# FUTURE DIRECTIONS FOR MULTIMODAL AREAWIDE LEVEL OF SERVICE HANDBOOK RESEARCH AND DEVELOPMENT

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The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation. This document was prepared in cooperation with the Florida Department of Transportation.

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# FUTURE DIRECTIONS FOR MULTIMODAL AREAWIDE LEVEL OF SERVICE HANDBOOK RESEARCH AND DEVELOPMENT

## 1.0 INTRODUCTION

Florida is one of the fastest growing states in the nation and it attracts a significant number of visitors on an annual basis. It is anticipated the state's population will continue to grow increasing from 17 Million currently, to 20 million by the year 2025. This rapid growth places a substantial demand on Florida's infrastructure and the funding needs for new highways and capacity improvements far exceed the available resources in Florida. On the Florida Intrastate Highway System (FIHS), nearly $46 billion of needs and only $16 billion in funding were identified over the next 20 years. The state has come to understand that it can no longer build its way out of congestion. Other methods such as increasing the ability to manage and operate the transportation system, reducing demand through better coordination of transportation and land use, and providing choices to travelers for using alternative modes, are major themes of the Florida Transportation Plan, which guides Florida Department of Transportation (FDOT) activities.

Florida Statutes were amended in 1999 to allow local governments to establish multimodal transportation districts (MMTDs) to promote development that favors pedestrian, bicycle and transit modes over the automobile, to develop professionally accepted techniques for measuring Level of Service (LOS) for automobiles, bicycles, pedestrians, transit and trucks, and to assist local governments in implementing multimodal LOS analysis. The FDOT has developed a series of tools to assess the LOS of each of the modes (automobile, truck, transit, pedestrian, and bicycle) and has established criteria and processes for the designation of MMTDs and areawide LOS measures. The MMTD can be used to promote a mixture of land uses, interconnected transportation networks, and high density land uses that are pedestrian and transit friendly in urban form and design. This project extends the analysis completed as a part of the development of the Multimodal Transportation Districts and Areawide Quality of Service Handbook (hereafter "MMTD Handbook" or "Handbook", developed by the Florida Department of Transportation. The long-term goals of this project are to further develop and extend the methodologies outlined in the MMTD Handbook.

### 1.1 Scope of Work

The Florida Department of Transportation recently adopted a manual entitled the MMTD Handbook. The Handbook outlines various methodologies for designation of an area as a Multimodal Transportation District. While all of the methodologies within the Handbook have been utilized in various settings throughout the country and scrutinized in academic literature, there is still a need further examine these methodologies as well as new methodologies in order to create a Handbook that is not only accurate, but also user-friendly. This paper seeks to analyze some of methodologies outline in the Handbook as well as examine new methodologies in the following areas: 1) the analysis of pedestrian connectivity; (2) the organization of activity centers along the corridor and the relationship between the MMTD and other land uses and activity centers nearby; (3) the nexus between land use and transportation analysis; and (4) the need for simplified analysis tools.

## 1.2 Organization of Paper

This paper is divided into five parts, including this introduction. The second part deals with the network connectivity. In this section, the current methodologies outlined in the Handbook are examined as well as other popular methods of measuring network connectivity. The third section discusses geographic information system (GIS) methodologies to identify high density activity centers and multimodal districts with a robust land use mix. The fourth section describes an ArcView script that tabulates accessibility between land uses based on network distance and multimodal level of service. The fifth, and final section, identifies simplified methodologies for application of the multimodal transportation districts. This section describes the methodology and the data requirements for analyzing the following aspects of MMTDs: (1) complementary mix of land use; (2) appropriate density and intensity of development; and (3) network connectivity.

## 2.0 METHODOLOGIES FOR MEASURING PEDESTRIAN CONNECTIVITY

### 2.1 Introduction

In order for Multimodal Transportation Districts to function properly, the presence of good pedestrian connectivity is critical. This will create a more pedestrian-friendly area by shortening the distances between origins and destination as well as affording pedestrians more choices for reaching their destination. Additionally, greater connectivity will allow for increased access to transit, which further enhances the functionality of the neighborhood.

Currently, there is a multitude of literature regarding various methodologies for measuring connectivity. Recognizing this fact, this research seeks to highlight and evaluate many of these methodologies. This paper is structured in a way that briefly summarizes a number of methodologies and then provides basic applications of selected methodologies. Finally an evaluation section is included that highlights both positive and negative aspects of each methodology and also outlines potential complications that may arise when using each methodology. Table 2.1.1 lists the methodologies evaluated, and summarizes the means of analysis and the standard for good connectivity.

