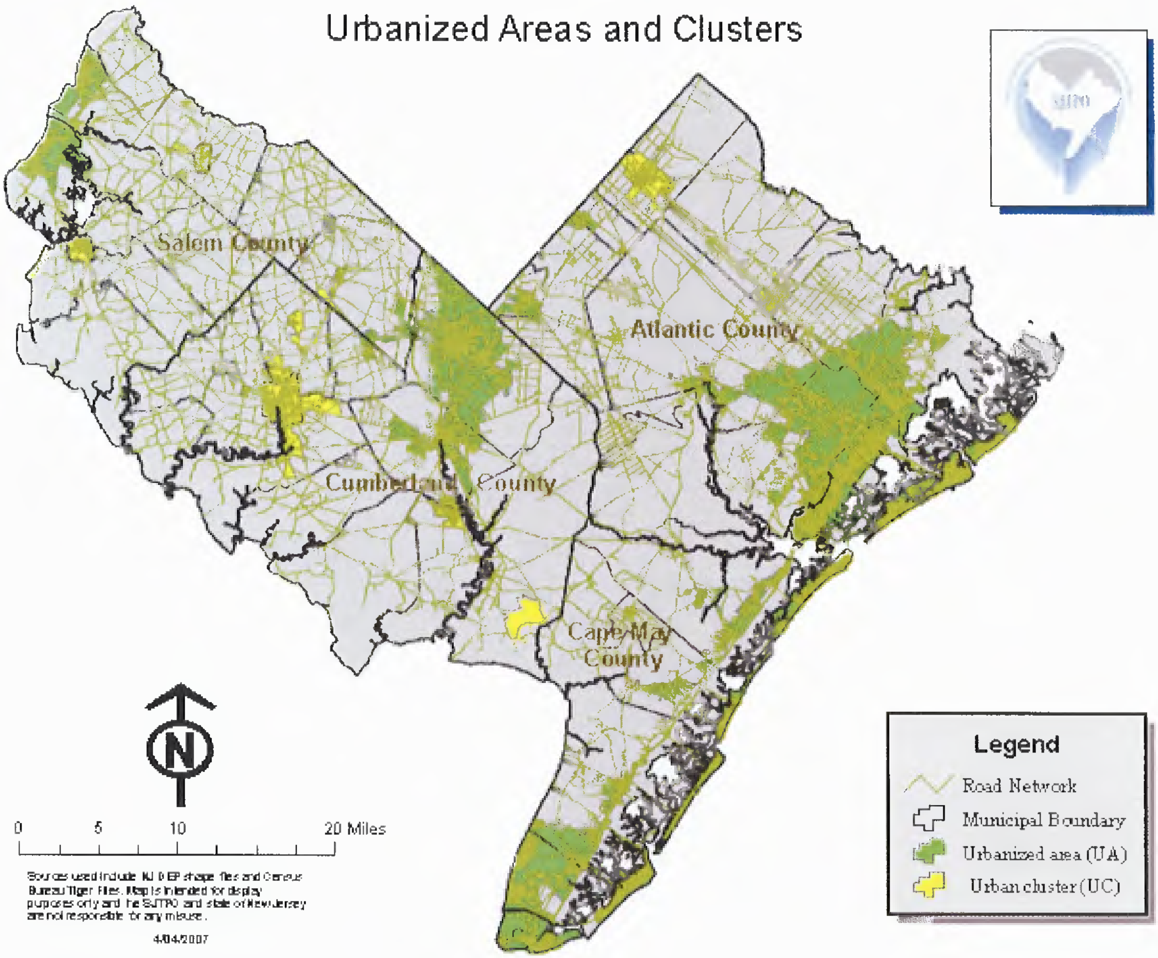

Figure 4.1 Urbanized areas and urban clusters in the SJTPO region.

Source: SJTPO regional profile (SJTPO, 2007a, p. 2)

In the period 2002-2004 SJTPO received $248.1 million in TIP funding. Federal funding for SJTPO in 2005 was $65 million (New Jersey Transportation Fund Authority, 2005). In 2007 this was $151 million but still formed only 6% of all New Jersey MPO funds (New Jersey Transportation Fund Authority, 2005).

Urbanized areas and urban clusters are home to 81% of the population of the SJTPO region. Atlantic County had the highest urbanized population (86%) in 2000, with the majority living in and around the entertainment and gaming center of Atlantic City. Salem County, located in the westernmost part of the SJTPO region, had the lowest percentage of urban population (59%). The projected population of the region for 2010 shows the highest population in and around Atlantic City and in Cumberland County, one of the fastest growing counties of the region (Figure 4.2). The total population of the SJTPO region in 2000 was 565,601 a meager 6.7% of the total population of New Jersey for an area that covers 20% of New Jersey's area (Cumberland County., 2007).

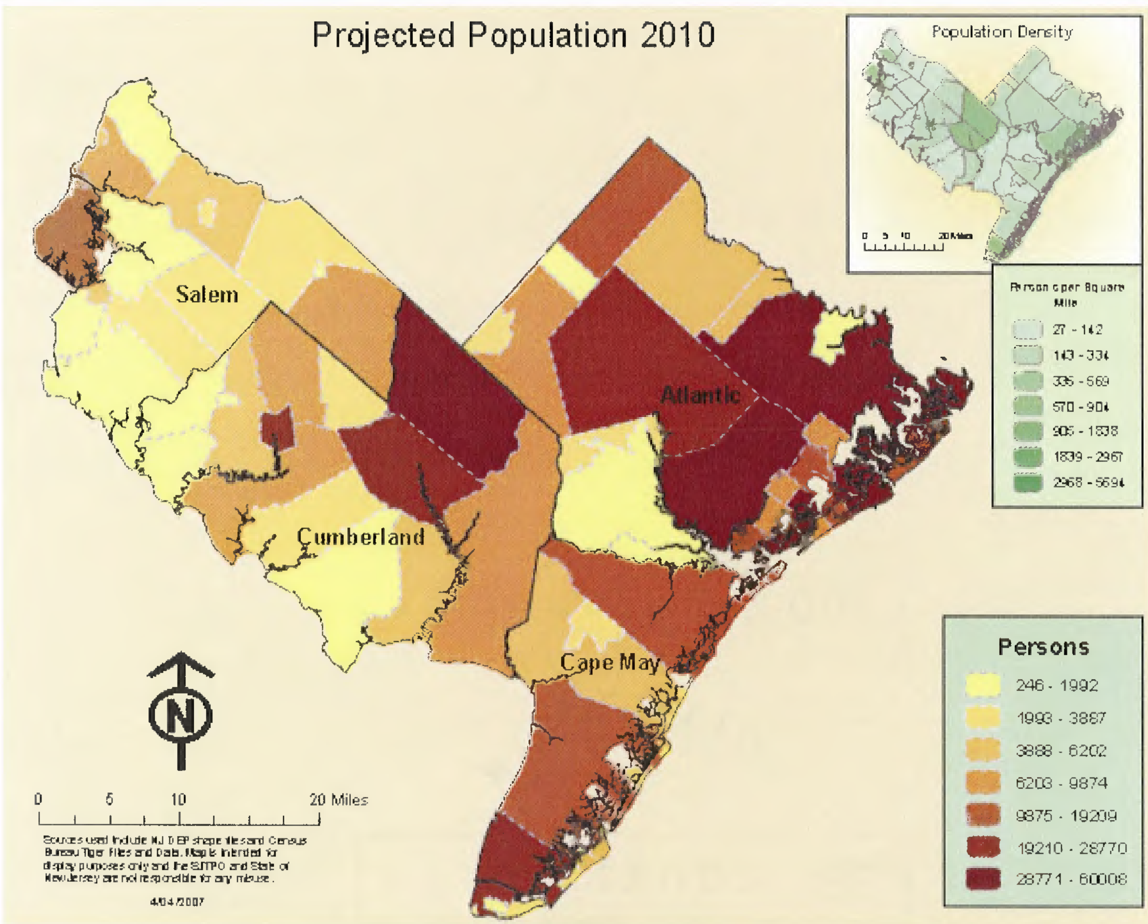

Figure 4.2 Projected population for 2010 of the SJTPO region.

Source: SJTPO regional profile,(SJTPO, 2007a, p. 15)

One of the reasons for the low density in SJTPO population is that almost 400,000 acres of the SJTPO region is preserved open space and almost 40,000 acres is preserved for farmland (Figure 4.3). Moreover, more than half of the SJTPO region is under the aegis of either the Coastal Area Facility Review Act (CAFRA) or the Pinelands National Reserve (PNR), both of which have restrictive zoning regulations for ecologically sensitive lands (Cumberland County., 2007).

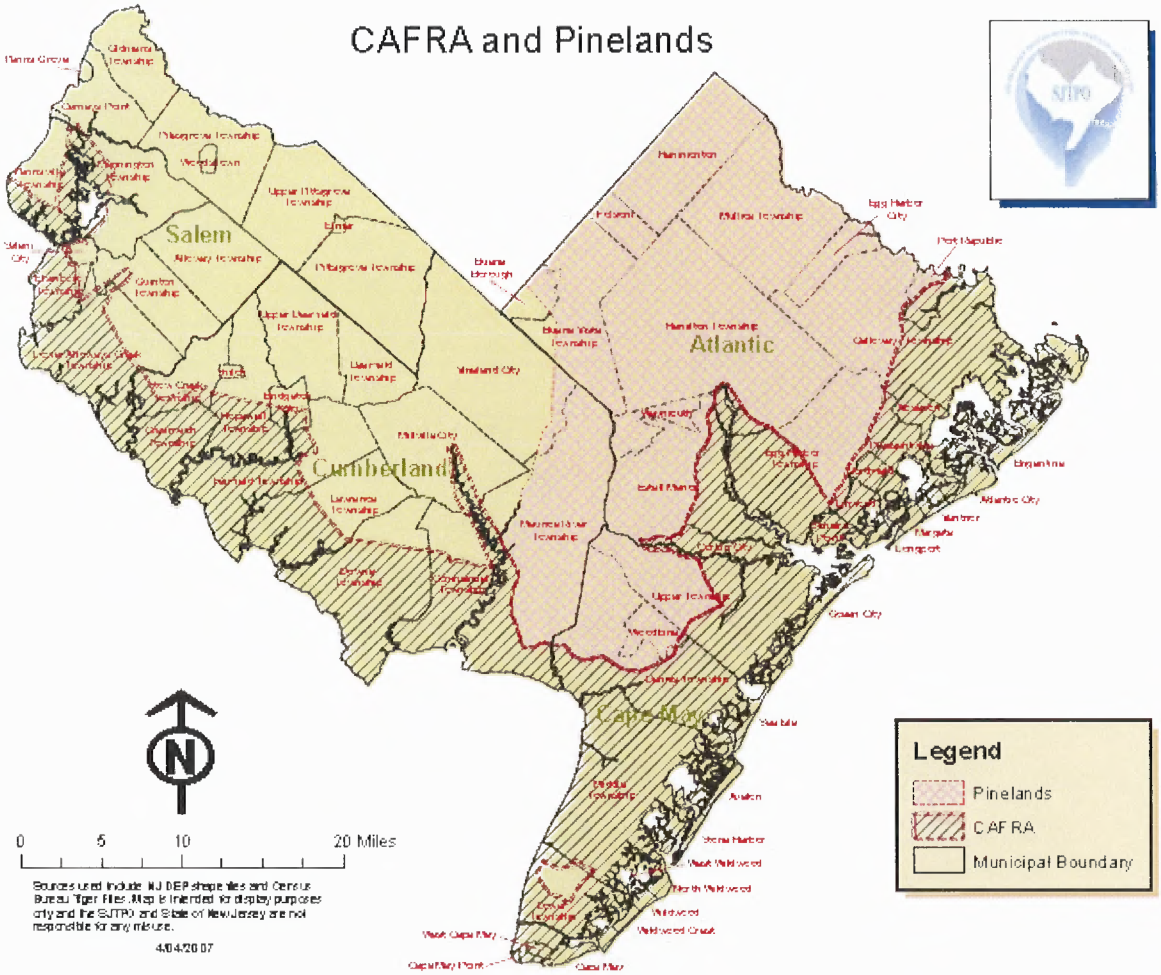

Figure 4.3 CAFRA and Pineland zones of the SJTPO region

Source: SJTPO Regional Profile (SJTPO, 2007a, p. 4)

Although the SJTPO region is a low density area, the population in the area is increasing and the future growth rate is expected to be greater than the New Jersey average. The expected rate of population growth for the ten year period 2000 to 2010 in the SJTPO region is 8.1% where the State population is expected to increase by 7% in the same period. The projected population of this area for 2035 is expected to increase by 84% since its 1980 population (Cumberland County., 2007).

The 5108 miles of paved roadways that exist in the SJTPO region form 13% of the total roadways that exist in New Jersey. In 2005 this network accounted for 11% of the state's daily vehicle miles traveled (DVMT) by 6.7% of the state's population. The DVMT, obtained from the Highway Performance Monitoring System, is considered to be one of the best measures of traffic flow over time (NJDOT, 2007a). The SJTPO region is thus primarily car-oriented; transit consists of some bus routes and a single rail line running from Atlantic City to Camden (which is outside the region). In 2005 the New Jersey Transit's South Division bus lines, which service the four SJTPO counties, carried 25 million passengers and the rail line carried 1.2 million riders (Cumberland County., 2007).

The SJTPO is governed by an eleven-member policy board consisting of an elected official from each county government, a municipal official elected from each county (specifically the Mayors of Atlantic City and Vineland) and one representative each from NJDOT, NJT and South Jersey Transportation Authority. The SJTPO's technical advisory committee, consisting of the Policy Board member staff, representatives of New Jersey Turnpike authority and Delaware River and Bay authority and the chairperson of the Citizens Advisory Committee (CAC), provides input to the Policy Board. The CAC consists of a broad cross-section of people including user groups, civic and business groups and environmental groups (Cumberland County., 2007).

The SJTPO has a full-time technical staff of three people. The interview process, which was primarily intended for this group, started with a request sent to the Executive Director of the SJTPO in June, 2007 (included in Appendix B) detailing the intentions of the research and requesting an interview date with staff members. This case study report is a result of the one-day interview that took place in August 2007 with the GIS Coordinator/ Transportation Planner and the Manager of Regional Planning of SJTPO, simultaneously, at their office in Vineland, New Jersey. The third technical staff member (also the Executive Director of the program), specialized in air quality issues and was in charge of making sure that the TIP process proceeded smoothly. He was briefly interviewed over the telephone and it was decided that he would not be included in the long interview as his expertise was in an area that was not relevant to this dissertation. The interview questions were of an open-ended format but followed the guidelines for the interview in Appendix C.

Apart from the interviews, the following case study was written by consulting the following SJTPO publications and web pages: *Environmental Justice Evaluation and Strategy* (2002b), *2025 Regional Transportation Plan* (2001a), *2025 Regional Transportation Plan: Public Outreach Plan* (2001b), Job *Access and Reverse Commute Plan* (2002d), *TIP Project Selection Process* (2007b), *Citizen's Guide to Transportation Planning Process* (2003) and *Procedures to Amend and Modify the SJTPO TIP and State TIP* (2006). As the number of technical staff is small, a large number of the above mentioned publications are written by consultants to SJTPO.

4.1.1 SJTPO's Implicit Considerations of Accessibility

The SJTPO considers accessibility implicitly both through the adoption of land use (LU) planning methods and through modal methods.

4.1.1.1 Land Use Methods There are two ways in which accessibility is implicitly considered in land use planning by SJTPO. The first is when following the land use regulations set by the federal, state and local authorities. *The New Jersey State Development and Redevelopment Plan* (2001), or what is commonly called *The State Plan*, identifies the urban centers, regional centers, towns, villages and hamlets. Of these state designated area, the urban centers, regional centers or towns are considered to be "mixed use [with]...mature network of private, public and civic institutions,...[providing] opportunities for civic engagement" (New Jersey Office of Smart Growth, 2001, p. 26). As of January 2008, there are no regional centers in the SJTPO jurisdiction (New Jersey Office of Smart Growth, 2008). Compact land use of towns and urban centers meets the state's sustainability goals of infrastructure efficiencies by reducing land consumption, total vehicle miles traveled and overall consumption of energy resources for transportation (New Jersey Office of Smart Growth, 2001, pp. 140-141).

The second implicit consideration of accessibility that the SJTPO region follows is the "Main Street New Jersey" program for the revitalization of traditional business districts. Eight SJTPO municipalities have been granted state funds from this program (New Jersey Office of Smart Growth, 2007). Main Street New Jersey relies on the underlying premise of increasing accessibility and hence economic activity for businesses in downtown areas by encouraging historic preservation in ways appropriate to today's marketplace (National Trust for Historic Preservation, 2008).

4.1.1.2 Modal Methods There are two modal methods for implicit accessibility consideration in the SJTPO region. The first is the State of New Jersey's Transit Village Initiative (TVI). TVI is a multi-agency program to increase accessibility primarily by encouraging citizens to use a variety of transportation modes for work and recreation. An offshoot of the state's Smart Growth policies, the TVI program assists municipalities with technical and financial expertise to become Transit Oriented Developments (TODs). Municipalities that successfully transform themselves to TODs are known as Transit Villages. The second method involves setting the goal to "promote transportation choices for the movement of people and goods" by the SJTPO in its Regional Transportation Plan (SJTPO, 2001a).

The only municipality in the SJTPO region that has been designated a Transit Village is Pleasantville in Atlantic County. Eleven site specific grants and projects (e.g., renovation of train station and pedestrian plaza) and several non-site specific grants and projects (e.g. development of commuter bike path) within half a mile of the Pleasantville train station helped this municipality attain its designation (Alan M. Voorhees Transportation Center., 2003).

The Regional Transportation Plan (RTP) guides transportation decision making by setting goals for the coming 25 years. One of the goals set in the SJTPO RTP for 2025 is to "promote transportation choices for the movement of people and goods" (SJTPO, 2002e, pp. 2-1). Policies spelled out in the RTP that support the goal of promoting transportation choices are specially relevant to the MPO's recognition of the need to address accessibility issues through multimodal methods. SJTPO aims to "expand and improve non-auto elements of the transportation system" (SJTPO, 2002e, pp. 2-1) by advancing projects that enhance mobility for bicyclists, pedestrians and train riders and that provide affordable mobility options for the transportation of the disadvantaged.

4.1.2 SJTPO's Explicit Accessibility Considerations

SJTPO considers accessibility explicitly in two ways; first in fulfilling Environmental Justice (EJ) requirements and second in fulfilling Job Access Reverse Commute (JARC) requirements. Both these requirements are federally mandated but give MPOs the freedom to fulfill these requirements in any manner of their own choosing.

In *Environmental Justice Evaluation Strategy* (SJTPO, 2002b) SJTPO defines and measures accessibility explicitly. This document was prepared per mandates to demonstrate compliance with Title VI of the 1964 Civil Rights Acts and The President's Executive Order on Environmental Justice and is one of the two places where accessibility is measured by the SJTPO. The MPO has no plans to update this document as no significant changes have occurred in its policies and its methods to measure or define accessibility since its initial publication in 2002.

In the *Environmental Justice Evaluation Strategy* (2002b) accessibility is explicitly defined as the "spatial distribution of potential destinations and the ability to reach desired destinations within a reasonable amount of time" (SJTPO, 2002a, pp. 5-1). The SJTPO believes that accessibility as defined above can be "applied separately to compare the accessibility of low income and minority communities to the accessibility of non low income and non-minority communities" (SJTPO, 2002a, pp. 5-1). The SJTPO also believes that this definition helps to measure accessibility in a disaggregate manner by travel mode like automobile, transit, walking and biking.

The SJTPO calculates accessibility by considering two factors: accessibility to jobs and to essential services. To calculate accessibility to jobs, "the number of all regional jobs accessible within 15, 30, and 45 minutes of the identified minority and low income communities were compared to the number of jobs accessible from the identified non-minority and non-low income communities" (SJTPO, 2002a, pp. 5-2). The cut off numbers of 15, 30 and 45 minutes were chosen after a survey of the cut off numbers used for accessibility analysis by several MPOs across the country (including Southern California's Community Link 21, San Francisco Bay area's 2001 Regional Transportation Plan: Equity Analysis and Environmental Justice Report and the Mid-Ohio Regional Planning Commission's Environmental Justice Report). SJTPO calculated the values for the number of jobs accessible within 15, 30 and 45 minutes by minority and low income communities and their counterparts (i.e., non-minority and non-low income) for both auto and transit. Employment centers (with more than 20 employees) were mapped using the 2001 New Jersey Department of Labor (NJDOL) information ES-202; while employment information was obtained from the employment estimated for 2025 by the SJTPO travel demand model and the actual employment for the year 1996.

To calculate accessibility to essential services, "the percent of minority and low income Traffic Analysis Zones (TAZs) within 15, 30, and 45 minutes of essential service destinations were compared to the percent of non-minority and non-low income TAZs within 15, 30, and 45 minutes of essential service destinations" (SJTPO, 2002a, pp. 5-2).

These values were obtained from the SJTPO travel demand model and calculated using network distances rather than straight line distances. SJTPO considers hospitals, colleges/vocational schools, and large supermarkets to be essential services. Like job accessibility, SJTPO measures accessibility to each of the above mentioned essential services for both auto and transit through network distances. Travel demand models forecast the travel behavior of the population after both future land use per the regional plans and future demographic composition obtained from statistical forecasting methods are completed.

SJTPO analyzes accessibility to jobs and to essential services under three separate conditions. In the first condition, SJTPO calculates existing accessibility using the base year 1996, the year in which its travel demand model was validated. In the second condition, SJTPO calculates the 2025 "no-build" situation which has no transportation improvements in it. In the final condition, SJTPO calculates the 2025 "plan" situation which has all the transportation improvements, specified per 2025 RTP, factored in. Accessibility is compared for each of these situations, for minority and low income populations and for their non-minority and non-low income counterparts. For example, the comparison of the "plan" to "no build" conditions for the low income and minority populations, calculated separately, demonstrates whether significant differences exist between these populations and non-minority and non-low income populations.

The method that SJTPO adopted in *Environmental Justice Evaluation Strategy* (2002a) to measure accessibility depends critically on how "communities of concern" are defined. SJTPO uses several characteristics of its population to identify the populations of interest. The characteristics of the population that are considered are race, income and other socio-economic characteristics "that serve as proxy measures of current poverty" (SJTPO, 2002c, pp. 3-1) such as per capita personal income (PCPI), Temporary Assistance for Needy Families (TANF) households, national school lunch program eligibility and zero-car households. (All acronyms are listed in Appendix A).

The data source used for determining population characteristics was primarily the US Census. Population statistics and racial composition were obtained from the 1990 and 2000 US Census data. These were used to determine changes in population in the SJTPO region by race, by county and by community. It was determined that in 2000, on average, municipalities had 31% minority population. This value was used as the threshold to determine if a municipality in the SJTPO region was an environmental justice area in 2000.

The economic characteristics of the population were obtained from various sources. The department of Health and Human services (HHS) issues poverty guidelines by family size and the US Census income data gives income by tract, block group and zip come tabulation area (ZCTA). These two sources are enough to identify geographically the areas where low income populations are concentrated. When *Environmental Justice Evaluation Strategy* (2002b) was published however the 2000 US Census income data was not available. The 1990 Census along with the 2002 TANF household statistics from The New Jersey Department of Human Services data and The National School Lunch Program (NSLP) eligibility data from the New Jersey Department of Education were used to locate families with low income and to determine their concentrations. The TANF database consists of households with children who are eligible for either reduced price or free lunch. The per capita income and poverty statistics were also used for the income calculations and were obtained from the 2002 Bureau of Economic Analysis data and were used to determine the average annual rate of income growth in each SJTPO county.

Being predominantly a rural and suburban region, where absence of an automobile causes significant hindrance to accessibility, SJTPO considers zero-car households to be a community of concern. The 1990 US Census data were used to determine which municipalities had proportions of population in zero-car households equal to or greater than the regional threshold. SJTPO defines communities of concern as "individual or concentrations of Traffic Analysis Zones (TAZs) that had proportions of minorities and/or persons in poverty at or above the regional threshold. The regional thresholds for proportions of minorities and persons in poverty were 31 percent and 10 percent respectively" (SJTPO, 2002c, p. 17).

Besides identifying communities of concern, SJTPO also determined the travel characteristics of its population through a household travel survey that it jointly conducted with the Delaware Valley Regional Planning Commission (DVRPC) in 2000. The survey data were at the household level and gathered information required for the SJTPO travel demand model. Participants in the survey were asked to provide socio-economic information and to keep a detailed travel diary for a 24-hour time period. Data from this survey resulted in identifying the travel characteristics of low income and minority populations and were used to identify the differences in travel characteristics between communities of concern and communities that were not. Notably, it was found that minority and low income households were much more likely to be zero-car households and hence dependent on non-auto modes of transportation. It was also found that minority and low income households generated a much lower number of trips than non-minority and non-low income households.

The environmental justice analysis done in the 2002 SJTPO study (SJTPO, 2002a) produced several findings. In all three scenarios described above (1996, "no-build," and "plan" 2025), minority and low income populations had access to fewer jobs for all three travel time thresholds when the mode of transportation was the automobile. However, when transit was considered minority communities had access to more jobs than their non-minority counterparts for all three time thresholds. When low income and non-low income groups were compared, it was found that there were no significant differences between them in the 30 and 45 minute thresholds in access to jobs via transit. In the 15-minute threshold however, low income communities won over non-low income ones in the number of jobs they could access. Not surprisingly, one could access 5 to 10 times the number of jobs by automobile than one could access by transit for all the scenarios. However, for all the communities considered, there was no significant change in accessibility for "no-build" and "plan" scenarios although there was an increase in accessibility from 1996 to 2025 when both auto and transit were considered.

SJTPO gives several reasons for the differences and similarities between various groups in job accessibility. They range from the increase in the number of suburban jobs, the concentration of minority communities in urban cores to the prevalence of transit services in city centers. The lack of difference in job accessibility between low income and non-low income groups, in the 30 and the 45-minute time thresholds, and the presence of difference between low income and minority groups were attributed to the fact that low income communities are more dispersed than minority communities.

Consequently, low income groups, living closer to non-low income groups, in the 30 and 45 minutes thresholds, do not differ much in accessibility to jobs via transit but differ significantly from minorities who primarily live in urban clusters where there is better transit service especially for jobs that are within the 15 minute time threshold. The increase in accessibility from 1996 to 2025 was attributed to the increase in population and projected growth in employment in the future. The transportation improvement projects accommodated the population increase but did not increase accessibility for the increased population of the future. SJTPO also concludes that this indicates that "the system benefits due to improvements were not inequitably distributed" (SJTPO, 2002a, pp. 5-5). The difference in accessibility to jobs by automobiles, for all thresholds of time, was attributed to the fact that a higher percentage of non-minority households have access to reliable automobile transportation than minorities.

The second explicit consideration of accessibilities is seen in SJTPO's document *Job Access and Reverse Commute Plan* (JARC) (2002d). JARC funds are subsidized by the federal government "to improve access to transportation services, to employment and employment related activities for welfare recipients and eligible low income individuals and to transport residents of urbanized areas and non urbanized areas to suburban employment opportunities" (FTA, 2008, p. 1). SJTPO Federal JARC funding, with its matching state funding, was $1,000,000 for each of the fiscal years 2006, 2007 and 2008 (NJDOT & NJT, 2007).

For JARC SJTPO explicitly considers accessibility both qualitatively and quantitatively. The first step taken by SJTPO is to meet with stakeholders, like the representatives from local transportation, planning and human service organizations, to identify their needs. The second step was to identify welfare clients who did not have "adequate access" (a phrase explained below) to transportation services. Data for this step were obtained from WFNJ/TANF for the SJTPO region.

The quantitative analysis of accessibility for JARC was conducted by mapping all the existing and proposed bus routes, obtained from New Jersey Transit (NJT), on a GIS map and then drawing a three-quarter mile buffer zone along each route on either side. This was used to find the service gaps in the region. First, welfare service clients who did not live in the buffer zone were considered "not served". Second, employers who were not located in the bus catchment areas were identified.

4.1.3 SJTPO's TIP Evaluation

SJTPO recognizes that the key component required to achieve environmental justice is to "ensure an equitable distribution of benefits derived from transportation improvements for minority and low income populations" (SJTPO, 2002f, pp. 6-1). They have therefore devised a method to evaluate whether their own TIPs are equitably distributed.

SJTPO has a clearly defined method to ensure the "equitable distribution of benefits" of TIP projects. The first step to analyze TIPs is to use a point system to prioritize all the possible projects. First sponsors assign points to projects and then SJTPO reviews and adjusts them in consultation with the sponsors. Points are given in seven categories: support the regional economy; improve safety; reduce congestion/promote mobility; protect and improve environment; preserve and maintain existing transportation; favor cost-effective projects. Subcategories of these seven categories that pertain to accessibility are only under "reduce congestion/ promote mobility" and are asked if mass transit options or operations would improve with the new project and if the project would improve mobility of an underserved population group (SJTPO, 2007b).

In the second step to analyze TIPs, all the projects that improved safety practices, repaired existing roadways or enhanced the local transportation system are mapped using GIS. These include intersection improvements, resurfacing of roadways, drainage upgrades and pedestrian/bicycle facility enhancements. In the 2002-2004 plans 27 such projects were identified.

These projects are divided into two categories: (1) roadway/intersection preservation and enhancement projects; and (2) pedestrian/ bicycle facility improvement projects. SJTPO considers even a partial inclusion of a TIP project within a TAZ, which contain population of concern higher than the average in the region, to be beneficial to the population of that TAZ. The percentages of projects in roadway/intersection preservation and enhancement projects and the pedestrian/bicycle facility improvement projects that benefited minority or low income TAZs were compared to the regional thresholds of minority and low income populations to determine if the benefits were equitably distributed. As an example, the result of the 2002-2004 study for the minority TAZs compared to the non-minority TAZs is shown in Table 4.1. A similar table was drawn out for the same two categories (viz. roadway/intersection reservation and enhancement projects and the pedestrian/bicycle facility improvement projects) for low income TAZs and compared to non-low income TAZs to determine if benefits were equitably distributed.

Table 4.1 Local Safety Enhancements and Preservation TIP Project: Comparison of Minority and Non-minority TAZs

	In (or partially in) Minority TAZ (s)		**Exclusively in Non-Minority TAZ**	
	% of projects by type	% of proje ct funding by type	% of projects by type	% of projects funding by type
Roadway/ Intersection Improvements	26.1	31.9	73.9	68.1
Pedestrian/ Bicycle Facility Improvements	50.0	53.8	50.0	46.2
Minority Benchmark	31			

Source: Environmental Justice Strategy and Evaluation (SJTPO, 2002b, pp. 6-3)

4.1.4 Visualization and Collaborative Planning Programs at SJTPO

Federal regulations require the inclusion of the public in the transportation planning process. Under the umbrella of the Public Involvement Policy (PIP) programs SJTPO has several specific plans. The role of the Citizen Advisory Committee is to keep an updated list of concerned citizens. The Public Outreach Program (POP) "informs and educates" the public about the RTP and about how citizens can have input into the development of transportation plans. It also reaches out to local advocacy groups to discover their concerns and to get their input on transportation plans made for the region. SJTPO disseminates the results of the environmental justice analysis to the public through the POP.

The SJTPO website has a wide range of resource materials that can be freely accessed by the public. The website is primarily on planning and transportation related issues with contact information of all key members of the organization. It is used as a tool to announce meetings and to post publications. To understand the needs and interests of the socioeconomic groups that populate their area of jurisdiction, SJTPO conducts structured interviews specifically designed for community-based organizations, social service agencies and organizations that work specifically for poverty alleviation and minority populations. Besides using their website, SJTPO disseminates information through mailings of newsletters and publishing reports that are available at no cost.

SJTPO thus has significant outreach efforts but undertakes no collaborative planning of any importance when making decisions about TIPs. SJTPO's visualization efforts are limited to the maps that are included in their reports and to images of how proposed projects would look like during outreach sessions.

4.2 Case 2: Delaware Valley Regional Planning Commission

The Delaware Valley Regional Planning Commission (DVRPC), situated northwest of the South Jersey Transportation Planning Organization region (see in Section 4.1), has jurisdiction over the four southwestern New Jersey counties of Gloucester, Camden, Burlington and Mercer together with the five southeastern Pennsylvania counties of Bucks, Chester, Delaware, Montgomery and Philadelphia. Established in 1682, three of the Pennsylvania counties, Bucks, Chester and Philadelphia (together with Montgomery County which was part of Philadelphia County and Northampton County which was part of Bucks County at that time) are the oldest counties in the state. DVRPC is thus a bi-state MPO; it is also an inter-county and inter-city organization. DVRPC was formed in 1965 and is 3,833 square miles in area and consists of 353 townships, boroughs and cities (Bickel, 2006).

The consolidated city and county of Philadelphia is the smallest county in the state but has the highest population. It is the sixth largest metropolitan area of the US (with 5.4 million people and 2.7 million jobs in 2000). In 2000 the DVRPC population was centered on the City of Philadelphia and was home to 28% of its population. As the largest and the oldest city in region, Philadelphia is expected to remain the "Metro Center" of the DVRPC region but this area is expected to loose 1% of its 2000 population by 2025. By 2025 DVRPC envisions six metro sub-centers in the region, five of which will lie wholly or partially in New Jersey (Figure 4.4). All of these sub-centers are currently in the process of development or are already developed; they are the mature cities of Trenton and Camden, the suburban townships of Cherry Hill/Voorhees/Marlton and the Route 1/Princeton corridor (DVRPC, 2005a).

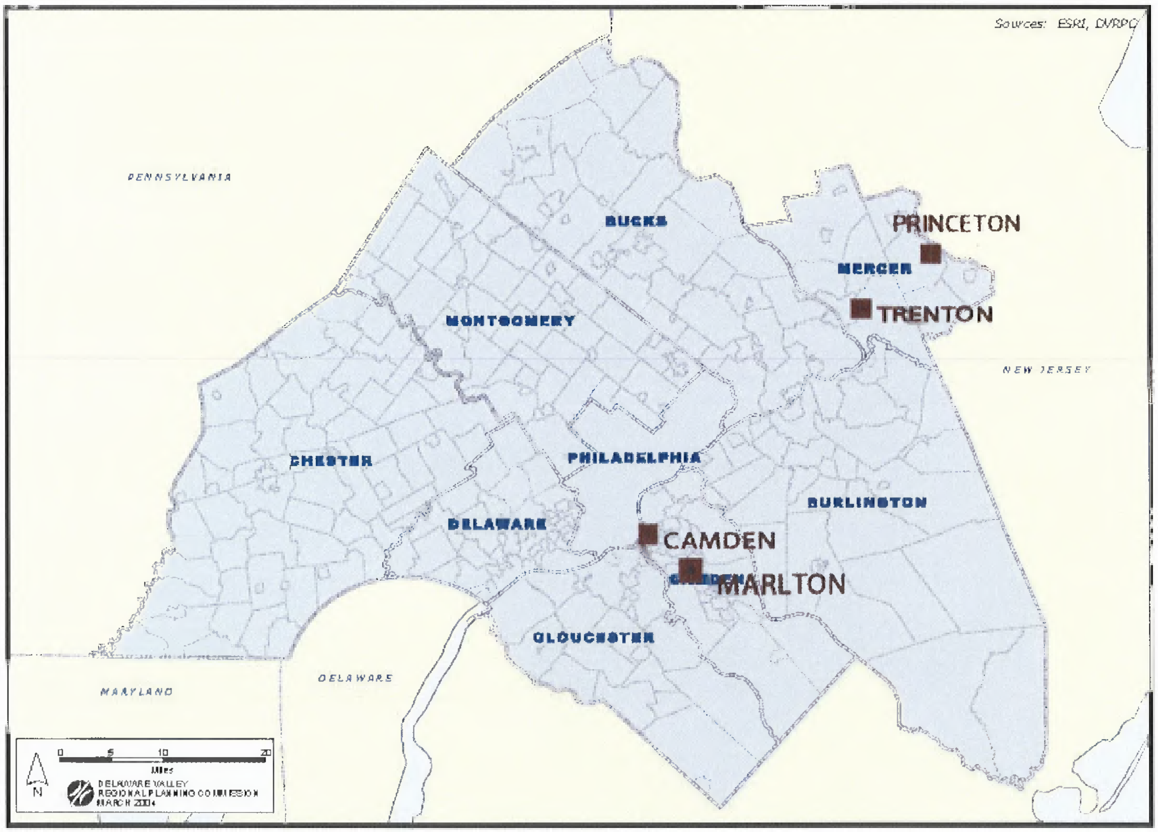

Figure 4.4 Metro centers and metro sub-centers of the DVRPC region

Source: DVRPC (2004b)

Although the Delaware Valley has some of the most fertile agricultural land in the nation, it has been historically developed for other uses. The region lost almost 6000 acres of farmland a year in the period of 1990-2000. Since then there has been more active farmland preservation in the area. Publicly owned open space in the DVRPC area is 13% of its total jurisdiction; most of this lies on the New Jersey side with Burlington County accounting for the largest percentage of open land (30%). Burlington County also has the greatest amount of total open land in terms of both number of acres and acres per 1000 people in the entire region. An important reason for this is that most of the open space in Burlington County is under the Pinelands National Reservation (PNR) area. Publicly owned, protected open land forms 21% of the four New Jersey counties but only 7% of the five Pennsylvania counties of DVRPC (DVRPC, 2004d).

The 2000 census indicates that of the 5,387,407 people living in the DVRPC region, 28.5% (or 1,537,760) lived in the four New Jersey counties. The New Jersey residents of the DVRPC region formed only 18.2 % of the total population of the State of New Jersey in 2000. The five Pennsylvania counties, on the other hand, were home to 31% of the state's population during the same time period (DVRPC, 2005a).

Population growth in the 10-year period prior to 2000, in the four New Jersey counties, was 5.8% which was higher than the average 3.2% growth of the DVRPC region but was lower than the average 8.9% growth of the State of New Jersey. The highest growth rate (10.7%) was in Gloucester Country and the lowest was in Camden County (1.2%) in the same period (DVRPC, 2004b). The 2025 forecast shows a similar pattern: Gloucester County is expected to increase by 27% and Camden County is expected to increase by 1% from their 2000 populations, retaining their respected rankings for growth rate among the New Jersey DVRPC communities (DVRPC, 2005a). The overall growth of 3.2% in the Pennsylvania counties, on the other hand, kept pace with the 3.4% growth of the state. Looking closely however, the City of Philadelphia lost 4.8% of its population but this was offset by an 8.8% gain in population in the four suburban Pennsylvanian counties.

The Philadelphia region ranks 11th in the nation for congestion and the annual hours of delay per worker has risen from 16 in 1982 to 38 in 2005 (Texas Transportation Institute, 2007). The percentage of people driving alone to work in the DVRPC region (PA's five counties—71%) is not far from the US average of 76.9% but the percentage of commuters using public transportation (11.4% in the five PA counties) is more than double the US average of 4.7% (JEK, 2007). The state's planning office considers the southeastern region (which consists of the DVRPC counties along with Berks, Lehigh and Northampton) to be "highly accessible given that 17,763.9 miles of roadways, representing 14.8 percent of the State's total highway miles, traverse the region" (PADCA, 2005, p. 1).

For the fiscal year 2008, DVRPC allocated $2 billion for 140 TIP projects in New Jersey and $3.5 billion for 600 TIP projects in Pennsylvania; of this $929 million was for roadways and $1.1 billion for transit. The 2007 revenues obtained by DVRPC for transportation related projects of this region was $23,538,736 (DVRPC, 2008a).

DVRPC has an 18-member board that is responsible for the entire organization and all the transportation decisions made in the nine-county region. The ten-member Executive Committee oversees general operations and fiscal matters of the organization. Members of the board are composed of state, county and city representatives from its member governments, as well as various participating, non-voting members and federal agency observers (DVRPC, 2008a).

Information for this case study was obtained by interviewing the Regional Planner and two Senior Transportation Planners in two one-day long interview sessions in August 2007 that took place in Philadelphia and Trenton. The interview questions were open-ended, but followed the guidelines in Appendix C. Apart from the interviews, information was collected from the DVRPC website and publications. Publications used were: *Twenty Years of Change: 2000 Census* (DVRPC, 2001), *Municipal Implementation Tools #5: Impact fees* (2004c), *Protected Open Space Inventory* (2004d), *Destination 2030: The Year 2030 Plan for the Delaware Valley* (DVRPC, 2006b), *Environmental Justice at DVRPC* (2007b), *Using Pennsylvania GIS Data for Transportation Planning* (2007e), *Improving Access to Opportunities in the Delaware Valley region: Coordinated Human Services Transportation Plan* (2007c), *Annual Report FY 2007* (2008a).

4.2.1 DVRPC's Implicit Considerations of Accessibility

DVRPC considers accessibility implicitly both through the adoption of land use methods and modal methods.

4.2.1.1 Land Use Methods The link between land use and accessibility has slowly evolved over time, but that they are related is indisputable (Stanilov, 2003). This link is scale dependent. Land use regulations that DVRPC follows are those set by the state and local authorities and are thus at a regional scale. DVRPC's role as a bi-state MPO makes matters complex as counties follow the land use regulations and long term goals of both the states in which they are located.

The *New Jersey State Development and Redevelopment Plan* (2001) published by the Office of Smart Growth categorizes the DVPRC municipalities on the New Jersey side of the region as urban centers, regional centers, towns, villages or hamlets by considering factors such as population, density, employment base and job-to-dwelling ratio. New Jersey links its growth management, and hence accessibility, to the municipality type. The New Jersey counties of the DVRPC region have two urban centers and six villages. The same type of categorization does not hold for Pennsylvania. Pennsylvania has nine classes of counties, four classes of cities and two classes of townships; boroughs are not classified. These are designated primarily by population (Governor's Center for Local Government Services, 2007). To increase consistency between the two states, DVRPC has devised a hierarchy of centers in its 2025 plan.

The classification of DVRPC centers is based upon a combination of current and future land uses and activity within the region. The centers are called metro centers, metro subcenters and regional centers. The central three square miles of Philadelphia is considered the region's metro center. It serves as the center for the entire DVRPC region with 280,000 jobs (forecasted to grow to 325,000 jobs in 2025), tourism, entertainment and for 49,000 residents (forecasted to grow to 56,000 in 2025) (DVRPC, 2006a).

The metro centers and sub-centers are shown in Figure 4.4. The metro centers are divided into mature urban centers (Trenton and Camden) and suburban growth centers (King of Prussia/Valley Forge, International Airport/I-95, Cherry Hill/Voorhees/Marlton and the Rout 1/Princeton Corridor). These six metro subcenters are core cities which act as major job and residence attractors (DVRPC, 2006a)

The third and final category is the regional centers. These are "emerging concentrations of industrial, office and retail facilities with residential concentration in both urban and suburban areas" (DVRPC, 2006a, pp. GM-4) and serve a county or a portion of a county. Depending on the stage of development, regional centers are further subdivided into county centers, revitalizing centers and growth centers. There are 38 county centers, 24 revitalizing centers and 27 revitalizing centers in the DVRPC region of Pennsylvania (DVRPC, 2002b).

New Jersey's Main Street Program has been revitalizing older business districts by bringing vitality back to abandoned downtowns and thereby increasing accessibility to businesses. DVRPC has Main Street Programs running in Burlington, Fairlawn, Glassboro, Lawrenceville and Woodbury in its New Jersey counties.