**Table 2.1.1 Summary of Methodologies**

| Methodology | Means of Analysis | Standard for Good Connectivity |
|---|---|---|
| Block Length (Handy *et al.* 2003) | Establishing thresholds for length of blocks | 300-600 feet |
| Pedestrian Route Directness (Hess 1997) | Uses the ratio of actual distance to traveled distance to determine a PRD index | Pre WWII Neighborhoods = 1.2 Post WWII Neighborhoods = 1.7 |
| Number of intersections (Cervero and Radisch 1996) | Measured as the number of intersections per unit of area | * |
| INDEX PRD Equation (Criterion 2002) | Calculates ratio by dividing the network distance by the straight-line distance as well as the number of parcels within .5 miles of a central node | 1.2-1.5 |

| | | |
|---|---|---|
| INDEX Street Network Density Equation (Criterion 2002) | Calculates ratio by dividing the total length of street centerlines by the area | 15-20 miles/square mile for urban areas<br>3-5 miles/square mile for rural areas |
| INDEX Pedestrian Network Coverage (Criterion 2002) | Percentage of street frontage with improved sidewalks on both sides. | 70%-90% for urban areas |
| INDEX Street Connectivity Equation (Criterion 2002) | Calculates the ratio of number of intersections to number of intersections and cul-de-sacs in an area | 0.7-0.9 |
| Pedestrian Environment Factor (Parsons Brinkerhoff Quade and Douglas 1993) | Grades four attributes of the pedestrian environment and determines a composite score | * |
| Link-Node Ratio (OTPB 1999 as quoted in Steiner *et al.* 2000: 25-26) | Determines the ratio of the number of links (road segments) to the number of nodes (intersections) | 1.4-1.8 |

* – No accepted standard

## 2.2 Summary of Methodologies

The following four methodologies (number of polygons, block length, number of intersections, street network) are all closely correlated and could even be considered interchangeable. For example, if an area has a high number of blocks, or polygons, per square mile, it will have a tendency to have a corresponding high number of intersections as well. Additionally, block length will be shorter (except for some anomalies).

The following four methodologies could all conceivably be applied without the use of computers or a GIS however, in some cases a GIS would make the process much less tedious.

### *2.2.1 Number of Polygons*

This methodology determines a pedestrian connectivity index based on the number of polygons per square mile. The term polygons could also be referred to as blocks however, when put into practice, there can sometimes be discrepancies between what constitutes a block. Because of this, polygons are counted instead of blocks to standardize the process.

Once the modal network is determined, polygons are drawn over the network and then counted. For good connectivity, the minimum number of polygons per square mile should be at least 50. Any number greater than 50 represents a higher connectivity (See Figure 2.2.1).

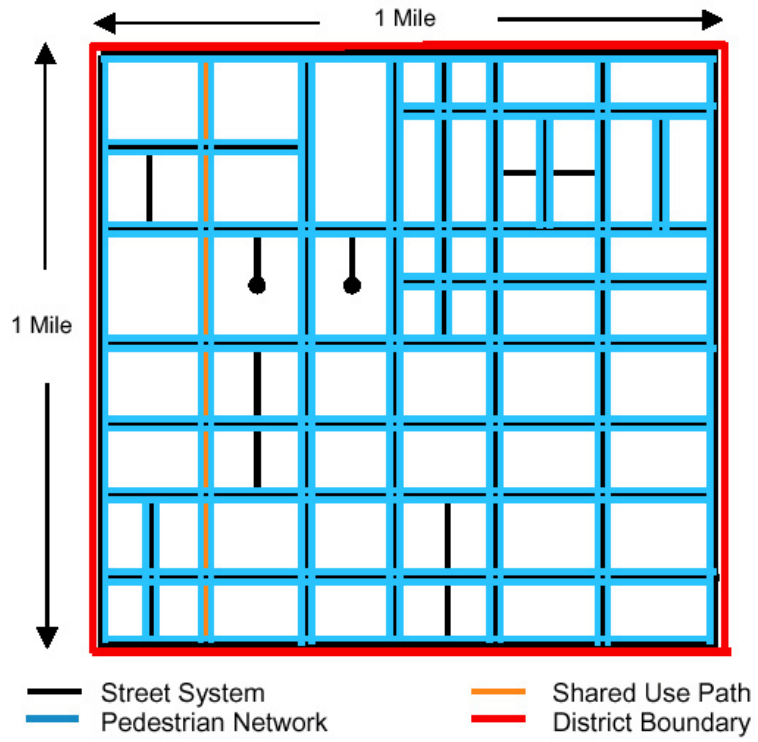



**Figure 2.2.1 MMTD Pedestrian Network**

### *2.2.2 Block Length*

Block length has been used in a number of different cities as a means for measuring pedestrian connectivity (Handy *et al*., 2003). This methodology relies on the premise that the shorter the length of a block is, the better the connectivity will be due to the fact that the pedestrian will not have to walk long distances to reach his destination. Block length can also be considered a proxy for determining the number of blocks in an area, which is the methodology currently recommended in the MMTD Handbook. The block length methodology is based on the fact that the shorter the blocks are in an area, the more intersections there are. This allows for more choices for reaching a specific destination on the pedestrian network. Many cities have adopted standards for block length that range from 300 to 600 feet.

### *2.2.3 Number of Intersections*

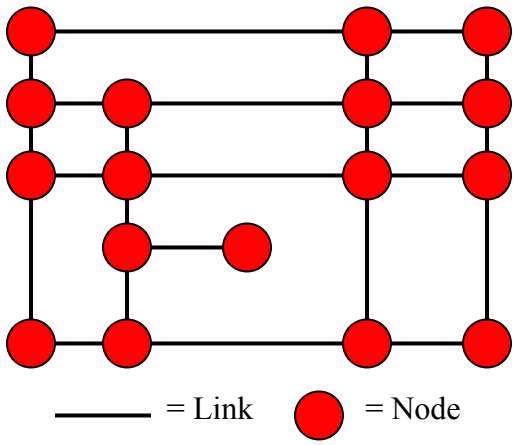
Cervero and Radisch performed a study of two neighborhoods in the San Francisco Bay area – one considered a more modern, automobile-dependent neighborhood and the other an older more compact, high-density neighborhood possessing characteristics of transit-oriented design (Cervero and Radisch 1995). In the study, the intersections present in each neighborhood were evaluated. These intersections were broken down into four-way intersections, T-intersections (3-way intersections), and cul-de-sacs, with a large number of four-way intersections correlating with a higher connectivity and a large number of cul-de-sacs correlating with a lower connectivity.

This method could easily be used to evaluate pedestrian connectivity once a performance standard is established. Because a gridded street network enhances the pedestrian connectivity of an area, a high number of four-way intersections for a given neighborhood would represent better connectivity. A high number of cul-de-sacs, on the other hand, would represent low pedestrian connectivity. Other studies using this principle include: Handy (1996), Cervero and Kockelman (1997), and Reilly (2002).

Boarnet and Crane (2001) used this technique of determining the number of four-way intersections in order to calculate a percent-grid of the street network. The street network was evaluated and judged to be one of the following: (1) a connected street (2) a cul-de-sac network; or (3) a mixture of the two.

### *2.2.4 Link-Node Ratio*

Another method of analysis is to determine connectivity is the number of links and nodes of a street network with links representing roadway segments and nodes representing intersections. This methodology relies on the premise that when more links are connected to more nodes there is greater network connectivity. In order to determine this connectivity index, the number nodes and the number of links are counted. The number of links is then divided by the number of nodes to determine the link-node ratio (See Figure 2.2.2). A perfect grid network has a connectivity index of 2.5 and the acceptable range is between 1.4 and 1.8 (OTPB 1999 as cited in Steiner *et al* 2000).




Connectivity Index = 24/17 = 1.41

**Figure 2.2.2 Example of Link-Node Methodology**

### *2.2.5 Street Density*

Matley *et al.* (2001) uses the measure of street network density to evaluate pedestrian connectivity. This method calculated the geometric lengths of TIGER streets and total census tract land areas to determine street network densities in street kilometers per square kilometer. This method relies heavily on the notion that a higher street density will have higher connectivity.

### *2.2.6 Pedestrian Route Directness*

Pedestrian Route Directness utilizes an equation that calculates the ratio of the network distance and the straight-line distance. The equation determines the ratio between specific origins and destination within the defined network (Hess 1997) (see Figures 2.2.3 and 2.2.4). Using this equation, the network distance would be the distance that the pedestrian would have to walk along specific corridors to reach the destination. The straight-line distance is the actual distance from the origin to the destination "as the crow flies."

**Pedestrian Route Directness (PRD) = network distance/straight-line distance**

**Figure 2.2.3 Pedestrian Route Directness Equation (Hess 1997)**

Ideally, the PRD value would be as close to one as possible, representing efficient pedestrian connectivity. Hess found that traditional, pre-WWII neighborhoods with a gridded street network tended to have a PRD value of 1.2 (1997). The PRD value of postwar neighborhoods, with the presence of cul-de-sacs, was 1.7.