4.2.1.2 Modal Methods The two parts of the DVRPC region, the New Jersey and the Pennsylvania sides, have different approaches for considering modal methods for accessibility. It is thus important to describe the differences in the approach to transit between these two neighboring states. The different attitude to transit in two parts of the same region has influenced accessibility considerations for the DVRPC region as a whole. New Jersey, being primarily an urbanized state, has a culture of paying special attention to transit needs. Pennsylvania on the other hand is primarily suburban and rural and has less familiarity with transit (Morris, 2005).

New Jersey and Pennsylvania adopted separate programs to encourage multi-modal methods of transportation. Since the mid-1990s New Jersey is considered to be a leader in transit friendly policies with SOM's publication *Planning for Transit Friendly Land Use: A Handbook for New Jersey Communities* (1994). Since 1999 the New Jersey Transit Village Initiative program (developed together with NJDOT), has helped 19 communities throughout the state achieve the status of a transit village. The Transit Village Initiative is not legislation but rather an offshoot of the State's Smart Growth policies that were set as goals in the 1997 *State Plan* (NJDOT, 2005). The DVRPC region has three transit villages (Collingswood, Riverside and Burlington City).

The program corresponding to New Jersey's TVI in Pennsylvania is the Transit Revitalization Investment District (TRID), legislation administered by the Pennsylvania Department of Community and Economic Development (PA DCED) and PennDOT. The Pennsylvania legislature passed TRID in 2004 and has a different approach to grants for transit oriented development from New Jersey. TRID promotes governmental interaction with the private sector and stresses larger scale implementation than New Jersey by requiring "a collection of projects, usually mixed use at a neighborhood scale that are oriented to a transit node" (DVRPC, 2005b). Unlike New Jersey, where a Transit Village Task Force, a governmental body, determines access to technical and financial assistance by evaluating a municipality's past and current activities, Pennsylvania does not have an oversight body for a single municipality. Rather, it encourages a group of municipalities or a county to plan together at a regional scale for transit oriented development.

A second difference between New Jersey's TVI and Pennsylvania's TRID is that Pennsylvania allows public transit authorities to purchase properties in a TRID to develop real estate and infrastructure to increase accessibility to their services. In New Jersey, on the other hand, it is the municipality that is given the authority to purchase property near the transit facility via condemnation but is given no special preference regarding its TOD status when purchasing properties (Mangini, 2005).

TRID depends on public involvement to develop a planning study that would define the parameters of land use, public improvements and implementation approaches. DVRPC's website says that, "in general, there is a lack of TOD incentives for local jurisdictions to include TOD in their plans, for developers to make the TOD process easier, for businesses and residents to accept changes in land use" (DVRPC, 2008d). To encourage public participation on transit issues, a TRID requirement, DVRPC has devised a game, "Dots and Dashes," in which participants, consisting of citizens and stakeholders of the region decide how money allocated for transit should be distributed among the various municipalities. Besides providing valuable input for the next long range plan Connection 2035, DVRPC hopes that this exercise will help build public awareness and a new vision for regional transit (DVRPC, 2008b).

The large number of stations in and around Philadelphia (340 in total) makes the city rank fifth among the top 10 metropolitan areas in the United States for future TOD demand (CTOD, 2004). The majority of the rail stations however remain Transit Adjacent Development (TAD) rather than transit oriented developments. A development that is physically close to a transit but is unable to fully capitalize on its proximity to a resource to promote economic and community development is known as a TAD.

The Keystone Principles and Criteria for Growth that Pennsylvania adopted in 2005 lists among other goals the "provision of housing with the location of jobs, public transit, services, schools and other existing infrastructure" and investment "in businesses that offer good paying, high quality jobs, and that are located near existing or planned water and sewer infrastructure, housing, existing workforce, and transportation access". These imply the importance of accessibility by modal methods (PADCA, 2005, p. 2). The importance was stressed further by recent research carried out by DVRPC that studied the level of service for bicyclists and pedestrians in *Increasing Intermodal Access to Transit* (DVRPC, 2006d).

4.2.2 DVRPC's Explicit Accessibility Considerations

DVRPC has no official definition of accessibility. However it does measure accessibility to key destinations like hospitals, employment centers and healthcare locations in the process of measuring regional environmental justice. Accessibility is also measured while evaluating the Coordinated Human Service Transportation Plan (CHSTP) which is an expanded version of the Job Access and Reverse Commute (JARC) Plan.

DVRPC's document *Environmental Justice Protocol: Making a difference…together* (2008c) treats accessibility as one part of the larger issue of environmental justice. DVRPC talks about three types of equity in its documents: procedural equity, geographical equity and social equity, using a conceptual framework first developed by Bullard and Johnson (1997). Procedural equity addresses questions of fair treatment to make sure that governing rules, regulations, and evaluation criteria are applied uniformly across communities. Geographical equity addresses the burdens and benefits that communities experience within a region and social equity looks into whether any particular community is discriminated against because of existing racial, political or economic biases in the larger society (DVRPC, 2008c). The following section describes geographical and social equity issues in EJ, as it is in these two areas that accessibility is considered.

DVRPC considers EJ analysis to be not just a quantitative, technical exercise but a qualitative process too. The qualitative aspect of EJ lies in the EJ-related policies and goals adopted in the long range plans, the Regional Airport System plan and the Job Access and Reverse Commute (JARC) plan (DVRPC, 2004b). The long-range plan and its policies have been discussed in the previous section (Section 4.2.1). The JARC Plan will be discussed later in this section. The Regional Airport System plan is beyond the scope of this dissertation and will not be discussed.

Since 2001 DVRPC has published a series of reports *...and Justice for All: DVRPC's Strategy for Fair Treatment and Meaningful Involvement of All People* (DVRPC, 2004a) that detail the steps that the organization has taken to evaluate environmental justice. They explain the methods the organization uses to address the federal EJ requirements. Over the period of 2001 to 2006 planning for EJ has evolved. *Environmental Justice at DVRPC* (2007b) is a comprehensive review of all the methods used for EJ and applications of some of the methods developed for EJ in other aspects of transportation analysis.

At DVRPC the method to measure EJ begins with identifying populations of concern, locating them in the region, plotting key destinations and overlaying the information on populations of concern and destination onto existing and proposed transportation networks to analyze the service gaps that exist for disadvantaged populations. According to DVRPc's own words "this analysis illustrates the existing accessibility conditions for residents of the region" (DVRPC, 2007b, p. 3). Based on this EJ analysis DVRPC planners evaluate their long range transportation plans and the capital program of transportation projects.

Since 2003 DVRPC has identified eight population groups as being communities of concern: non-Hispanic minorities, Hispanic, elderly over 85 years, persons with physical disabilities, people with limited English proficiency, female heads of household with children, carless households, and households in poverty. The 2000 census gives tract level data for these groups. Poverty guideline was obtained from HHS data to determine the number of people in poverty; the total number of people in each of the other designated population groups was identified from census data. Knowing the population of the entire nine county area the average regional thresholds were determined. DVRPC considers any census tract that meets or exceeds the regional average to be an EJ area for that population group. These numbers for non-Hispanic minority was 24%, for Hispanics 5%, elderly over 85 2%, people with physical disabilities 7%, people with limited English proficiency 2%, carless households 16%, female head of households 8% and households in poverty 11% (DVRPC, 2007b).

DVRPC uses the method degree of disadvantage (DOD) to identify the communities of concern. DVRPC identifies the DOD of a particular census tract by identifying whether it is an EJ area according to one or more of the eight criteria above. DVRPC maps each census tract with the number of indicators that they meet. Areas are grouped together according to the number of indicators they possess: seven to eight, five to six, three to four, one to two or zero. Tracts with four or more DODs have the greatest environmental justice concerns. DVRPC does not have an explicit hierarchy of the various DODs. It is thus possible for a tract to have four DODs and yet not be in poverty (DVRPC, 2007b).

In the 1,387 census tracts of the DVRPC region, 74% of the 4.2 million people live in a tract that has at least one DOD. Tracts with one to two DODs are the largest in number, followed by zero DODs, and then five to six DODs. Urban cores of the cities of Philadelphia, Trenton, Camden and Chester have the largest share (82%) of the 92 tracts that have seven to eight DODs. Of these, the city of Philadelphia has the greatest number of tracts that have four or more DODs, a finding that is not surprising for an area that has the highest diversity and concentration of population (DVRPC, 2007b).

After identifying the census tracts that are at or above the regional thresholds for the populations of concern and determining the DODs for each of these tracts, DVRPC creates a Quality of Life Factors map. Quality of Life Factors are defined as "attributes or services that potentially mitigate the disadvantaged status of many areas"(DVRPC, 2002a, p. 25). These include the destinations that EJ communities need to reach (like employment centers, hospitals, child day-care centers) and the infrastructure that they use to reach their destination (like arterial highways, transit systems and JARC services). The Quality of Life Factor map consists of overlays of a ¼ mile buffer on each side of all transit lines, arterial highways and JARC transportation services to hospitals, employment centers and child care centers. DVRC defines Quality of Life as one's connectivity (defined by the proximity of a census tract to the arterial highways of the region or to transit or a JARC service) to centers of employment, hospitals, day-care and community center. The overlaying of the degrees of disadvantage with the quality of life "reflect the positive and negative influences of the region's infrastructure system and key services" (DVRPC, 2007b, p. 14).

JARC was initially set up as a part of TEA-21 to mitigate the transportation challenges inner city dwellers and welfare recipients face to get to suburban jobs. With the passage of SAFTEA-LU, JARC has evolved to formula-based funding for equitable and stable distribution of funds for locally-developed transportation programs for the disadvantaged. For DVRPC Federal JARC funding, with its matching state funding, was $2,000,000 for each of FY 2006, 2007 and 2008 (NJDOT, 2007b; NJDOT & NJT, 2006).

In 2005, with the enactment of SAFETEA-LU, the JARC program became a component of the Coordinated Human Service Transportation Plan (CHSTP). The CHSTP is a program set up in response to a mandate, set by the Federal Coordinating Council on Access and Mobility, to consolidate programs. The mandate United We Ride (UWR) aimed to "share resources in order to provide the best human service transportation (DVRPC, 2007c, p. 8). It required that three federal programs (of which JARC is one) already existing in transportation planning organizations achieve one or more of the following goals: "more cost effective service delivery, increased capacity to service unmet needs, improved quality of service, and provide services which are more easily understood and accessed by riders" (DVRPC, 2007c, p. 4). One of the requirements of the CHSTP is a gap analysis of existing services and a study of unmet needs to increase accessibility to goods and services. To fulfill this federal requirement DVRPC updated its *Job Access and Reverse Commute Transportation Plan: Access to Opportunities in the Delaware Valley Region* (DVRPC, 2002c) to the more recent *Improving Access to Opportunities in the Delaware Valley Region: Coordinated Human Service Transportation Plan* (DVRPC, 2007c). Both of these DVRPC publications, among other things, list federally-funded projects by county that help overcome barriers to jobs by providing services to commuters.

Although the CHSTP is a national program, a bi-state agency like DVRPC faces the inevitable differences in the approach to this federal requirement adopted on the two sides of the state-line that divides this MPO. New Jersey has a well developed state-initiated County Transportation Coordination Process; no equivalent exists in Pennsylvania. DVRPC joined with Mercer County and through stakeholder meetings and data analysis created a Potential Rider Map for CHSTP (DVRPC, 2007b). In Pennsylvania the Southeastern Pennsylvania Transportation Authority (SEPTA) and the Transportation Management Associations (TMAs) in each county are the main players in transportation coordination (DVRPC, 2007c).

DVRPC's CHSTP strategy for the region is to "improve accessibility with non-traditional initiatives." It plans to "expand hours on key routes to support non-traditional work hours, invest in last-mile connector service, develop partnership to establish service in areas that are not served and to explore non-traditional transportation" (DVRPC, 2007c, p. 58). It does see a need to measure the transportation service gaps that exist for its welfare recipients.

DVRPC starts with understanding the unmet transportation needs of the region by studying the existing transit and paratransit facilities together with population distribution. Particular attention is paid to the elderly, the disabled and transit dependent low income populations. These populations were identified by the National Center for Health Statistics (NCHS) poverty guidelines and the 2000 Census.

The method used for the CHSTP program to measure accessibility is similar to that used for determining EJ. Here a ¼ mile buffer drawn around existing rail stations and along 1/8 mile for bus, trolley and subway lines was defined as the catchment area for transit services. Data for this were obtained from SEPTA, Port Authority Transit Corporation (PATCO) and New Jersey Transit. Major employers (with at least 375 workers) in the region were then identified (from InfoUSA) and the level of transit service to their facilities was determined by noting if their premises were within ½ mile of a transit service. Para-transit providers (data obtained from Greater Philadelphia Chamber of Commerce) were also considered in this calculation (DVRPC, 2007c).

Since most accessibility considerations assume motorized transportation, DVRPC published *Increasing Intermodal Access to Transit* (2006d) to study non-motorized access to transit stations. Six stations, three in New Jersey and three in Pennsylvania, were chosen to analyze bicycle and pedestrian levels of service in a one-mile and one-quarter mile radii of the stations, respectively. Several physical characteristics of a road and the nature of the traffic on the road were studied for suitability of each mode of non-motorized travel. The Level of Service (LOS) that the stations provided for pedestrians and bicyclists were compiled from statistically significant results of human interaction with physical characteristics of the six stations to calculate the accessibility in each station. DVRPC then assigned letter grades to each segment of the road and these were plotted using different colors on a GIS map.

4.2.3 DVRPC's TIP Evaluation

DVRPC evaluates TIPs in several ways. The first way overlays TIP locations on a map of the Regional Transportation Plan that delineates EJ areas (drawn per their DOD characteristics), services that determine Quality of Life and amenities. The overlay primarily points out that the "map addresses the amenities which best fill the gaps for disadvantaged populations: proximate health care, potential employment and a means to access the region's decentralized job centers" (DVRPC, 2004b, p. 49).

It is important to note that an overlay map such as the above can point out that a TIP may not be directly in a disadvantaged area but may be connected, through a Quality of Life factor like a JARC program, to necessities like hospitals, child-care and other amenities (DVRPC, 2007d). Also, a TIP not in an EJ area can benefit an EJ area "especially if the TIP occurs on a highway or within a transit project that is used by a particular disadvantaged population" (DVRPC, 2006c, p. 2).

When selecting a TIP project DVRPC makes sure that it meets one or more of its six planning goals. These goals focus on improving safety, reducing congestion, rebuilding the transportation infrastructure, enhancing the environment, improving mobility or linking transportation improvements to land use and economic development. A set of evaluation criteria is in place to make sure that these goals are met. Three evaluation criteria set for the goal "improving mobility" are related to accessibility. The first checks whether the project serves to coordinate or integrate transportation systems. The second checks whether the all segments of the population are provided with "system accessibility" that increases affordable transportation. The third makes sure that the Americans with Disabilities Act and Title VI are obeyed (DVRPC, 2006b).

The third is a process required by federal regulation. It requires MPOs with more than 200,000 people to have a "Congestion Management Process" (CMP) that enhances mobility, improves operations and increases capacity by selecting appropriate TIPs that would enhance overall performance of the system. The CMP is thus an important process that determines TIPS.

4.2.4 Visualization and Collaborative Planning Programs at DVRPC

In 2001 DVRPC established an Environmental Justice Public Involvement Task Force to engage the public in their EJ efforts. The Task Force helped other DVRPC staff understand the EJ concepts and to identify ethnic and social issues with input from the public. More recently, members of the task force were folded into the Regional Citizen

Committee (RCC) to bring a more holistic approach to the commission's public participation activities. The RCC, considered by the DVRPC Board to be an advisor to them, is the only committee that has open membership to any member of the public who would like to participate in the regional planning and decision making process. RCC has a non-voting seat at the Board meetings.

DVRPC has created a position for a person to monitor its activities to make sure that it is compliant with all federally-mandated Title VI regulations. The Title VI Coordinator is not only in charge of all compliance issues but is also responsible for assessing the communications and public involvement strategies that DVRPC adopts.

DVRPC's publication *Public Participation Plan: A Strategy for Citizen Involvement* (2007a) explains the role of the public and the stakeholders in transportation planning. Beginning from an elementary explanation of what a MPO does, this publication gives details about how to join committees, what the requirements of the federal transportation plans are, what the Title VI and EJ protocols are, and, in general, helps stakeholders and the public understand how they can participate effectively in the planning process. This publication is not only for stakeholders and the public but also for DVRPC staff members and its board.

DVRPC updates information on its Spanish website on a regular basis. It announces meetings, agendas, staff contact information and information about how one can reach out to the organization. Almost all of DVRPC's current publications are available on this website. DVRPC publishes a large number of transportation and planning related documents. The library, housed at their office in Philadelphia, is open to stakeholders and the public and has a full-time librarian managing it. DVRPC announces projects, programs and actions through newsletters published three times a year which are emailed to a list of people who have chosen to sign up to receive such a newsletter.

DVRPC has set up various ways to let the public know about its planning efforts, including having one-on-one and group interactions with the public and the stakeholders. One-on-one interactions include setting up information centers to respond to individual questions, giving interviews at community fairs to people who have specific questions, conducting telephone and internet surveys to get feedback from the public and the stakeholders. Group interactions include public hearings to allow people to voice their concerns, intensive problem-solving charrettes to build an open communication channel with stakeholders, workshops to solicit ideas, focus groups meetings with targeted stakeholders and most recently, simulating the planning prioritization through a game. DVRPC used this last method in September 2007 to build consensus among stakeholders for building transit projects.

DVRPC thus has an excellent outreach program but undertakes no collaborative planning of any importance when making decisions about TIPs. DVRPC's visualization efforts are limited to the maps that are included in their reports and to images of how proposed projects would look like that are presented at project information sessions. The "Dots and Dashes" game is the only other form of visualization practiced by the organization in a collaborative process.

4.3 Case 3: North Jersey Transportation Planning Authority

The North Jersey Transportation Planning Authority (NJTPA) is the northern-most MPO in New Jersey and has jurisdiction over 13 counties: Bergen, Passaic, Middlesex, Sussex Warren, Morris, Essex, Hudson, Union, Somerset, Hunterdon, Monmouth and Ocean. It also has jurisdiction over 384 of New Jersey's 567 municipalities where 6.3 million people reside and where 3.5 million jobs exist per the 2000 Census. It is the fifth most populous MPO in the US, has a technical staff of 50 people and in 2005-2006 had an operating budget of $12.6 million (NJTPA, 2007g).

The eastern part of the NJTPA jurisdiction is primarily urban and the western parts of NJTPA are primarily suburban and rural. The primary job market of eastern NJTPA is New York City, the largest city in the US. Projected population of the region for 2010 is 6.7 million (NJTPA, 2005c).

The Newark-New York region ranks second in the nation for travel delays due to congestion and the percentage of people driving alone to work. It ranks tenth in annual hours of delay per worker, which is 46 hours (Texas Transportation Institute, 2007). The NJTPA region has the nation's third largest transit system, operated by the statewide public transit system, New Jersey Transit. It operates light rail, heavy rail, busses and subway systems, most of which originate in the New York- Newark area. This eastern part of the NJTPA region has the state's highest transit use. Figure 4.5 is a map of the transit system of the region.

Between 1990 and 2000 population growth in the NJTPA region was 9.69%, increasing from 5.75 million to 6.31 million. Of the 557,360 total population increase in this region in the same period, 94.2% were minorities (35.7% of the region's population in 2000). In this period the counties of Essex, Hudson and Passaic accounted for almost a quarter of the growth in the minority population. A smaller percentage of the regional population (8.3 %) of the total of 523,500 persons was considered low income.

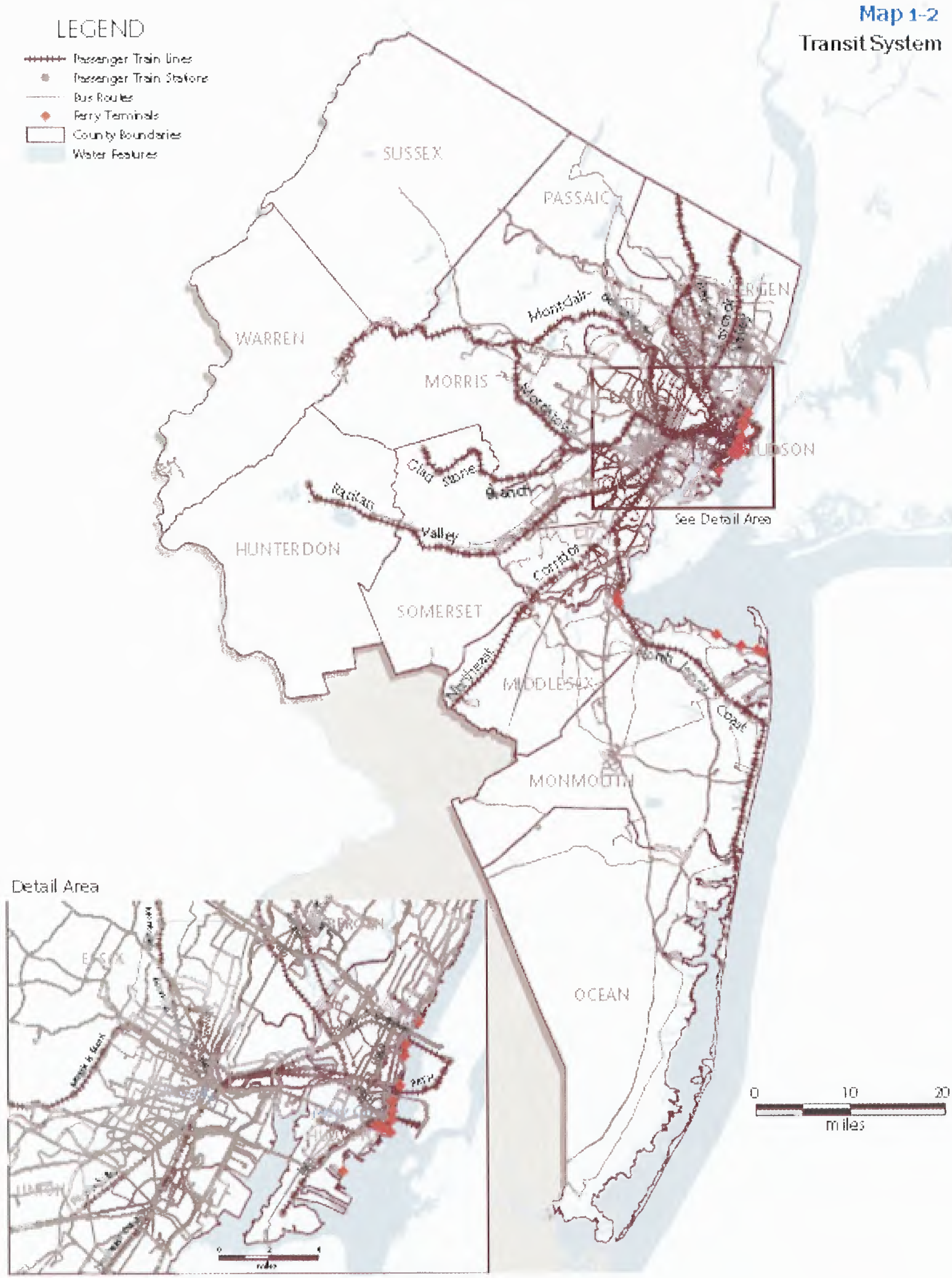

Figure 4.5 Transit system of the NJTPA region

Source: Regional Transportation Plan (2005e, p. 4)

The growth rate of the low income people was relatively faster than the total population (25.4%) in the years 1990-2000. The largest numbers of low income people were in Essex (120,000), Hudson (93,149) and Passaic (59,072). Together these three counties accounted for one-third of the growth of the low income increase between 1990 and 2000 (NJTPA, 2002, 2005c).

The NJTPA Board comprises one elected representative from each of its 13 counties and two of its largest cities, Newark and Jersey City. Other members of the board include a governor's representative, the Commissioner of the New Jersey Department of Transportation, the Executive Directors of New Jersey Transit and the Port Authority of New York and New Jersey and a citizens' representative who is appointed by the Governor (NJTPA, 2005a).

This case study was prepared by interviewing the following nine staff members of NJTPA: Director of Systems Planning and Data Forecasting, Deputy Executive Director of Administration and Communications, Manager of GIS and Forecasting, Manager of System Analysis, Manager of Public Affairs and two Senior Planners. Several NJTPA publications were also consulted, on the Internet or otherwise. The publications reviewed are *Regional Job Access and Reverse Commute Transportation Plan* (1999), *Data Sources, GIS Analytical Methods and MPO Regional Coordination* (2001), *Environmental Justice Regional Analysis: Baseline and Time Series Data* (2002), *Regional Transportation Plan: Access and Mobility* (2005e), *Are We There Yet? Progress Toward the Region's Transportation Goals* (2005b), *NJTPA Environmental Justice Regional Analysis: Proportional Distribution of Benefits of Transportation Projects in the NJTPA Region* (2006), *An Overview of the FY 2007-2010 Transportation*

Improvement Program: Introduction (2007e), *NJTPA*, *Regional Transportation Plan for Northern New Jersey* (2007f), *Project Prioritization Criteria* (2007b), *North Jersey Strategy Evaluation: Regional Transportation Needs* (2007c), *An Overview of the FY2007-2010 Transportation Improvement Program* (2007e) and (1999).

4.3.1 NJTPA's Implicit Considerations of Accessibility

NJTPA considers accessibility implicitly both through the adoption of land use methods and through modal methods.

4.3.1.1 Land Use Methods NJTPA follows land use regulations mandated by the State of New Jersey and the local authorities of all the areas under its jurisdiction. Besides the mandates, NJTPA considers accessibility implicitly through land use methods in three places in its publications.

All the NJTPA counties follow the New Jersey State Development and Redevelopment Plan (2001). The State Plan aims to strike a balance between growth and conservation and has designated certain municipalities as one of five kinds of centers. Urban centers are at the top of this hierarchical list. They are followed by regional centers, towns, villages and finally hamlets. NJTPA counties have the highest percentage of the total designated growth areas in New Jersey: six of nine urban centers, the sole regional center of the state, 12 of 21 towns, and 9 of 14 villages. So far no municipality has been designated a hamlet in New Jersey (New Jersey Office of Smart Growth, 2008).

Implicit consideration of accessibility in NJTPA publications appears in three places. The first document, *Are We There Yet? Progress Towards the Region's Transportation Goals* (2005b), highlights six distinct goals set up in 1995 by stakeholder groups, the public, and NJTPA's partner agencies. One of the goals is to "provide affordable, accessible and dynamic transportation systems responsive to current and future customers" (NJTPA, 2005b, p. 1). Although the term accessibility is explicitly mentioned, it is neither defined or measured and so is considered to be an implicit measure. An accessibility consideration next appears in the long term plan *Access and Mobility 2030* (NJTPA, 2005a). This updated version of the 2002 long term plan "couples concerns for facilitating the movement of goods (mobility) with a focus on better satisfying the purpose of travel -- namely facilitating access…" (NJTPA, 2005a, p. 5). Third, and finally, accessibility concerns appear in NJTPA's Strategy Evaluation Program, which is "an effort to assess localized transportation needs and issues" (NJTPA, 2007c, p. 30). All of the above mentioned documents and practices are interrelated. Both the Strategy Evaluation conducted in 2001-2002 and *Are We There Yet? Progress Towards the Region's Transportation Goals* (2005b) were written as parts of the long range plan *Access and Mobility 2030* (NJTPA, 2005a). Not surprisingly, NJTPA's concern for accessibility in all of the above mentioned cases is similar and is carried out by defining and by measuring accessibility.

In the Strategy Evaluation Program, developed in 2001-2002, NJTPA listed eight performance measures to analyze transportation planning decisions. Accessibility was one of the measures. The process compared municipalities to one another based on the eight performance measures. NJTPA produced maps that showed whether municipalities met the predetermined threshold for each measure.

In 2006, the revised Strategy Evaluation process for the 2009 long range plan no longer considered the eight performance measures present in the 2001-2002 study. The new Strategy Evaluation, an evolved version of the old process, built upon the 2001-2002 input from participating agencies. It differs from the earlier version in three ways. First, the eight performance measures used in the earlier version were discarded. Six new performance categories, this time making use of the experience from the earlier version and keeping in mind NJTPA's Regional Capital Investment Strategy (RCIS) were set up. Second, setting the same threshold for each performance measure for all municipalities, disregarding the nature of the municipality, was abandoned. Instead a place-based approach was adopted such that places of similar nature could be compared. Third, the 2002 NJTPA Congestion Management Process (CMP) -- an outcome of SAFETEA-LU -- was included in the Strategy Evaluation Process. The CMP is a planning tool that helps mitigate unacceptable levels of traffic interference (or congestion) at a regional level by identifying problem areas and suggesting multimodal and other strategies.

The new place-based approach designates 397 "places" in the 384 municipalities under NJTPA jurisdiction. Ten place types are identified by factors such as population density, job density, number of shopping malls, nature of economic activities, street pattern, square feet of office space and number of office employees. Explaining the concept on their website, NJTPA argues that "place types are drawn from those land use patterns, economic activities, and transportation options that have a dominant influence on transportation demand, traffic patterns, and mode choice" (NJTPA, 2007d, p. 1). The ten place types are : urban center, urban area, mature metropolitan, metropolitan with office, metropolitan with shopping center, suburb, vacation area, rural town and rural area. The key reason for designating place types was to be able to set separate thresholds for each performance measures for each place type and to be able to compare similar places within a type to one another. NJTPA obtained municipality approval before designating a place type to it.

Explicitly, accessibility was neither a performance category nor a performance measure in the new Strategy Evaluation process; it was however considered implicitly. The six new performance categories that NJTPA created focused on discovering areas that had transportation needs. Need was determined by the conditions that people faced in using highways and intermodal transportation. The six identified areas of need are "roadway hotspot delay," "unexpected roadway delay," "routine roadway delay," "transit share," "access to major destinations/center," and "walk/bike share."

The first three performance categories used for the new Strategy Evaluation process are the highway measures that "paint a picture of where overflowing roadways hinder or constrain accessibility" (NJTPA, 2007d, p. 2). The second three performance categories, considered Smart Growth measures, also affect accessibility but none of the six measures consider accessibility directly. The two instances where NJTPA considers accessibility directly are in its Environmental Justice and JARC analyses. (Section 4.3.2 elaborates both the indirect and direct measures.)

The Main Street New Jersey program, set up to revitalize downtowns and traditional business districts, implicitly enhances accessibility by bringing together clients and businesses primarily through architectural and urban design interventions by making downtowns physically attractive. The handbook *Design Guidelines: Main Street New Jersey* (New Jersey Office of Smart Growth, 2002) helps municipalities that are interested in participating in this program. The NJTPA region has 13 Main Street programs, the largest number in the State of New Jersey.

4.3.1.2 Modal Methods Transit oriented developments are compact, multiuse developments that not only conserve open space but also increase accessibility by encouraging people to use multimodal travel methods (TRB, 2005). Municipalities in New Jersey that have shown a strong inclination for developing the area around their transit stations into compact mixed-use developments with a strong residential component are assisted by an inter-agency Transit Village Initiative taskforce to help them in their efforts. A large number of the municipalities in the NJTPA region have station areas that have deteriorated over time and have been helped by the task force. Consequently 15 of the 19 transit villages of the State of New Jersey are in the NJTPA region.

Implicit consideration of accessibility through modal methods also appears as one of the six goals in RTP *Access and Mobility 2030* (2005a). The goal states "enhance system coordination, efficiency, and intermodal connectivity" (NJTPA, 2005a, p. 6). Prioritization of projects, using Strategy Evaluation and CIS, are guided by this goal.

4.3.2 NJTPA's Explicit Accessibility Considerations

Definitions of accessibility appear in two NJTPA publications. The most recent definition, written for the Strategy Evaluation process, on the NJTPA website, describes accessibility as "how readily people and goods can reach desired destinations" (NJTPA, 2007f, p. 1). An older definition appears in *Are we there yet? Progress towards the region's transportation goals* (NJTPA, 2005b). In it accessibility is defined as "the number of opportunities (such as job, shopping, etc.) that can be reached from a given location within a given amount of travel time by auto, transit, or non-motorized modes" (NJTPA, 2005; p. 4). This second definition of accessibility forms the basis of NJTPA's accessibility measurements for EJ analysis. NJTPA considers this definition to be a measure of "the range of possibilities available to travelers" (NJTPA, 2005a, p. 4).

NJTPA used the first definition, together with the investment strategy prioritized by its board, to choose which performance categories to determine the transportation needs of the region in a procedure called Strategy Evaluation. Although accessibility is *not* explicitly measured in this procedure, in the process of identifying needs based on a vision of future development, Strategy Evaluation does measure factors that *affect* accessibility. The pattern of future development in transportation is determined only after long, intense collaboration between counties, municipalities and other agencies. Once the future objectives or performance categories are agreed upon, performance measures are identified and performance targets are established "to assess priorities for improving accessibility and mobility" (NJTPA, 2007d, p. 1). NJTPA analysts quantified each of the six performance categories by a performance measure with its own threshold that indicated whether a certain place had a need for transportation improvement or not.

The first performance category, "roadway hotspot delay," was measured by the percentage of total trip time spent in extreme congestion. The second category, "unexpected roadway delay," was the number of potential accidents that could happen on roads to and from a certain place. The third category, "routine roadway delay," was the delay in minutes per trip caused by the excess time taken to travel to one's destination over what it would have taken in free flowing traffic. "Transit share," the fourth performance category is measured by the percentage of commuting trips that are taken by transit. Although "access to major destination/center," the fifth category, has the word "access" in it, it cannot be considered a measure of accessibility for it is the average trip length that a person makes. It is rather, as mentioned earlier, one of the five measures that *affects* accessibility. The sixth and final category, walk/bike share, is measured by the percentage of all trips taken by walking or biking.

All of the performance categories, except transit share, used data from NJTPA's regional transportation model. The transit share data were obtained from the Census Transportation Planning Package (CTPP). It is important to note that the model considers only major roads in its calculations. The regional transportation model takes into account all the trips associated with (from and to) a place and is validated regularly by survey data, traffic count data and census data.

Using ESRI's ArcGIS NJTPA explicitly measures accessibility in fulfilling Federal Environmental Justice requirements (NJTPA, 2007a, p. 1). The first step that NJTPA takes to measure accessibility, for EJ evaluation, is to identify EJ communities. In NJTPA's own words, EJ communities may include "transportation disadvantaged" populations. These consist of not only the low income and the minority households but also the disabled, the elderly, households without a car and people with limited English proficiency. These groups are sometimes overlapping and each of these groups has different transportation needs. NJTPA plans to address this in a future version of its EJ analysis.

Unlike the Strategy Evaluation process, which is place based, identification of EJ communities are based on block groups. NJTPA designates a block group to be an EJ community for minorities, mobility-impaired and elderly people where the number of people in a block group exceeds the regional average for block groups for that community. Low income communities are identified differently. If 20% or more (a number obtained by NJTPA's JARC analysis conducted in 1999) of a block group was below the poverty level, as determined by the 2000 census, that block group was considered to be a low income EJ community (NJTPA, 2002).

Subsequently, NJTPA has identified a municipality to be an EJ community if more than half of a municipality's block groups contain 55% or more minority population or 15% or more low income population. Other thresholds that are used to determine if a municipality is an EJ community are the number of TANF and food stamp recipients, Free and Reduced Lunch Program students and the municipality distress index. In municipalities, as in bock groups, cut off points were set "where natural breaks occurred in the distribution" (NJTPA, 2007a).

Once EJ communities are identified, NJTPA follows its own definition of accessibility to form a measure based on travel time from a community (EJ and non-EJ) to a destination for two modes of transportation: 40 minutes by highway and 60 minutes by transit. Destinations that NJTPA considers are: jobs, job-training centers (taking into account the number of programs they offer), childcare centers (taking into account the cost of using the facility), health care centers, hospitals and grocery stores. The data for these destinations are obtained from a variety of New Jersey agencies, including the Departments of Human Services, Transportation, and Community Affairs.

Instead of just summing up the number of facilities that fall within the travel time of each mode, or putting a gradation of weights to the destinations depending on their proximity (akin to a gravity model), NJTPA plans to take into account two important aspects of the accessibility of a facility to a person in its future calculations: the competition that a population faces from communities outside their own, for the facilities that lie within the prescribed isochrone zone for each mode of transportation and the matching of the facilities to the population who seek out for the facilites. The manager for System Analysis at NJTPA called this "competitive accessibility." No map of such consideration was available at the time of the interview.

The *Regional job access and reverse commute transportation plan* (1999) considers accessibility for the inner city poor to suburban jobs. Suburban jobs are difficult to access by inner city poor primarily because of lack of transportation from the city to the suburb in the morning and from the suburb to the city in the evening, a commute that is reverse to the flow of traffic. The FTA provides matching funds, to that provided by the state DOT, for plans for inner city reverse commuting by private organizations (Multisystems Inc., Mundle & Asso., Simon & Simon Research Asso., & Econometrics Inc., 2000). Reverse commuters are not the only group of people who face spatial mismatch. Young and middle aged people who have to take care of aged parents or young children and the elderly and the disabled who need to access health and community services face accessibility problems that JARC plans address (Congress, 2004a). Federal JARC funding with the matching state grant for NJTPA was $5,000,000 for each of the FYs 2006, 2007 and 2008 (NJDOT, 2007b).

To analyze service gaps NJTPA created GIS maps with ½ mile buffer on transit lines to measure the number of childcare, adult daycare facilities, training centers and employers within this zone. Next they identified the location of TANF recipients, mapped poverty and employment concentrations (20% or more of a block-group's population below the 2000 census poverty line was considered low income) and identified the underserved areas (NJTPA, 2001).

4.3.3 NJTPA's TIP Evaluation

NJTPA projects are developed in three stages: transportation planning, Project Pipeline and TIP. At the transportation planning stage, needs of the region are identified and evaluated. At the second stage, Project Pipeline, possible alternative solutions to the identified problems along with their planning and engineering are studied. TIP, the final stage, is the formal commitment stage when a budget for the implementation of the projects is laid out (NJTPA, 2005d).

For regions with more than 200,000 people, such as NJTPA, a congestion management process (CMP) is required by ISTEA and TEA-21 to guide transportation decisions. The CMP gives NJDOT and NJTPA a framework for measuring congestion. It also helps to identify potential projects. Until recently, NJTPA determined that the first stage of project development would be set by the CMP and the funding guidelines laid out in its Capital Investment Strategy (CIS). The NJTPA board decided upon this crucial stage by keeping in mind its commitments to the RTP, that includes expanding transit, enhancing efficiency, optimizing the system, improving freight, augmenting bicycle and pedestrian travel and encouraging Smart Growth (NJTPA, 2005d).

Beginning in 2007, representatives of the sub-region in which a prospective project is to be built are shown the results of the Strategy Evaluation and are included in the process of TIP evaluation. In this process, the NJTPA staff analyzes the needs of the region using the Strategy Evaluation described earlier in this chapter. This process, which aims to "gauge accessibility," uses the CIS set up by the NJTPA board (NJTPA, 2007b). The needs highlighted by the Strategy Evaluation process help to identify and prioritize the sub-regions in which TIP candidates should be located. The final project prioritization, based on the RTP, is determined by NJTPA and its implementation agencies NJDOT and NJ Transit.

Since 2004, an additional evaluation of the TIP is completed during the final stage. To help prioritize projects, a set of questions is asked about it and depending on the answers, points (which can at most add up to 1000) are awarded. Questions are placed in six broad categories: environment, user responsiveness, economic, system coordination, repair/maintenance/safety and security and finally land use and transportation planning. Each of these categories, except "repair/maintenance/safety and security" includes at least one question pertaining, implicitly or explicitly, to accessibility. When counted together a third of the points (adding up to 333) are assigned to accessibility concerns.

The question about a TIP project in the "environment" category is "Does it provide benefits or reduce burdens to low income, minority, elderly or mobility-impaired communities (communities of concern for EJ)?" When the answer is "high" (which can mean the project addresses safety, decreases truck traffic, reduces noise or improves accessibility to employment), it is awarded the maximum number of points assigned for a question, which in this case is 36.

The question in the "user responsiveness" category that pertains to accessibility is: "Will it provide benefits to the regional transportation system?" (Maximum 30 points) The "economic" category has two questions pertaining to accessibility. The first is "Will the facility improve access to major tourism/recreation facility?" (Maximum 23 points) and the second is "Will it improve access to job opportunities?" (Maximum 56 points)

The "system coordination" category has three questions pertaining to accessibility. The first is "Will it provide linkages to other existing transportation systems?" (Maximum 38 points) The second is "Will it provide bicycle or pedestrian improvement?" (Maximum 37 points) and the final is "Will it improve access to airport/seaports/freight facilities/Urban Enterprise Zones (UEZs)?" (Maximum 26 points)

Two of the three questions in the "land use/transportation planning" category pertain to accessibility. The question "Will it serve distressed municipalities?" has a maximum point value of 38 when it serves a municipality designated as distressed by the Department of Community Affairs. If the project in not within a distressed community, it is awarded no points. The second question, pertaining to accessibility, in this category is: "Has the project emerged from the planning process required to establish a Transportation Development District (TDD), Transportation Improvement District (TID), Transportation Enhancement District (TED) designated Transit Village, other comprehensively planned public-private partnership, or other officially adopted improvement district?" (Maximum 49 points) (NJTPA, 2007b).

Federal mandates dominate fund allocations for transportation programs. The Federal Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), which formerly was the Intermodal Surface Transportation Efficiency Act (TEA-21), led the board to make safety the top priority and to allocate a substantial portion of the budget (60%) to the maintenance and preservation of existing infrastructure. The rest of the budget complies with NJTPA's planning priorities.

4.3.4 Visualization and Collaborative Planning Programs of NJTPA

NJTPA's public outreach program provides a variety of ways to obtain public input to the planning process ranging from a website where people can leave comments, without leaving their homes, to meeting the agency's officials face to face.

On their website, NJTPA publishes a calendar listing meetings, their location and their agendas, recent publications and studies undertaken by the organization. It also provides a "feedback forum" allowing anyone to leave a comment. The website also offers subscriptions to NJTPA's newsletters and interaction with the NJTPA Online Transportation Information System (NOTIS), a mapping system where one can get details about planned and committed transportation projects (TIPs).

In 2007 NJTPA conducted an intensive outreach program, in an open house format, which it considers to have been a success. In this I-78 corridor transit study, information sessions were not formalized. To begin, people walked around boards that carried information about the project and were free to approach NJTPA spokes people (not technical staff) who were there to answer questions that they had one-on-one. A power point presentation was then made about the project. At the end of the presentation, people were encouraged to ask questions or leave comments for which sheets of paper were provided. A web-based survey conducted after this presentation received 5000 responses and people had the option of leaving their email addresses for further contact. To NJTPA's surprise, 2000 people took up the offer. In planning this program, NJTPA involved local elected officials to get their feedback before reaching out to the public.

Of all of their outreach programs, NJTPA has attempted to touch upon accessibility, in their publications *Regional Transportation Plan* (NJTPA, 2007f), *Are We* *there Yet?* (NJTPA, 2005b), *NJTPA Strategy Evaluation: Regional Transportation Needs* (NJTPA, 2007c) and EJ reports (NJTPA, 2002, 2006, 2008). These documents are all available to the public on the World Wide Web.

NJTPA has a very good outreach program but undertakes no collaborative planning of any importance when making decisions about TIPs. NJTPA's visualization efforts are limited to the maps that are included in their reports and to images of how proposed projects would look, presented during project outreach.

CHAPTER 5

COMPARISON AND EVALUATION OF CASES

Chapter Four, three New Jersey MPOs were studied to determine how each of them considers accessibility, evaluates TIPs and conducts its federally mandated collaborative planning process. This chapter compares and evaluates the three cases. The framework for the comparison is the conceptual framework for considering accessibility outlined in the literature review section (Chapter Two). The next chapter, Chapter Six, develops a GIS-based measure of accessibility that can be used by the MPOs for a collaborative planning process.

5.1 Comparison and Evaluation of Accessibility Considerations by MPOs

To make sure MPOs are following federal regulations, TEA-21 mandates that every three years or less, the FHWA and the FTA certify all previously identified and new MPOs to allow them to keep their designation as metropolitan planning organizations (Dempsey, Goetz, & Larson, 1997). This certification process requires State DOTs and MPOs to conduct self certification reviews. The review process examines, among other factors, the metropolitan planning process and the MPO's adherence to Title VI requirements (Sanchez & Wolf, 2005). The three New Jersey MPOs employ their own ways of adhering to Title VI equity requirements and; in extension, the way they consider accessibility -- a measure of one of the dimensions of equity. The differences between MPOs in this regard are apparent when presented in a tabular form (Table 5.1).

Table 5.1 Explicit and Implicit Accessibility Considerations by the three NJ MPOs

Accessibility Consideration		**SJTPO**	**DVRPC**	**NJTPA**
Implicit consideration	By land use: Number of designated centers	1 Urban Center, 3 Township, 5 Villages	2 Urban Centers, 6 Township (in NJ), 1 Metro Center, 7 Metro Sub-centers, 89 Regional Centers (in PA)	6 Urban Centers, 1 Regional Center, 12 Towns, 9 Villages
	By land use: Number of Main St projects	8	5 (in NJ), not a PA project	13
	By land use: Other		Keystone principles and criteria for growth: "Redevelop first," "concentrate development," "provision of housing with the location of jobs, public transit, services, schools and other existing… infrastructure"	Place-based Strategy Evaluation for determining needs: highway and Smart Growth measures
	By modal methods: Number of TVI (NJ) or TRID (PA)	1 TVI	3TVIs, No TRIDs	15 TVIs
	By modal methods: as policy	"promote transportation choices for people and goods" in RTP "Expand and improve non-auto elements of the transportation system"	"invest in businesses that offer good paying, high quality jobs, and that are located near … housing, existing workforce, and transportation access"-- Keystone principles and criteria for growth	"enhance system coordination, efficiency, and intermodal connectivity."
Explicit consideration	Accessibility defined	Yes	No	Yes
	Accessibility measured	In EJ analysis In JARC analysis	In EJ analysis In CHSTP analysis	In EJ analysis In JARC analysis

5.1.1 Comparison and Evaluation of Implicit Considerations of Accessibility

As is apparent in Table 5.1, the implicit considerations of accessibility are different from one MPO to another depending upon the state to which it belongs and the nature of the development in its jurisdiction.

Comparison of accessibility consideration using land use methods indicates that NJTPA, being more developed than SJTPO, has more Main Street Programs and designated centers. Although, centers are places that encourage economic activity and development, it is meaningless to compare designated places in New Jersey to that of Pennsylvania as the two states use different criteria to designate places. However, the Pennsylvanian Keystone Principles and Criteria for Growth are similar to New Jersey's Smart Growth principles which underlie most New Jersey planning. Both are accessibility enhancing plans that have several common underlying principles. Designated places in both states mimic Roseland's (2005) "urban village" and promote compact land use patterns and stress mixed use zoning. This basic idea is carried out in different scales for different sizes of the cities in both New Jersey and Pennsylvania.

NJTPA has a place-based Strategy Evaluation Program that "generates recommendations for specific strategies and programs to benefit particular areas" (NJTPA, 2007d, p. 1). The Strategy Evaluation Program quantitatively measures several factors using the NJTPA travel demand model that consides accessibility implicitly. This method is unique to NJTPA as neither DVRPC nor SJTPO has a systematic method of focusing on analyzing the entire region under their jurisdiction to isolate portions of their metropolitan planning regions that need special attention regarding accessibility.

New Jersey's Transit Village Initiative and Pennsylvania's Transit Revitalization Investment Districts fall under the gamut of initiatives that focus on transit oriented development. They are similar in nature but have different levels of acceptability in the two states. New Jersey has a very long history of promoting transit oriented development due to the density of its development, high levels of congestion on its roads and proximity to one of the country's largest urban conglomeration (New York City). Transit is thus acceptable and, unlike Pennsylvania, is welcome in the congested parts of the state. Other than Philadelphia, most of DVRPC's portion of Pennsylvania is suburban or rural in nature. It is only since the 1990s that transit has come under serious consideration in this state. The SJTPO region, although in New Jersey, is located in its least densely populated area and hence does not have transit orientation as the northeast portions of the state.

The implicit considerations of accessibility, both by land use and by modal methods, do not lend themselves well to quantitative comparisons and measurements. The effects of implicit considerations of accessibility can, however, be measured quantitatively. Thus they are an important part of any study on accessibility and any measure of accessibility should be able to account for the changes brought about by outcomes of plans that implicitly considered accessibility.

5.1.2 Comparison and Evaluation of Explicit Considerations of Accessibility

The case studies reveal that explicit consideration of accessibility in MPOs occurs primarily in the measurement of Environmental Justice (EJ) and in creating the Job Access and Reverse Commute (JARC) Plans. Both EJ and JARC are federal mandates that are uniformly used by all MPOs but the cases studied indicate that they are conducted differently in different regions. All three New Jersey MPOs, to varying degrees, give primary importance to EJ. JARC analysis is similar to EJ analysis and so will not be discussed separately. SJTPO, being small, had a private consultant carry out the analysis; both DVRPC and NJTPA have full-time employees solely dedicated to EJ analysis for considerable periods of the year.

EJ is usually associated with hazardous waste sites and is rooted in Title VI of the 1964 Civil Rights Act. In transportation planning it is mandated through a Department of Transportation order (USDOT, 1997) that has three principles; the first forbids disproportionately high and adverse effects of transportation projects on low income and minority groups; the second mandates that low income and minority groups receive timely and proportionate shares of the benefits from transportation, and the third mandates that these populations be involved in the transportation decision making process (USDOT, 1997).

EJ analysis aims at measuring equity. Accessibility is an outcome of equity and cannot be a proxy for equity. According to Sanchez (2008) equity has three significant dimensions: outcome (accessibility to jobs and other services or wage levels), inputs (investments or funding levels), and outputs (level of service provided with the funding like service location and frequency of service). Accessibility is just one measure of the "outcome" dimension. Thus a complete EJ analysis needs to study equity with respect to funding, the level of service the funding provides, and the ability of that funding to provide accessibility. Whether MPOs comprehensively consider the various dimensions of equity and their corresponding measures, or whether the measures of accessibility that they use are able to capture inequities, is beyond the scope of this dissertation.

This dissertation is concerned with the implicit and explicit consideration of accessibility by the case study MPOs. As accessibility is explicitly measured in the process of EJ analysis, this process has been studied in detail. The interviews and the documentation provided by the three New Jersey MPOs indicate that the "outcome" dimension of Title VI/ EJ requirements are fulfilled by the three MPOs in a three-step procedure. The steps vary in their methodology from one MPO to another but they all broadly follow a predefined intent and have a similar pattern. First, the MPOs identify and map locations of communities that they think that they should be concerned about in order to fulfill EJ requirements. Second, they draw buffers to determine catchment areas. Third, they assess quantitatively the benefits and gaps of the existing transportation system by using GIS.

5.1.2.1 Identification of Communities of Concern Federal laws mandate that low income and minority communities need to be considered when EJ analysis is performed. All three MPO's define communities of concern as including people in addition to the two basic population groups, low income and minority, which the Federal laws require them to consider. Each MPO, however, identifies a different set of communities. Moreover, each MPO has a different definition for the communities they are concerned about. Even for the basic set of low income and minority communities, which they are required to be concerned about by law, definitions as to which group of people is a low income or a minority group differ from one MPO to another. A table of how each New Jersey MPO identifies its community of concern is provided below (Table 5.2).

Table 5.2 Communities of Concern Considered for Environmental Justice by NJ MPOs

	SJTPO	**DVRPC**	**NJTPA**
Communities of concern	TAZs with portions of minority, low- income and households without cars at or above respective regional thresholds of each	Census tract with more density than regional average for: non-Hispanic minority, Hispanic, elderly over 85, persons with physical disability, people with limited English capacity, female head of household with child, carless households, households in poverty	Block groups with low income (20% or more were less than Census threshold), minority, mobility-impaired and elderly (more than regional average) Municipalities with >55% of its block groups resided by minorities OR >15% of its block groups are resided by low income populations + TANF, school lunch and Municipality Stress index
Sources of Data	2002 Bureau of Economic Analysis, 1990 and 2000 Census, TANF, NSLP, NJDOL ES-202	Census	Census, NLSP, New Jersey Municipality Stress Index, TANF

FHWA's environmental justice order (FHWA, 1998), outlining the compliance with Executive Order 12898, defines "low income" to be people whose "household income is at or below the Department of Health and Human Services (HHS) poverty guidelines" (FHWA, 1998, p. 2). Poverty guidelines issued yearly by the HHS, used for determining financial eligibility for administrative purposes, are a simplification of poverty thresholds. The poverty threshold, issued yearly by the Census Bureau, is a statistical measure used for calculating the number of people in poverty (HHS, 2008). Both the threshold and the guideline numbers are applied nationally without regard to local differences in cost of living.

Two of the three MPOs studied (SJTPO and DVRPC) use the HHS guideline to determine the number of households that are low income. The percentages of households that are low income are then averaged over the entire region to determine the threshold for the inclusion as low income for the unit of analysis chosen by a MPO. So the thresholds used by the MPOs are not the same thresholds used by the Census Bureau. The thresholds for all other communities of concern are determined similarly by calculating the regional average for the unit of analysis chosen by the MPO. The third MPO (NJTPA) identified low income communities based on the research conducted for its JARC plan in 1999. Per this research, a community was considered low income "if 20 percent or more of their population was in poverty according to the 2000 Census" (NJTPA, 2002, p. 1).

Although MPOs are directed by FHWA to follow current HHS guidelines, it is not always possible to use the directive for identifying low income communities. For example, when *Environmental Justice Strategy and Evaluation* (SJTPO, 2002b) was published, the income data for the 2000 Census was not available. So SJTPO used the 1990 Census data together with the latest TANF and NSPL's Free and Reduced Price Lunch Program data instead for determining low income TAZs. In identifying communities of concern, SJTPO collaborated with DVRPC and so, degree of disadvantage, a concept developed by DVRPC, appears in their table. Table 5.3 elaborates in detail how communities in the SJTPO region are identified.

In essence, each of the three New Jersey MPOs uses a different method to identify its low income population. All three MPOs measure their other communities of concern in the same way; they calculate regional averages for each community to determine the threshold. NJTPA, however, also looks at municipalities (over and above block groups) to determine EJ communities. Cut points are set at "natural breaks" making it arbitrary and difficult for the public to understand their methodology. .

Table 5.3 Method for Identifying Communities of Concern in SJTPO region

Factors Present	Criteria	Geographic Unit	Category
Minority Poverty	At or above 2000 minority regional threshold of 31% Or At or above 1990 poverty regional threshold of 10%	TAZ	Meets on community of concern threshold
Minority or Poverty and one or more additional degrees of disadvantage*	At or above minority or poverty regional threshold and at or above the regional threshold for one or more additional degrees of disadvantage**	TAZ for minority, poverty, and zero-car households; TAZ and adjacent TAZ for TANF households and free or reduced price lunch eligibility	Meets one community of concern threshold and exhibits one or more additional degrees of disadvantage
Minority and Poverty	At or above minority and poverty regional thresholds	TAZ	Meets both community of concern thresholds
Minority and poverty	At or above minority and poverty regional thresholds	TAZ	Meets both community of concern thresholds
Minority, Poverty and one or more additional degrees of disadvantage	At or above minority and poverty and one or more additional degrees of disadvantage regional thresholds	TAZ for minority, poverty and zero-car households; TAZ and adjacent TAZ for TANF households and free or reduced price lunch eligibility	Meets both community of concern thresholds and exhibits one or more additional degrees of disadvantage

* Additional degrees of disadvantage include TANF households, Free or Reduced Price Lunch Program
** The regional thresholds for additional degrees of disadvantage are: 10 or more TANF households in a TAZ or an adjacent TAZ, 41% or more students of a school located in a TAZ or an adjacent TAZ eligible for free or reduced price lunch, and 13% or more zero-car households in a TAZ

Source: SJTPO (2002c, p. 18)

FHWA allows states and localities to use their own "higher threshold as long as the higher threshold is not selectively implemented and is inclusive of all persons at or below the HHS poverty guidelines" (FHWA, 2008, p. 1). MPOs are thus consistent with

USDOT's order 5610.2 which states that "a person whose median household income is at or below the Department of Health and Human Services poverty guidelines" is a low income person (USDOT, 1997, p. 18381)

FHWA's order defines minority as "a person who is Black, Hispanic, Asian American or American Indian/Alaskan native" (FHWA, 1998, p. 2). SJTPO and NJTPA follow this definition of minority but DVRPC sub-divides minorities into Hispanic and Non-Hispanic minorities. All three organizations calculate regional averages to obtain the threshold value for minorities in their region. DVRPC includes additional communities of concern like female head of household, car-less households and households deficient in English language skills which give the organization a better idea of communities that they intend to reach.

Each MPO uses its own unit of geographic analysis to calculate EJ. SJTPO's EJ study (SJTPO, 2002b), conducted by a consultant, uses transportation analysis zones. This unit, usually used for traffic analysis in UTDMs consists of "one or more census blocks, block groups or census tracts" (US Census, 2001, p. 1). SJTPO uses TAZs from their 1996 traffic model while DVRPC uses the US Census data unit, the census tracts and NJTPA uses a combination of census units (block groups) political boundary (municipalities). A discussion of whether this grouping is legitimate, for the purposes of the analysis that the MPOs undertake follows, but what is important here is that none of the MPOs use the same unit of aggregation. This difference in aggregation not only makes it impossible to compare them but, more importantly, the results of the analysis would differ significantly if one unit is chosen over another.

The arbitrary nature of aggregating geographical data into units like TAZ, census blocks or census block groups, as done by the three case study MPOs, leads to two sources of uncertainty. Both these uncertainties are endemic to all spatially aggregated data. The first uncertainty, known as the Modifiable Areal Unit Problem (MAUP) points out how the same dataset can produce different results in an analysis when the data is either aggregated using varying spatial resolution (scale effect) or by varying the pattern of the regions created (aggregation or zoning effect) (Klinkenberg, 2002; Monmonier, 1996). The scale and aggregation can thus be gerrymandered "to create apparent spatial distributions which are unrepresentative of the scale and configuration of real-world geographic phenomenon" (Longley, Goodchild, Maguire, & Rhind, 2005, p. 148).

The second problem that is endemic to the spatial aggregation carried out by the case study MPOs, known as the ecological fallacy, consists of thinking "that relationships observed for groups necessarily hold for individuals" (Freedman, 1999, p. 1). Consequently, even dominant characteristics of a group cannot be assigned to individuals of the same group. Low income, minority or any other community of concern assignment to a aggregation of people can thus be a disservice to people who belong to the communities of concern but do not live in an area that an MPO considers to be a community of concern by the way it chooses its unit of analysis. Ecological fallacy is related to MAUP and both of these uncertainties arise in the processes by which all three MPOs identify their communities of concern.

5.1.2.2 Determination of Destinations All three MPOs identify jobs as destinations. Table 5.4 lists all the destinations that the three New Jersey MPOs consider. DVRPC considers destinations differently from NJTPA and SJTPO. Instead of identifying destinations that EJ communities try to access, DVRPC considers Quality of Life Factors that identify six elements pertaining to accessibility. Quality of Life Factors consist of access to public transit, arterial highways, regional employment centers, job access reverse commute routes, hospitals and day care centers (DVRPC, 2004b).

Table 5.4 Destinations Considered for Environmental Justice by New Jersey MPOs

	SJTPO	DVRPC	NJTPA
Destination	Jobs and essential services (hospitals, colleges/vocational schools, supermarkets)	"Quality of Life Factors": regional employment centers hospitals, child day-care center	Jobs, job-training facilities, day-care centers, hospitals, grocery stores, colleges, vocational training schools and supermarkets.
Source of Data	2002 Bureau of Economic Analysis, NJDOL ES-202, travel demand model	Delaware Valley Child Care Council	NSLP

DVRPC considers all six factors together in their environmental justice determination. Three of the Quality of Life factors pertain to the destinations that EJ communities try to reach and three pertain to the infrastructure that they use to arrive there. NJTPA and SJTPO, on the other hand, consider destinations as objects independent of the transportation network that exists to arrive at a destination. Essentially though, DVRPC's approach to the problem is similar to SJTPO's and NJTPA's in that EJ communities need to access destinations using the infrastructure and whether the destinations are considered together with the infrastructure, or separately, as in the case of NJTPA and SJTPO, there is no significant difference for the multilayer method of analysis (discussed later in this section) that is used by all three MPOs. DVRPC's method of grouping the infrastructure and the destination thus has no special advantage over the methods employed by NJTPA and SJTPO who consider destination and modes of transportation separately.

Employer data is considered differently by the three MPOs. The ES-202 data, used by SJTPO, only includes businesses with 20 or more employees. Small employers are thus excluded from the SJTPO's EJ analysis. NJTPA claimed in its interview that it sorts jobs by pay scale and sector to match EJ populations and that it also considers job training centers that specifically target low income groups; however, no such map was produced by NJTPA.

NJTPA also claimed that they take into consideration competition that a destination site receives from other destinations of similar nature. For children's day care centers for example, NJTPA factors in all the children in the "catchment area" of a day care center that compete for a spot at a center by considering the cost of care, number of children each center can accommodate and the age group that the center admits. The same kind of competition is considered for job training facilities by taking into account the kinds of training that a facility offers, and the number of seats available for training. Once again NJTPA produced no map indicating such considerations. SJTPO and DVRPC do not consider the quality of the destinations used for EJ calculations.

5.1.2.3 Accessibility Analysis by MPOs Accessibility is calculated after communities of concern and destinations are identified. All three MPOs essentially use the same method: multilayer proximity analysis. In this, the simplest form of multilayer spatial analysis, several layers of information are stacked on top of each other (similar to acetate overlays) on a base map. Each layer (or theme) uses the same projection, is perfectly aligned to the layer below, and contains a single attribute (a destination or a proximity buffer). The combined layers show where overlaps occur (Pamuk, 2006).

New Jersey MPOs use their own regions as base maps but have two options for determining proximity. In the first method, buffers are drawn from the EJ communities or destination points to delineate catchments. The buffer could be a circle with the distance measured as a straight line (Euclidian distance) or could be measured along the actual network in which the travel takes place (Manhattan distance). In the second method a given distance is measured perpendicular to the line of travel along its entire length from the origin to the destination. This creates a buffer (on both sides of the line of travel) to delineate the distance up to which people are served along that line. The second method gives a more accurate measure of distance and the people served but both methods assume that all locations within a buffer have the same level of accessibility. Table 5.5 gives a summary of the methods used by the three New Jersey MPOs studied.

Table 5.5 shows that the accessibility measure used by SJTPO and NJTPA is a "spatial opportunity measure" (discussed in Section 2.3.1.4. in the Literature Review chapter). It is by far the most commonly used accessibility measure and is based on the opportunities available to people within a certain period of time or a fixed distance. This is a "potential" measure of accessibility that lacks a direct relationship between individual choice and accessibility. Thus all people living in a chosen geographic unit of analysis (a TAZ for SJTPO, a census block group for NJTPA or a census tract for DVRPC) are assigned a fixed value for their accessibility regardless of their individual choices. NJTPA and SJTPO use the simplest of all the spatial opportunity measures, that of Wachs and Kumagai (1973) in which isochrone opportunities (jobs and services) are cumulatively added together.

Table 5.5 Methods used to Measure Accessibility by New Jersey MPOs

	SJTPO	DVRPC	NJTPA
Travel Path	Freeways, arterials and transit	Freeways, arterials, collectors, local roads and transit	Freeways, arterials and transit
Travel Mode	Automobile, transit	Automobile, transit, walking and biking	Automobile, transit
Buffer Size	n/a	¼ mi buffer on both sides of transit path	n/a
Travel Time	Number of TAZs 15, 30 and 45 minutes from services Number of Jobs within 15, 30 and 45 minutes from TAZ	n/a	Number of jobs and services within 40 min of auto and 60 min of transit ride
Walk and Wait time	Not considered	n/a	Not considered
Travel Distance	Network		Network
Communities considered for comparison	Minority vs. Non-minority and Low income vs. non-low income	All EJ communities with 4 or more DODs	EJ and non-EJ
Other consideration	Base year 1996 compared to "no-build" and 2025 "plan" conditions for both minority vs. non-minority and low income vs. non-low income	Study done on non-motorized access to transit: Bicycle and pedestrian LOS (for intermodal transit access)	Competition faced by population
Source of Data	SJTPO travel demand model		

Table 5.5 also indicates that SJTPO and NJTPA use the first method of proximity analysis where catchments are drawn around either the communities or the destinations while DVRPC uses a buffer around its transit routes. In their travel time calculations SJTPO and NJTPA do not take into account either the time taken to walk and wait for transit services or the time taken to stop at intersections for traffic lights. None of the MPOs consider any form of multimodal transport from origin to destination.

A few assumptions underlie the method of proximity analysis used by the MPOs. All New Jersey MPOs assume that if a buffer touches or is inside a polygon indicating the boundaries of a community of concern, the entire population living within the boundary can avail of whatever the buffer offers (jobs, services or transit). First, members of the community who, for example, can not walk to a transit stop are not given the opportunity to have a personal preference expressed. Second, it is assumed that availability of transit to an EJ community means that the transit service operates during the hours that a person needs it. Third, it is assumed that availability of transit means that the transit can take an EJ community member to the destinations s/he desires.

Macro-level analyses, such as these, group people and assume that everyone in the group behaves similarly. What is worse is that the regional MPO gets to decide on the behavior with no input from any members of the group. A micro-level analysis of accessibility, on the other hand, would require detailed qualitative studies which would be overwhelming for any planning organization to undertake given the size of the region under their jurisdiction and the time limitations that are imposed on them. Neither NJTPA nor SJTPO carries out any survey or other means to get an understanding of the travel preference of EJ communities.

5.2 Comparison and Evaluation of TIP Evaluation Methods used by MPOs

Technical aspects of TIP selection for MPOs that serve more than 200,000 people, like DVRPC and NJTPA, are largely dependent on the CIS investment principles that they follow. The CIS, built on strategies laid out in the RTP, have the following principles: make travel safer, fix it first, expand public transit, improve roads but add few, support walking and bicycling (NJDOT, 2006). Smaller MPOs like SJTPO do not need to have investment principles. SJTPO has a point system for itself that follows the directives laid out in the RTP. This point system is a priority list and similar to the CIS but more relevant to a MPO that is set in a region that is not highly urbanized.

None of the New Jersey MPOs has a tool that measures the effect a proposed TIP would have on the current or the future population. Other than tools that forecast travel demand, tools made by MPOs are geared to meet EJ requirements. EJ tools intend to demonstrate that the TIPs selected by the MPOs are not biased against EJ communities.

5.3 Comparison and Evaluation of Visualization and Collaborative Planning

The case studies indicate two important issues: first, none of the New Jersey MPOs explicitly convey information about accessibility to the public; and second, none of the MPOs participate in collaborative planning of any significance in their choice of TIPs.

New Jersey MPO efforts to reach out to the public seem to be primarily confined to outreach of two kinds. The first kind of outreach is disseminating federally mandated information like announcement of meeting schedules that are open to the public and information about how environmental justice calculations are performed. All three New Jersey MPOs undertake well organized outreach programs -- a federal mandate; DVRPC in addition has a library, open to the public, with a librarian solely dedicated to disseminating information about the organization and its various publications. The second kind of outreach is disseminating information about a particular project. Information about projects is intended to both inform the public about the progress of projects and to get a steady stream of feedback as the project progresses. This second kind of outreach is primarily aimed to quell criticism about projects that are complex in nature and/or take a long time to complete. An example of a successful outreach effort of the latter kind is NJTPA's I-78 project that had a significant sized population participate both in the information sessions and the follow up on the Internet. All three MPOs are keen on improving their outreach efforts and look for ways to increase participation

EJ information is freely available to the public at the websites of all the MPOs. Measuring accessibility is a part of the EJ analysis. None of the MPOs conduct the EJ analysis (and thereby measure accessibility) in a collaborative manner with the public. Moreover, none of the MPOs defined accessibility fully and their representation of the elements to measure accessibility has MAUP uncertainty. Almost all spatial aggregation produces MAUP but none of the MPO documentation mentions the presence of this possible error. This calls for a different approach to measuring accessibility than those currently used by the MPOs.

TIP selection process in all three MPOs is carried out without any significant effort to involve the public. Regional needs are determined by TACs who are heavily dependent on the little understood UTDMs. This calls for simpler, preferably visual explanation of TIPs that can meaningfully engage the public.

To increase transparency, MPOs are required to be the "forum for cooperative transportation decision making for the metropolitan area" (FHWA, 2005) and in that capacity, they need to involve the public in collaborative planning processes that are both meaningful and easy to understand. Visualizing an operational performance of a TIP may be one such involvement. This aspect of TIP visualization is a neglected part of the transportation planning process and has been called out in the research agenda of transportation visualization (Hughes, 2004). As the literature on transportation visualization indicates, it is just the physical design aspect of transportation projects, in the form of realistic 3D rendering that dominates the field. Visualizing accessibility, in part, helps bridge the gap between notions of design and notions of value.

CHAPTER 6

CONSTRUCTION OF A GIS-BASED MEASURE OF ACCESSIBILITY

In Chapter Five the various ways that accessibility is considered by New Jersey MPOs was compared and evaluated. It was apparent that all three New Jersey MPOs measure accessibility in the process of performing EJ analysis and that they make significant efforts to disseminate an explanation of the process by which they carried out their EJ analysis. There was no evidence however of any collaborative planning on the part of any of the MPOs in measuring accessibility or explaining the change of accessibility as a result of a TIP. In this chapter a GIS-based measure of accessibility that can be used for visually evaluating TIPs is developed. The following chapter (Chapter Seven) is a summary of the entire research process.

6.1 Developing a GIS-Based Measure of Accessibility

To develop a GIS-based measure of accessibility the conceptual framework for considering accessibility (Figure 2.1) is adopted and all the explicit and the implicit considerations of accessibility discussed so far are revisited in order to select the one that would be most appropriate for collaborative planning.

6.1.1 Developing a GIS-Based Measure from Explicit Considerations

Explicit considerations of accessibility occur in the literature and in the case studies. To develop a measure for this study both the literature and the case studies are reviewed once again to select an appropriate measure.

The literature review reveals that accessibility has been conceived variously as gravitational pull (Hansen, 1959), as being dependent on the nature of the connectivity (Ingram, 1971), as a aggregate spatial opportunity measure (M. Q. Dalvi, 1979), a spatial choice measure (Ben-Akiva & Lerman, 1979), or a measure that is economics-based (Breheny, 1978). All these ideas were initiated before 1980. In the 1980s these ideas were further developed and fine tuned but essentially they stayed true to the original conceptualizations.

In its later evolution, starting from the late 1990s through the 2000s, accessibility measures take a non-zonal approach by disaggregating data to the individual level. These measures (STAMs) conceptualize accessibility to be shaped by the restrictions imposed on an individual and the choices an individual makes and maps them in space-time coordinates (Kwan, 1998; H. Miller, 2004). Designed for transportation planning projects, the STAM developed by Miller and Wu (2000) conceptualizes the effect of individual level activity on the transportation infrastructure and can be used to visualize change in accessibility at the individual level at the urban scale. This measure takes into account the constraints an individual faces but is not conducive for use by a MPO for their collaborative planning efforts. MPOs use accessibility measures to justify EJ compliance for groups of people (those living in a TAZ for SJTPO, census tract for DVRPC and census block group for NJTPA) and unless personal-level travel data is obtained from random samples of people from these population aggregation units, MPOs will not be able to use this measure. Since an accessibility measure for this study was specified to be developed from the data that a MPO possess or has easy access, STAMs are not a good candidate for consideration here.

The comparison of communities of concern demonstrates that each MPO has a different definition for the communities they are concerned about. Even for the basic set of low income and minority communities, for which they are required to be concerned about by law, the definition of which groups of people are low income or minority differs from one MPO to another. Since MPOs measure accessibility from the communities of concern the measure is not consistent across the case studies. To develop a measure that is independent of the definition of a community of concern, accessibility in this study is measured from the destinations considered.

The accessibility measure developed here is different in other ways as well. First, it overcomes an issue brought up by STAM proponents. Developers of STAM argue that it is erroneous to measure accessibility from a single point (like a point of residence) for all activities as people make multi-stop, multi-purpose journeys chaining together several chores in a single trip (Kwan, 2000; H. Miller & Wu, 2000). The accessibility measure developed here overcomes this problem by measuring accessibility from the destinations rather than from points of departure.

Second, the accessibility measures mentioned in the literature review (including STAMs) are "hard" or objective and deterministic and constructed from "reported facts, quantitative estimates, systematic opinion surveys" (Malczewski, 2004, p. 8). The measurement conceived here is "soft" in the sense that it incorporates subjective information that indicates priorities and preferences of non-random samples drawn from diverse group of stakeholders, clients and interest groups. Malczewski (2004) names these two interrelated GIS perspectives as techno-positivist perspective and socio-political, participatory perspectives. The accessibility measure developed here is derived from a socio-political participatory perspective. According to this view, "rationality is based not on pure logic and the abstract evaluation of evidence but rather on an informed consensus formed by a community of individuals in a particular place and time" (Klosterman, 2001a, p. 10).

For the purposes of developing a measure, the most comprehensive definition of accessibility available in literature is needed. Accessibility is defined to be "the extent to which the land use transport system enables (groups of) individuals…to reach activities or destinations by means of a (combination of) transport mode(s)" (Geurs & Ritsema van Eck, 2001, p. 19). Geurs and Ritsema van Eck's definition has four basic components: (1) a transportation component that reflects the time and cost involved in traveling; (2) a land use component that gives us the distribution of the supply side; (3) a temporal component that identifies the time limitations within which one operates; and (4) an individual component that reflects a person's ability and needs.

The first component, transportation, is elaborated in the *Guidebook for Assessing the Social and Economic Effects of Transportation Projects* (Forkenbrock & Weisbrod, 2001) where the distance a person has to travel, the time it takes to travel, the cost of traveling (monetary costs like tolls paid, vehicle operating cost or non-monetary costs like the environmental impact caused), and safety factors in traveling are considered to be the most important factors for measuring accessibility. I consider the environmental and the safety factors, later in this study, as possible extensions. For now I confine the transportation factor to the "cost" incurred by the time spent and distance traversed to access a destination. This conception of the "cost" of travel is the key to the understanding the tool developed.

The second part of the accessibility definition is the land use component that gives "the distribution of the supply side" or, in other words, the destinations that people are trying to reach. The destination list is that suggested by Forkenbrock et al. and is an expanded list of the destinations that are already used by MPOs: access to basic services, access to markets and access to quality of life destinations. This list comprehensively covers the destinations travelers who live in urban areas deem important (Forkenbrock, Benshoff, & Weisbrod, 2001). The NAICS codes of the exact businesses that are deemed to fall in these categories are listed in Appendix G.

6.1.2 Developing a GIS-Based Measure from Implicit Considerations

The case studies indicate that implicit considerations of accessibility are primarily accessibility-enhancing efforts, by land use and by modal methods, which do not lend themselves well to quantitative measurements for which GIS is designed. It is important to note however that when viewed through the lens of the cost of transportation it is apparent that implicit considerations of accessibility aim to minimize transportation cost by reducing time and distance of travel. Thus, the GIS-based tool will be able to detect changes in accessibility when an accessibility-enhancing design element is added to a transportation plan.

6.2 Geographic Considerations for the GIS-Based Measure of Accessibility

The first step in building a GIS-based tool is to develop a finite representation of the perceived problem in a model. Models "collapse reality into a form that enables us to communicate the essence of a phenomenon" (Batty, 2005, p. 42). There are several elements about the problem of measuring accessibility that needs to be conceptualized:

(1) the geographic representation; (2) the geographic conceptualization of the infrastructure that forms the basis of all accessibility calculations and (3) the scale at which the accessibility measure is developed. The discussion below also includes description of how MPOs have dealt with these issues.

6.2.1 Geographic representation

The design of a GIS-based tool starts with the development of the GIS database – a repository of geographically-referenced data along with related descriptions for efficient storage and retrieval by many users. Efficient storage means that the contents must be carefully selected, simplified, aggregated, to fit within the limited capacity of a computer's storage device (Longley, et al., 2005).

The scheme for the GIS database is based upon the geographic representation selected and is determined not only by the definition of the problem one is trying to solve but also by the nature of the intended spatial analysis. Individual geographic entities can be represented as features (points, lines or polygons); continuous surfaces can be represented, among other representations, as rasters or imagery (Arctur & Zeiler, 2004).

In their explicit consideration of accessibility during EJ and JARC calculations, MPOs identify communities of concern, determine catchment areas and perform accessibility analysis. The case studies indicate that the communities of concern are represented by polygons in the form of TAZs (SJTPO), census tracts (DVRPC) or census block groups (NJTPA). Catchment areas are also represented variously by the three MPOs. In documents published before 2007, DVRPC identifies job centers to be polygons. *Environmental Justice at DVRPC* (2007b) does not have any maps showing job representation. NJTPA and SJTPO do not have any representation of jobs in maps but they aggregate the total number of jobs in travel time buffers implying that the jobs are points.

In accessibility analysis representation has at least two important effects on the outcome of the analysis. First, MPOs use centroids of the polygons that designate the communities of concern as the point of reference from which accessibility is measured. Besides the fact that the threshold levels for the designation is arbitrarily determined, the very fact that a MPO can select an arbitrary polygon suggests that the MAUP exists.

Second, all three MPOs consider "time of travel" as the only "cost" that determines the size and shape of the catchment area polygon. SJTPO and NJTPA measure time for automobile travel by assigning a uniform speed throughout the travel on a network represented exclusively by freeways and arterials. DVRPC uses the full spectrum of pavement: freeways, arterials, collectors and local roads for the representation of its network and obtains travel times from simulations of data from travel time surveys to determine cost (DVRPC, 2004b). Transit times are dealt with similarly by the organizations. All three MPOs consider transit and automobile modes separately and each is given equal importance when measuring total accessibility.

6.2.2 Modeling the City Infrastructure for GIS

Haining asserts that the quality of a model "involves assessment of the appropriateness of the spatial representation of an object and the level of detail provided" (2003, p. 59). Judging the appropriateness of representation of a measure of accessibility is difficult as no universally accepted, unambiguous "true" measure exists for accessibility. This also means that there are "many ways of operationalizing the measurement of the concept both in terms of what variables to include and which types of arithmetic or logical operations to use [for its] construction" (Haining, 2003, p. 59). The measurement used here for accessibility is a potential "cost" of travel to specified destinations. This "cost" has two components: time taken to travel and the distance traveled

Time taken to travel is determined by the mode of travel and the speed limit imposed on each segment of the street. For every mode of travel an impedance factor (listed in Table E.3) is considered. For pedestrians, for example, impedance is due to the time taken to stop at crosswalks. Cost of travel depends on the distance traveled.

The underlying road network dataset was built from data obtained from Navteq, a private street data vendor whose detailed road network data for every segment of road in the United States is considered to be very reliable by industry standards. An agreement was signed (see Appendix L) with Navteq to obtain the data needed to develop the accessibility measure. NavStreets, the name of the dataset, provides 120 attributes for each edge (portion between two nodes) of the network. Attributes are detailed and include, but are not restricted to, street names, speed limit, addresses range for each side of the street, number of lanes, nature of lane barrier (painted or physical) nature of road (ramp, freeway etc), signage, one way restrictions, and heavy vehicle restriction to name a few. The level of detail considered for building the underlying network dataset on which all the accessibility measurements are made was determined by the attributes available from NavStreets. The attributes used in the model are street names, one way restrictions, speed limits on each road segment, automobile restrictions, bike restrictions, pedestrian restrictions and bus restrictions. It was assumed that all turns are allowed at every intersection. In other words, turn restrictions are not considered except onto one-way streets, which are prohibited in the appropriate direction. The number of lanes in a road is also not considered.

6.2.3 Conceptualization of Multiple Scales of Study

The literature review on accessibility measures shows that accessibility has been conceived at three scales: city-region, metropolitan-region and global. Since the scale -- the metropolitan region – at which transportation planning is undertaken, and the unit of analysis in the first, qualitative part of this study, is not the scale at which people move on a daily basis, or the scale at which many measures of accessibility are conceived in the literature, it is necessary to clarify and conceptualize the multiple scales at which accessibility can be conceived.

A recent article in *Progress in Planning* suggests that, "planning taken as a social science, is deeply connected with ecology"(Vasishth, 2008, p. 101). Ecology, according to the article, with its "nested levels of organization" serves as an excellent metaphoric model for an "evolving complex system" like transportation planning that has hierarchical, nested scales of jurisdictional and operational organization (Vasishth, 2008).

Vasishth's nested scales are conceived and developed for urban planning where the smallest of the scales is designated as the city-region. Neighborhoods that are "functionally related in their interactions and exchanges" constitute a city-region (Vasishth, p. 117). Though a neighborhood is smaller in size relative to a city region, it does not have the political power to make planning decisions for itself; consequently it does not appear as the lowest level. Whereas Vasisth extends this hierarchical concept from city-region to states and nations, for this dissertation scale is conceived at corresponding entities in transportation planning. The city region is conceived to be the smallest unit in transportation planning as cities have transportation ordinances they pass for traffic in their jurisdiction. Several city-regions, each distinct, yet interrelated, may constitute a metropolitan planning region. Several metropolitan planning regions in turn can form a transportation zone and many zones together can form an entire country. Vasishth defends his nested levels by saying:

> The very act of conceiving a region in this nested manner allows us to separate out exchange processes and functional relationships by levels of organization, to then choose spatial and temporal scales suitable to capture the processes and functions thought relevant at each named level, and so trace connectivities across levels of organization (2008, p. 117).

This conceptualization helps to separate transportation planning into two of its lowest scales: the scale at which people live and work -- the city-region, and the scale at which transportation planning takes place -- the metropolitan region. Since accessibility is "the extent to which the land use transport system enables (groups of) individuals…to reach activities or destinations by means of a (combination of) transport mode(s)" (Geurs & Ritsema van Eck, 2001, p. 19) and since people interact with their personal set of activities within a city-region (Bania, Coulton, & Leete, 1999; Parr, 2008; Zhang, Shen, & Sussman, 1999) the accessibility measure in this study is developed at the city-region scale.

The MPO's choice of scale is problematic. Although the majority of people move at a city-region scale, all analyses MPOs perform are at the metropolitan region scale. NJTPA and SJTPO aggregate all jobs at this scale to get the total number of jobs.

DVRPC delineates employment centers that "have at least 500 employees and have an employment density of at least .5 employees per acre"(DVRPC, 2005a, p. 3) to calculate accessibility also at this large scale.

6.2.4 Determining the City-Region

The accessibility tool is developed at the smallest of the scales conceptualized for transportation planning in Section 6.2.3: the city-region. Atlantic City, the largest city in the SJTPO region, is selected as the city-region to be studied. Section 3.2.3 elaborates on why Atlantic City is appropriate for this study.

Although the concept of a city-region is not new, there is no definition in the literature as to what exactly constitute a city-region (Tosics, 2007). It has been understood to be the urban region around a core business district (Pain, 2008; RodrÃguez-Pose, 2008). For the purposes of this study, the Atlantic City city-region is considered to be monocentric. The municipalities that define the city-region are identified from the Census Transportation Planning Package (CTPP) by the number of people coming to work in Atlantic City from all municipalities around it. The CTPP contains "tabulations by place of residence, place of work, and for flows between home and work" (NJDOL, 2000, p. 1). Appendix N identifies these numbers and selects the municipalities that are geographically contiguous and supply almost 80 percent of the working population of Atlantic City. All the eleven municipalities except one are in Atlantic County. Alphabetically, these cities, other than Atlantic City itself, are: Absecon, Brigantine, Linwood, Longport, Margate, Northfield, Ocean City (in Cape May County), Pleasantville, Somers Point and Ventor City.

6.3 The Accessibility Tool and Suitability Modeling

The accessibility tool developed here is based on the concept of suitability modeling. Suitability modeling is a method used to either identify sites that have the most or the least potential for a specific purpose (when a set of potential sites exist) or to search the boundaries of lands that have a predetermined set of characteristics, when there are no potential sites (Malczewski, 2004). The second definition of suitability modeling is used here to develop a measure of accessibility. A short history of the suitability modeling method gives a clearer understanding of the method.

6.3.1 History of Suitability Modeling and its Applications

One of the earliest uses of suitability modeling, in urban planning, was in the design of Central Park in New York City in 1893. Frederick Law Olmstead, the principal designer of the park, in his landscape architectural practice worked with Charles Elliot and Warren Manning, to overlay transparent sheets on sunlit windows ("sunprints") to understand the multiple characteristics of the land and to simultaneously visualize diverse factors that determined the suitability of natural and constructed design elements. Manning later developed the system of suitability he developed at Olmstead's office in his national plan for natural and scenic resources and went on to develop one of the first land classification schemes for the United States. In 1962 Christopher Alexander and Marvin Manheim refined the idea of suitability by adding weights to various factors; but it was Ian McHarg's book *Design with Nature* (1969) that first outlined the classic approach to land use suitability as it is used today (Collins, Steiner, & Rushman, 2001).

Using transparent overlays has some drawbacks. The human eye has limits to the number of layers that it can interpret at one time. The overlay method is more suitable for discrete than continuous data and the relative importance of one layer over the other is not possible to express explicitly in transparent overlays. With the advent of GIS these problems were removed and suitability modeling became one of its classic applications. The raster method of storage of spatial data renders itself particularly useful for performing suitability modeling as data is expressed as a matrix of uniform rectangular cells which contain both location coordinates and attribute values. The attribute values can either be continuous or discrete and several raster layers can be overlaid on one another in the manner in which transparent sheets are laid, but in GIS they can additionally be combined algebraically or otherwise, to get new layers.

Suitability modeling has been taken beyond its beginnings in landscape design where it is still used extensively (Steiner, 2008). It is now also widely used in ecology and conservation biology to identify natural habitats (Mollot & Bilby, 2008; Rondinini & Boitani, 2007), in land use analysis to determine a planning area's supply of land that is appropriate for development (Carr & Zwick, 2007; Whitley & Wei-Ning, 1993), in the integration of the above fields(Gordon, Simondson, White, Moilanen, & Bekessy).