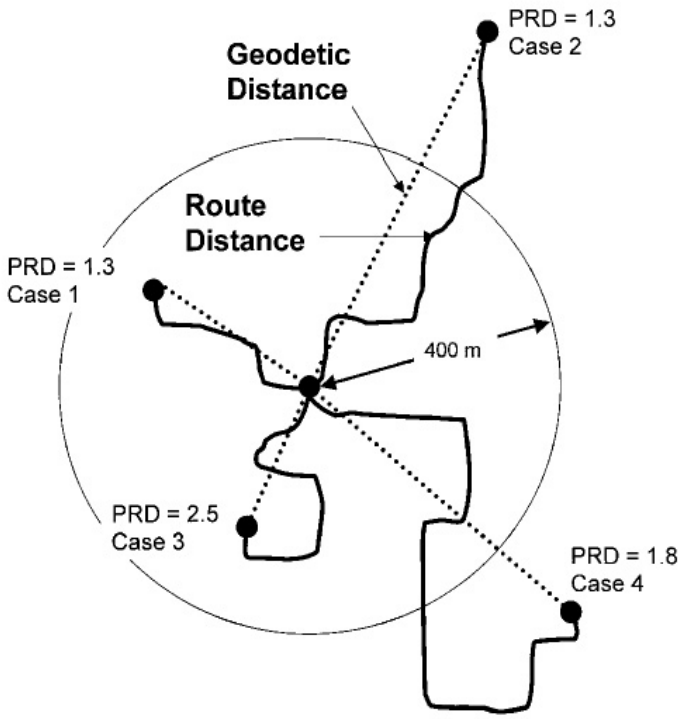



**Figure 2.2.4 Illustration of use of PRD Equation (Randall and Baetz 2001)**

### *2.2.7 Smart Growth INDEX Indicators*

The Environmental Protection Agency's Smart Growth INDEX (INDEX), developed by Criterion Planners/Engineers Inc., is a GIS-based sketch tool used for simulating alternative land-use and transportation scenarios and evaluating their outcomes using various performance indicators. The following indicators are all integrated into the tool

and can all be used as a means for measuring connectivity. In the program, all of these indicators are used in combination with each other as well as with other indicators to produce an overall result. For the purpose of this research, each indicator is discussed individually.

2.2.7.1 Pedestrian Route Directness Indicator

INDEX uses a similar version of Hess's Pedestrian Route Directness equation as one of its indicators. INDEX's PRD indicator calculates the average ratio of walking distances from random sample origin points to a central node versus straight-line distances between the same points. This is calculated for a one-half mile straight-line radius of the central node (see Figure 2.2.5).

$$\frac{\sum \frac{Network_{p-cn}}{Straightline_{p-cn}}}{n}$$

$Network_{p-cn}$ = nework distance from parcel p to the closest central node

$Straightline_{p-cn}$ = straightline distance from parcel p to the closest central node

$n$ = number of parcels with 1/2 mile of a central node (straightline distance)

**Figure 2.2.5 Smart Growth INDEX PRD Equation (Criterion 2002: 37)**

While INDEX's PRD use the network distance and straight-line distance, it also incorporates the number of parcels within a one-half mile radius of a central node. According to the INDEX, areas with favorable route directness will score 1.5 or less while unfavorable areas will score higher than 1.5 (Criterion 2002).

2.2.7.2 Street Network Density Indicator

In addition to the PRD indicator, INDEX also uses another indicator that measures street network density which could potentially be useful in measuring pedestrian connectivity. This method calculates the ratio of the length of street centerlines in the network versus the total area (see Figure 2.2.6). The scores achieved using this method range anywhere from 3–5 mi./sq. mi. in rural areas to 15–20 mi/sq. mi. in urban area (Criterion 2004).

$$\frac{\sum L_s}{\sum A_a}$$

$L_s$ = length in feet of street segment $s$.

$A_a$ = area in square miles of study area polygon $a$.

**Figure 2.2.6 Smart Growth INDEX Street Network Density Equation (Criterion 2004: 53)**

The indicator of street network density may not provide an accurate measure of connectivity due to the fact that it only calculates the street network itself. It does not account for the presence of a sidewalk nor does it account for the connectivity of the street network. However, the INDEX has two other performance indicators, sidewalk

completeness and street connectivity, which could both potentially be used in conjunction with the street network density indicator to provide a more accurate measure of pedestrian connectivity.

2.2.7.3 Pedestrian Network Coverage

The INDEX's pedestrian network coverage indicator determines the percentage of street frontage with improved sidewalks on both sides (see Figure 2.2.7).

$$\frac{\sum (C_s * L_s)}{\sum L_s}$$

$C_s$ = percent of sidewalk completeness for street segment $s$.
$L_s$ = length in feet of street segment $s$.

**Figure 2.2.7 Smart Growth INDEX Pedestrian Network Coverage Equation (Criterion 2004: 61)**

2.2.7.4 Street Connectivity Indicator

The INDEX's street connectivity indicator calculates the ratio of the number of intersections in a defined area to the number of intersections and cul-de-sacs (see Figure 2.2.8). Areas with high street connectivity will score between 0.7 and 0.9 while poorly connected networks will have a score between 0.3 and 0.5.

$$\frac{I}{C+I}$$

$C$ = number of cul-du-sacs in the study area.
$I$ = number of intersections in the study area.

**Figure 2.2.8 Smart Growth INDEX Street Connectivity Equation (Criterion 2004: 49)**

The following two methodologies (pedestrian/bicycle friendliness and pedestrian environment factor) rely more on simple observations or data collection instead of mathematics and geography. In contrast to other methodologies, these measures consider more than one dimension.

### *2.2.8 Pedestrian/Bicycle Friendliness*

Holtzclaw has developed another method that could potentially be used to calculate street connectivity. This method uses an equation to calculate a Pedestrian/Bicycle Friendliness factor (PFF). In this study, the PFF is used in conjunction with other variables to quantify the relationship between auto ownership and driving in order to develop a Location Efficient Mortgage (LEM) (Holtzclaw *et al* 2002).