6.3.2 Hypothesis for a Measure of Accessibility using Suitability Modeling

Whatever the application, suitability analysis is essentially an analytic process that requires a set of sequential steps to identify the most appropriate land for a certain purpose. It has been used primarily in ecology and land use planning because in both cases it is a property of the ideal land for a predetermined cause (like habitat of a species or the ideal piece of land for a certain purpose) that is deemed central to a problem that uses suitability modeling.

In a similar manner, to identify the most appropriate area for the purpose of accessibility to a particular destination by the criteria of time or cost, the methods of suitability modeling can be used to identify the boundaries of the area that have predetermined accessibility characteristics in terms of time or cost. The idea that certain parts of a city-region are more suitable for accessing a certain amenity is extended to different sets of amenities to get a value for all amenities at a particular location.

The case studies suggest that MPOs meet with the public on a regular basis and also websites to provide information and collect feedback. If MPOs are willing to collect information about the transportation mode choice of people the purpose of their trips then their accessibility by time considerations and by distance considerations can be mapped using suitability modeling. It is assumed in this model that people make trips only to basic destinations, markets and quality of life destinations and that people have mode preferences for each of these destinations. I hypothesize that accessibility to each destination can be overlaid on each other and added together, as in a suitability model, to get a value for total accessibility. Moreover, I hypothesize that this measure of accessibility can be used to assess the change in accessibility before and after a TIP.

6.3.3 Construction Details of the Measure of Accessibility

Handy distinguishes between planning for accessibility and planning for mobility and suggests that measures of accessibility used in planning should have "share of jobs or other destinations within specified travel times or distances," "measures of travel options," and "measures that focus on the needs of specific population groups" (Handy, 2005a, p. 137). Bertolini et al. state that the accessibility measure must meet two basic requirements: "it must be consistent with the uses and perceptions of the residents [and]

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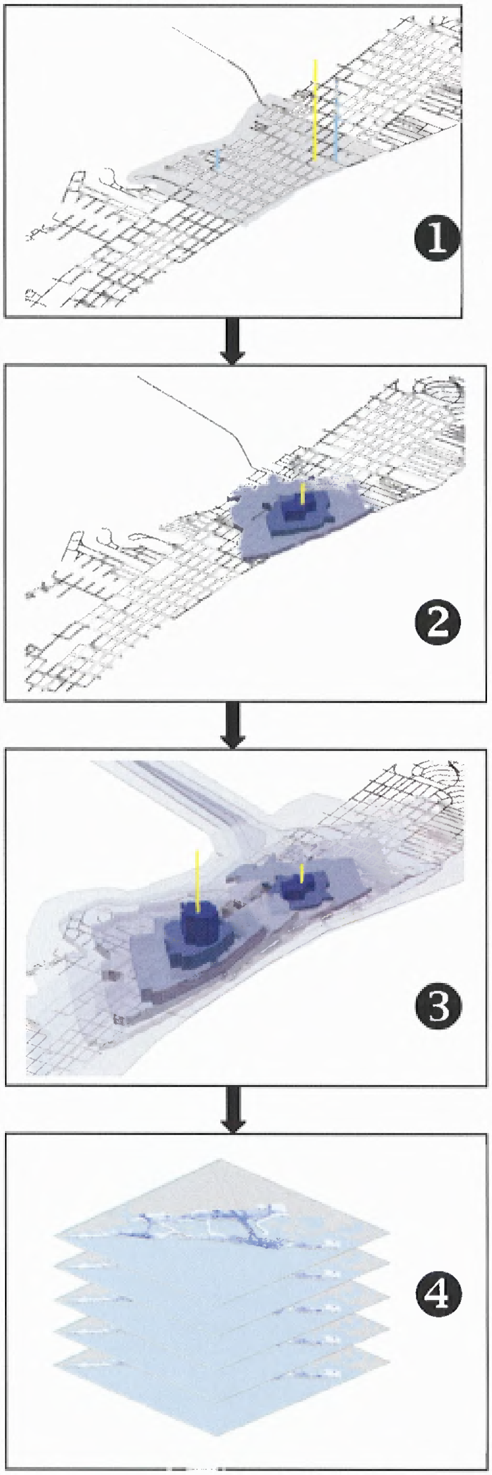

1	Optional step	Destinations in a census tract aggregated to weighted mean center. (Value of destination proxy indicated by cyliner height).
2	Network Analyst	Service areas (based on mode of transportation) genrated from the mean center. Each service area increases by network time and distance intervals.
3	Gravity Model	Importance of successive service areas decrease by inverse of network distance. Service areas generated from each destination are weighed by a normalized (by region) proxy.
4	Rastarization	Five output rasters (1 for each mode combination) are weighed by mode preference of collaborating public.
5	Measure	Accessibility calculated per suitability modeling principles

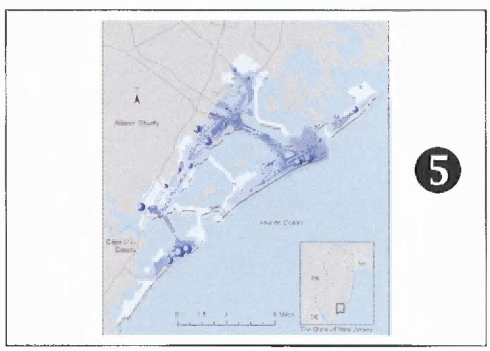

Figure 6.1 Visual flow diagram of the model used to measure accessibility.

Step one of Figure 6.1 shows two day care centers being aggregated to a single mean center. The location of the mean day care center is obtained by weighing each center by the number of children it accepts. The height of the geographic mean center is determined by the proxy used for the destination. For day care centers, the proxy used is the total number of children accepted at all day care centers in the census tract. The proxy varies with the destination type; markets for example use their total square foot area as the proxy.

In the second step of the flow diagram the mean center of daycare centers in each tract is the location from which rings of suitability polygons are calculated for each mode of travel. The suitability polygons are created by using the "service area" concept of ArcGIS Network Analyst. A service area is the region encompassing an amenity that can be reached within a predetermined period of time (or several time intervals) using a specified mode via the network. Service areas are also determined by the distance (or several distance intervals) traversed via the network. Amenities considered here are basic destinations, markets and quality of life destinations.

The third step of the model is the crucial step that determines how the values of the polygons decay over time and distance. As time/distance increases, and one moves away from the amenity, the value of the concentric polygons decreases. It is assumed that the decrease is inversely proportional to the network time or the network distance traveled. All polygons generated from a single amenity are weighed by a normalized value of the proxy used for the amenity. The normalization is carried out over the entire region under consideration. Thus in the case of day care centers, each of the polygons is weighed by the percent of total number of children of the region that are accepted by the day care centers in a tract.

The model described above is essentially a gravity model of accessibility measured via network distance or network time. The concept of the basic gravity model was first presented by Hansen (1959). Hansen used a weight factor to give importance to larger centers and kept the exponent factor of the denominator of his gravity model to describe "the effect of the travel time between the zones" (p. 74). Ingram (1971) tested out several exponent factors and came to the conclusion that "the function should be reasonably flat topped in the region of the origin, the descent from the plateau should be smooth and the curve should reach zero at infinity" (p. 105). The function used here is completely flat topped at the region around the origin (innermost polygon). As one moves away from the center values decrease sharply at pre-defined break points and is zero at infinity. The descent can be smoothened by using smaller time/distance intervals for the break points. The decay function used here is the inverse of the values of the time or distance assigned to each polygon. The time and distance values used to create the service areas are listed in Table 6.1

As there are several amenities, a large number of polygons are generated from each census tract. In the fourth step of the model all the polygons, generated by each census tract, are added up for each amenity and each mode separately to get the value of total accessibility. The values of accessibility for each mode and for each destination are then added together using the concept of suitability modeling (step 5).

Appendix F is a list of models created to generate the value of accessibility. Each model in the list logically works identically and is based on the steps depicted in the flow diagram Figure 6.1. Appendix O thus visually depicts one of the models using ArcGIS 9.3 ModelBuilder. The model used to add accessibility values for the various modes and destinations is also depicted in Appendix O. All the maps generated by the models are depicted in Appendix H.

Table 6.1 Travel Distance and Travel Time Breaks by Mode of Transportation

Mode of Transportation	Travel Distance Break in miles	Travel Distance Break in feet	Mid-point of Travel Break	Travel Time Break in minutes	Mid-point of Time Break
Walking	1/8	660	330	3	1.5
	1/4	1,320	990	6	4.5
	1/2	2,640	1,980	12	9
	3/4	3,960	3,300	18	15
	1	5,280	4620	24	21
	Above 1	Above 5280		Above24	
Biking	1/2	2,640	1,320	3	1.5
	3/4	3,960	3,30	4.5	3.75
	1	5,280	4,620	6	5.25
	1-1/4	6,600	5,940	7.5	6.75
	1-1/2	7,920	7,260	9	8.25
	Above 1-1/2	Above 7920		Above 9	
Auto	1/2	2,640	1,320	2	1
	1	5,280	3,960	4	3
	1-1/2	7,920	6,600	6	5
	2	10,560	9,240	8	7
	2-1/2	13,200	11,880	10	9
	Above 2-1/2	Above 13,200		Above 10	

6.3.4 Suitability Modeling and Network Analysis

The Network Analyst extension of the ArcGIS software "provides [a] network based spatial analysis ...using a sophisticated network data model" (ESRI, 2009, p. 2). A network-based analysis of a place uses a representation of the actual roads. A network data model is a representation of this network stored in the form of nodes and edges.

The properties of the nodes and the edges of the network and the relationships between them that are relevant to solve or understand a particular problem are key elements of the GIS modeling. The development of this representation, or the network model, is thus the central element of any network analysis problem.

A network dataset is "the core geodatabase network model for representing undirected networks" (ESRI Developers Network, 2009). A transportation network is considered an undirected network (as opposed to a directed network like that of utility networks) as "cars and trains are autonomous objects that can move freely" (Zeiler, 1999, p. 129). The two key elements to decide on the construction of the network dataset are the nature of its connectivity (or spatial coincidence) at the nodes and the nature of its traversability of its edges. Traversability is the method or mechanism of getting from one edge to another. Turn limitations at nodes or intersections determine traversability and not connectivity.

Multimodal networks are set up by forming connectivity groups. Connectivity groups define how networks of different modes are connected by identifying the nodes at which a person traveling on one network can transfer to another. For example the pedestrian and the bike networks are connected to the bus network only at the bus stop nodes. This implies that a person walking on the street or on a bike can transfer to the bus network only at bus stops even if the street on which the person is walking, biking or traveling on a bus are all coincident.

The traversability of the network edge is determined by several factors. These include one-way restrictions imposed by the city ordinances, mode restrictions imposed by traffic police and weight restrictions imposed on bridges by engineers to name a few. Appendix E shows the details of the connectivity and the traversability model.

The NAVStreets data on which the network dataset is built had to be modified to make it suitable for the purposes of this dissertation. The modification required values travel velocities in each mode of transportation. The sources from which the values of these velocities were obtained are listed in Appendix E.

6.3.5 Suitability Modeling Method Used

In *Smart Land Use Analysis: The LUCIS Model* (2007), a method for identifying land use opportunities using suitability is outlined. This method is modified here to develop a measure of accessibility. The process begins with a single (or multiple) statement(s) of intent. For this study, they are the following:

Intent

1) Identify areas most suitable for accessing

a) Basic destinations in Atlantic City

b) Markets in Atlantic City

c) Quality of Life centers in Atlantic City

2) Compare the suitability before and after the implementation of a TIP

Basic destinations are jobs, schools, daycare centers, hospitals, financial institutions and financial institutions. Markets are for food and non-food items. Quality of life destinations are theaters, restaurants, activity centers (physical and non-physical), personal care and other services.

The statement of intent is broken into goals, which identify what is to be accomplished, and supporting objectives, which identify how each of the goals is to be achieved. An example of a goal and its supporting objective for the intent "Identify areas most suitable for accessing basic destinations" would be

Goal

Identify area most suitable for accessing jobs

Objective:

Identify area most suitable to go to work time-wise

A third or a fourth tier of supporting statements can be added as needed:

Subobjectives:

Identify area most suitable for driving to work

Identify areas most suitable for driving, walking and then taking the transit to work

Identify areas most suitable for biking to work

Identify areas most suitable for walking to work

Identify areas most suitable for walking and then taking the transit to work

A complete list of subobjectives used to build the full model is listed in Appendix F. The nomenclature for the models is that used by Carr and Zwick (2007):

6.3.6 Suitability Model in Collaborative Planning

MPOs try to engage the public in several ways and think of innovative ways to entice members of the public to come to their information sessions but none of the MPOs engage the community in any kind of process for reaching informed consensus on TIPs. All three New Jersey MPOs publish the finalized TIPs on their websites and have information sessions for the public on large projects that will disrupt businesses and roads for extended periods of time. Their established relationships with their communities could easily be extended to gather information about the modes of transportation that the communities prefer to use when they venture out from their home by using a questionnaire similar to that included in Appendix D. This information is required for the GIS-based measuring tool developed here.

The relative importance of each of the five travel types considered differs from one individual to the other. Mathematical procedures exist that systematically bring together individual preferences to capture the preference of an entire group of people into simply "high", "medium" and "low" (or any odd number greater than three) preference for each component of each goal. It is in this step that a community's values are integrated into the measurement of accessibility by incorporating these values as weights.

After the values that a community places on various modes of transportation are calculated for each destination, the final step is to identify and gather the data needed to map each component of each goal and then add the raster versions of the maps, with weights reflecting the community's preferences. This results in a raster map with a range of values starting from low preference for all components to high preference for all components with all possible preference combinations in between. In the process of assigning various values to the various modes and combination of modes the tool meets Handy's concern for both "measures of travel options," and "measures that focus on the needs of specific population groups" (2005a).

The simplicity of the theoretical concept of suitability modeling makes it an ideal candidate for spatial decision support systems in land use planning where the public, with varying levels of education and understanding of scientific concepts, are brought together to make land use decisions. In practice though, land use suitability modeling has to deal with potential land use conflicts that need mathematical techniques like multi-criteria decision analysis. In its adaptation in transportation planning this problem does not arise as elements for which suitability is being considered are not conflicting.

People prefer different modes of transportation for each purpose of travel (Anable & Gatersleben, 2005). This is a key assumption on which the accessibility measuring tool developed in this dissertation is based. When a questionnaire, like the one in Appendix D, is used to elicit comparative assessments of mode preference for each kind of destination from a group of people it is expected that a large variety of combination of preferences will be obtained. A structured approach to combine the variety of results is to use arithmetic operations to determine an overall rank of the preferences (usually performed by group methods). Details about these methods are beyond the scope of this dissertation. Comprehensive knowledge about these methods is available at the Spatial Decision Support Knowledge Portal (University of Redlands, 2009). For the purpose of this dissertation an Excel-based random number generator was written to obtain weights. These weights are indicated in Appendix F for submodels that are used for the accessibility calculations for this study.

Figures 6.2 through 6.6 illustrate one complete set of outputs to calculate accessibility for a single destination (day care centers) for all the five different modes and mode combinations considered in this study. Figure 6.7 is the total accessibility to day care centers calculated by weighing Figures 6.2 through 6.6 by the mode choice preference of the people of the region. Maps for accessibility to all other destinations after the construction of a TIP (and some for before construction) are in Appendix H.

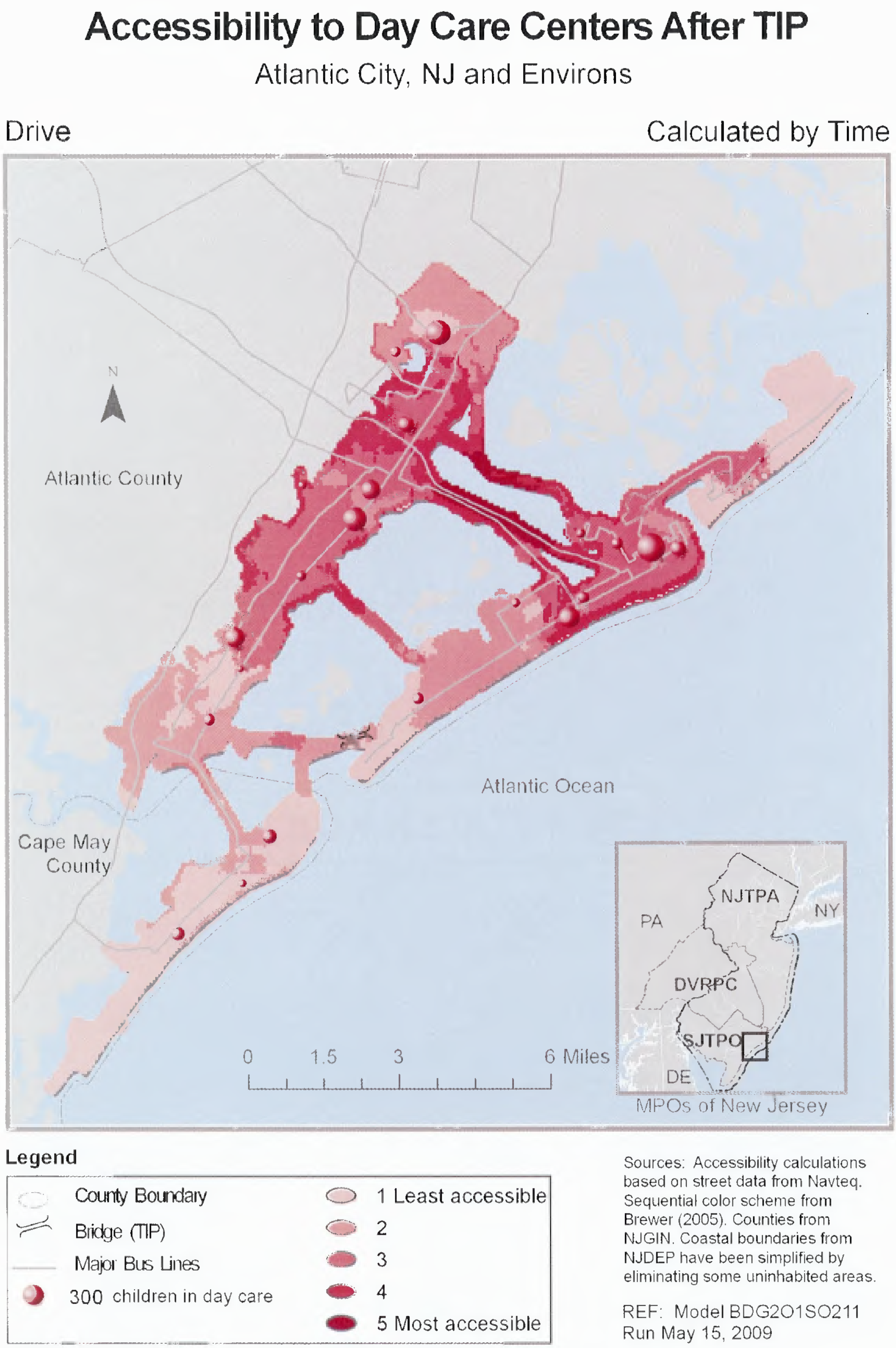

Figure 6.2 Output of model BDG2O21SO211

Figure 6.3 Output of model BDG2O21SO212

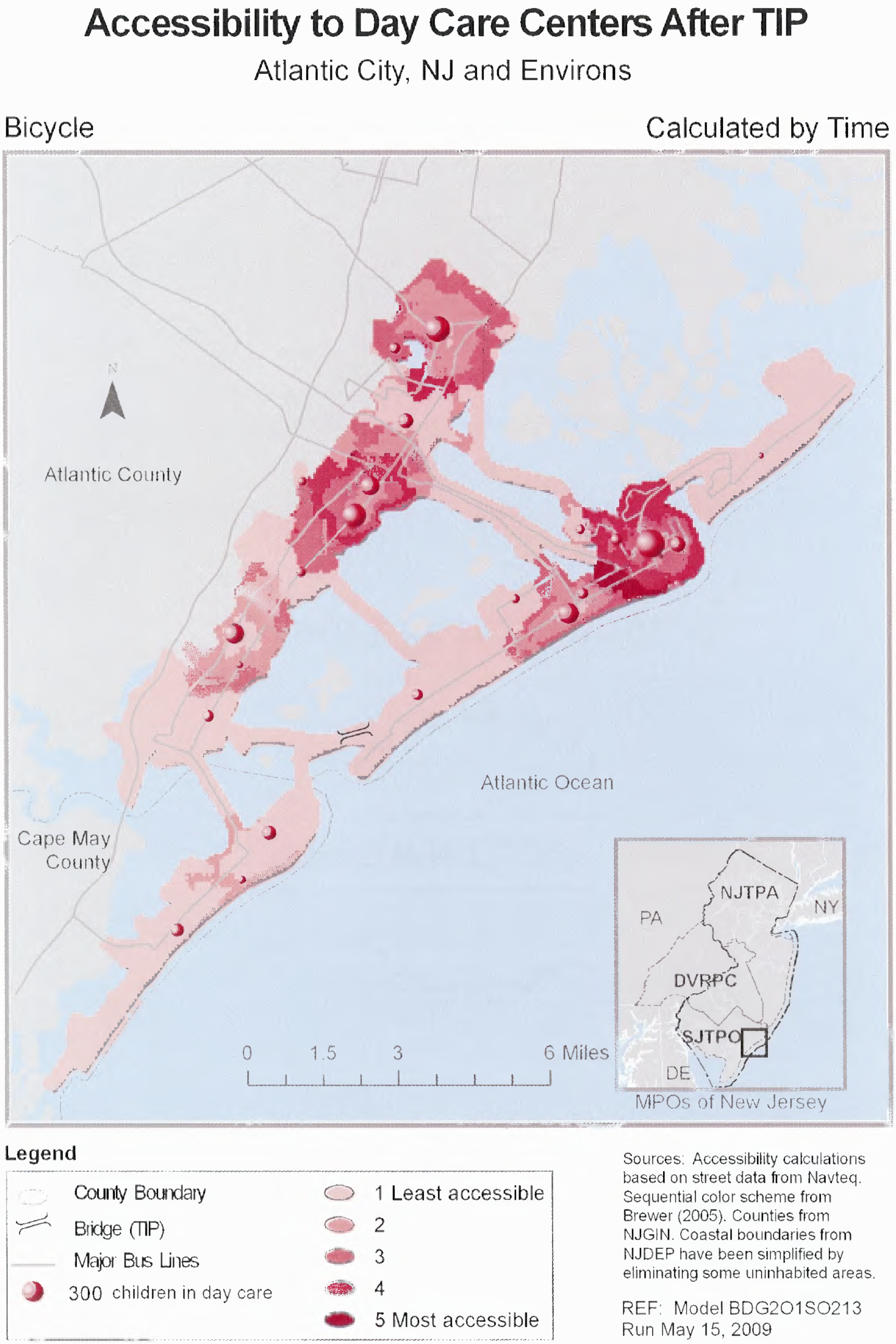

Figure 6.4 Output of model BDG2O21SO213

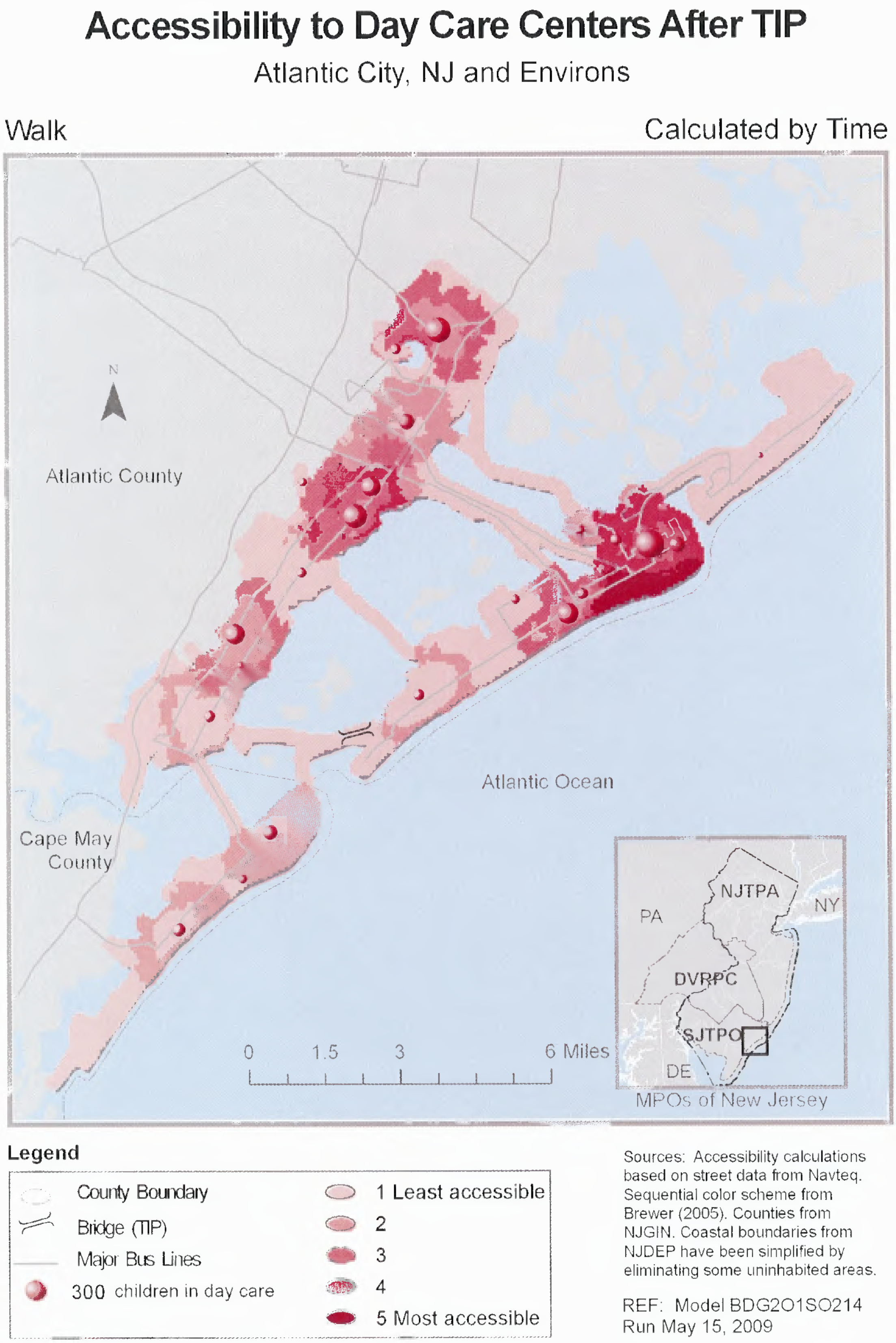

Figure 6.5 Output of model BDG2O21SO214

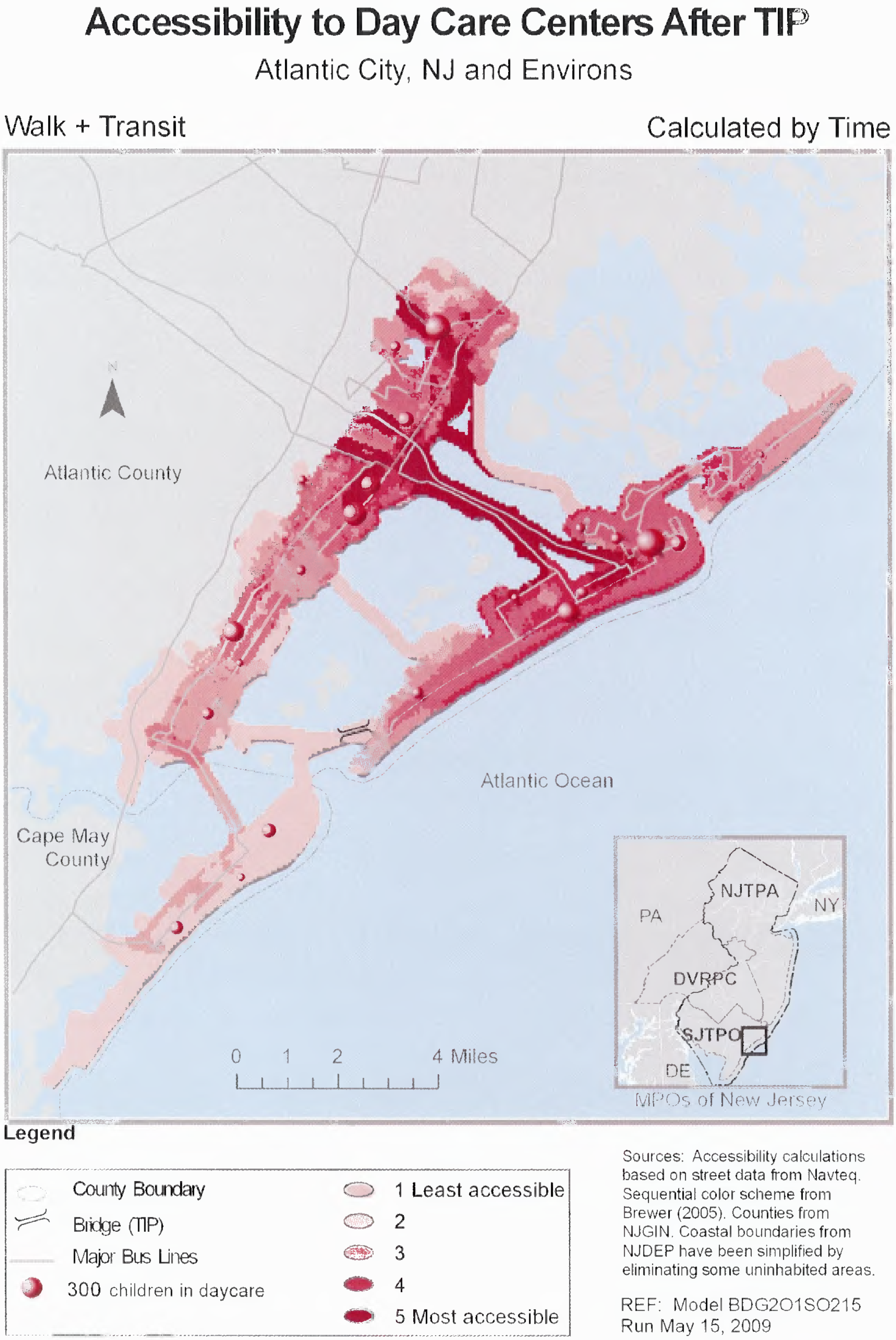

Figure 6.6 Output of model BDG2O21SO215

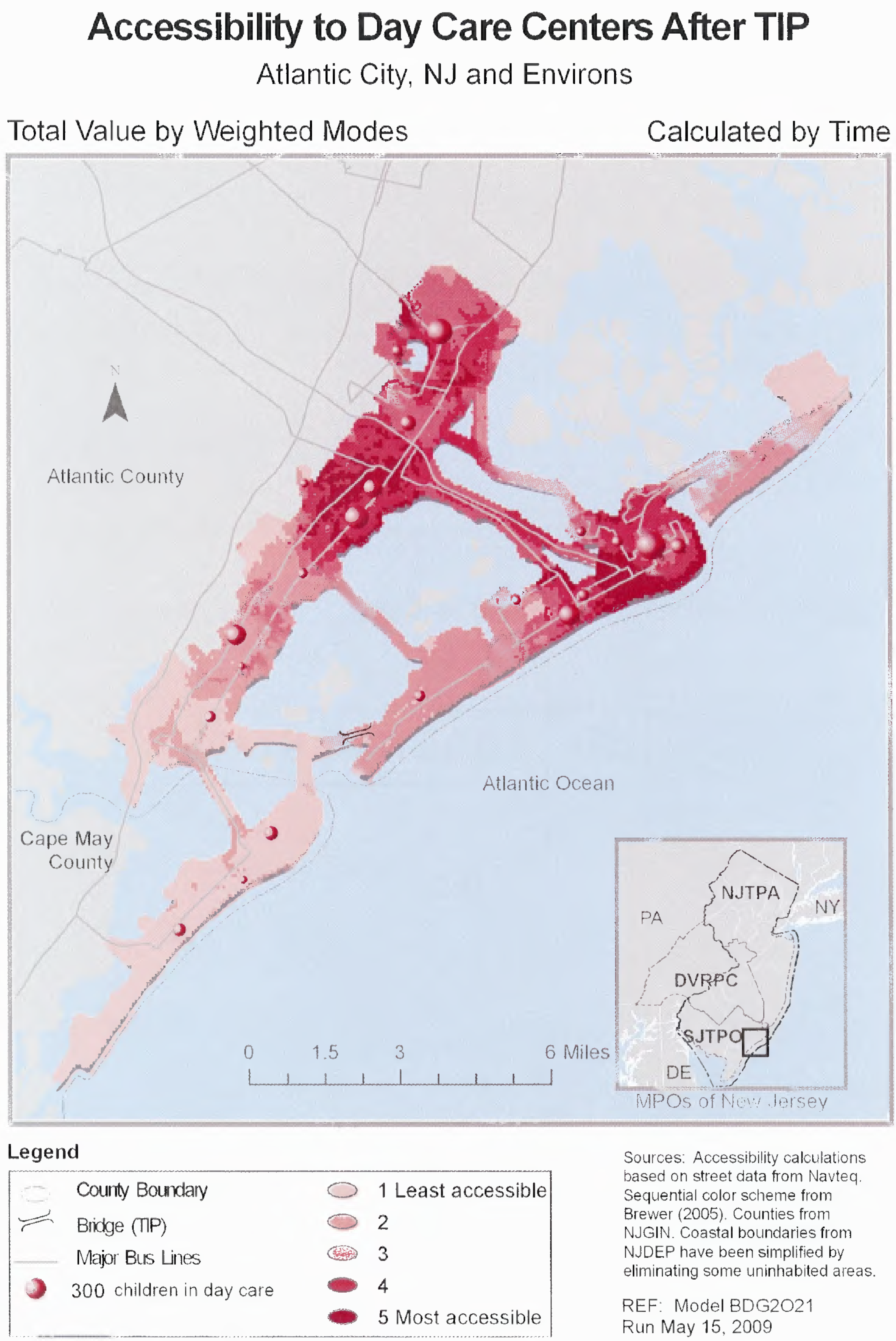

Figure 6.7 Output of model BDG2O21

6.3.7 Modeling Levels

The complete or the desired level of the model considers all destinations mentioned in Appendix F. As adding destinations adds the size the time taken to run the model, for the purposes of this dissertation, a fully working model is developed with a smaller dataset than the desired level. The size of the dataset is further reduced for a demonstration model for the MPOs. The demonstration model uses a fully functional submodel with all documentation written out. The demonstration model is the smallest of the set of three nested models and is the absolute essence of the complete model. Figure 6.8 illustrates the demo model as it appears in ArcGIS 9.3.

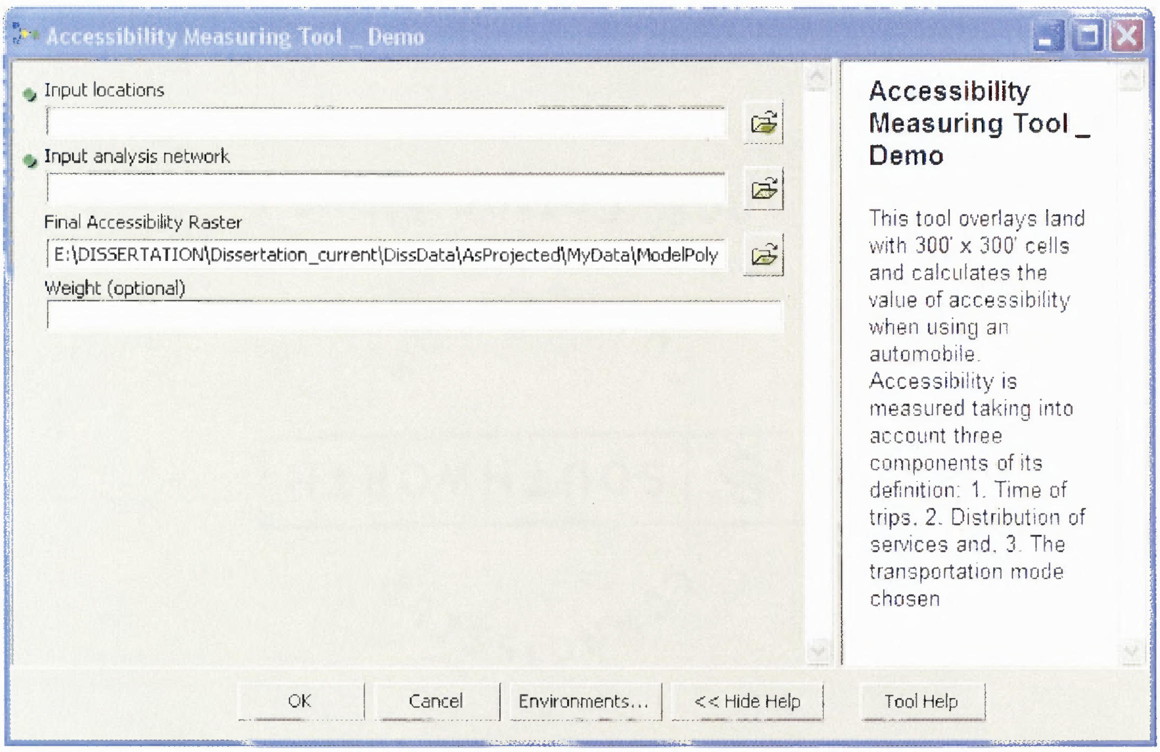

Figure 6.8 The accessibility measuring tool in ArcGIS 9.3.

Table 6.2. compares the properties of the three levels of the model.

Table 6.2 Comparison of the Levels of Modeling

	Demonstration Level	Dissertation Level	Desired Level
Network dataset	All properties	All properties	All properties
Basic destinations	Daycare centers	Jobs Daycare Centers	Jobs Daycare Centers Schools Hospitals Laundry facilities Financial institutions
Market destinations	None considered	Food	Food Non-food
Quality of life destinations	None considered	Physical activity	Physical activity Nonphysical activity Theaters Restaurants Personal care services Other services
Model documentation	Fully developed	Not developed	Not developed
Travel modes considered	Walk and transit	Walk Bike Auto Walk and transit Auto, walk and transit	Walk Bike Auto Walk and transit Auto, walk and transit
Travel impedances considered	Travel time	Travel time Travel cost	Travel time Travel cost Environmental impact of travel Travel safety
Data aggregation	By census tracts	By census tracts	By TAZ or as desired by the user. No aggregation is required
Sensitivity analysis performed	Yes	No	No

6.4 Findings

The findings of this research can be categorized into: data issues, modeling issues and user issues.

6.4.1 Data Problems

Several problems about the data arose when constructing the model. First, the street data, on which the entire network model was built, had some issues that needed attention. There are several street maps that are available for GIS analysis. US Census has downloadable street files for free called TIGER files. Most other data are collected by private companies and are expensive. According to their own admission, the "positional accuracy [of the TIGER files] varies with the source materials used....and the information provided is for the purpose of statistical analysis and census operations only"(US Census, 2003, p. 1). Since the measure of accessibility required a measure of distance, besides statistical analysis and census operations, TIGER data was not considered for building the model.

The bus routes data, obtained from New Jersey Transit (NJT), is based on street maps produced by Navteq. Bus routes are drawn exactly on accurate street lines to calculate and keep track of fleets. In their own words Navteq is a private producer of "premium-quality digital map data" and has the "the industry's most accurate and extensive street centerline database"(Navteq, 2009, p. 1). Although other street data is available, to match the bus routes provided by New Jersey Transit, NAVStreets, the street data compiled by Navteq was chosen for the street base maps. The NAVStreet data is "enhanced with aerial photos and differential GPS to accurately position roads" (Navteq, 2008, pp. i-iii).

Coincidentally a map of Atlantic City attractions obtained from Atlantic County was also based on Navteq data. However when these three sets of street data (one obtained directly from Navteq, the second obtained from Atlantic County GIS Office and the third obtained form New Jersey Transit in the form of bus routes) were combined; they did not coincide. Moreover, both the Atlantic County GIS Office and NJT confirmed that they had not modified the Navteq data. The data obtained from Navteq for this research directly was used as both the other sets of data had trimmed down attributes to suit their application but the data obtained from Navteq was original data and had all the 120 attributes. These attributes were trimmed to suit the accessibility measure developed here. Consequently, the bus stop information obtained from NJT had to be topologically aligned by the "points must be covered by line" rule where the NAVStreet lines were given lower priority of movement than bus stops.

The second problem arose from the data used in locating basic destinations, markets and quality of life destinations. These were obtained from Reference USA, a database compiling detailed information about US businesses. The database contains the names, addresses, number of employees and the type of business by its North American Industry Classification System (NAICS) code. The NAICS codes used for the measurement of accessibility are listed in Appendix G. When the location of each and every business in Atlantic City, downloaded from Reference USA, was considered individually, to run in the model, ArcGIS failed repeatedly with the message saying "unexpected error." The same model however ran with no problem when the number of businesses was reduced to 15. Developers of ArcGIS Network Analyst at ESRI confirmed that the size of the dataset with all the businesses was too large for Network Analyst to handle. They suggested that the employment data be aggregated before it was run in the model.

6.4.2 Modeling Problems

In the first attempt to build the model, the entire population of basic services, markets and quality of life destinations was considered which made the conceptualization of the model deterministic and the amount of data sizeable. Limitations of the ArcGIS software to handle this data called for aggregation of data as a possible way to reduce the volume of data. Now the model was no longer deterministic but contained uncertainties associated with the aggregation method used.

Data can be aggregated in several ways. The simplest method to aggregate points is to add the number of points that lie within a boundary. The data boundaries used do not have any meaning if the boundaries divide points into groups that have no relation to the nature of the problem for which the boundaries are built. All boundaries, however well thought out, are subject to MAUP issues.

ArcGIS has built-in tools to identify the general characteristics of a spatial layout of points; they are mean center (geographic center), standard deviation ellipse (measures whether distribution of features exhibit a directional trend) and standard deviation circle (the degree to which features are dispersed). Besides these tools that identify general characteristics, ArcGIS has tools for exploratory spatial data analysis (ESDA). The central objective of ESDA is data or information visualization that is "concerned with the provision of many graphical views of a data set as part of an on-going process of understanding and gaining insight into the data -- that is identifying the properties of the data" (Haining, 2003, p. 189). For exploratory spatial data analysis formal, statistical models are not needed unless the analysis involves hypothesis testing for spatial randomness.

Spatially grouping data meaningfully can be done at a global (or whole map) scale or at a local scale. A single statistic using "broader areas of randomness or dispersion" (Fotheringham, 2000, p. 28) for a global region may ignore potentially relevant clustering in subregions. For this reason regionalization, "a special form of classification where basic spatial units are grouped together on the basis of a set of defined criteria" (Haining, 2003, p. 200), has been developed by several analysts (Cislaghi, Biggeri, Braga, Lagazio, & Marchi, 1995; Eagles, Katz, & Mark, 1999; Haining, Wise, & Ma, 1998; Macmillan, 2001). These developments work on Euclidian rather than network distances. Okabe, in a series of articles has developed a set of tools for spatial analysis, SANET, on a network which include regionalization (A. Okabe, Satoh, Furuta, Suzuki, & Okano, 2008; Atsuyuki Okabe & Yamada, 2000). SANET could not be used as it was developed for an earlier version of ArcGIS and is not compatible with the current version of the software.