The PFF is the number of census blocks per hectare plus an adder based on the mean year the housing was build with bonuses for traffic calming, good pedestrian conditions, bicycle lanes, paths, and bicycle parking (See Figure 2.2.9)

**Pedestrian/Bicycle Friendliness = Street Grid + Year Build + Bonuses**

**Street Grid = (# of census blocks)/(developed hectares)**
**Year Built = 0.7 is the median year built is 1939 or earlier according to the census; 0.6 if build 1940-42; 0.5 if 1943-45; 0.4 if 1946-48; 0.3 if 1949-50; 0.2 if 1951-52; 0.1 if 1953-55; 0 if 1956 or newer.**
**Bonuses: traffic calming credit up to 1.0 and bicycle credits up to 0.5**

**Figure 2.2.9 Holtzclaw's Pedestrian/Bicycle Friendliness Factor (Holtzclaw *et al.* 2002)**

The logic behind the use of the mean year built of housing in the equation is that older neighborhoods tend to have a fine street grid, sidewalks, narrow streets, slower traffic and buildings closer to the sidewalk. Holtzclaw notes that if direct measurements of the continuity, width and quality of sidewalks, nearness of buildings to the sidewalk, and traffic safety been available, it would have been preferable to use these measurements instead of the mean year the housing was built.

### *2.2.9 Pedestrian Environment Factor*

Parsons, Brinckerhoff, Quade and Douglas (1993) have developed a Pedestrian Environment Factor (PEF), which is a composite measure of four elements of the built environment: ease of street crossings, sidewalk continuity, local street characteristics and topography. To determine the PEF, each of Portland, Oregon's 400 zones in the regional travel demand forecasting model network were assessed individually. Each of the four attributes were graded on a three point scale and the zones were then given a score with 12 being the highest and four being the lowest. Table 2.2.1 shows which elements are measured.

**Table 2.2.1 Measurement of Pedestrian Environment Factor**

| Element | Evaluation Criteria |
|---|---|
| Ease of street crossing | –Width, extent of signalization, and traffic volumes were evaluated for key intersections |
| Sidewalk continuity | – Extensiveness of sidewalks of principal arteries currently served or arteries that will likely be served by transit in the future |
| Local street characteristics (grid vs. cul-de-sac) | – Extent of gridded street patterns in each zone and distance between intersections. |
| Topography | – Extensiveness of sloping terrain as well as steepness of the slopes |

Source: Parsons, Brinckerhoff, Quade and Douglas (1993)

While the topography element of the PEF might not be applicable to Florida in terms of the slope of terrain, it could however, be modified to include such aspects as presence of tree canopy over the pedestrian network to reduce heat. While the sidewalk continuity and local street characteristics elements are similar to the pedestrian connectivity measures discussed in the Smart Growth INDEX, the ease of street crossing element in

the PEF seeks to evaluate a useful impedance factor that is important in calculating any pedestrian connectivity index. Instead of superficially taking into account the number of intersections in a defined area, the ease of street crossing element also looks at the nature of the intersection such as the width and signalization which is where other connectivity measures fall short.

### 2.3 Application of Selected Methodologies

In an effort to identify and evaluate various measures of connectivity in a "real-world" setting, a case study was performed in Gainesville, Florida. In order to identify potential neighborhoods that would lend themselves well to this case study, an analysis was performed on Gainesville's roadway network. Using a GIS, a map was created using a roads shapefile from Geographic Data Technologies. Major arterials, as defined by the North Central Florida Regional Planning Council (NCFRPC), were separated out from local roads. The analysis consisted of grading each roadway on a scale of one to four depending on the number of major arterials to which the roadway had access. For example, if a local street had access to three major arterials, it was given a score of three. By performing this analysis it was possible to determine which neighborhoods have the highest connectivity with regards to major arterials (See Figure 2.3.1).