As regionalization efforts using SANET failed and as this is a transportation problem, it was decided that a TAZ level of aggregation would be used. This idea too had to be abandoned for two reasons. First the downloadable TAZ boundaries obtained from the census website are based on TIGER data and so do not match the more accurate NAVstreet street database that was used for the analysis. NJTPA, at its website, has TAZ data but the extent of the TAZs at this website did not cover all the 11 municipalities under study. Second, the census tracts are larger than TAZs. The model had already failed because of its size and so it was safer to run the model by aggregating it by a larger unit of area (and hence have a smaller input). A sensitivity analysis is performed on the models, in a later section, to test how the aggregation level affects outcome.

6.4.3 User Response

A seven minute video made about the accessibility measuring tool called by the same name as this dissertation was sent out (via an invitation from the website it was posted), to the technical departments of the three New Jersey MPOs. This video can be accessed via the Internet at the address provided in the reference section of this dissertation

(Sarkar, 2009). The video is expected to be at this location until the host (screencast.com) decides to stop or move their website. Apart from the three New Jersey MPOs a fourth MPO was added to the sample to overcome sampling errors. The fourth MPO is the Mid-Region Council of Governments (MRCOG), a four county MPO located around New Mexico's capital Albuquerque. MRCOG is the MPO for Bernalillo, Valencia, Torrance and Sandoval counties of New Mexico and is a council of governments. MRCOG is structured slightly differently from the three New Jersey MPOs but follows the same federal mandates regarding transportation planning and has the same pressures of increasing collaborative planning as the New Jersey counterparts.

The video (Sarkar, 2009) that was sent out to the four MPOs was an introduction to the demo level of the tool with a demonstration of how the tool operated. The primary question asked of the MPOs in the video was whether they thought that the tool constructed for the dissertation could be used for collaborative planning. The answer to this question was a yes from all four MPOs.

Participants were also encouraged to add any additional comments that they pleased. NJTPA's comment was "presenting information visually about accessibility and how it is affected by transportation improvements can help participants in a planning process come to a common understanding. The wide range of destination types you reference is also valuable in bringing in different perspectives, recognizing that transportation serves many diverse purposes." DVRPC's comment was that "we have been struggling to figure out better ways to analyze TIP for selection of projects…this seems to be a possible answer...this may also help us analyze CHSTP projects. We may be able to look into how the accessibility component improves when a change is made to a route or when a TIP is added. I think this is pretty powerful. SJTPO's summed it up as "pretty neat."

Regarding visualization NJTPA's comment was that "the visualization is effective and understandable. You'll probably want to expand/clarify legends and labeling so that the audience can orient itself quickly." SJTPO suggested that "it may be helpful to use the same color for both the 'before' and the 'after' maps. It would also be helpful if the before and after maps were side by side."

Regarding cost issues, SJTPO suggested that the change be recorded, if possible, "as a dollar amount per year and compared to the cost of a project." DVRPC asked "how are the cost and time numbers significant? What is the actual impact in terms of number of people?"

Concerns expressed by NJTPA were "I would be interested in the precise mathematical formulation. There are serious challenges in deriving meaningful measures on this subject." On a similar note SJTPO said that they "would like to know how exactly it was calculated." Details about how the model worked was not included in the seven minute video.

On a more general note NJTPA wrote that "one of the biggest difficulties with applying accessibility performance measures on a wide scale is that it takes a major change in the system to produce significant effects. The example you show illustrates what such a major change can do, but so many of the improvements that are considered by planners are much smaller in scope. But accessibility is important for them too, it just may be that the improvements are hard to grapple with using existing quantitative tools. This emphasizes the continued importance of such research, of course."

6.5 Sensitivity Analysis of Tool Parameters

The representation used by a modeler is a personal choice whose sensitivity to change needs to be tested. The systematic identification of assumptions made in constructing a model that can potentially alter the results of the analysis substantially is known as sensitivity analysis. Sensitivity analysis is commonly used to assess models (Goodchild, 2005). For the accessibility tool developed in the study, a sensitivity test is developed and applied on the demo model.

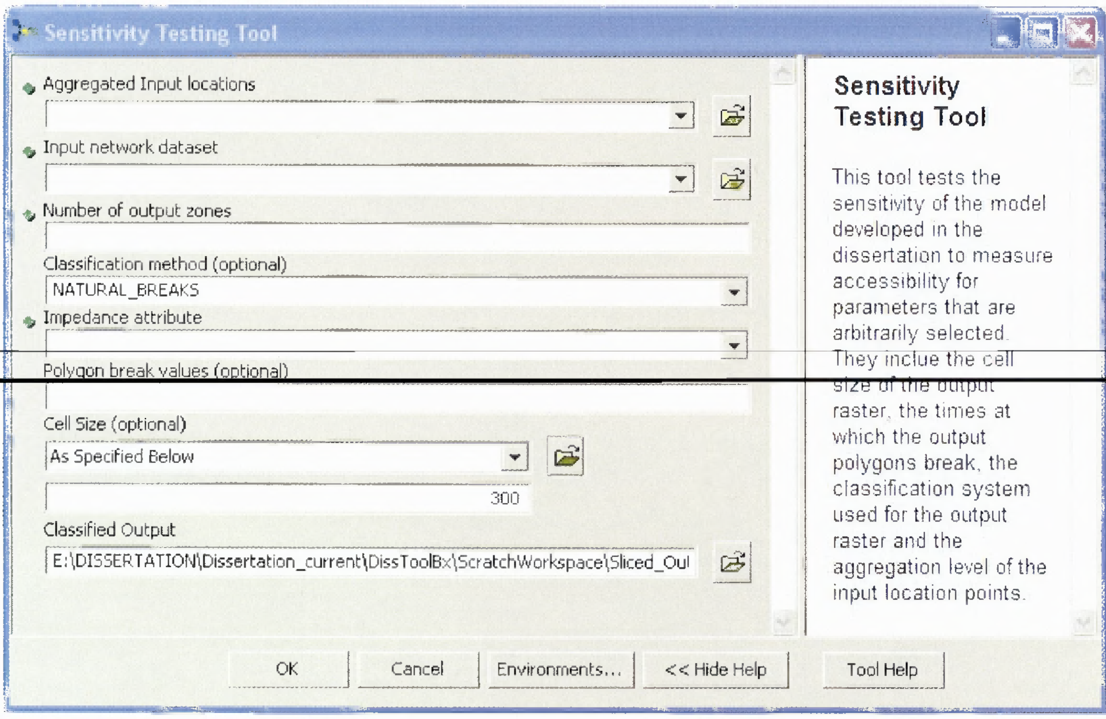

Figure 6.9 Tool developed for testing sensitivity of accessibility measuring model

Table 6.3 lists the parameters tested for sensitivity measures at ten random points A to J on the output of the demo model using a tool, illustrated in Figure 6.9, developed for the accessibility model. These random points were generated using Hawth's Tool (Beyer, 2004).

Table 6.3 Sensitivity Analysis at Random Points by Raster Value (in a 1 to 5 scale)

		Random Pt	**Accessibility Value at Random Points**							
		(A)	3	3	3	3	4	2	4	3
		(B)	2	2	2	2	2	1	3	2
		(C)	4	4	4	3	3	3	5	3
		(D)	3	3	3	3	3	2	4	3
		(E)	4	4	4	4	2	3	5	3
		(F)	4	4	4	3	5	3	5	3
		(G)	1	1	1	1	2	1	2	2
		(H)	2	2	2	2	2	1	3	2
		(I)	1	1	1	1	1	1	1	1
		(J)	2	2	2	2	2	1	2	1
Model Parameter	**Parameter Function**	**Parameter Values**								
Raster cell size	Determines output resolution of analysis	330 ft (+10%)		•						
		300 ft	•			•	•	•	•	•
		270 ft (-10%)			•					
Brea point of Polygons	Determines the input resolution of the analysis	2.2 min 4.4 min 6.6 min 8.8 min 11 min				•				
		2 min 4 min 6 min 8 min 10 min	•	•	•			•	•	•
		1.8 min 3.6 min 5.4 min 7.2 min 9 min					•			
Raster Classification	Determines suitability value	Equal Interval						•		
		Natural Breaks	•	•	•	•	•			
		Equal Area							•	
Aggregation Level	Determines MAUP implications	TAZs								•
		Census tracts	•	•	•	•	•	•	•	

Key:
Italicized Values indicate values used in demo version of model
Shade indicates values that as same as those obtained for the Demo model

A sensitivity testing tool was developed for the accessibility tool. Model output values at the ten random points indicate that the accessibility tool is not at all sensitive to the cell size of 300 chosen to run the model. It is somewhat sensitive to the breakpoints of 2, 4, 6, 8 and 10 minutes of travel time and to the level of aggregation used for the daycare centers. It is extremely sensitive to the method used for classifying raster values.

The results of the sensitivity testing show that the choice of cell size for the accessibility tool is appropriate. The sensitivity to the travel time breakpoints is expected. The break point numbers can be determined by MPOs per the characteristics of their region. High density urban regions need shorter break times than regions of lower density. Jenk's classification by natural breaks looks for minimum variance within each class and for data that is classified in time ranges, as above; this classification is likely the most appropriate. Equal area breaks into classes such that each class is approximately equal in area and equal intervals divides the range of values into equal divisions -- neither of which have any significance to data that is generated by inputting time ranges

6.6 Limitations of model

Though suitability modeling is a very useful mapping tool for collaborative transportation planning, there are some limitations. First, the nature and kind of relationships existing in the real world, which are incorporated in the model, are at the discretion of the model builder or the analyst. Thus, the selection of a different set of properties and relationships at the model construction stage can produce a different set of results. The subjective nature of this selection gives rise to uncertainties. One way to control the subjectivity is to encapsulate subjective uncertainty in a pair of bounding values within which the range of all possible values may lie (Ray & Burgman, 2006).

The MPO staff member who would administer the model for a collaborative planning situation needs to understand the subjective uncertainties of the model. The outcome of the model is dependent on the choice of the subjective parameters and decision-making will be greatly enhanced with a transparent model where all the parameters can be adjusted by the tool administrator. If, however, the staff member does not have a full understanding, the transparency needs to be reduced. The decision of the level of transparency to be built into the tool will depend on the MPO and thus there does not exist any one size fits all version of the tool, this is a limitation.

Geurs and Ritsema van Eck's (2001) definition of accessibility, the basis of this accessibility tool, has a time component that has been ignored. Including the time component would allow a temporal variation of accessibility during the entire day to be factored in. Accessibility would vary during the day per bus and train schedules.

The network dataset on which the accessibility tool is based does not include turn restrictions (except onto one-way streets) and counts of the number of lanes available at different locations. This was for simplification purposes only.

The accessibility measurement created here fails to directly account for mobility, physical differences, structural barriers and individual limitations that affect travel time among people. The mode choice selected by people is used as a proxy for these individual variations. The model can be modified to display an individual accessibility very easily. It would then no longer be a tool for collaborative planning but one for individual planning.

The accessibility measuring tool developed here does not consider trip chaining simply because, unlike UTDMs, this model is not based on trips that people make. It is based on the choice people make of the mode of travel they would prefer, the destinations they go to and the importance of the destinations.

The destinations considered in the tool are aggregated by census tract. This introduces MAUP errors in the output accessibility values. It is hoped that in another 5 years computing powers will be higher and it will no longer be necessary to aggregate destinations. Disaggregated data does not have MAUP implications.

CHAPTER 7

CONCLUSION

7.1 Summary of Findings and their Importance

The sea change brought about in the focus of transportation planning, by statutes and regulations passed since the 1990s, mandated empowerment of the local and consideration of intermodality. SAFETEA-LU signed into law in 2005 sharpened this tone by requiring collaborative planning and visualization techniques for TIPs.

Case studies indicate that metropolitan transportation planning authorities in New Jersey, in varying degrees, have come up with innovative ways to engage the public through the Internet and otherwise but none of their methods engage the public in collaborative planning to visualize the value of their planning effort in terms of how a TIP enhances their daily lives. Visualization efforts at the three MPOs are primarily limited to the maps that are included in the reports and to images of how proposed projects would look like. Involving the public in collaborative planning processes, in all three MPOs studied, remains limited to disseminating information about impending projects and getting feedback about them. Visualization techniques used by New Jersey MPOs do not involve mapping the outcomes of transportation improvement programs.

The tool developed here takes into account the current practices of the New Jersey's transportation planning organizations and suggests possible ways to incorporate the values of a community in their collaborative planning process. Values on transportation modes vary by community. No known evaluation of transportation projects are visualized based on such values.

The literature review chapter cites a sizeable number of accessibility measures developed since 1959. Early measures are based on properties of the built environment while later measures take into account characteristics of people. Space-time measures, the youngest group of measures, incorporate not only a person's behavior in space but also take into account the time limitations experienced by a person. It does not however consider the values of a community. The measure developed in this dissertation takes into account individual variation of value about transportation modes for different destinations by expressing it as a part of a community's wish.

The accessibility measuring tool is envisioned to fulfill some of the requirements outlined in the transportation statues and regulations of the past twenty years. It takes into account the trend towards engaging the public that all the statues since 1990 have emphasized. It also takes into account new project elements of pedestrian walkways and bicycle transportation that were not considered before SAFETEA-LU. Most importantly though, it helps a MPO to visualize an outcome of the transportation planning process that takes into account all the modes of transportation taken together or separately, as desired.

Time tested modeling methods have been used in a new way in this dissertation. The gravity model is used as a generalized measure of concentration and can be replaced by any interaction model one desires. However, this is the first time that suitability modeling has been used to measure accessibility. Also, suitability modeling has never been used in transportation planning.

Case studies indicate that New Jersey MPOs measure accessibility primarily when they perform environmental justice calculations. In doing so, they follow the letter of the law, but not the intent of the law. Each MPO in New Jersey defines communities that they are concerned about uniquely. Accompanying analyses are heavily dependent on methods used by each MPO which are also unique. Though slight variations of the methods can result in widely varying results, none of the MPOs mention this fact.

There are two accessibility rasters, one calculated by time and the other calculated by distance, that are obtained as end products of the tool developed in this dissertation. These rasters can be calculated before and after a TIP (as shown in Figures H.37 through H.40) to obtain the difference in values of accessibility at different points of the region. The accessibility rasters can also be used to obtain an accessibility field that can be developed for each region or each MPO. MPOs can use zonal statistics to get values of accessibility for the communities that they are concerned about by drawing polygons as they desire and check if proposed TIPs change accessibility in any way. This would greatly reduce the time taken to do environmental justice calculations as they are practiced currently.

Yet again there is another measure of accessibility! This measure however is different from other measures in several ways. First, this measure of accessibility focuses on incorporating visualization into the transportation planning process. Second, it considers intermodality without being a space-time measure. Third, it engages the public in collaborative planning. Fourth it has the possibility of full and fair participation by all potentially affected communities in the transportation decision making process. All of the above are SAFETEA-LU requirement. Moreover, use of zonal statistics on the accessibility raster that is product of the tool developed here can yield part of environmental justice calculations in a much more efficient and uniform manner.

7.2 Notions of Accessibility Not Considered by the Tool

Accessibility, in the tool developed in this dissertation, is determined by the properties of an area, viz. the distance and time taken to travel to an amenity taking into account the travel preferences of an entire city-region. This simple approach is just the starting point for a more nuanced view of accessibility that can take into consideration issues that have not been considered here for the sake of simplifying the problem.

One issue that has not been considered is the quality of an amenity; amenities being basic destinations, markets and quality of life destinations. For instance, the broad categories of food stores, in market destination, lumps all types of food stores under this single category. The mere existence of more than one accessible food store, however, does not add any additional value to a place if all the equally accessible food stores sell the same kind of food. Essentially, once basic needs are met, it is diversity in accessibility and degree of choice offered among accessible resources that become more important than the total sum of the number of accessible food stores (Lynch, 1981). This can be easily done with the current model by considering each subcategory of NAICS descriptions (Appendix G) individually instead of considering them together as has been done here. For example "fish and vegetable markets" and "fruits and vegetable markets" can be considered separately instead of considering them under the "food stores" supergroup.

However, taking the quality of accessibility to its logical end may move the measurement away from a group of people to an individual. For instance, even if a large number of jobs may be easily accessible from a place that a person lives, it does not mean that this person has better job opportunities at that particular place than a place where can be considered separately instead of considering them under the "food stores" supergroup.

However, taking the quality of accessibility to its logical end may move the measurement away from a group of people to an individual. For instance, even if a large number of jobs may be easily accessible from a place that a person lives, it does not mean that this person has better job opportunities at that particular place than a place where cost or the time taken to access jobs is less. It is the quality or suitability of the jobs, and not the quantity, that would be a better measure of job accessibility for that specific person. In essence "meaningful access is not absolute." Meaningful measures of accessibility for the individual depend on what the individual wants to access at a time that is suitable to him or her. Space time accessibility measures discussed in the literature review are based on this notion of accessibility. The measure of accessibility proposed here though is not for the individual but for a group of people.

The perception of time is another issue that has not been taken into consideration in this dissertation. Often commuting time under a certain limit is indistinguishable while every minute over a certain time is more burdensome to commuters. This issue may be solved by breaking the service area polygons into smaller time zones at the higher end and larger time zones at the lower end. What exactly these times are needs to be researched.

The accessibility measuring tool developed here for collaborative planning can be easily accommodated into the outreach efforts undertaken by the New Jersey MPOs. All the case study MPOs and an additional MPO who were shown the accessibility tool agreed that this tool could be handy for their current collaborative planning efforts. The tool can be easily modified for calculating individual accessibility and letting the public evaluate the change in accessibility with the construction of a TIP for the set of amenities that matter to a person individually. This would require changes in the way that MPOs currently interact with the public but may be more attuned to federal legislation in transportation.

7.3 Future Research

The enthusiastic feedback obtained from all MPOs indicates that the tool can be further developed in several ways. These include considering all the factors, identified in section 7.2, that were not considered when developing the tool. Several other factors can also be researched.

Spatial interactions happen across levels of scale and spatial characteristics are scale dependent. Accessibility analysis can thus be carried out one scale at a time with the understanding that for a different scale the accessibility pattern will be different. Multi-scale suitability modeling would be an interesting study.

The numbers used here for indicating public preferences for different modes of transportation were randomly generated. A real collaborative planning process could be carried out to test the effectiveness of the tool.

The tool uses time and distance as impedance characteristics of the network. In addition, a safety measuring element and a carbon footprint of travel have been incorporated into the tool but have not been used. SAFETEA-LU requires a review of the TIP project selection criterion based on safety. SAFETEA-LU also requires metropolitan plans to include discussion of environmental mitigation activities and air quality conformity. The tool could possibly include environmental mitigation efforts by

MPOs by indicating differences in the emission footprint of carbon and other transportation byproducts before and after the completion of TIPs in their region.

Environmental justice calculations can be made by counting the number of people who fall in every service area by time and distance and then compared to see how people in different socioeconomic groups are served. In a similar manner gender differences (or differences between any subsections of the populations) in accessibility can be studied using this tool. This would be especially effective if temporal considerations are also factored into the calculations.

Also, with the rapid development of web mapping and the increasing power of computers, this research can be developed in several ways. Public preferences can be gathered over the Internet and web mapping can show results.

7.4 My Interest in Transportation Planning

My interest in transportation planning started when I went to India for a three year stay beginning in 2000. Cities across the country were upgrading their transportation infrastructure at an unprecedented pace to combat high levels of traffic congestion. The solutions sought out for every case seemed to follow a single pattern irrespective of the local conditions: building highway style overpasses over congested areas and widening roads, at the cost of sidewalks, to increase automobile speed. Misplaced pride in modernity, of which the overpass became a symbol, was not only defacing the historic essence of cities, some more than a thousand years old, but also riding rough over the very fabric of an urban system that had sustained bustling street life for centuries--maybe at a slower pace.

Now, almost ten years later, Indian cities remain just as congested. Overpasses surely have increased the speed of automobiles, but people can no longer see across streets unless they peer through the underbellies of the gigantic structures. Human-powered vehicles are forced to take circuitous routes and pedestrians are given the least importance in the design. These multimillion dollar projects came at a price not only to the citizens of the country who paid for them through taxes but also to the pedestrians and human-powered vehicle owners who form the majority of street users and have been relegated to much lesser importance than automobiles.

Transportation improvement projects certainly were long overdue. If however the value of proposed projects were assessed by a collaborative planning process that took into account the mode choice of people who live and work around the projects, transportation design outcomes may have been different!

APPENDIX A

GLOSSARY

CAAA	Clean Air Amendment Act
CAC	Citizens Advisory Committee
CAFRA	Coastal Area Facility Review Act
CHSTP	Coordinated Human Service Transportation Plan
CIS	Capital Investment Strategy
CMP	Congestion Management Program
CTAA	Community Transportation Association of America
CTPP	Census Transportation Planning Package
CTOD	Center for Transit Oriented Development
DOD	Degrees of Disadvantage
DOT	Department of Transportation
DVMT	Daily Vehicle Miles Traveled
DVRPC	Delaware Valley Regional Planning Organization
EIS	Environmental Impact Statement
EJ	Environmental Justice
ES-202	State-level unemployment compensation record
ESDA	Exploratory Spatial Data Analysis
FHWA	Federal Highway Association
FTA	Federal Transit Association
FY	Fiscal Year

GIS	Geographic Information System
HHS	Health and Human Services
ISTEA	Intermodal Surface Transportation Efficiency Act
JARC	Job Accessibility and Reverse Commute
JEK	Jacobs, Edwards and Kelcey
LOS	Level of Service
LU	Land Use
LRP	Long Range Planning
MAUP	Modifiable Area Unit Problem
MCDA	Multicriteria Decision Analysis
MPO	Metropolitan Transportation Organization
MSA	Metropolitan Statistical Area
NAICS	North American Industry Classification System
NCHRP	National Cooperative Highway Research Program
NCHS	National Center for Health Statistics
NEPA	National Environmental Policy Act
NJDOL	New Jersey Department of Labor
NJDOT	New Jersey Department of Transportation
NJT	New Jersey Transit
NJTPA	North Jersey Transportation Planning Organization
NOTIS	NJTPA Online Transportation Information System
NSLP	National School Lunch Program
NTIS	National Technical Information Service

PADCA	Pennsylvania Department of Community Affairs
PADCED	Pennsylvania Department of Community and Economic Development
PATCO	Port Authority Transit Corporation
PCPI	Per Capita Personal Income
PennDOT	Pennsylvania Department of Transportation
PIP	Public Involvement Policy
POP	Public Outreach Program
PNR	Pinelands National Reserve
POP	Public Outreach Program
PPGIS	Public Participation Geographical Information System
PSS	Planning Support Systems
RCIS	Regional Capital Investment Strategy
RCC	Regional Citizen's Committee
RTP	Regional Transportation Plan
SAFTEA-LU	Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users
SEPTA	Southeastern Pennsylvania Transit Authority
SJTPO	South Jersey Transportation Planning Organization
STAM	Space Time Accessibility Measure
STIP	State Transportation Improvement Program
TAD	Transit Adjacent Development
TANF	Temporary Assistance for Needy Families
TAZ	Transportation Analysis Zone
TEA-21	Transportation Equity Act for the 21st Century

TDD	Transportation Development District
TED	Transportation Enhancement District
TELUS	Transportation Economic Land Use System
TID	Transportation Improvement District
TIP	Transportation Improvement Program
TOD	Transit Oriented Development
TRB	Transportation Research Board
TRID	Transit Revitalization Investment District
TVI	Transit Village Initiative
UEZ	Urban Enterprise Zone
UPWP	Unified Planning Work Program
UTDM	Urban Travel Demand Model
UWR	United We Ride
USDOT	United States Department of Transportation
WFNJ	Workforce New Jersey
ZCTA	Zip Code tabulation Area

APPENDIX B

LETTER OF REQUEST

The director of each of the three MPOs in the case study was sent the following letter by mail requesting an interview date. The sample shown here is for SJTPO. The other two MPOs received similar letters by mail.

June 14, 2007

Director, SJTPO

782 S. Brewster Rd.

Unit 6B

Vineland, NJ 08360

(856)794-1941 (phone)

(856)794-2549 (fax)

Dear Director:

I am working on my Ph.D. Dissertation in Urban Systems, a joint NJIT/Rutgers Program. My dissertation thesis is Accessibility in Metropolitan Transportation Planning: Visualizing a GIS-based measure for Collaborative Planning. My Dissertation Proposal received approval from Professor Lyna Wiggins, Ph.D. of the Bloustein School of Public Planning and Policy and the rest of my committee and I am preparing to conduct the data gathering phase of my research and analysis.

There are two goals in this research. The fist goal is to construct a GIS-based measure (or a composite measure) of accessibility, using existing literature and new technology, based on data that is readily available to an MPO. The second goal is to develop a visualization tool (or a set of tools), that will support the understanding of accessibility issues, in transportation planning.

If you could allow me access to yourself and primary staff members for a short interview about accessibility issues in transportation planning it would be make it possible for me to conduct this research. I would need from you:

a) Date/s on which I can come in to interview you and your staff (after July 15)

b) The appropriate list of employees that I can interview

In return, I will provide you with a copy of the model for use in present and future accessibility studies.

Your assistance in this effort will most certainly be appreciated. Please feel free to contact me with any questions that you may have.

Sincerely

Aditi Sarkar

1050 George Street, #9I, New Brunswick, NJ 08901

(732) 317 4973

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APPENDIX C

QUESTIONNAIRE FOR MPOS

The three New Jersey MPOs (SJTPO, DVRPC and NJTPA) were interviewed in the summer months of 2007. The interviews were of open format and exploratory in nature and were modified according to what was deemed appropriate for the organization and the person interviewed. The questions asked, however, followed a prepared guideline that was approved by the IRB process and was built from a combination of the conceptual framework of understanding the issue of accessibility and questions that arose from studying the websites of the three MPOs.

Questions for the Director (D) of the Metropolitan Planning Organization:

1) (D1) How has your organization chosen to answer the following question, from the Federal Highway Authority, during the Metropolitan Planning Organization certification review process?

2) Does the planning process have an analytical process in place for assessing the regional benefits and burdens of transportation system investments for different socio-economic groups? Does it have a data collection process to support the analysis effort? Does this analytical process seek to assess the benefit and impact distributions of the investments included in the plan and TIP (or STIP)?

3) How does the planning process respond to the analyses produced? Imbalances identified?

4) (D2) The US congress has identified the following as one of its objectives to guide the expenditure of federal funds in metropolitan transportation planning

process: “Increase the accessibility and mobility options available to people and for freight.”

5) How do you decide whether a prospective project increases or decreases accessibility?

6) (D3) Who are the key players in the decision making process in your organization?

7) (D4) How do you balance the technical analysis by the MPO staff (considered to be unbiased and competent) against special interests who participate actively in the decision-making process to determine regional transportation needs and priorities?

8) (D5) Do you have set rules of engagement for participants in the MPO decision-making process?

9) (D6) Does your MPO define the participants and their individual role in the decision-making process?

10) (D7) How many of the following groups attend your stakeholder/customer meetings?

11) (D8) Do you have any process in place (like a survey) to know whether the information that you are presenting in a collaborative meeting will be understood by everyone?

12) (D9) Who decides, at the stakeholder/ customer meeting, the key issues that are at stake?

13) (D10) Which of the following do you think most closely describes how stakeholders/ customers meet planners to collaborate?

14) a) In the same room at the same time

15) b) In the same room at different times

16) c) In different rooms at the same time

17) d) In different rooms at different times

18) (D11) What is the average number of people that you get in each group?

19) (D12) Do you meet with all the groups at the same time?

20) (D13) [If answer to D12 is no] How do you tailor your meetings to different stakeholders/customers?

21) (D14) [If answer to D12 is no] Do you define the role of key players in this process?

22) (D15) Do group members share computers in the collaboration process?

23) (D16) Do people belonging to different groups share the same computer?

24) (D17) Will it be possible to communicate with the stakeholder/ customer groups, to get feedbacks, as I develop my tool?

Questions for the Policy Board (PB) member of the Metropolitan Transportation Planning Organization

25) (PB1) Is accessibility an element in decision-making process of your organization?

26) (PB2) [If yes to PB1] how is accessibility an element in your planning?

27) (PB3) Does your MPO encourage any program like "Smart Growth," "New Urbanism," "Transit Oriented Development" or any other special program that increases accessibility?

28) (PB4) [If yes to PB3] Which ones have you used?

Questions for Technical Committee (TC) member of the Metropolitan Transportation Planning Organization

29) (TC1) Does your organization define accessibility?

30) (TC2) [If yes to TC1] How does your organization define accessibility?

31) (TC3) Do you measure accessibility in any stage of your planning process?

32) (TC4) [If yes to TC3] How do you measure accessibility?

33) (TC5) [If yes to TC3] At which stage do you measure accessibility?

34) (TC6) [If yes to TC3] Does your organization convey the information of the measured accessibility to the stakeholders/customers?

35) (TC7) [If yes to TC6] Do you convey the information of your measurement of accessibility to the stakeholders/customers?

36) (TC8) [If yes to TC7] How do you convey the information?

37) (TC9) How do you measure accessibility in cases like "smart growth," "new urbanism" and "transit-oriented design?"

38) (TC10) What kind of practices do you have in place to communicate to groups with varying needs and levels of understanding?

39) (TC11) What data sets do you use to measure accessibility?

40) (TC12) What is the format in which information presented to the stakeholders/ customers?

41) (TC13) Other than those on the public domain, what data sets do you possess that I can use for developing a measure of accessibility?

APPENDIX D

QUESTIONNAIRE TO IDENTIFY MODE CHOICE

An individual's mode choice could be identified by asking him/her to rank the mode choice for accessing basic destinations, markets and quality of life destination. Rankings of this nature from several individuals can be merged together mathematically to identify the mode choices of a community.

Table D.1 Possible Questionnaire for Community to Understand their Mode Choice

Table D.1 Possible Questionnaire to Gather Information on Mode Choice

	Time of travel	Cost of travel	Environmental effects of your travel
Questions on basic destinations			
When going to work, what makes you decide on your mode of transportation?			
If you have children and need to pick/drop them off at a daycare, what is important to you?			
What of the following most concerns you about doctors and hospitals that you visit?			
If you or a member of your family is going to school, what is important you or that member?			
If you seek financial institutions (like coin operated laundries or drycleaners) what is important to you?			
If you need to go to financial institutions, what is important to you?			
Questions on market destinations			
When you go food shopping what is important to you?			
When you go shopping for non-food items what is important to you?			
Questions on Quality of Life Destinations			
If and when you go for a recreational activity (like fitness center, golf club) what is important to you?			
If and when you go in for non-physical activity (like library, museum etc) what is important to you?			
If and when you go to theaters, what is important to you?			
If and when you go to restaurants, what is important to you?			
If and when you go for personal care (like barber shops or beauty salons), what is important to you?			

APPENDIX E

THE NETWORK DATASET

The network dataset is the base on which the suitability analysis is based. The two important aspects of the network dataset are the connectivity policies at the nodes and the traversability properties of the edges.

Table E.1 Connectivity Policies of the Network Dataset

Table E.2 Traversability Policies of the Network Dataset

Table E.3 Travel Velocities and Travel Time on the Network Dataset by Mode

Table E.1 Connectivity Policies of the Network Dataset

Source	Connectivity Policy	Network Number				
		1	2	3	4	5
Automobile	Any Vertex	Y	N	N	N	N
Bike	Any Vertex	N	Y	N	N	N
Bus	Any Vertex	N	N	Y	N	N
Pedestrian	Any Vertex	N	N	N	Y	N
RailRoad	End Point	N	N	N	N	Y
BusStops	Honor	N	Y	Y	Y	N
Parking	Override	Y	N	N	Y	N
RRStation	Honor	N	Y	N	Y	Y

Key: Y=Yes connectivity exists, N = No connectivity does not exist

Table E.2 Traversability Policies of the Network Dataset

Name	Usage	Units	Data Type
Auto Travel	Restriction	Unknown	Boolean
Auto Weight	Restriction	Unknown	Boolean
Bike Travel	Restriction	Unknown	Boolean
Bike Weight	Restriction	Unknown	Boolean
Bus Travel	Restriction	Unknown	Boolean
Feet	Cost	Feet	Double
Max Auto Wt	Descriptor	Unknown	Integer
Max Bike Wt	Descriptor	Unknown	Integer
Max Ped Wt	Descriptor	Unknown	Integer
One way	Restriction	Unknown	Boolean
Pedestrian	Restriction	Unknown	Boolean
Ped Weight	Restriction	Unknown	Boolean
Rail Travel	Restriction	Unknown	Boolean
Travel Time	Cost	Minutes	Double

Table E.3 Travel Velocities and Impedance factors on the Network Dataset by Mode

Mode	Velocity of travel in mph	Impedance factor due to traffic
Auto	Speed Limit set by city	.5
Bike	18*	.5
Pedestrian	3.25**	.75

Source:
*http://www.bikecommuteweek.com/bcm_forum/topic.asp?TOPIC_ID=117 for bike speed
**http://www.bellaonline.com/articles/art20257.asp for pedestrian walking speeds

APPENDIX F

MODELS

The Accessibility Tool consists of several submodels based on a single concept model Figure F.1. The model at the Desired level is a sum of submodels formed from a combination of one item from each of "destination," "travel impedances" and "travel modes." All the submodels together make the complete tool. The following list the concept model and all the tables.

Key for Tables F.1 through F.14:

<u>Underline</u>	Submodel used for creating the Demonstration model.	
	This submodel exists at Demonstration, Dissertation and Desired levels.	
Italics	Submodel used for creating the Dissertation model.	
	This submodel exists at Dissertation and Desired levels only.	
Regular	Submodel used for creating the Desired model.	
	This submodel exists at the Desired level only.	
Goal X	Identify areas most suitable for accessing X	
X	Jobs, daycare centers, doctors and hospitals etc.	
Objective XY	Identify areas most suitable for accessing X considering Y	
Y	=1	most suitable time-wise
	=2	most suitable distance-wise
	=3	most suitable environmental impact wise (not included in Dissertation and Demonstration level calculations)
	=4	most suitable safety wise (not shown, only at the Desired level)
SO	Subobjective	
SOXYZ	Identify areas most suitable for accessing X considering Y by mode Z	
Z	= 1	automobile
	= 2	automobile + walk + work
	= 3	bike
	= 4	walk
	= 5	walk + transit

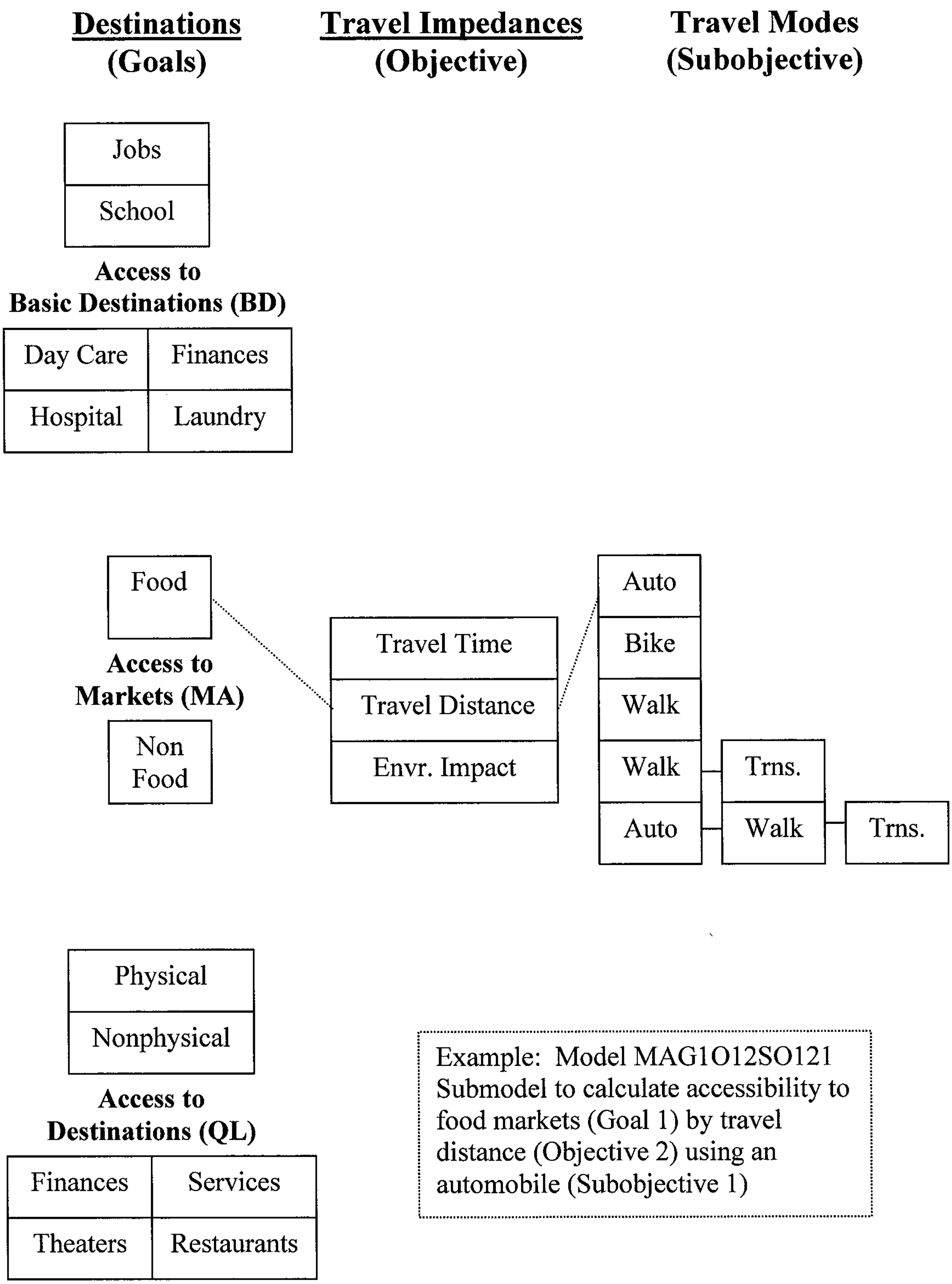


Figure F.1 Concept model.

Key: Trns. = Transit, Envr.= Environmental

Table F.1 Model Purpose (Subobjective) and Objectives for Basic Destination Goal 1

Destination	Goal	Objective	Subobjective	Purpose	Weight
BD	*1* (jobs)	*1.1*	*1.1.1*	*Identify areas most suitable for driving to work*	*59.31*
			1.1.2	*Identify areas most suitable for driving + walking + transit to work*	*38.27*
			1.1.3	*Identify areas most suitable for biking to work*	*0.37*
			1.1.4	*Identify areas most suitable for walking to work*	*1.09*
			1.1.5	*Identify areas most suitable for walking + transit to work*	*.95*
		1.2	*1.2.1*	*Identify areas most suitable for driving to work*	*41.29*
			1.2.2	*Identify areas most suitable for driving + walking + transit to work*	*50.76*
			1.2.5	*Identify areas most suitable for walking + transit to work*	*7.95*
		1.3	1.3.1	Identify areas most suitable for driving to work	
			1.3.2	Identify areas most suitable for driving + walking + transit to work	
			1.3.5	Identify areas most suitable for walking + transit to work	

Table F.2 Model Purpose (Subobjective) and Objectives for Basic Destination Goal 2

Destination	Goal	Objective	Subobjective	Purpose	Weight
BD	2 (daycare)	2.1	2.1.1	Identify areas most suitable for driving to daycare	14.12
			2.1.2	Identify areas most suitable for driving + walking + transit to daycare	22.61
			2.1.3	Identify areas most suitable for biking to daycare	22.39
			2.1.4	Identify areas most suitable for walking to daycare	26.13
			2.1.5	Identify areas most suitable for walking + transit to work	14.75
		2.2	*2.2.1*	*Identify areas most suitable for driving to daycare*	*17.02*
			2.2.2	*Identify areas most suitable for driving + walking + transit to daycare*	*39.94*
			2.2.5	*Identify areas most suitable for walking + transit to daycare*	*43.04*
		2.3	2.3.1	Identify areas most suitable for driving to daycare	
			2.3.2	Identify areas most suitable for driving + walking + transit to daycare	
			2.3.5	Identify areas most suitable for walking + transit to daycare	

Table F.3 Model Purpose (Subobjective) and Objectives for Basic Destination Goal 3

Destination	Goal	Objective	Subobjective	Purpose	Weight
BD	3 (doctors and hospitals)	3.1	3.1.1	Identify areas most suitable for driving to doctors and hospitals	
			3.1.2	Identify areas most suitable for driving + walking + transit to doctors and hospitals	
			3.1.3	Identify areas most suitable for biking to doctors and hospitals	
			3.1.4	Identify areas most suitable for walking to doctors and hospitals	
			3.1.5	Identify areas most suitable for walking + transit to doctors and hospitals	
		3.2	3.2.1	Identify areas most suitable for driving to doctors and hospitals	
			3.2.2	Identify areas most suitable for driving + walking + transit to doctors and hospitals	
			3.2.5	Identify areas most suitable for walking + transit to doctors and hospitals	
		3.3	3.3.1	Identify areas most suitable for driving to doctors and hospitals	
			3.3.2	Identify areas most suitable for driving + walking + transit to doctors and hospitals	
			3.3.5	Identify areas most suitable for walking + transit to doctors and hospitals	

Table F.4 Model Purpose (Subobjective) and Objectives for Basic Destination Goal 4

Destination	Goal	Objective	Subobjective	Purpose	Weight
BD	4 (schools)	4.1	4.1.1	Identify areas most suitable for driving to schools	
			4.1.2	Identify areas most suitable for driving + walking + transit to schools	
			4.1.3	Identify areas most suitable for biking to schools	
			4.1.4	Identify areas most suitable for walking to schools	
			4.1.5	Identify areas most suitable for walking + transit to schools	
		4.2	4.2.1	Identify areas most suitable for driving to schools	
			4.2.2	Identify areas most suitable for driving + walking + transit to schools	
			4.2.5	Identify areas most suitable for walking + transit to schools	
		4.3	4.3.1	Identify areas most suitable for driving to schools	
			4.3.2	Identify areas most suitable for driving + walking + transit to schools	
			4.3.5	Identify areas most suitable for walking + transit to schools	

Table F.5 Model Purpose (Subobjective) and Objectives for Basic Destination Goal 5

Destination	Goal	Objective	Subobjective	Purpose	Weight
BD	5 (laundry services)	5.1	5.1.1	Identify areas most suitable for driving to laundry services	
			5.1.2	Identify areas most suitable for driving + walking + transit to laundry services	
			5.1.3	Identify areas most suitable for biking to laundry services	
			5.1.4	Identify areas most suitable for walking to laundry services	
			5.1.5	Identify areas most suitable for walking + transit to laundry services	
		5.2	5.2.1	Identify areas most suitable for driving to laundry services	
			5.2.2	Identify areas most suitable for driving + walking + transit to laundry services	
			5.2.5	Identify areas most suitable for walking + transit to laundry services	
		5.3	5.3.1	Identify areas most suitable for driving to laundry services	
			5.3.2	Identify areas most suitable for driving + walking + transit to laundry services	
			5.3.5	Identify areas most suitable for walking + transit to laundry services	

Table F.6 Model Purpose (Subobjective) and Objectives for Basic Destination Goal 6

Destination	Goal	Objective	Subobjective	Purpose	Weight
BD	6 (financial institutions)	6.1	6.1.1	Identify areas most suitable for driving to financial institutions	
			6.1.2	Identify areas most suitable for driving + walking + transit to financial institutions	
			6.1.3	Identify areas most suitable for biking to financial institutions	
			6.1.4	Identify areas most suitable for walking to financial institutions	
			6.1.5	Identify areas most suitable for walking + transit to financial institutions	
		6.2	6.2.1	Identify areas most suitable for driving to financial institutions	
			6.2.2	Identify areas most suitable for driving + walking + transit to financial institutions	
			6.2.5	Identify areas most suitable for walking + transit to financial institutions	
		6.3	6.3.1	Identify areas most suitable for driving to financial institutions	
			6.3.2	Identify areas most suitable for driving + walking + transit to financial institutions	
			6.3.5	Identify areas most suitable for walking + transit to financial institutions	

Table F.7 Model Purpose (Subobjective) and Objectives for Market Destination Goal 1

Destination	Goal	Objective	Subobjective	Purpose	Weight
MA	*1* (food stores)	*1.1*	*1.1.1*	*Identify areas most suitable for driving to food stores*	*18.9*
			1.1.2	*Identify areas most suitable for driving + walking + transit to food stores*	*34.53*
			1.1.3	*Identify areas most suitable for biking to food stores*	*17.96*
			1.1.4	*Identify areas most suitable for walking to food stores*	*16.06*
			1.1.5	*Identify areas most suitable for walking + transit to food stores*	*12.54*
		1.2	*1.2.1*	*Identify areas most suitable for driving to food stores*	*2.35*
			1.2.2	*Identify areas most suitable for driving + walking + transit to food stores*	*68.68*
			1.2.5	*Identify areas most suitable for walking + transit to food stores*	*28.96*
		1.3	1.3.1	Identify areas most suitable for driving to food stores	
			1.3.2	Identify areas most suitable for driving + walking + transit to food stores	
			1.3.5	Identify areas most suitable for walking + transit to food stores	

Table F.8 Model Purpose (Subobjective) and Objectives for Market Destination Goal 2

Destination	Goal	Objective	Subobjective	Purpose	Weight
MA	2 (non food stores)	2.1	2.1.1	Identify areas most suitable for driving to non food stores	
			2.1.2	Identify areas most suitable for driving + walking + transit to non food stores	
			2.1.3	Identify areas most suitable for biking to non food stores	
			2.1.4	Identify areas most suitable for walking to non food stores	
			2.1.5	Identify areas most suitable for walking + transit to non food stores	
		2.2	2.2.1	Identify areas most suitable for driving to non food stores	
			2.2.2	Identify areas most suitable for driving + walking + transit to non food stores	
			2.2.5	Identify areas most suitable for walking + transit to non food stores	
		2.3	2.3.1	Identify areas most suitable for driving to non food stores	
			2.3.2	Identify areas most suitable for driving + walking + transit to non food stores	
			2.3.5	Identify areas most suitable for walking + transit to non food stores	

Table F.9 Model Purpose (Subobjective) and Objectives for QL Destination Goal 1

Destination	Goal	Objective	Subobjective	Purpose	Weight
QL	*1* (physical activity centers)	*1.1*	*1.1.1*	*Identify areas most suitable for driving to physical activity cent.*	*37.33*
			1.1.2	*Identify areas most suitable for driving + walking + transit to physical activity cent.*	*3.35*
			1.1.3	*Identify areas most suitable for biking to physical activity cent.*	*34.28*
			1.1.4	*Identify areas most suitable for walking to physical activity cent.*	*19.68*
			1.1.5	*Identify areas most suitable for walking + transit to physical activity cent.*	*5.37*
		1.2	*1.2.1*	*Identify areas most suitable for driving to physical activity cent.*	*20.37*
			1.2.2	*Identify areas most suitable for driving + walking + transit to physical activity cent.*	*35.80*
			1.2.5	*Identify areas most suitable for walking + transit to physical activity centers*	*43.83*
		1.3	1.3.1	Identify areas most suitable for driving to physical activity cent.	
			1.3.2	Identify areas most suitable for driving + walking + transit to physical activity cent.	
			1.3.5	Identify areas most suitable for walking + transit to physical activity centers	

Table F.10 Model Purpose (Subobjective) and Objectives for QL Destination Goal 2

Destination	Goal	Objective	Subobjective	Purpose	Weight
QL	2 (non physical activity centers)	2.1	2.1.1	Identify areas most suitable for driving to non physical activity	
			2.1.2	Identify areas most suitable for driving + walking + transit to non physical activity	
			2.1.3	Identify areas most suitable for biking to non physical activity	
			2.1.4	Identify areas most suitable for walking to non physical activity	
			2.1.5	Identify areas most suitable for walking + transit to non physical activity centers	
		2.2	2.2.1	Identify areas most suitable for driving to non physical activity	
			2.2.2	Identify areas most suitable for driving + walking + transit to non physical activity	
			2.2.5	Identify areas most suitable for walking + transit to non physical activity centers	
		2.3	2.3.1	Identify areas most suitable for driving to non physical activity	
			2.3.2	Identify areas most suitable for driving + walking + transit to non physical activity	
			2.3.5	Identify areas most suitable for walking + transit to non physical activity centers	

Table F.11 Model Purpose (Subobjective) and Objectives for QL Destination Goal 3

Destination	Goal	Objective	Subobjective	Purpose	Weight
QL	3 (theaters)	3.1	3.1.1	Identify areas most suitable for driving to theaters	
			3.1.2	Identify areas most suitable for driving + walking + transit to theaters	
			3.1.3	Identify areas most suitable for biking to theaters	
			3.1.4	Identify areas most suitable for walking to theaters	
			3.1.5	Identify areas most suitable for walking + transit to theaters	
		3.2	3.2.1	Identify areas most suitable for driving to theaters	
			3.2.2	Identify areas most suitable for driving + walking + transit to theaters	
			3.2.5	Identify areas most suitable for walking + transit to theaters	
		3.3	3.3.1	Identify areas most suitable for driving to theaters	
			3.3.2	Identify areas most suitable for driving + walking + transit to theaters	
			3.3.5	Identify areas most suitable for walking + transit to theaters	

Table F.12 Model Purpose (Subobjective) and Objectives for QL Destination Goal 4

Destination	Goal	Objective	Subobjective	Purpose	Weight
QL	4 (restaurants)	4.1	4.1.1	Identify areas most suitable for driving to restaurants	
			4.1.2	Identify areas most suitable for driving + walking + transit to restaurants	
			4.1.3	Identify areas most suitable for biking to restaurants	
			4.1.4	Identify areas most suitable for walking to restaurants	
			4.1.5	Identify areas most suitable for walking + transit to restaurants	
		4.2	4.2.1	Identify areas most suitable for driving to restaurants	
			4.2.2	Identify areas most suitable for driving + walking + transit to restaurants	
			4.2.5	Identify areas most suitable for walking + transit to restaurants	
		4.3	4.3.1	Identify areas most suitable for driving to restaurants	
			4.3.2	Identify areas most suitable for driving + walking + transit to restaurants	
			4.3.5	Identify areas most suitable for walking + transit to restaurants	

Table F.13 Model Purpose (Subobjective) and Objectives for QL Destination Goal 5

Destination	Goal	Objective	Subobjective	Purpose	Weight
QL	5 (services)	5.1	5.1.1	Identify areas most suitable for driving to services	
			5.1.2	Identify areas most suitable for driving + walking + transit to services	
			5.1.3	Identify areas most suitable for biking to services	
			5.1.4	Identify areas most suitable for walking to services	
			5.1.5	Identify areas most suitable for walking + transit to services	
		5.2	5.2.1	Identify areas most suitable for driving to services	
			5.2.2	Identify areas most suitable for driving + walking + transit services	
			5.2.5	Identify areas most suitable for walking + transit to services	
		5.3	5.3.1	Identify areas most suitable for driving to services	
			5.3.2	Identify areas most suitable for driving + walking + transit to services	
			5.3.5	Identify areas most suitable for walking + transit to services	

Table F.14 Model Purpose (Subobjective) and Objectives for QL Destination Goal 6

Destination	Goal	Objective	Subobjective	Purpose	Weight
QL	6 (personal care centers)	6.1	6.1.1	Identify areas most suitable for driving to person care centers	
			6.1.2	Identify areas most suitable for driving + walking + transit to person care centers	
			6.1.3	Identify areas most suitable for biking to person care centers	
			6.1.4	Identify areas most suitable for walking to person care centers	
			6.1.5	Identify areas most suitable for walking + transit to person care centers	
		6.2	6.2.1	Identify areas most suitable for driving to person care centers	
			6.2.2	Identify areas most suitable for driving + walking + transit to person care centers	
			6.2.5	Identify areas most suitable for walking + transit to person care centers	
		6.3	6.3.1	Identify areas most suitable for driving to person care centers	
			6.3.2	Identify areas most suitable for driving + walking + transit to person care centers	
			6.3.5	Identify areas most suitable for walking + transit to person care centers	

APPENDIX G

NAICS DESCRIPTION OF DESTINATIONS

The tables in this appendix list all the travel destinations that are considered when calculating accessibility by their NAICS descriptions.

Table G.1 Basic Destinations Considered for Accessibility Tool by NAICS Descriptions

Destination Type: Basic Destination	NAICS description
Jobs	*
Daycare	Child daycare services
Doctors and Hospitals	Freestanding emergency medial centers General medical and surgical hospitals Office of chiropractors Offices of dentists Offices of miscellaneous mental health physicians Offices of miscellaneous health practitioners Offices of optometrists Offices of physicians except mental health Offices of podiatrists Offices of specialty therapists Psychiatric and substance abuse hospitals
Schools	Colleges and Universities Elementary and secondary schools Fine art schools Miscellaneous schools and instruction
Financial institutions	Coin-operated laundries and drycleaners Dry-cleaning and financial institutions
Financial Services	Commercial banking Credit unions Financial transaction processing and clearing

* Includes all businesses other than those that are self employed; too numerous to list.

Table G.2 Markets Considered for Accessibility Tool by NAICS Descriptions

Destination Type: Markets	**NAICS description**
Food Stores	All other specialty food store Confectionery and nut Stores Convenience stores Fish and seafood markets Food health supplement stores Fruit and vegetable markets Pharmacies and drug stores Supermarkets and other grocery stores
Non Food Stores	All other general merchandise stores Children's and infants clothing store Clothing accessories store Cosmetic and beauty supply stores Discount department stores Family Clothing Stores Hardware stores Hobby toy and game stores Luggage and leather goods stores Men's clothing store Optical goods stores Other clothing stores Pet and pet supplies stores Radio TV and other electronics stores Shoe stores Sporting goods stores Store retailers not specifies elsewhere Video tape and disc rental Women's clothing stores

Table G.3 Quality of Life Destinations Considered by NAICS Descriptions

Destination Type: Quality of Life	NAICS description
Physical Activity	Amusement and theme parks Amusement arcades Fitness and recreational sports centers Golf courses and country clubs
Non-Physical Activity	Libraries and archives Museums Nature parks and other similar institutions News dealers and newsstands
Theaters	Motion picture and theaters except drive-ins Theater companies and dinner theaters
Restaurants	Drinking places alcoholic beverages Full-service restaurants Limited-service restaurants Retail bakeries Snack and non-alcoholic beverage bars
Services	Child and youth services Civil and social organizations General automotive repair Miscellaneous ambulatory health care services Other individual and family services Other personal care services Pet care except veterinary services Religious organizations Services for the elderly and disabled Vocational rehabilitation services
Personal Care	Barber Shops Beauty Salons Nail Salons

APPENDIX H

MAPS

The output files of the accessibility tool are maps. These maps have been numbered by the model number that created them. The key is as follows:

Figure H.1 Output of model BD1O11SO111

Figure H.2 Output of model BD1O11SO112

Figure H.3 Output of model BD1O11SO113

Figure H.4 Output of model BD1O11SO114

Figure H.5 Output of model BD1O11SO115

Figure H.6 Output of model BD1O11

Figure H.7 Output of model BD1O12SO121

Figure H.8 Output of model BD1O12SO122

Figure H.9 Output of model BD1O12SO125

Figure H.10 Output of model BD1O12

Note: Output of models BD2O21SO211, BD2O21SO212, BD2O21SO213, BD2O21SO214, BD2O21SO215 and BD2O21 are Figure 6.2 through Figure 6.7

Figure H.11 Output of model BD2O22SO221

Figure H.12 Output of model BD2O22SO222

Figure H.13 Output of model BD2O22SO225

Figure H.14 Output of model BD2O22

Figure H.15 Output of model MA1O11SO111

Figure H.16 Output of model MA1O11SO112

Figure H.17 Output of model MA1O11SO113

Figure H1. Output of model BD1O11SO111

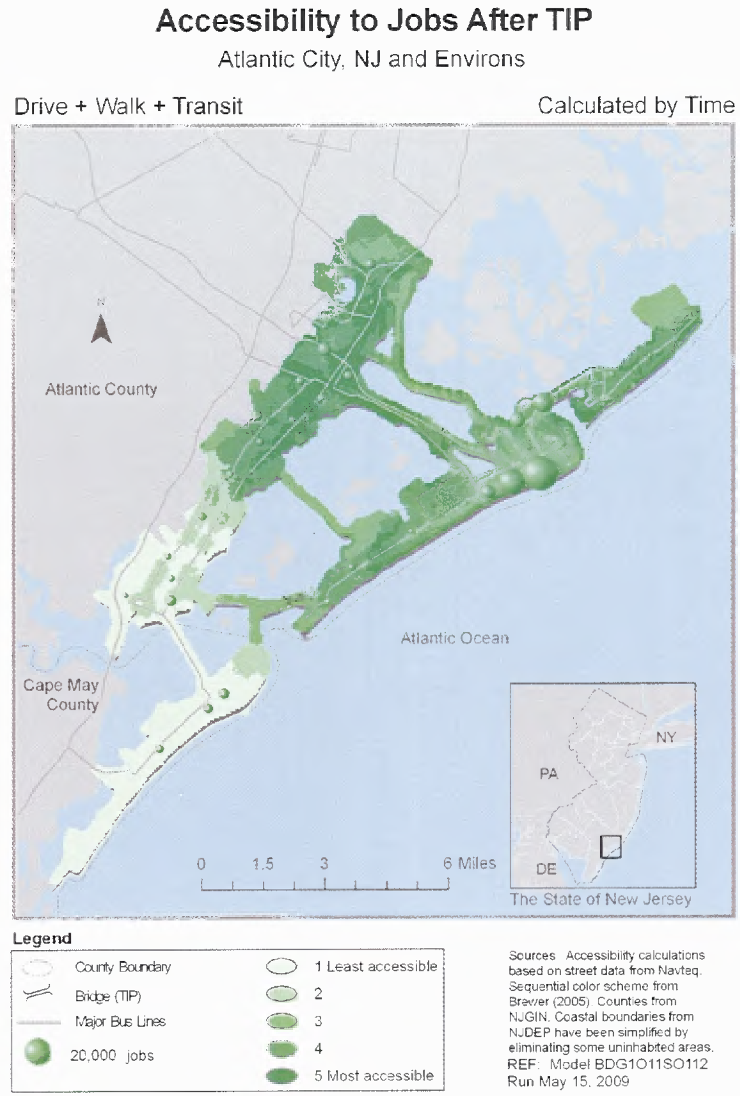


Figure H2. Output of model BD1O11SO112

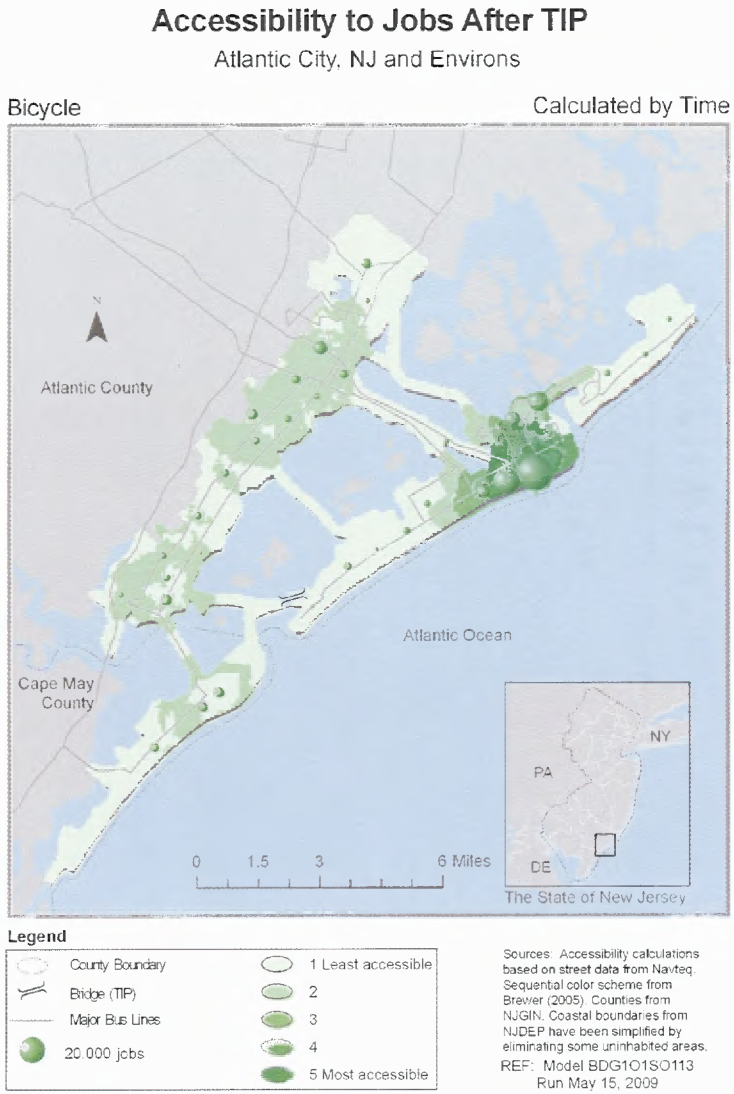


Figure H3. Output of model BD1O11SO113

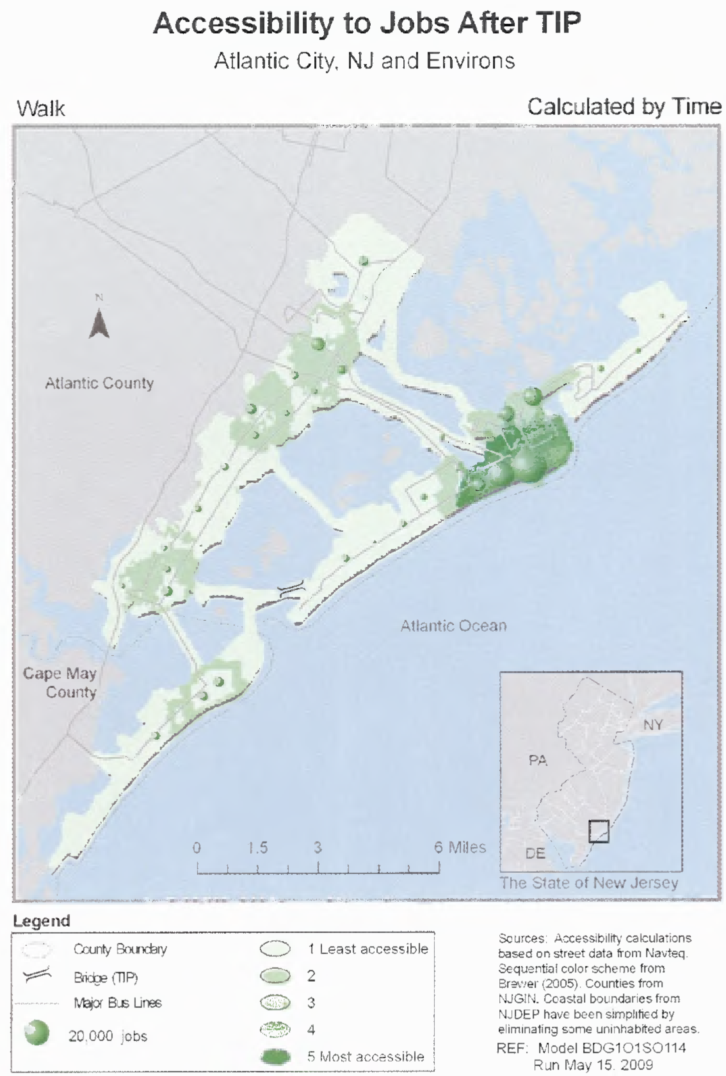


Figure H4. Output of model BD1O11SO114

Figure H5. Output of model BD1O11SO115

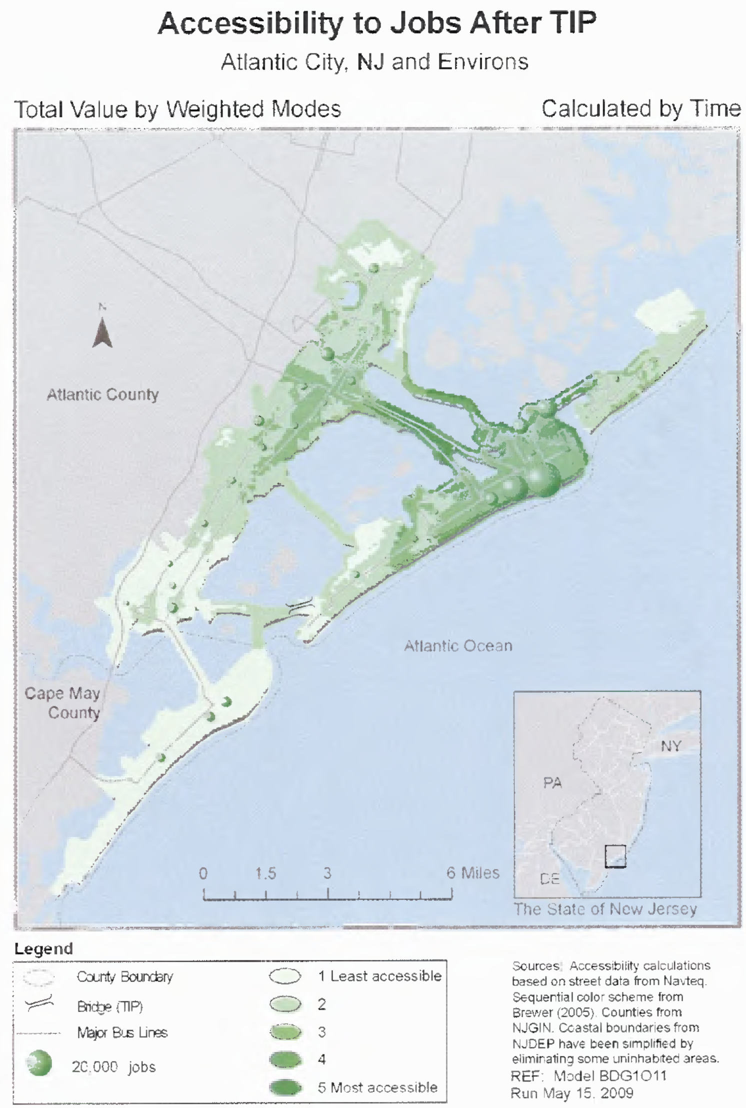


Figure H6. Output of model BD1O11

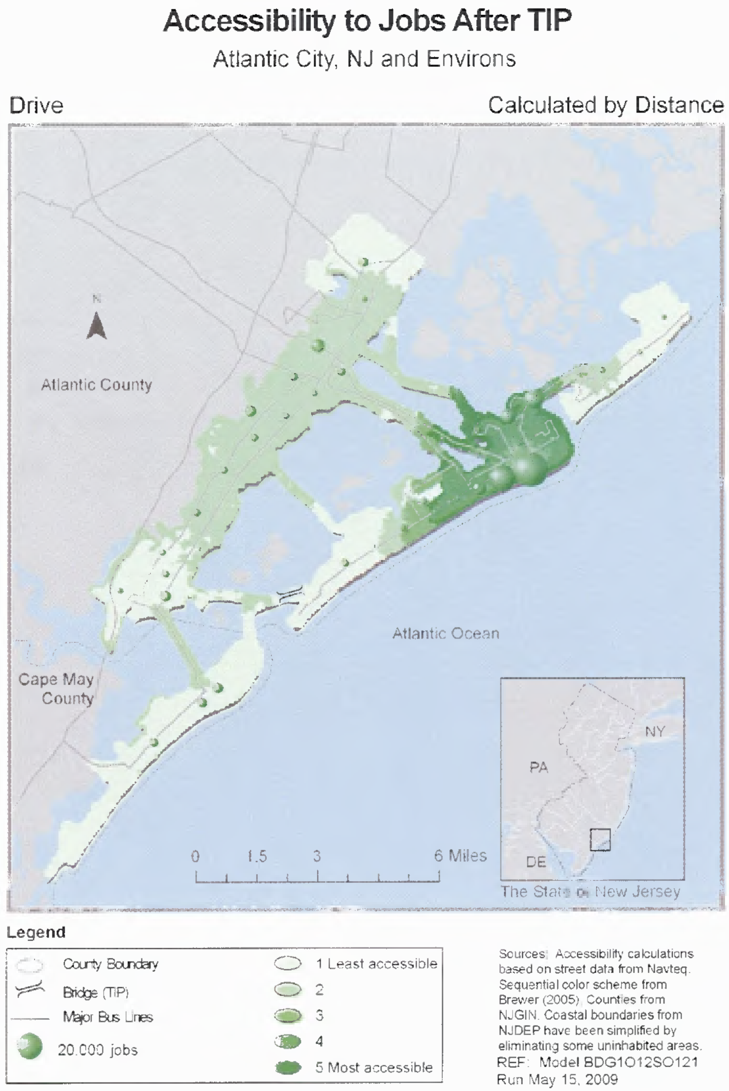


Figure H7. Output of model BD1O12SO121

Figure H8. Output of model BD1O12SO122

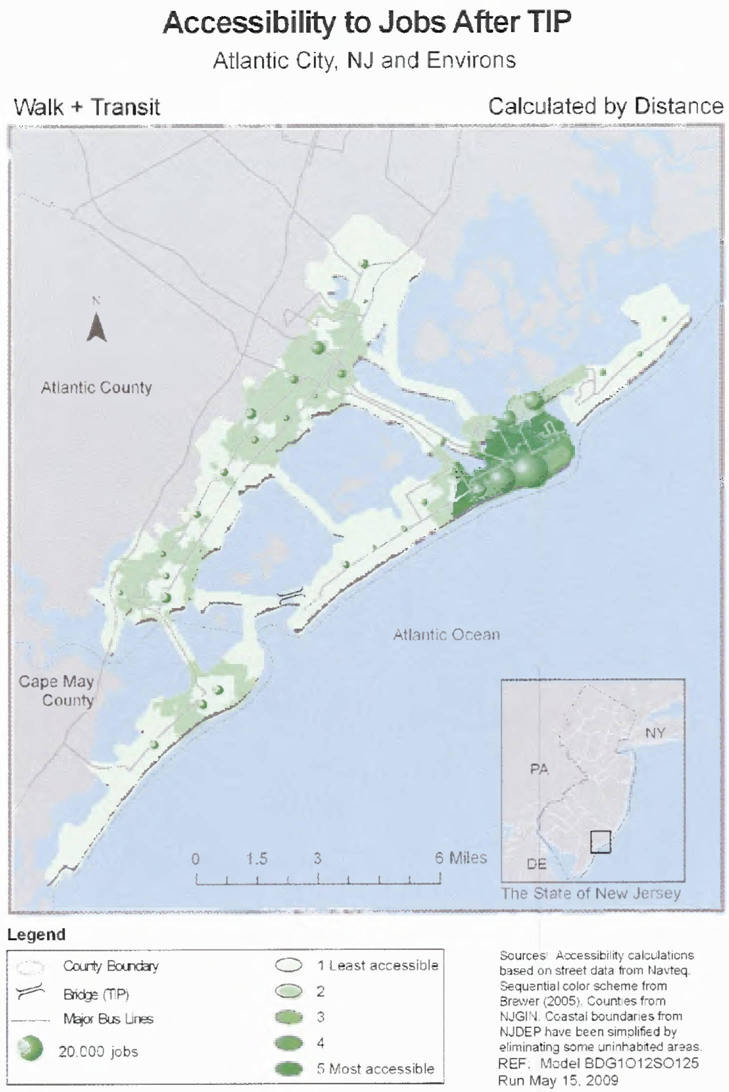


Figure H9. Output of model BD1O12SO125

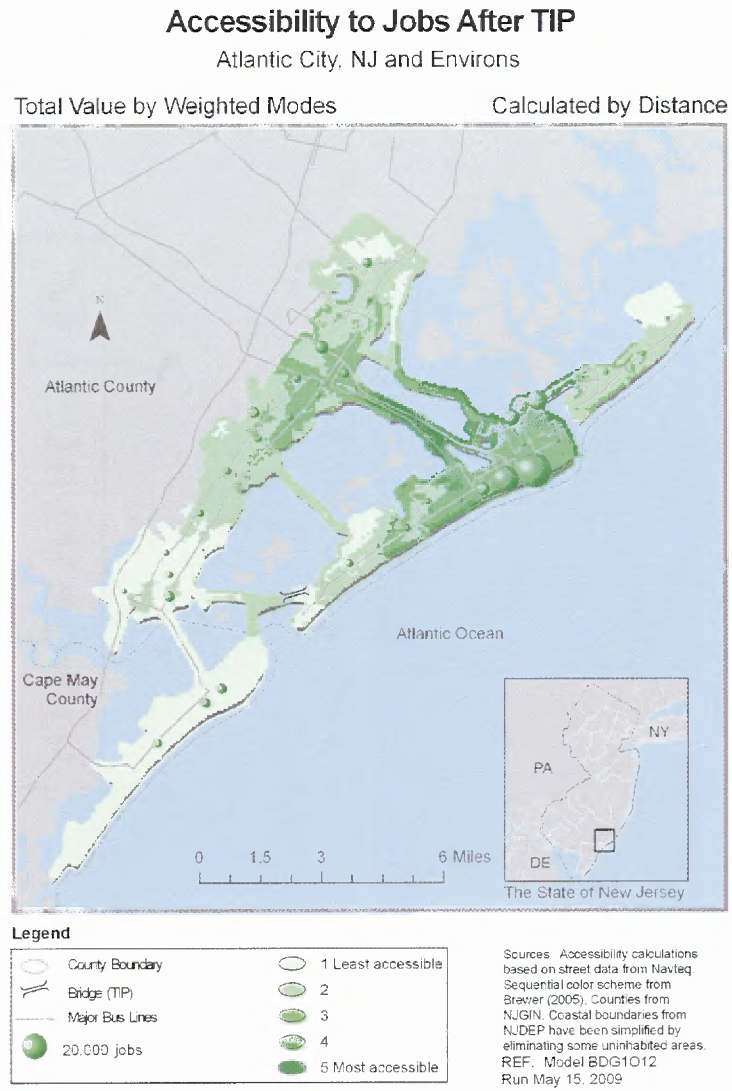


Figure H10. Output of model BD1O12

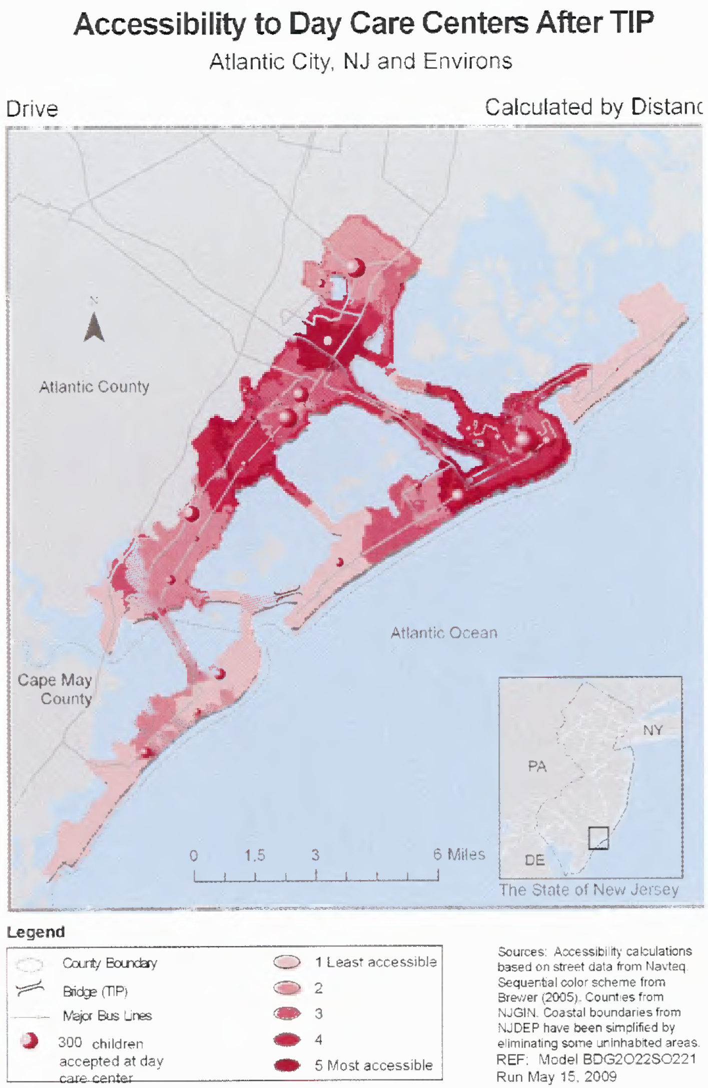


Figure H11. Output of model BD2O22SO221

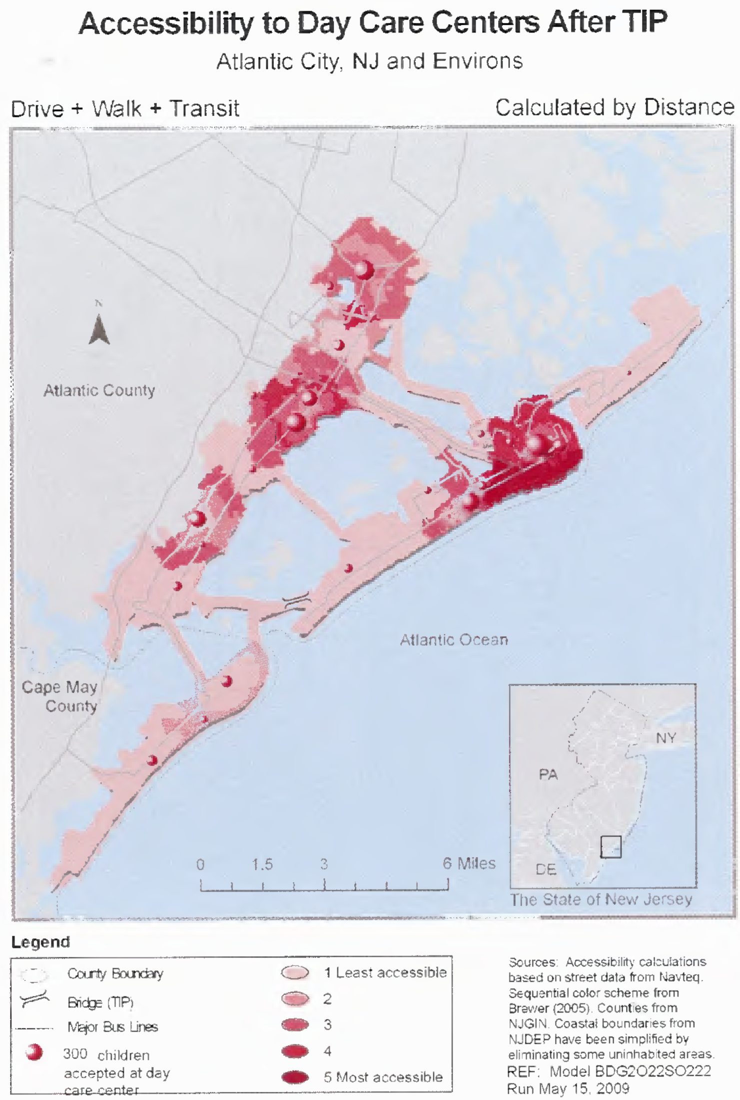


Figure H12. Output of model BD2O22SO222

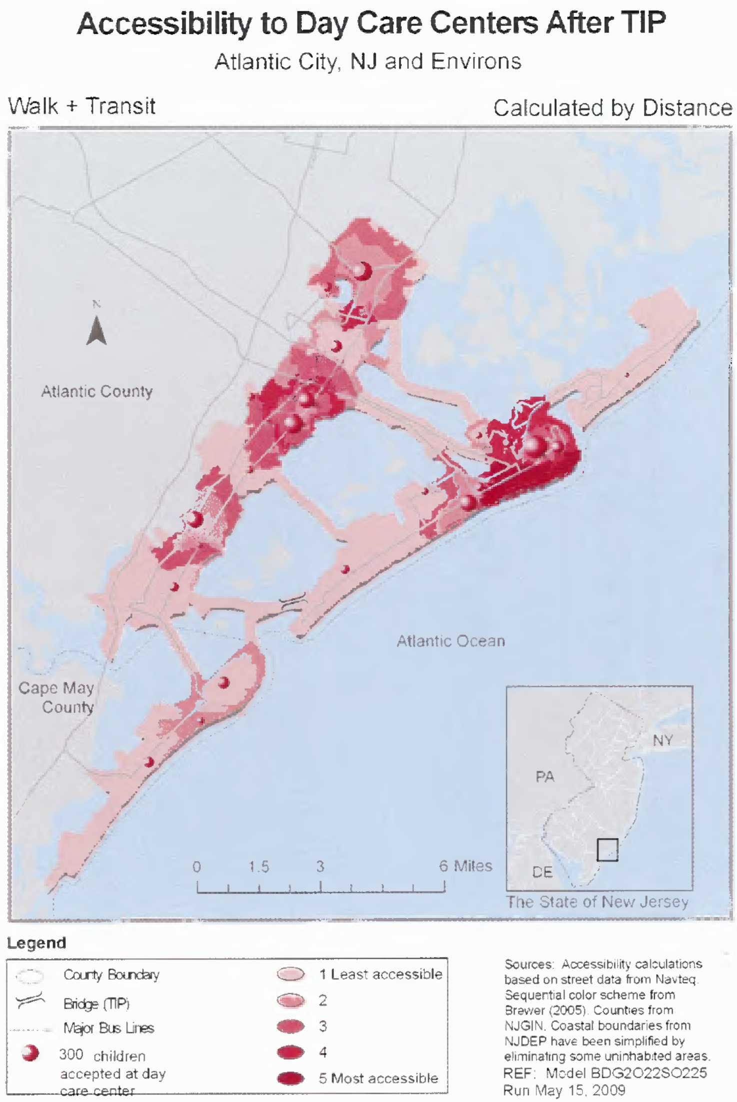


Figure H13. Output of model BD2O22SO225

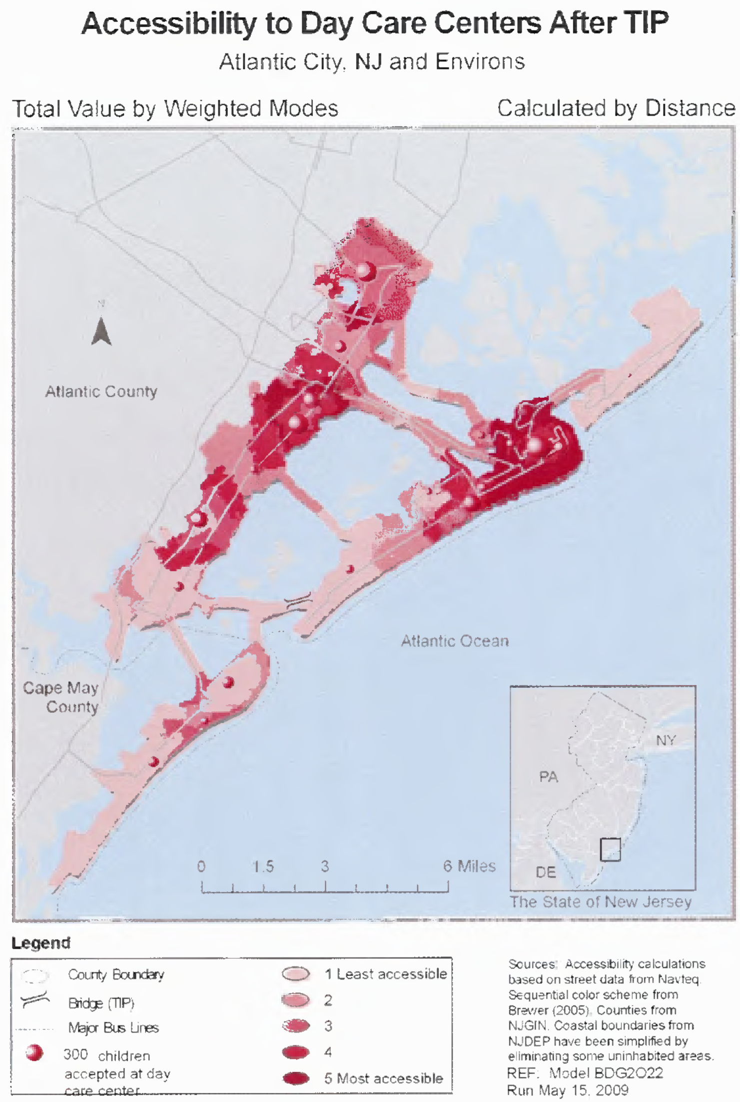


Figure H14. Output of model BD2O22

Figure H15. Output of model MA1O11SO111

Figure H16. Output of model MA1O11SO112

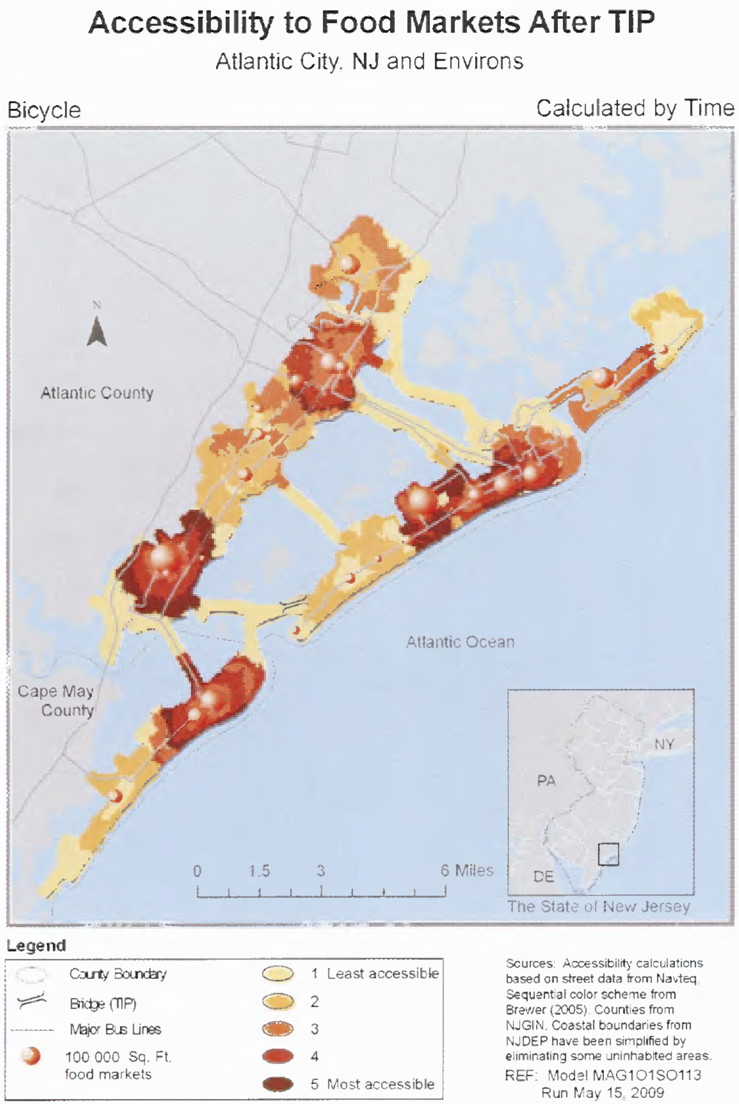


Figure H.17 Output of model MA1O11SO113

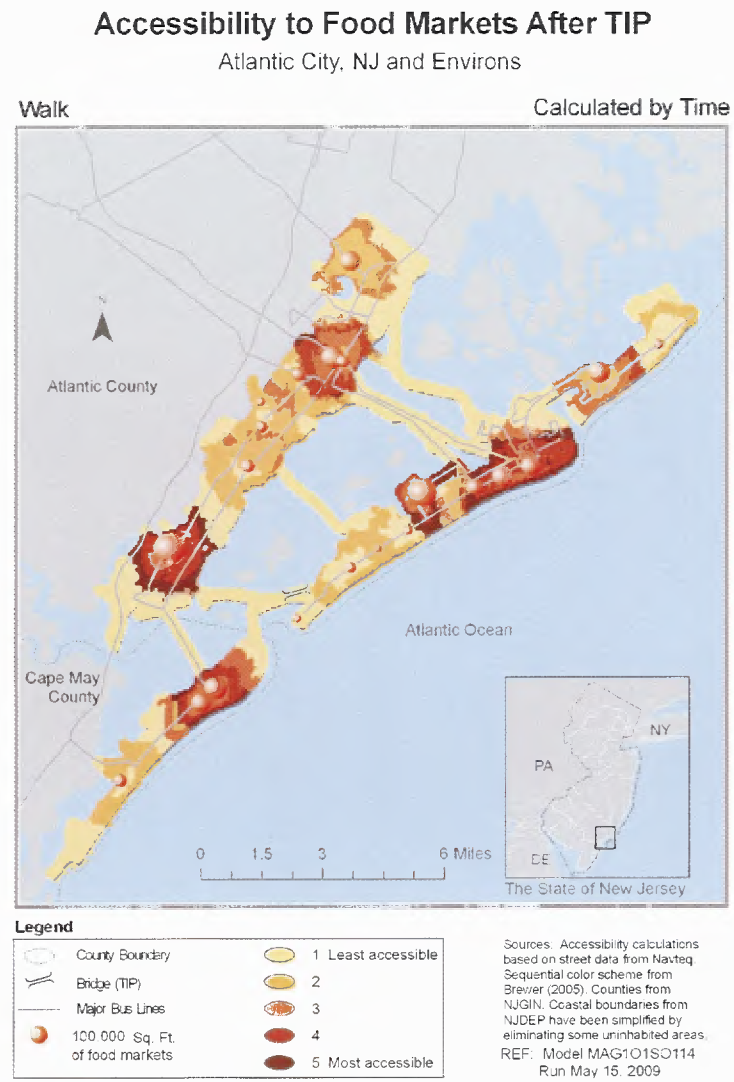


Figure H18 Output of model MA1O11SO114

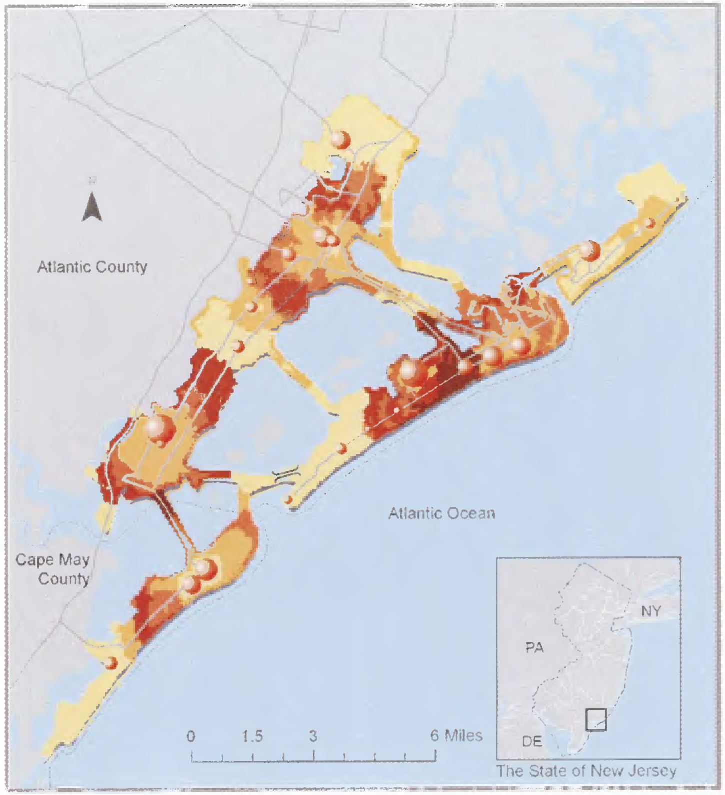
Figure H19. Output of model MA1O11SO115

Figure H20. Output of model MA1O11

Accessibility to Food Markets After TIP

Atlantic City, NJ and Environs

Drive — Calculated by Distance



Legend

County Boundary
Bridge (TIP)
Major Bus Lines
100,000 sq. ft. food market
1 Least accessible
2
3
4
5 Most accessible