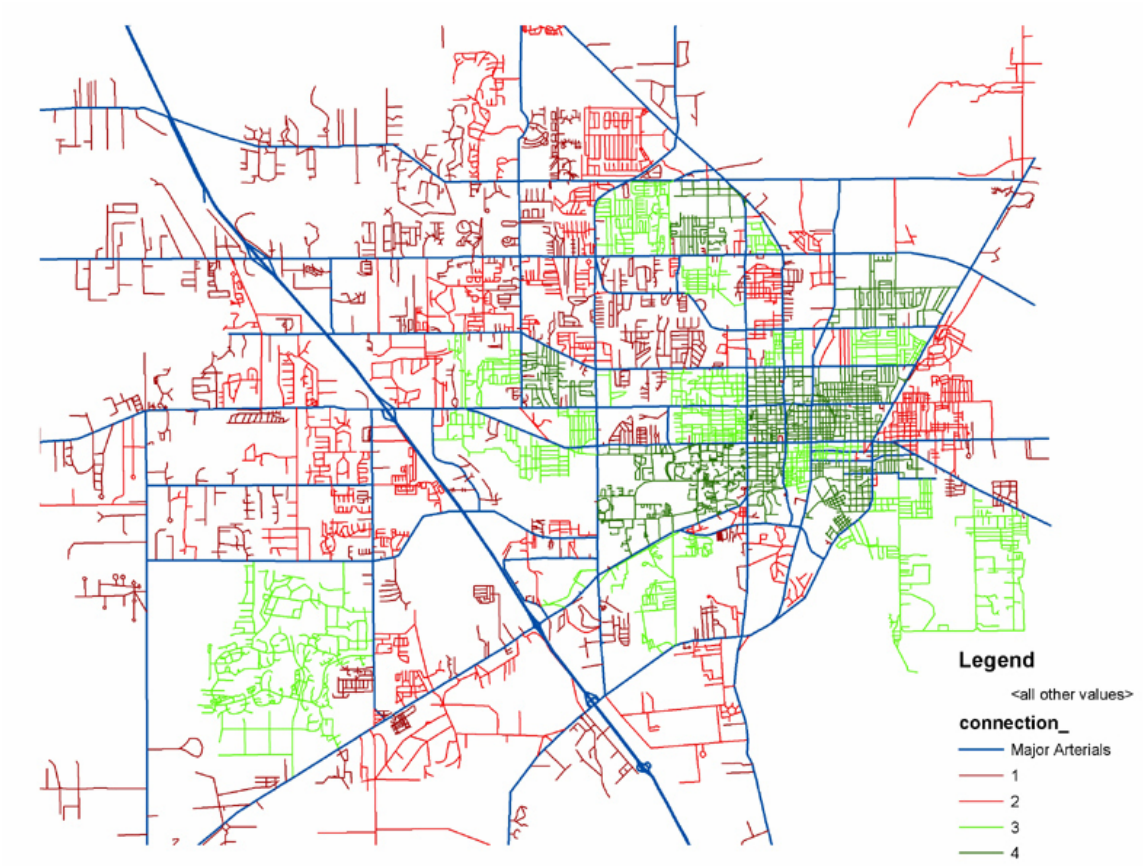



**Figure 2.3.1 Gainesville, Florida Roadway Connectivity**

After performing this preliminary analysis, it was decided that two neighborhoods with a connectivity score of three would be used for the case study. While these areas both have access to three major arterials, they are perceived as being very different (See Figure 2.3.2). One is a traditional, grid-like street network (See Figure 2.3.3) and the other has a more curvilinear street network with the presence of cul-de-sacs (See Figure 2.3.4). The two cases studies are of differing sizes but most types of analysis normalize for this difference in scale (e.g., they measure the number of blocks per square mile).

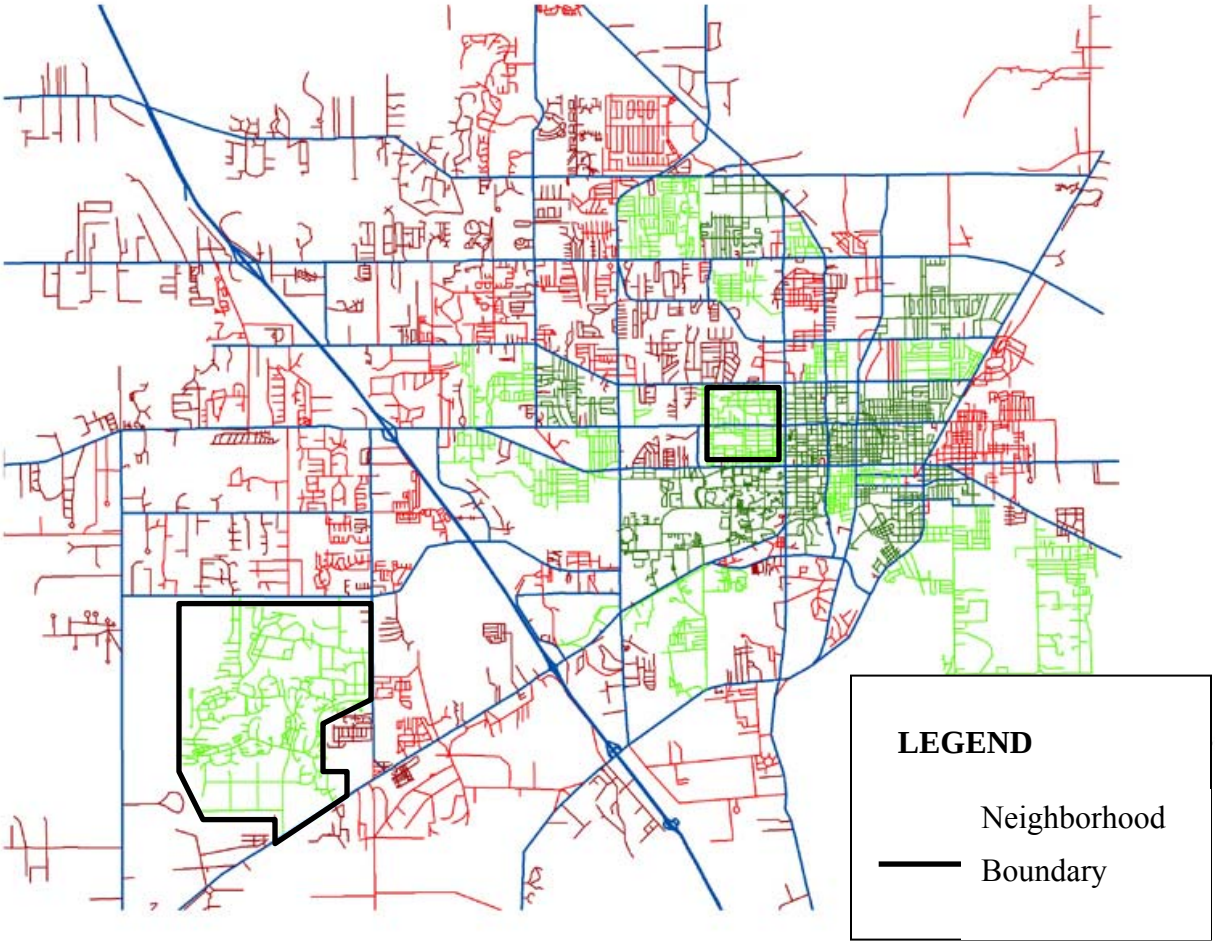



**Figure 2.3.2 Case Study Areas**

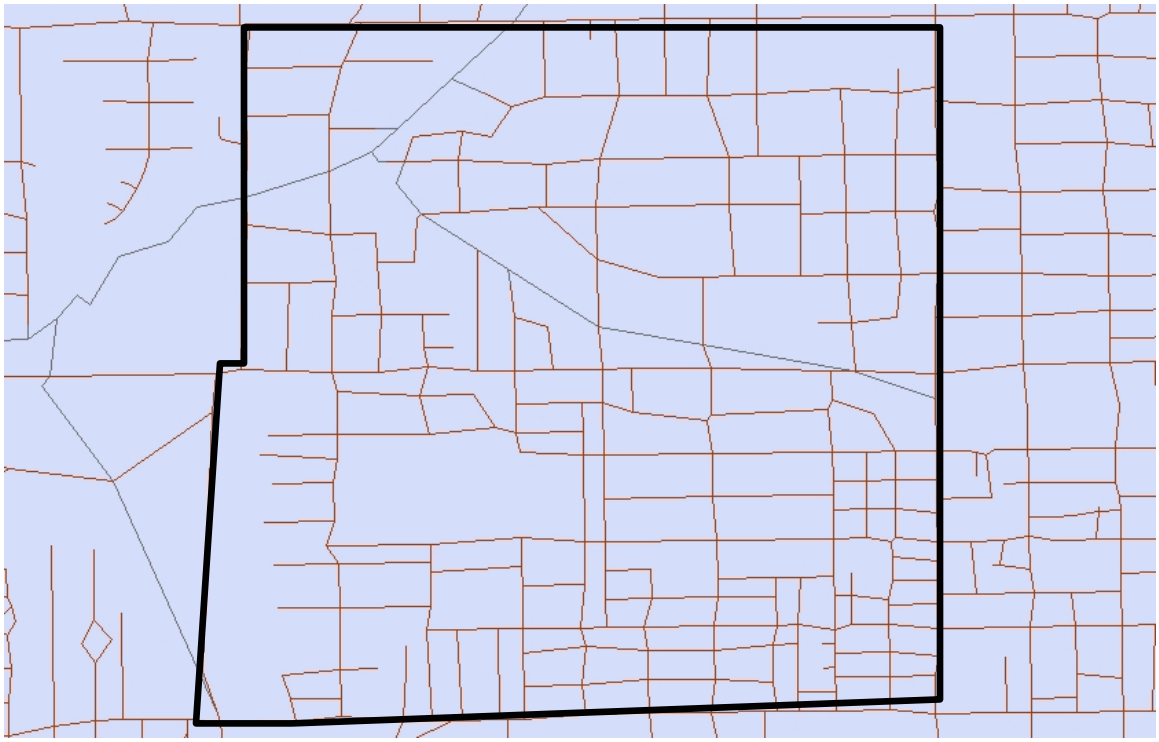


**Figure 2.3.3 Grid-like Street Network**

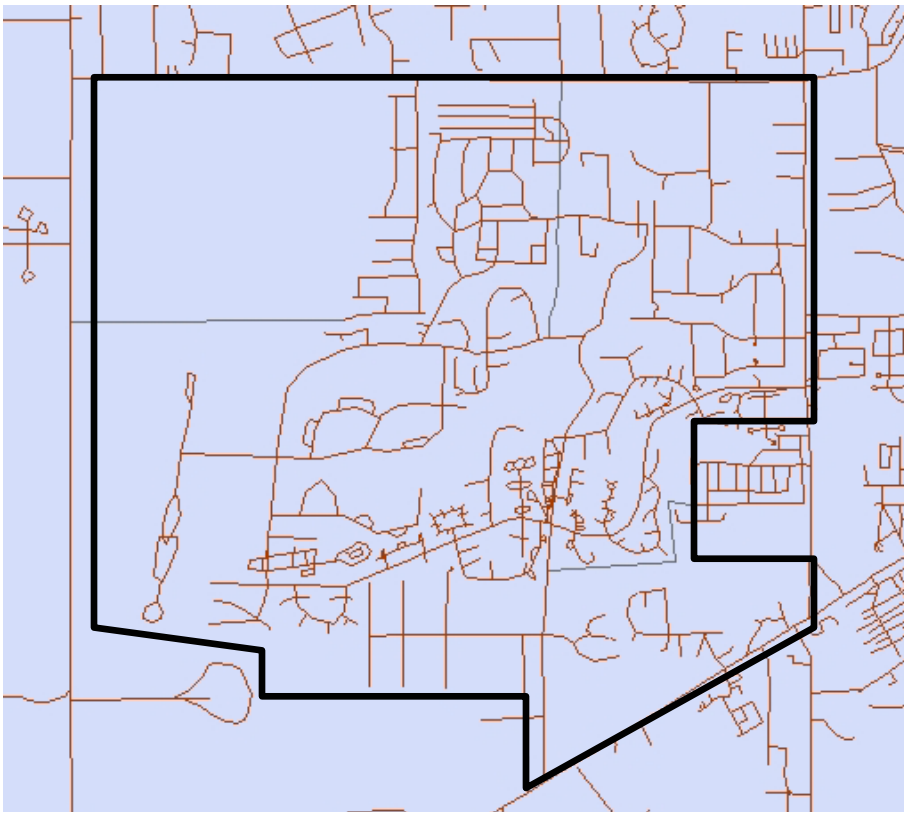


**Figure 2.3.4 Curvilinear Street Network**

The following sections apply four methodologies to the two neighborhoods in Gainesville to illustrate how they are used and to understand their strengths and limitations. These methodologies were narrowed down from the array of methods because they are most commonly used in current practice. Additionally, each of these methodologies has a known acceptable range to which the case study can be compared. This allows for an insightful case study illustration.

### *2.3.1 Number of Polygons or Blocks*

This methodology uses the number of polygons per square mile as a proxy for measuring the roadway connectivity. According to the FDOT MMTD Handbook (FDOT 2003a), 50 polygons per square mile or greater is an acceptable level of connectivity. The results of both of these analyses are listed in Table 2.3.1. Using this method on grid-like street network proved to be fairly simply. However, when this methodology was applied to the curvilinear street network, it proved to be problematic. Because it is sometimes difficult to determine where polygons are in a neighborhood with many cul-de-sacs, it can be difficult to determine an accurate number of polygons per square mile. This could potentially skew the results of the analysis.

**Table 2.3.1 Number of Blocks (per Square Mile) in Case Study Neighborhoods**

| Grid Network Neighborhood | Curvilinear Neighborhood | Acceptable Range (FDOT 2003a) |
|---|---|---|
| 135 | 6.1 | >50 |

### *2.3.2 Block Length*

Using the street network of both neighborhoods, five different blocks were chosen randomly. Different blocks in each neighborhood were chosen in order to try and represent the overall block formation of each area. The length of each block was determined using the distance tool in ArcGIS and the average of these