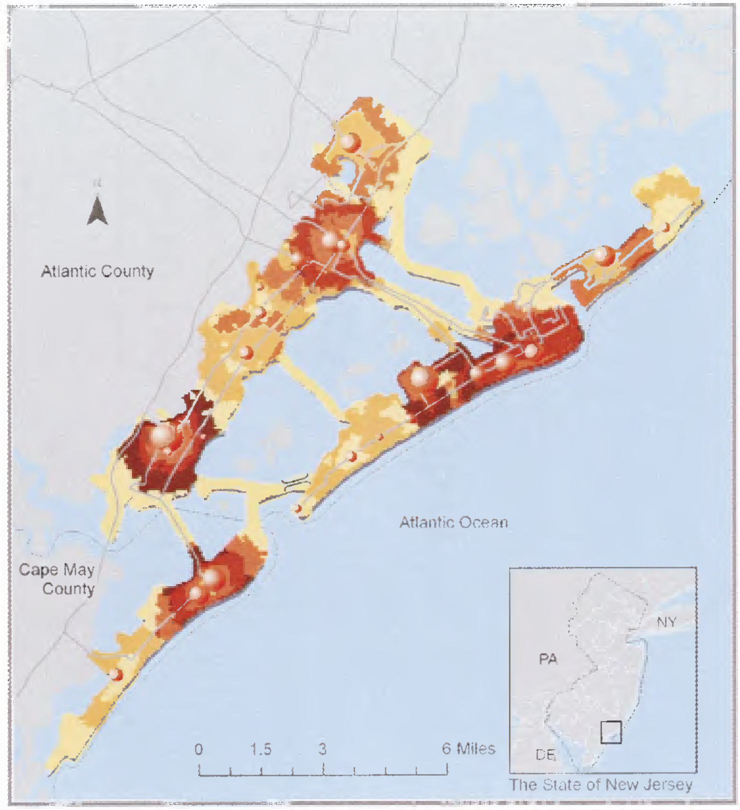
Sources: Accessibility calculations based on street data from Navteq. Sequential color scheme from Brewer (2005). Counties from NJGIN. Coastal boundaries from NJDEP have been simplified by eliminating some uninhabited areas.
REF: Model MAG1O12SO121
Run May 15, 2009

Figure H21. Output of model MA1O12SO121

Accessibility to Food Markets After TIP

Atlantic City, NJ and Environs

Drive + Walk + Transit — Calculated by Distance



Legend

County Boundary
Bridge (TIP)
Major Bus Lines
100,000 sq. ft. food market
1 Least accessible
2
3
4
5 Most accessible

Sources: Accessibility calculations based on street data from Navteq. Sequential color scheme from Brewer (2005). Counties from NJGIN. Coastal boundaries from NJDEP have been simplified by eliminating some uninhabited areas.
REF: Model MAG1O12SO122
Run May 15, 2009

Figure H22. Output of model MA1O12SO122

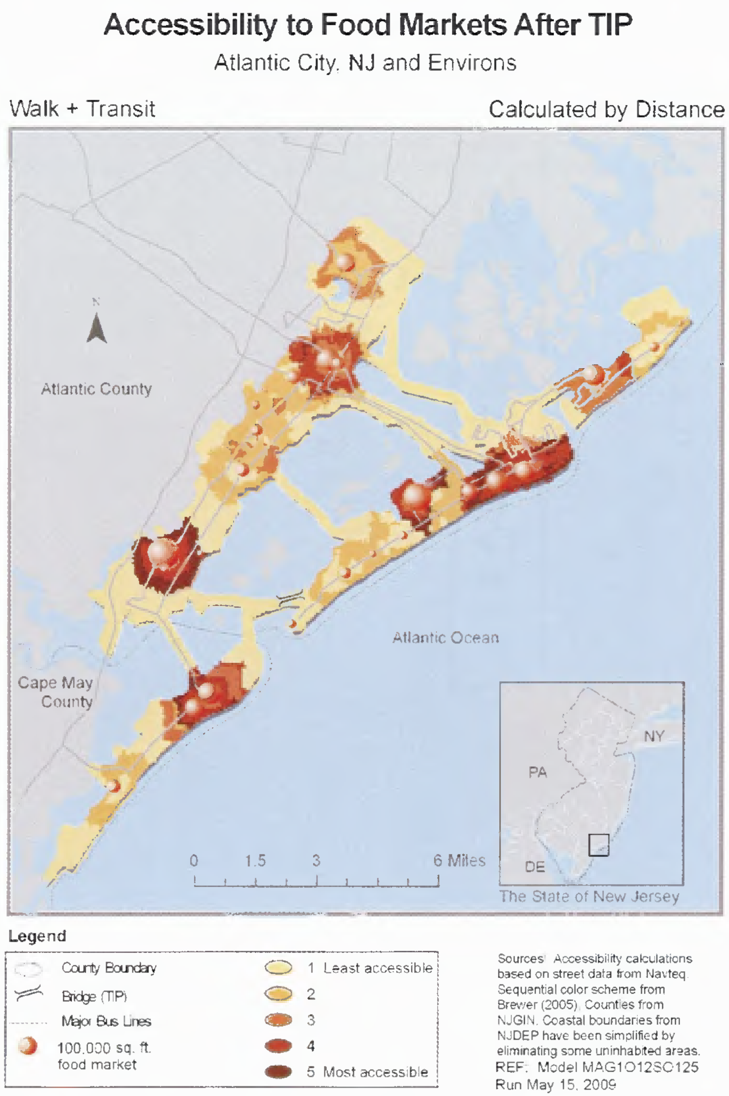


Figure H23. Output of model MA1O12SO125

Figure H24. Output of model MA1O12

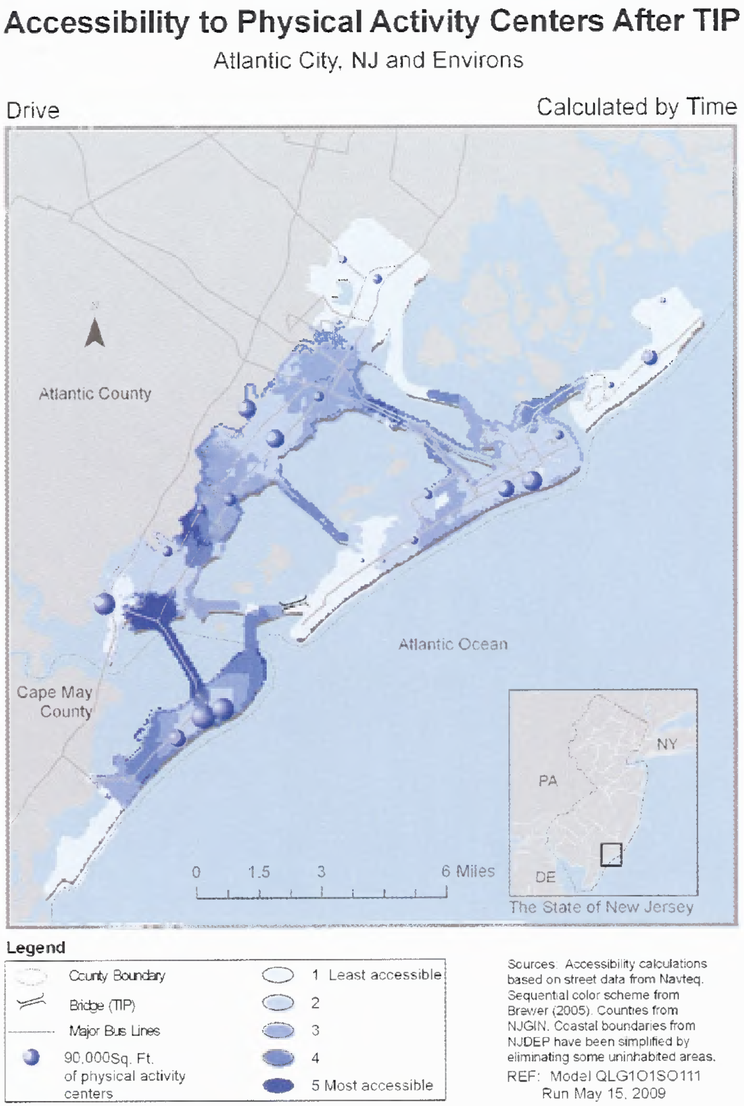


Figure H25. Output of model QL1O11SO111

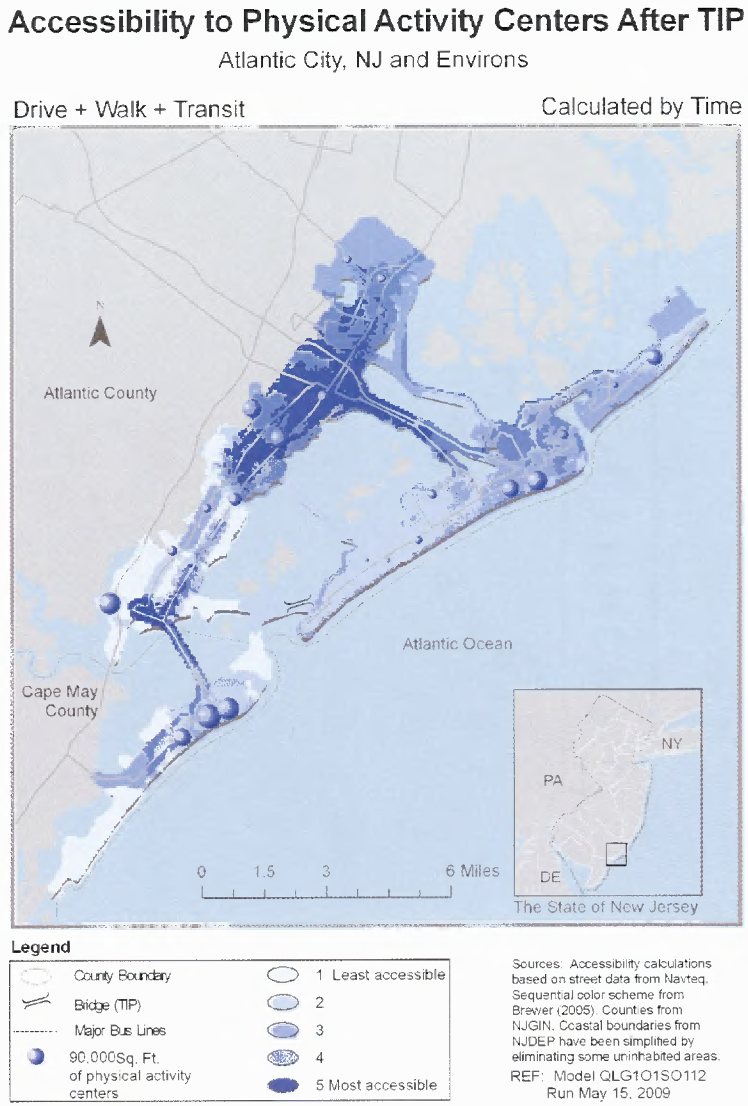


Figure H26. Output of model QL1O11SO112

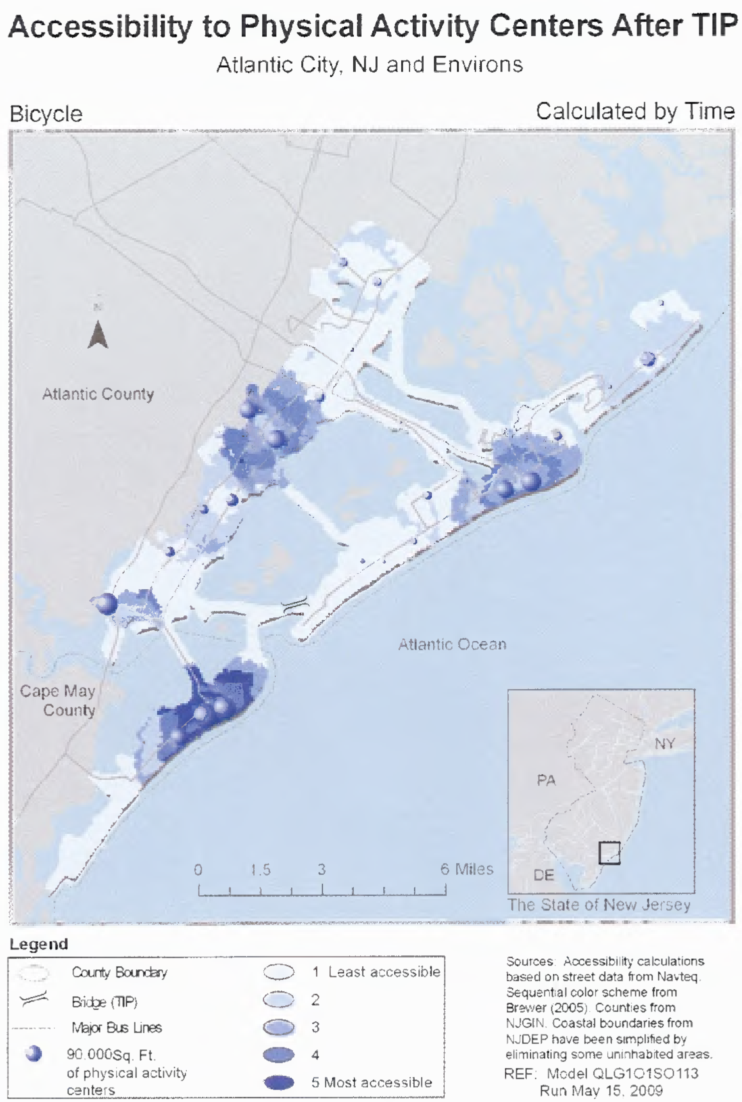


Figure H27. Output of model QL1O11SO113

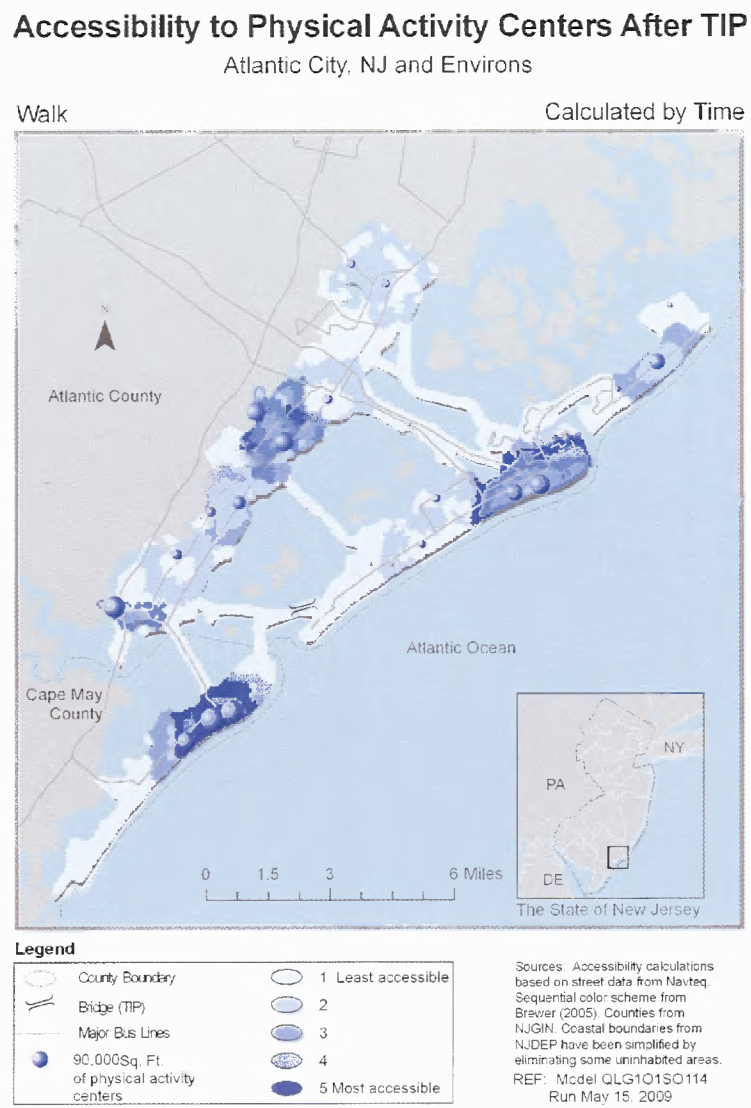


Figure H28. Output of model QL1O11SO114

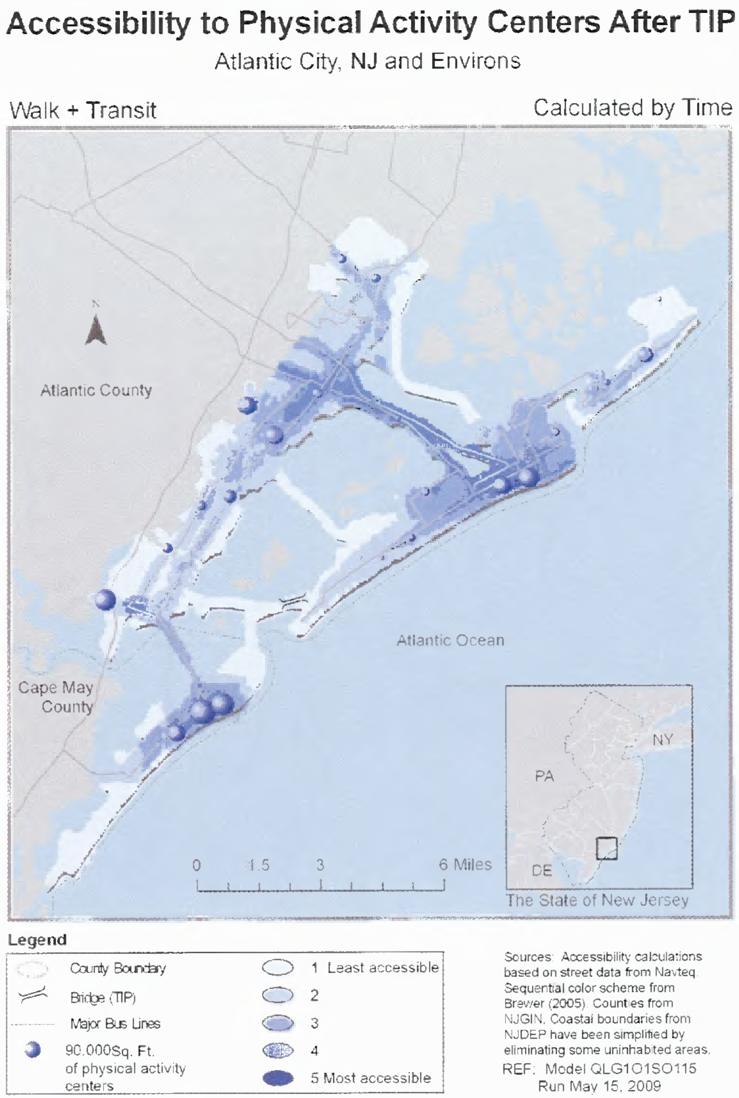


Figure H29. Output of model QL1O11SO115

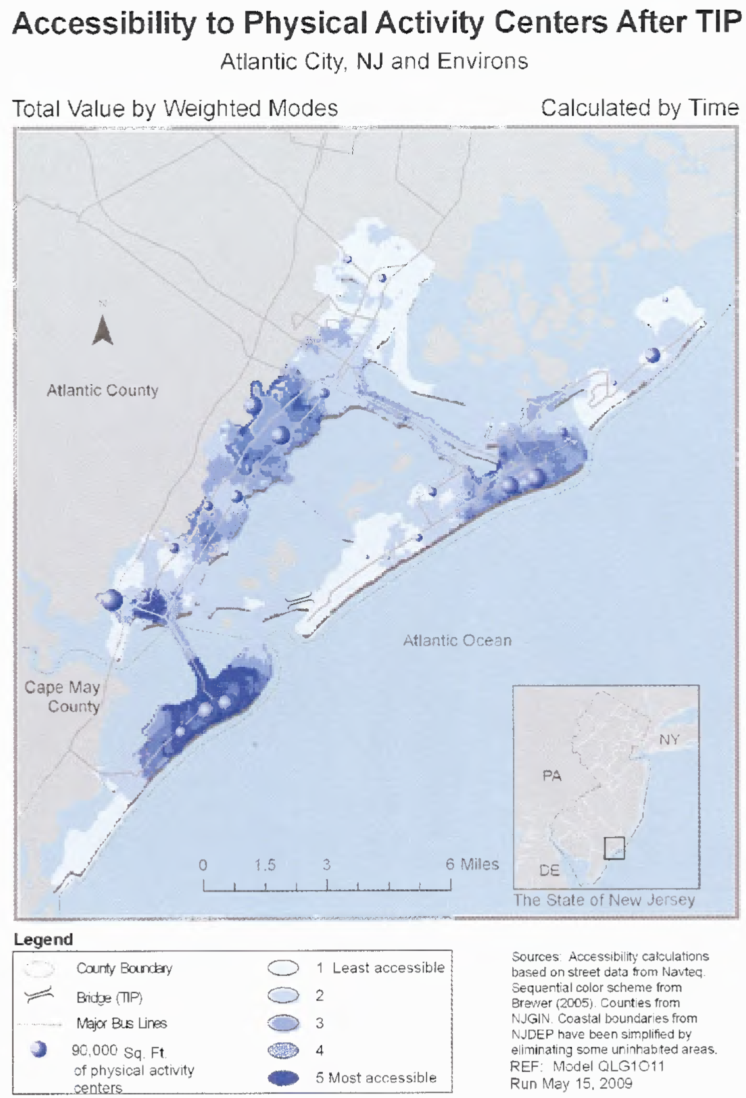


Figure H30. Output of model QL1O11

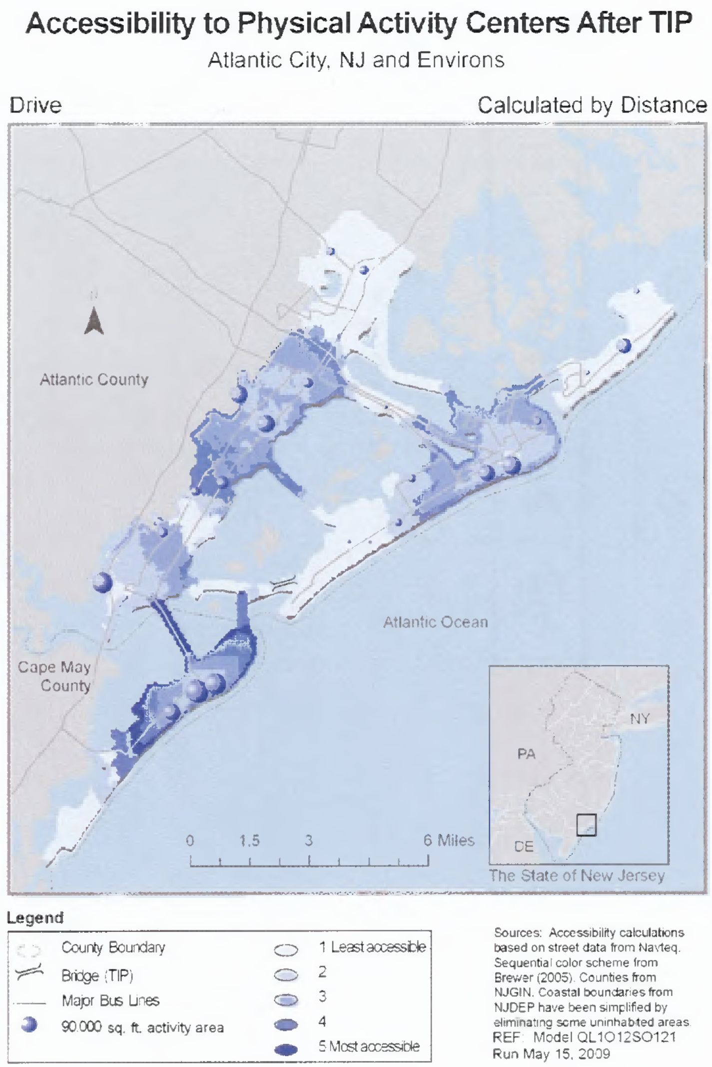


Figure H31. Output of model QL1O12SO121

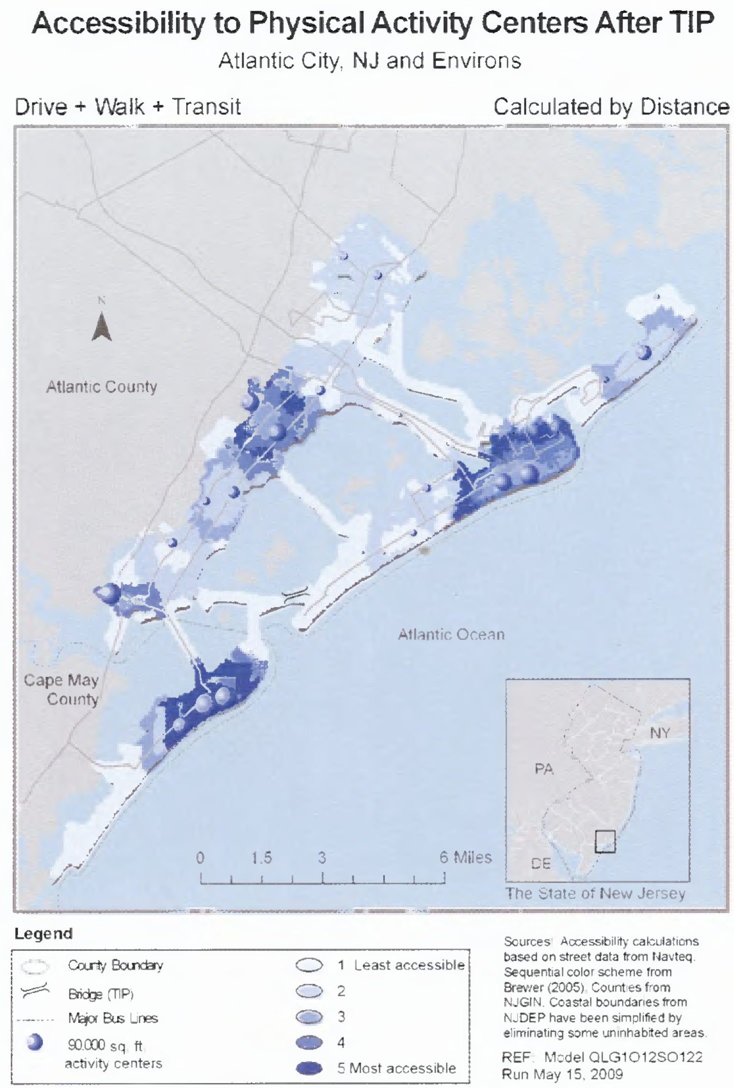


Figure H32. Output of model QL1O12SO122

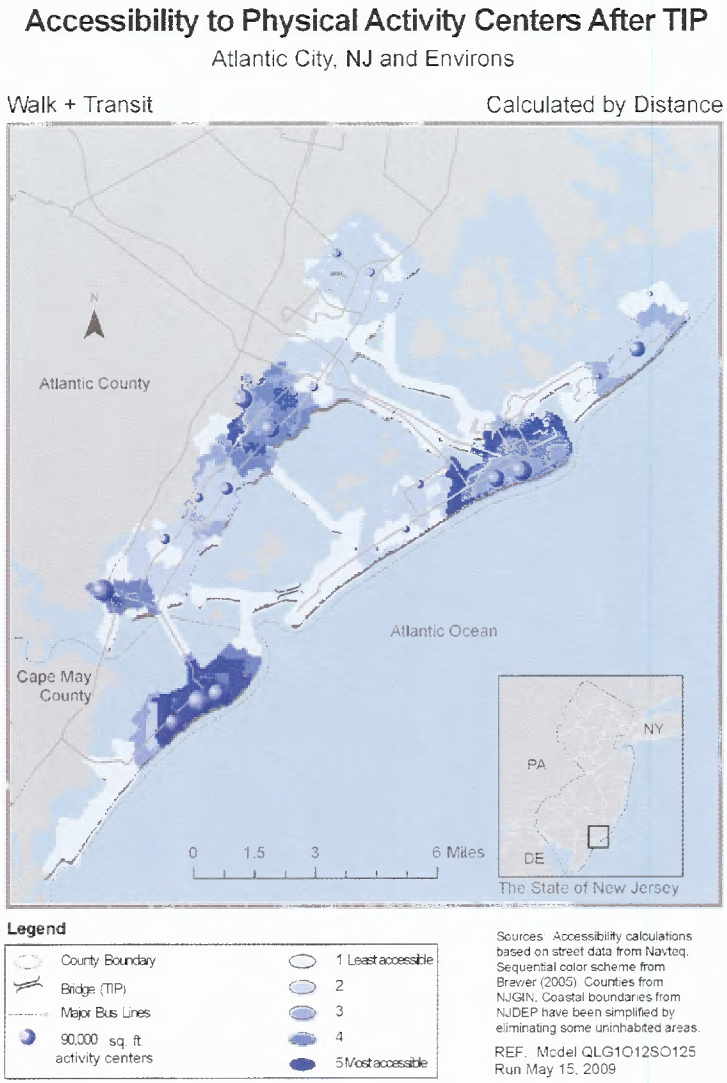


Figure H33. Output of model QL1O12SO125

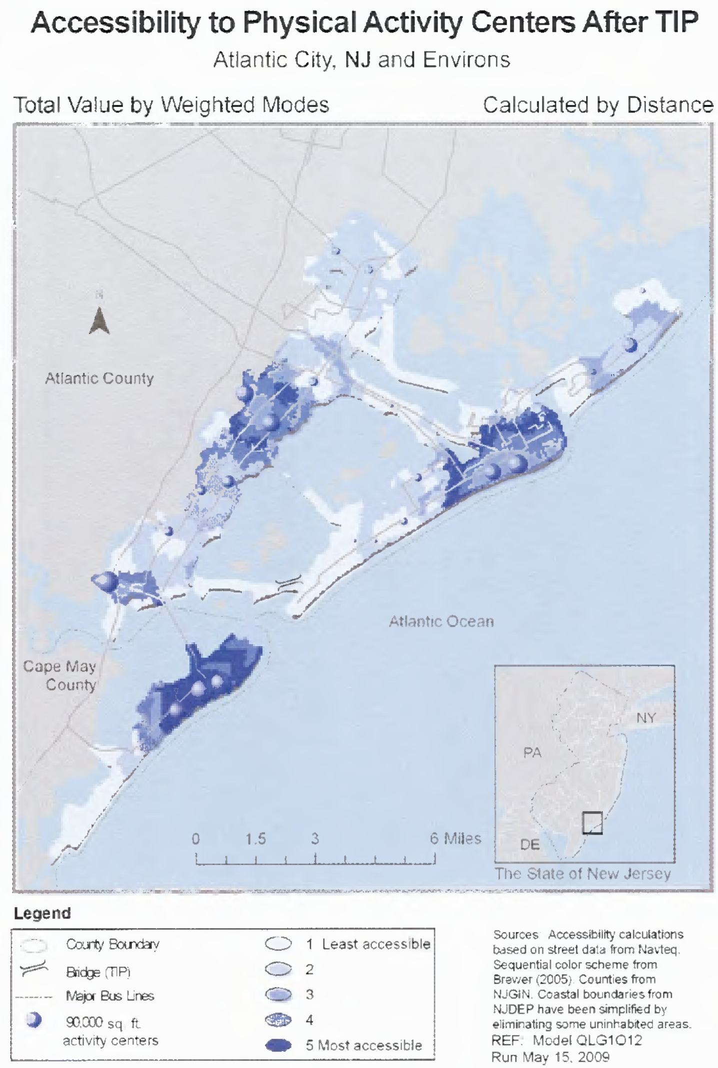


Figure H34. Output of model QL1O12

Accessibility to Jobs and Day Care Centers After TIP

Atlantic City, NJ and Environs

Total value by weighted modes Calculated by Time

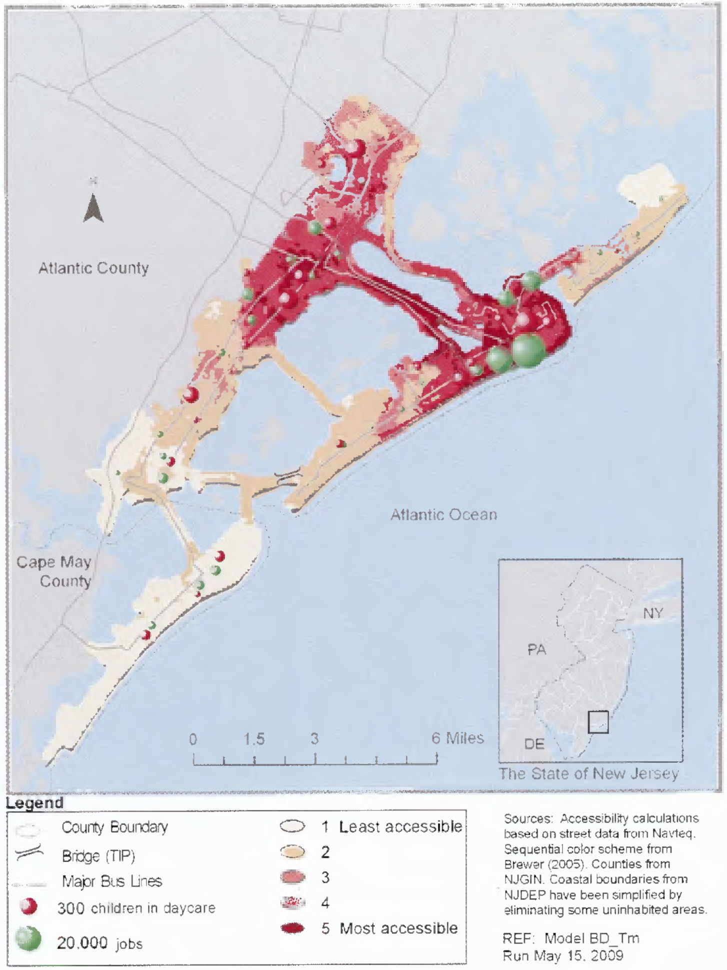


Figure H35. Output of model BD_Tm

Accessibility to Jobs and Day Care Centers After TIP

Atlantic City, NJ and Environs

Total Value by Weighted Modes Calculated by Distance

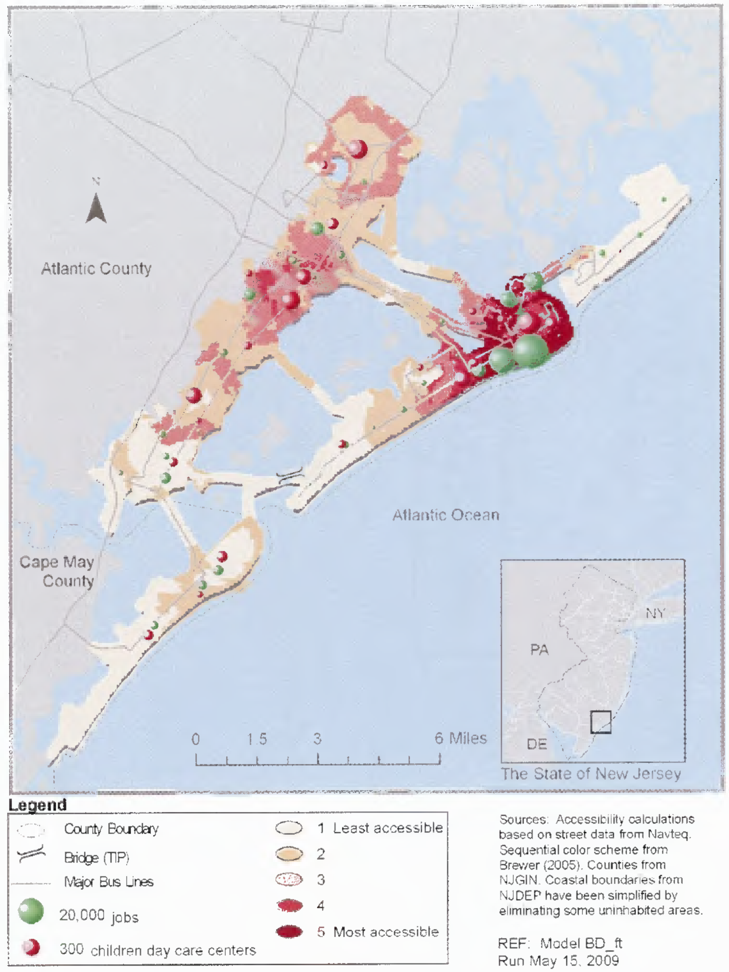


Figure H36. Output of model BD_Ft

Figure H37. Output of model Acc_Tm

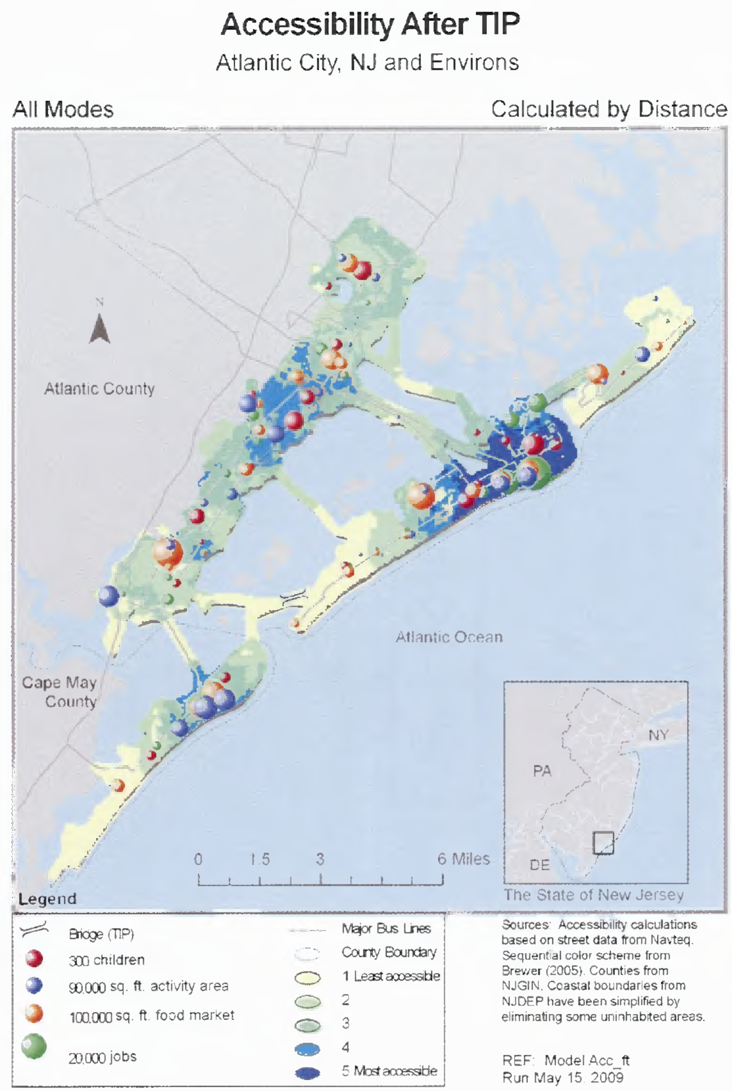


Figure H38. Output of model Acc_Ft

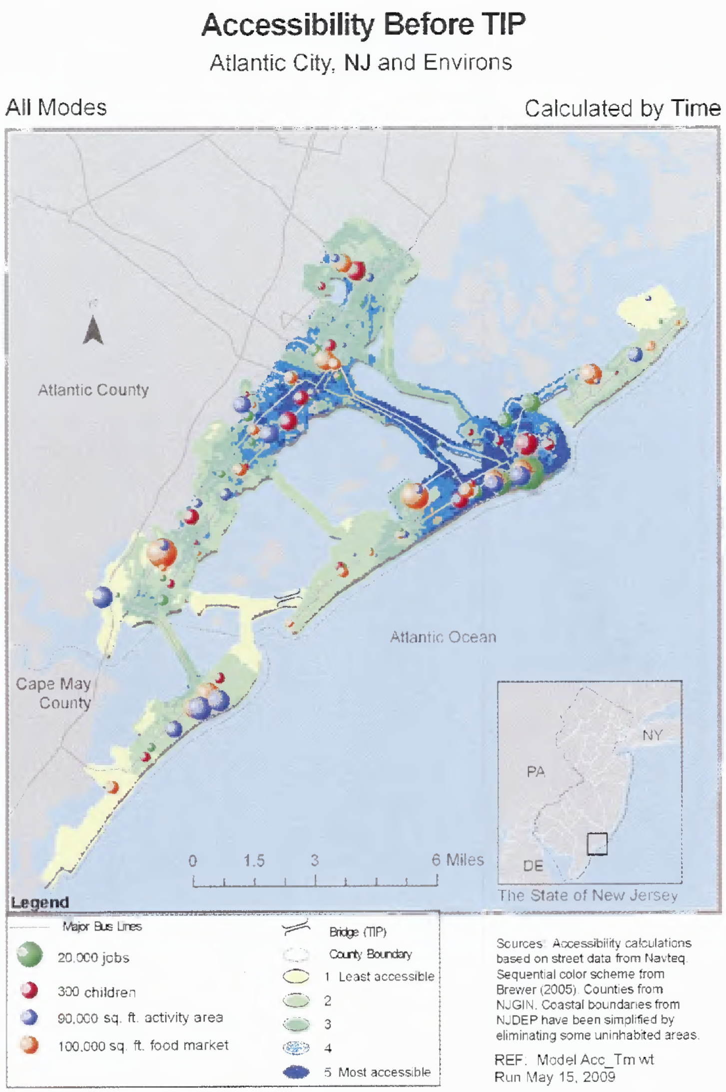


Figure H39. Output of model Acc_Tmwt

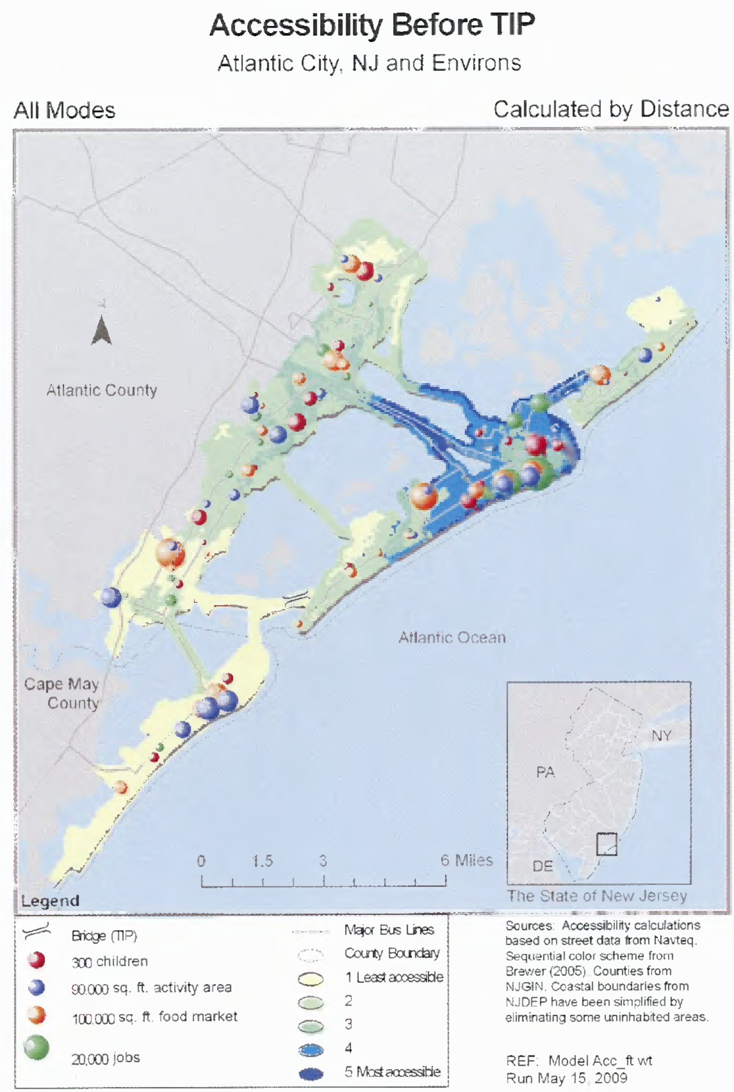


Figure H40. Output of model Acc_Ftwt

APPENDIX I

IRB CONSENT FORM

The following consent form, pre-approved by an IRB process, was signed by all interviewees for this dissertation.

NEW JERSEY INSTITUTE OF TECHNOLOGY
323 MARTIN LUTHER KING BLVD.
NEWARK, NJ 07102

CONSENT TO PARTICIPATE IN A RESEARCH STUDY
TITLE OF STUDY:
Accessibility in Metropolitan Transportation Planning: Developing a GIS measure for Geovisualization

RESEARCH STUDY:

I,______________________________, have been asked to participate in a research study under the direction of Dr(s). Lyna Wiggins, Karen Franck, Wansoo Im, Robert Czerniak. Other professional persons who work with them as study staff may assist to act for them.

PURPOSE:

This research has two goals. The fist goal is to construct a GIS-based measure (or a set of measures) of accessibility, using existing literature and new technology, based on data that is readily available through an MPO. The second goal is to develop a geovisualization tool (or a set of tools), that will support the understanding of accessibility issues to the general public, stakeholders and customers of an MPO.

DURATION:

My participation in this study will last for _____I hour_.

PROCEDURES:

I have been told that, during the course of this study, I will be asked open ended questions on how accessibility is measured in my organization.

PARTICIPANTS:

I will be one of about ______6_____participants in this study.

EXCLUSIONS:

I will inform the researcher if any of the following apply to me:

I do not know the answer to the question asked.

RISKS/DISCOMFORTS:

I have been told that the study described above does not involve any risks and/or discomforts.

There also may be risks and discomforts that are not yet known.

I fully recognize that there are risks that I may be exposed to by volunteering in this study which are inherent in participating in any study; I understand that I am not covered by NJIT's insurance policy for any injury or loss I might sustain in the course of participating in the study.

CONFIDENTIALITY:

I understand confidential is not the same as anonymous. Confidential means that my name will not be disclosed if there exists a documented linkage between my identity and my responses as recorded in the research records. Every effort will be made to maintain the confidentiality of my study records. If the findings from the study are published, I will not be identified by name. My identity will remain confidential unless disclosure is required by law.

VIDEOTAPING/AUDIOTAPNG: (NEED TO INCLUDE ONLY IF APPLICABLE)

I understand that I will be audio taped during the course of this study. Audio tapes will be stored for I year after the end of this project (expected October 2008). After that time, the tapes will be erased by recording over my recorded sessions.

The tapes will be stored in a locked office at NJIT and will not be made available to anyone except Lyna Wiggins, Rutgers University, Karen Franck, NJIT, Wansoo Im, UMDNJ, Robert Czerniak, NMSU and Aditi Sarkar, NJIT who are involved in this research.

PAYMENT FOR PARTICIPATION:

I have been told that I will receive $____0_____ compensation for my participation in this study.

RIGHT TO REFUSE OR WITHDRAW:

I understand that my participation is voluntary and I may refuse to participate, or may discontinue my participation at any time with no adverse consequence. I also understand that the investigator has the right to withdraw me from the study at any time.

INDIVIDUAL TO CONTACT:

If I have any questions about my treatment or research procedures, I understand that I should contact the principal investigator at:

Lyna Wiggins, Bloustein School of Planning and Public Policy, Rutgers University,
Civic Square Building, 33 Livingston Avenue, New Brunswick, NJ 08901,
Tel: (732)932 5475, email: lyna@rci.rutgers.edu

Aditi Sarkar
Urban Systems, University Heights
NJIT

Newark, NJ 07102
Tel: (505) 571 2406, email: accessresearcher@hotmail.com

If I have any addition questions about my rights as a research subject, I may contact:

Dawn Hall Apgar, PhD, IRB Chair
New Jersey Institute of Technology
323 Martin Luther King Boulevard
Newark, NJ 07102
(973) 642-7616
dawn.apgar@njit.edu

SIGNATURE OF PARTICIPANT

I have read this entire form, or it has been read to me, and I understand it completely. All of my questions regarding this form or this study have been answered to my complete satisfaction. I agree to participate in this research study.

Subject Name:____

Signature:____

Date:_________________________

APPENDIX J

DISCLOSURE OF FINANCIAL RELATIONSHIPS

The following form was filled out to disclose that that there were no financial relationships between the organizations studied in this dissertation and the investigators.

The following form must be completed by all Principal Investigators and members of the research team. Please use a separate form for each person.

Date:_____July 16, 2007_____________

Name (Print): ____Aditi Sarkar_________________________________

This form shall be completed by all members of the research team.

1. Funding Source. Does the research involve financial relationships that could create potential or actual conflicts of interest?

Yes
No

How is the research supported or financed?

____

____

2. Payment for Services. Are you receiving any salary and other payment for services (e.g., compensation in the form of equipment, consulting fees; honoraria, study design; management position, independent contractor, service on advisory committees or review panels for for-profit entities, board membership of for-profit entities; seminars, lectures or teaching engagements for for-profit entities) for this research?

Yes
No

If Yes, note amounts with explanation of source and activities:

____

____

If Yes, is this payment affected by the study outcome?

Yes
No

If Yes, explain:

____

____

Do you receive payment per participant or incentive payments?

Yes
No

If Yes, note amounts with explanation of terms.

3. Equity (Ownership) Interests. Do you have any and all equity interests or ownership interests (e.g. stock, stock options, partner) in entities related to the research activity?

Yes
No

If Yes, note amount with explanation of source:

4. Other Financial Interests or Relationships. Do you have any financial interests in the product, including patents, trademarks, copyrights, or licensing agreements?

Yes
No

If Yes, note amount with explanation of source:

5. Incentives. If involved in any research activity will you receive any money, gift or anything of monetary value above and beyond the actual costs of enrollment, conduct of the research, and reporting on the results, including, but not limited to, finders fees, referral fees, recruitment bonuses, an enrollment bonus for reaching an accrual goal or similar types of payments?

Yes
No

If Yes, note amount with explanation of source:

6. Other. Are there any other interests or relationships (including volunteer services) that might constitute a conflict of interest or an appearance of conflict of interest in connection with the research project?

Yes
No

If Yes, note amount with explanation of source:

APPENDIX K

IRB APPROVAL

The following approval was obtained from the Institution Review Board for continuing research for second year.

Institutional Review Board: HHS FWA 00003246
Notice of Approval
IRB Protocol Number: E101-07

Principal Investigator: Aditi Sarkar and Karen Franck, Urban Systems

Title: Accessibility in Metropolitan Transportation Planning: Visualizing a GIS Measure for Collaborative Planning

Performance Site(s): Off-Site Sponsor Protocol Number (if applicable):

Type of Review: FULL [ ] EXPEDITED [X]

Type of Approval: NEW [ ] RENEWAL [X] REVISION [ ]

Approval Date: July 30, 2008 Expiration Date: July 29, 2009

1. ADVERSE EVENTS: Any adverse event(s) or unexpected event(s) that occur in conjunction with this study must be reported to the IRB Office immediately (973) 642-7616.

2. RENEWAL: Approval is valid until the expiration date on the protocol. You are required to apply to the IRB for a renewal prior to your expiration date for as long as the study is active. It is your responsibility to ensure that you submit the renewal in a timely manner.

3. CONSENT: All subjects must receive a copy of the consent form as submitted. Copies of the signed consent forms must be kept on file with the principal investigator.

4. SUBJECTS: Number of subjects approved: 18.

5. The investigator(s) did not participate in the review, discussion, or vote of this protocol.

6. APPROVAL IS GRANTED ON THE CONDITION THAT ANY DEVIATION FROM THE PROTOCOL WILL BE SUBMITTED, IN WRITING, TO THE IRB FOR SEPARATE REVIEW AND APPROVAL.

Dawn Hall Apgar, PhD, LSW, ACSW, Chair IRB July 30, 2008

APPENDIX L

NAVTEQ APPROVAL

The following legal document was signed with Navteq, a private digital map producer to use their street data for developing the accessibility measuring application for this dissertation.

NAVTEQ ¶

¶

NON-DISCLOSURE·AND·EVALUATION·AGREEMENT·(North·America)¶

¶

This·Evaluation·Agreement·(the·"Agreement"),·dated·as·of·the·latest·date·of·signature·below·(the·"Effective·Date"),·is·between·NAVTEQ·North·America,·LLC,·a·Delaware·limited·liability·company·(together·with·its·parent·company·and·its·parent·company's·subsidiaries,·"NT"),·and·the·person·or·entity·identified·in·the·signature·line·below·("Company").¶

¶

1. → License.··With·respect·to·each·Schedule·attached·hereto:··NT·grants·Company·the·non-exclusive,·non-transferable,·non-sublicensable,·restricted·right,·for·the·Term·set·forth·in·the·Schedule,·to·use·and·evaluate·the·data,·software,·documentation·or·other·items·or·information,·in·each·case·as·described·under·each·Schedule·hereto·(the·"NT·Materials")·solely·for·the·Business·Purpose·defined·in·the·Schedule·(the·"Business·Purpose"),·which·is·incorporated·herein·by·reference.··Unless·Company·enters·into·a·separate·agreement·with·NT·which·specifically·extends·the·Term,·or·Company·signs·a·license·agreement·with·NT·which·allows·Company·to·retain·the·NT·Materials,·Company·will,·within·ten·business·days·after·the·expiration·of·the·Term,·return·all·such·NT·Materials,·or·certify·in·writing·that·all·such·NT·Materials·have·been·destroyed.¶

2. → Term·and·Termination.··The·term·of·this·Agreement·shall·commence·on·the·Effective·Date·and·shall·expire·on·the·later·of·the·third·anniversary·thereof·or·the·latest·date·of·expiration·or·termination·of·any·Schedule·entered·into·prior·to·such·third·anniversary.··NT·may·terminate·this·Agreement·and/or·any·Schedule·at·any·time·in·the·event·of·any·breach·by·Company.··The·obligations·described·in·Sections·3·and·5·shall·continue·for·five·(5)·years·from·the·date·of·disclosure·and·shall·survive·any·earlier·termination·of·the·Agreement.¶

3. → Restrictions.··Company·shall·not·copy·or·reproduce·any·NT·Materials,·except·with·NT's·prior·written·authorization.··Company·shall·not·disclose,·publish,·sell,·transfer,·distribute·or·otherwise·reveal·any·NT·Materials·to·any·third·party·whatsoever,·except·with·NT's·prior·written·authorization.··Company·shall·not·disassemble,·decompile·or·otherwise·reverse·engineer·any·NT·Materials.··¶

4. → Ownership/Assignment.··NT·is·the·owner·of·the·NT·Materials·and·derivations·therefrom,·including·all·intellectual·property·rights·thereto.··Nothing·stated·herein·shall·be·deemed·to·grant,·transfer,·assign·or·set·over·unto·Company·any·right,·title,·interest·or·ownership·of·the·NT·Materials,·all·of·which·is·hereby·expressly·reserved·by·NT.··Company·may·not·assign·its·rights·or·obligations·under·this·Agreement.¶

5. → Confidentiality.··In·addition·to·the·NT·Materials·provided·under·this·Agreement·and·identified·in·a·Schedule,·NT·and·Company·possess·and·may·provide·to·each·other·certain·other·confidential·and·proprietary·information·in·connection·with·the·discussion·and·evaluation·of·a·potential·business·relationship·relating·to·NT's·navigable·database·and·other·technology·and·information.··NT·and·Company·desire·that·any·such·information·provided·shall·be·kept·confidential·by·the·other·party;·and·each·party·is·willing·to·keep·the·other·party's·information·confidential·in·accordance·with·the·terms·and·conditions·set·forth·in·this·Agreement.¶

(a) → For·purposes·of·this·Agreement,·"Confidential·Information"·means·and·includes·any·and·all:·(i)·written·information·which·is·marked·or·identified·as·confidential·at·or·prior·to·the·time·of·disclosure,·and·(ii)·oral·or·visual·information·identified·as·confidential·at·the·time·of·disclosure·and·summarized·in·written·form·promptly·after·such·oral·or·visual·disclosure.¶

(b) → Each·party·further·agrees·to·use·the·same·means·it·uses·to·protect·its·own·confidential·and·proprietary·information,·but·in·any·event·not·less·than·reasonable·means,·to·prevent·disclosure·and·to·protect·the·confidentiality·of·Confidential·Information·received·from·the·other·party.¶

(c) → The·foregoing·shall·not·prevent·either·party·from·disclosing·Confidential·Information·which·belongs·to·such·party·or·which·(i)·is·in·or·becomes·part·of·the·public·domain·through·no·act·or·omission·of·the·receiving·party,·(ii)·can·be·demonstrated·by·the·receiving·party·as·being·known·to·the·receiving·party·previously,·(iii)·is·rightfully·obtained·by·the·receiving·party·from·a·third·party,·(iv)·is·independently·developed·by·the·receiving·party·without·use·of·the·other·party's·Confidential·Information,·(v)·is·required·to·be·disclosed·pursuant·to·a·requirement·of·a·governmental·agency·or·law·so·long·as·the·disclosing·party·provides·the·other·party·with·notice·of·such·requirement·prior·to·any·such·*disclosure.*¶

(d) → Except·as·expressly·set·forth·in·this·Agreement,·nothing·stated·herein·shall·be·construed·to·grant·or·confer·any··rights,·title,·or·ownership,·including·but·not·limited·to·intellectual·property·rights,·in·or·to·any·Confidential·Information·disclosed·hereunder.··The·parties·expressly·agree·that·the·provision·of·Confidential·Information·hereunder·and·discussions·held·in·connection·with·the·Business·Purpose·shall·not·prevent·either·party·from·pursuing·similar·discussions·with·third·parties·or·obligate·either·party·to·take,·continue,·or·forego·any·action·relating·to·the·Business·Purpose.··Any·estimates·or·forecasts·provided·to·the·other·party·shall·not·constitute·commitments.¶

¶
¶
¶
¶

6. → Disclaimer·and·Limitation.··COMPANY·ACKNOWLEDGES·THAT·NT·AND·ITS·LICENSORS·ARE·PROVIDING·THE·NT·MATERIALS·TO·COMPANY·"AS·IS"·AND·THAT·THE·NT·MATERIALS·ARE·NOT·NECESSARILY·REPRESENTATIVE·OF·ANY·CORRESPONDING·COMMERCIAL·PRODUCT·OF·NT.··NT·AND·ITS·LICENSORS·

NAVTEQ

MAKE NO GUARANTEES, REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE NT MATERIALS, EXPRESS OR IMPLIED, ARISING BY LAW OR OTHERWISE, INCLUDING BUT NOT LIMITED TO, EFFECTIVENESS, COMPLETENESS, ACCURACY OR FITNESS FOR A PARTICULAR PURPOSE. WITHOUT LIMITING THE FOREGOING, NT AND ITS LICENSORS EXPRESSLY DISCLAIM ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE AND ANY WARRANTY OF NON-INFRINGEMENT. NT AND ITS LICENSORS SHALL NOT BE LIABLE FOR ANY CLAIM, DEMAND OR ACTION, IRRESPECTIVE OF THE NATURE OF THE CAUSE THEREOF, OR FOR ANY LOSS, INJURY OR DAMAGES, DIRECT OR INDIRECT, INCLUDING WITHOUT LIMITATION, AMOUNTS REPRESENTING LOSS OF REVENUES OR PROFITS, LOSS OF BUSINESS OR CONTRACTS, PERSONAL INJURY, PRODUCT LIABILITY, PROPERTY DAMAGE OR INDIRECT, CONSEQUENTIAL OR PUNITIVE DAMAGES ARISING OUT OF COMPANY'S USE, POSSESSION OR EVALUATION OF THE NT MATERIALS OR FROM ANY DEFECT IN THE NT MATERIALS. NOTWITHSTANDING THE FOREGOING, IN NO EVENT SHALL NT'S LIABILITY WITH RESPECT TO THIS AGREEMENT EXCEED FIVE HUNDRED (500) DOLLARS.

7. <u>Indemnity</u>. Company agrees to indemnify and hold harmless NT and its licensors from and against any and all claims, liabilities, losses and expenses, including reasonable attorneys' fees, arising out of Company's use of the Information.

8. <u>Governing Law</u>. This Agreement shall be construed in accordance with the laws of the State of Illinois without giving effect to the conflict of laws provisions. The United Nations Convention of Contracts for the *International Sale of Goods* shall not apply to this Agreement.

9. <u>Export Law</u>: To the extent that any such export laws, rules or regulations prohibit NT from complying with any of its obligations hereunder, such failure shall be excused and shall not constitute a breach of this Agreement.

10. <u>Entire Agreement</u>. This Agreement together with its Schedules constitutes the entire agreement between the parties regarding the subject matter hereof and supersedes any and all prior negotiations, promises, commitments, undertakings and agreements of the parties relating thereto.

11. <u>Notices</u>. All notices required or permitted under this Agreement shall be delivered by hand, fax or nationally recognized overnight courier addressed if to NT and if to Company at the NT Address and the Company Address set forth in this Agreement. All such notices and other written communications shall be effective (1) if sent by overnight courier, two business days after mailing, and (2) if sent otherwise, upon delivery as evidenced by proof of receipt.

12. <u>Equitable Relief</u>. Nothing in this Agreement shall prevent the Disclosing Party from seeking appropriate equitable relief, in addition to whatever remedies it may have at law, for any and all of the Receiving Party's breaches of its obligations under this Agreement.

13. <u>Modifications and Validity of Signature</u>. This Agreement is provided in a pre-printed or read-only electronic form published by NT. The provisions of this Agreement may be modified *only in writing and if signed* by duly authorized representatives of the parties which, in the case of NT, is an Officer of the corporation. General Managers (under that title) of business units of NT are authorized to sign this Agreement in its unmodified form. In the event that this Agreement contains modifications and is signed by a NT Business Unit Manager or other employee, agent or other representative of NT other than an Officer, such modifications shall be null and void and this Agreement shall be construed as if such modifications had not been made.

Company: N/A	NAVTEQ North America, LLC
By (signature): ______________________	By: ______________________
Name (print): Aditi Sarkar	Name (print): Lawrence M. Kaplan
Title: Student of NJ Institute of Technology	Title: EVP, GC & Corporate Secretary
Date: Dec 22, 2008	Date: ______________________
Address for Legal Notices:	Address for Legal Notices: NAVTEQ Attention: Legal 425 West Randolph Street Chicago, Illinois 60606 Legal Fax No.: (312)894-7228
Street: P.O. Box 2052	
City, State, Zip: Las Cruces, NM 88004	
Attention: Aditi Sarkar	
Phone #: 575 571 2406	
Fax #: 575 522 5166	☐ EXPORT CONTROL CHECK
NT Requester: ▯▯▯▯▯	Date: ▯▯▯▯▯ By: ▯▯▯▯▯

Page Break

NAVTEQ

Evaluation Schedule No. ___ (Standard)

This Schedule to the Evaluation Agreement identified below between NAVTEQ North America, LLC ("NT") and Company is made and entered into as of the Effective Date set forth below.

1. Company: N/A
2. Date of Evaluation Agreement: As of latest date of signature on the Evaluation Agreement.
3. Effective Date of this Schedule: Dec 22, 2008
4. Term: A period of three (3) months commencing on the Effective Date.
5. Business Purpose: Evaluation of NAVTEQ Materials for possible use in Company's application.
6. NAVTEQ Materials to be provided:
   a.) Test & Taste Sample Data: ☐ North America ☐ Europe ☐ World Markets
   b.) North America Data Coverage Areas: (check applicable boxes, limit of 2)
      Parentheses denotes portions of states
      ☐ DCA1 CA, NV
      ☐ DCA2 AZ, CO, ID, MT, NM, OR, UT, WA, WY, (TX)
      ☐ DCA3 IA, KS, MN, MO, NE, ND, SD, (IL, MI, WI)
      ☐ DCA4 AR, LA, MS, OK, (TN, TX)
      ☐ DCA5 (IL, IN, MI, OH, WI)
      ☐ DCA6 KY, WV, (IN, MD, NY, OH, PA, TN)
      ☐ DCA7 CT, ME, MA, NH, RI, VT, (NJ, NY)
      ☒ DCA8 DE, DC, VA, (MD, NJ, NC, PA)
      ☐ DCA9 AL, FL, GA, SC, (NC)
      ☐ DCA10 Hawaii
      ☐ DCA11 Canada
   c.) Europe Data Coverage Areas: (check applicable boxes, limit of 2)
      ☐ Albania ☐ Austria/Switzerland ☐ Baltic States ☐ Benelux
      ☐ Bosnia-Herzegovina ☐ Bulgaria ☐ Croatia ☐ Czech Republic
      ☐ France ☐ Germany ☐ Great Britain/Ireland ☐ Greece
      ☐ Hungary ☐ Italy ☐ Kaliningrad ☐ Macedonia
      ☐ Poland ☐ Romania ☐ Scandinavia ☐ Serbia & Montenegro
      ☐ Slovak Republic ☐ Slovenia ☐ Spain/Portugal ☐ Turkey
      ☐ Other _____ _____
   d.) Map Voice Data: ☐ NAmerica ☐ Austria ☐ France ☐ Germany ☐ Great Britain ☐ Italy ☐ Spain ☐ Netherlands
   e.) Zagat Survey for NAVTEQ: ☐ Restaurant Guides ☐ Restaurant, Travel & Leisure Guides
   f.) ☐ Extended Listings, NAmerica
   g.) ☐ NAVTEQ Transport, United States
   h.) ☐ Core POIs, NAmerica
   i.) ☐ NAVTEQ Discover Cities, NAmerica
   j) ☐ Traffic Tables, NAmerica
   k.) ☐ NAVTEQ Traffic Patterns, United States
7. Format: ☐ GDF ☐ SIF+ ☐ ArcView ☐ MapInfo ☐ RDF ☐ ODF
8. Evaluation Fee: No fee shall apply to the NT Materials provided hereunder.
9. NAVTEQ Requester: _____

Company: N/A	NAVTEQ North America, LLC
By (signature): ______________________	By: ______________________
Name (print): Aditi Sarkar	Name (print): Lawrence M. Kaplan
Title: Student of NJIT	Title: EVP, GC & Corporate Secretary
Date: Dec 22, 2008	Date: ______________________
Address for Legal Notices: Street: P.O. Box 2052 City, State, Zip: Las Cruces, NM 88004 Phone #: 575 571 2406 Fax #: 575 522 5166	Address for Legal Notices: NAVTEQ Attention: Legal 425 West Randolph Street Chicago, Illinois 60606 Legal Fax No: (312) 894-7228
Shipping Address (if different from above): Street: _____ City, State, Zip: _____ Attention: _____ Phone #: _____	

APPENDIX M

MODEL TESTING

The suitability model used is tested for adequacy of the number of variables used to predict the value of accessibility in literature to those that are considered in this study

Table M.1 Variables Used to Measure Accessibility in Tool Compared to the Variables Used to Measure Accessibility in Literature by Measure Type

Table M.1 Variables Used to Measure Accessibility in Tool Compared to the Variable Used to Measure Accessibility in Literature by Measure Type

Accessibility Measure Type in Literature by	**Variable considered in Literature**	**Meets research requirements**	**Variable considered in Tool Developed**
Proximity-based Measure			
Brans, Engelen and Hubert (1981)	Network distance	Yes	Yes
Current, Revelle, Cohon (1987)	Minimization of both path (median distance) and travel time	Yes	Yes
Ingram (1971)	Relative accessibility, degree to which two places are connected	Yes	No
Gravity-Based Measure			
Hansen (1959)	Inverse to size of activity area	Yes	No
Ingram (1971)	Straight line and Manhattan distance based	Yes	No
Spatial Opportunity Measure			
Wachs and Kumagai (1973), Cerney (1973), Shen (1998)	Cumulative opportunity, Isochrone (number of opportunities within certain time)	Yes	No
Dalvi and Martin (1976)	Attractiveness of opportunities	Yes	Yes
Craig (1978)	Accessibility to road network, services, regional activities using suitability	Yes	Yes
Breheney (1978), Koenig (1980)	Weighted sum of facilities	Yes	Yes
Small (1992)	Attractiveness weighed by impedance	Yes	Yes
Arentze (1994)	Multipurpose, multi stop travel in agglomeration of facilities	Yes	No
Handy and Niemeier (1997)	Number of shops within certain time	Yes	No
O'Sullivan, Morrison and Shearer (2000)	Isochones for public transport	Yes	No
Thompson (2001)	Total number of	Yes	No

Accessibility Measure Type in Literature by	Variable considered in Literature	Meets research requirements	Variable considered in Tool Developed
	jobs by transit		
Shen (2002)	Number of jobs from home	Yes	No
Continued from previous page…			
Spatial Choice Measures			
Ben-Akiva and Lerman (1979)	Random utility - individual's travel decision process viewed as set of alternatives w/random components for non-predictable factors	No	No
Koenig (1980)	Random utility with particular probability distributions	No	No
Other Economics-Based Measure			
Guy (1977)	Cost of traveling to supply, impedance	Yes	Yes
Leonardi (1981)	Consumer surplus or net benefit as decreasing function of travel costs	Yes	Yes
Forkenbrock and Weisbrod (2001)	Cost of travel along with 3 other factors	Yes	Yes
Space Time Measures			
Miller (2004)	Urban activity prisms	No	No
Wu and Miller (2001)	Considers time variation in network	No	No
Harris (2001)	Competitive accessibility between opportunities	No	No
Berglund (2001)	Path-based measure with zonal weights	No	No
Weber and Kwan (2002)	Variable travel time	No	No

APPENDIX N

IDENTIFYING THE ATLANTIC-CITY CITY-REGION

All calculations in this dissertation are based on Atlantic City and its surrounding municipalities. The choice of the municipalities was based on the number of workers that held jobs in Atlantic City. Municipalities that were not contiguous to Atlantic City or was not in New Jersey was not included among the municipalities considered.

Table N.1 Municipalities with more than 100 people working in Atlantic City

Table N.1 Municipalities Considered for the Atlantic City City-Region

FIPS	Municipality*	No. of Workers	Reason for Exclusion from Atlantic City City-Region
00100	Absecon City	1220	
02080	Atlantic City	11035	
04120		110	Not in New Jersey
07600	Bridgeton City, Cumberland	130	Not contiguous to Atlantic City
07810	Brigantine City	3200	
10000	Camden City, Camden	170	Not contiguous to Atlantic City
20350	Egg Harbor City	470	Not contiguous to Atlantic City
29430	Hammonton Town	465	Not contiguous to Atlantic City
40440	Lindenwold Borough, Camden	125	Not contiguous to Atlantic City
40530	Linwood City	710	
43890	Margate City	1280	
46680	Millville City, Cumberland	195	Not contiguous to Atlantic City
49560	Mystic Is., Ocean County	680	Not contiguous to Atlantic City
51000	Clinton Hill, Essex	155	Not contiguous to Atlantic City
52950	Northfield City	1260	
54315		235	Not in New Jersey
54360	Ocean City, Cape May	905	
59640	Pleasantville	3680	
60000		265	Not in New Jersey
60030	Pompona, Galloway township	880	Not contiguous to Atlantic City
68430	Somers Point	1385	
74210	Tuckerton Borough, Ocean County	170	Not contiguous to Atlantic City
75620	Ventnor City	3235	

*Only municipalities with more than 100 people commuting to Atlantic City are considered.

Source: Census Transportation Planning Package 2000 from http://www.fhwa.dot.gov/ctpp/

APPENDIX O

MODEL VISUALIZATION

All models in this dissertation were built using ArcGIS 9.3 ModelBuilder. ModelBuilder is an application used to create, edit and manage GIS models. Figure O.1 is a model whose final product is the value of accessibility calculated by time. Figures O.2 through Figure O.4 are sequentially buried in the model depicted in Figure O.1.

Figure O.1 Model to calculate the value of accessibility by time.

Figure O.2 Submodel BD_Time to calculate the value of accessibility by time.

Figure O.3 Submodel BDG1O11 to calculate accessibility value by time.

Figure O.4 Submodel BDG1O11SO115 to calculate the accessibility value by time

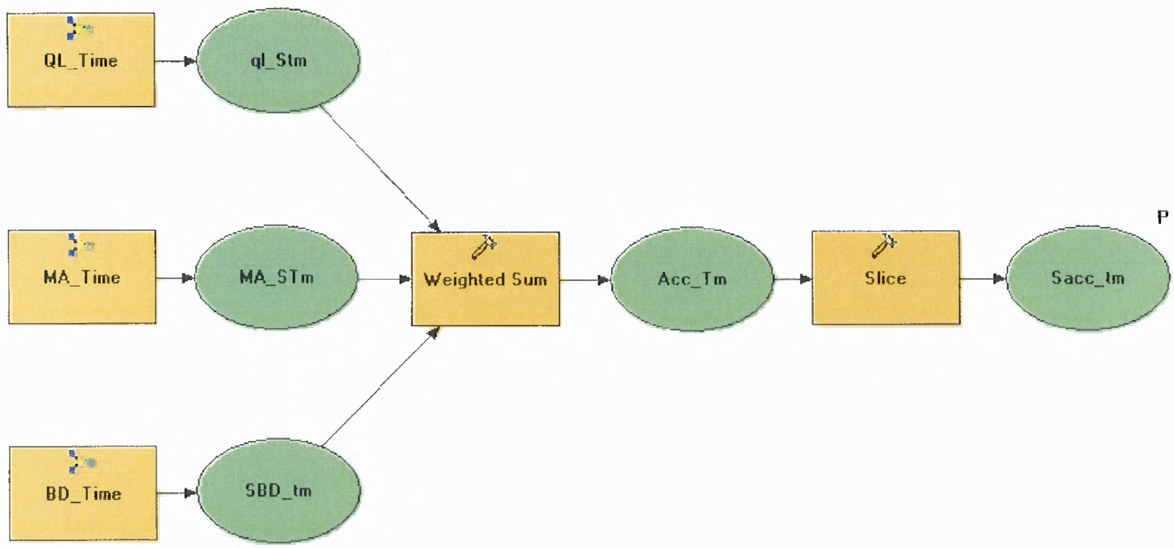


Figure O.1 Model to calculate the value of accessibility by time.

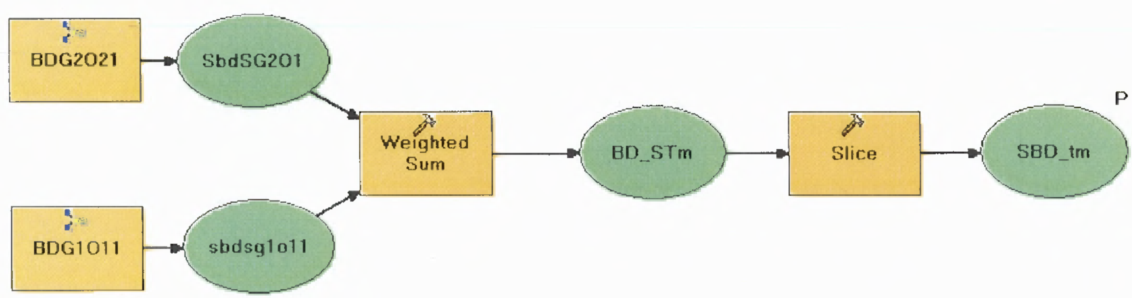


Figure O.2 Submodel BD_Time to calculate the value of accessibility by time.

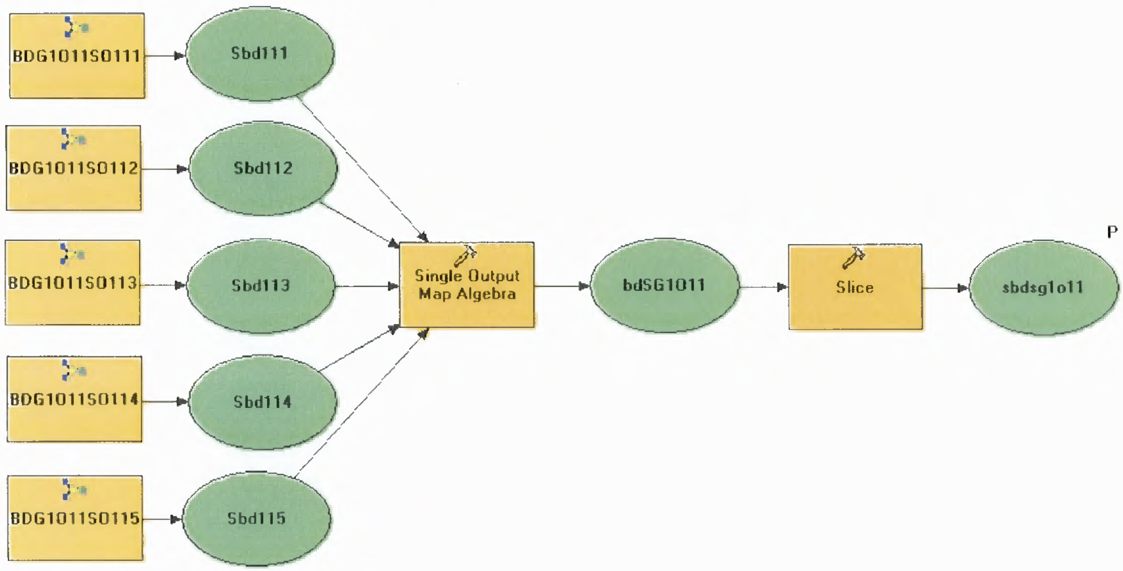


Figure O.3 Submodel BDG1O11 to calculate accessibility value by time.

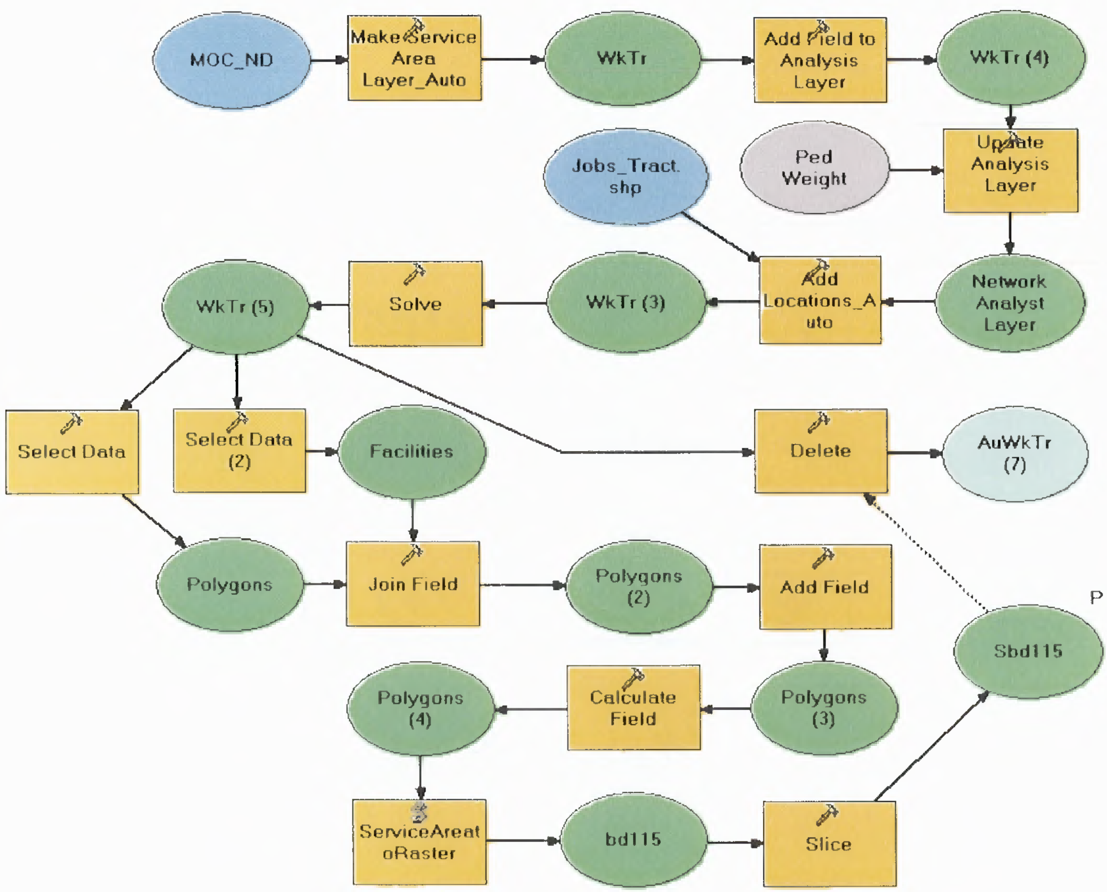


Figure O.4 Submodel BDG1O11SO115 to calculate the accessibility value by time

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