blocks was then calculated to determine an overall average block length size. Three of the five in the grid street network were less than 600 feet in length while two were above that threshold. In the cul-de-sac neighborhood, all test blocks were above the threshold. The results are shown in Table 2.3.2. In practice, the length of all blocks in the neighborhood would be calculated and compared to the standard.

**Table 2.3.2 Block Size for Sample in Grid Network and Curvilinear Neighborhood**

| | Grid Network Neighborhood | Curvilinear Neighborhood |
|---|---|---|
| Block 1 | 990 ft. | 1171 ft. |
| Block 2 | 431 ft. | 719 ft. |
| Block 3 | 474 ft. | 2515 ft. |
| Block 4 | 819 ft. | 1224 ft. |
| Block 5 | 345 ft. | 1413 ft. |
| Average Block Size | 611 ft. | 1409 ft |
| Acceptable Range (Handy *et. al*. 2003) | 300–600 ft. | |

### *2.3.3 Pedestrian Route Directness*

In order to demonstrate the pedestrian route directness methodology, an origin and destination were randomly selected. The distance tool in ArcGIS was then used to determine both the distance from each origin to destination on the street network as well as the straight-line distance (See Figures 2.3.5 and 2.3.6). This method could be used prior to the analysis of network accessibility between trip attractors and producers that is discussed in Section 4 of this paper. For example, the distance pedestrians would need to walk between their residence and a nearby commercial or services establishments could be measured.

For the grid-like street network, the network distance was measured to be 3,761 feet while the straight-line distance was measured to be 2,700 feet. Using the PRD equation, the ratio was calculated to be 1.3 (see Figure 2.3.5).

The network distance for the curvilinear neighborhood was measured to be 5,584 feet and the straight-line distance 2,260. The PRD ratio was then calculated to be 2.47, much higher than the grid-like street network (See Figure 2.3.6).

**Figure 2.3.5 PRD Route of Travel, Grid-like Street Network**

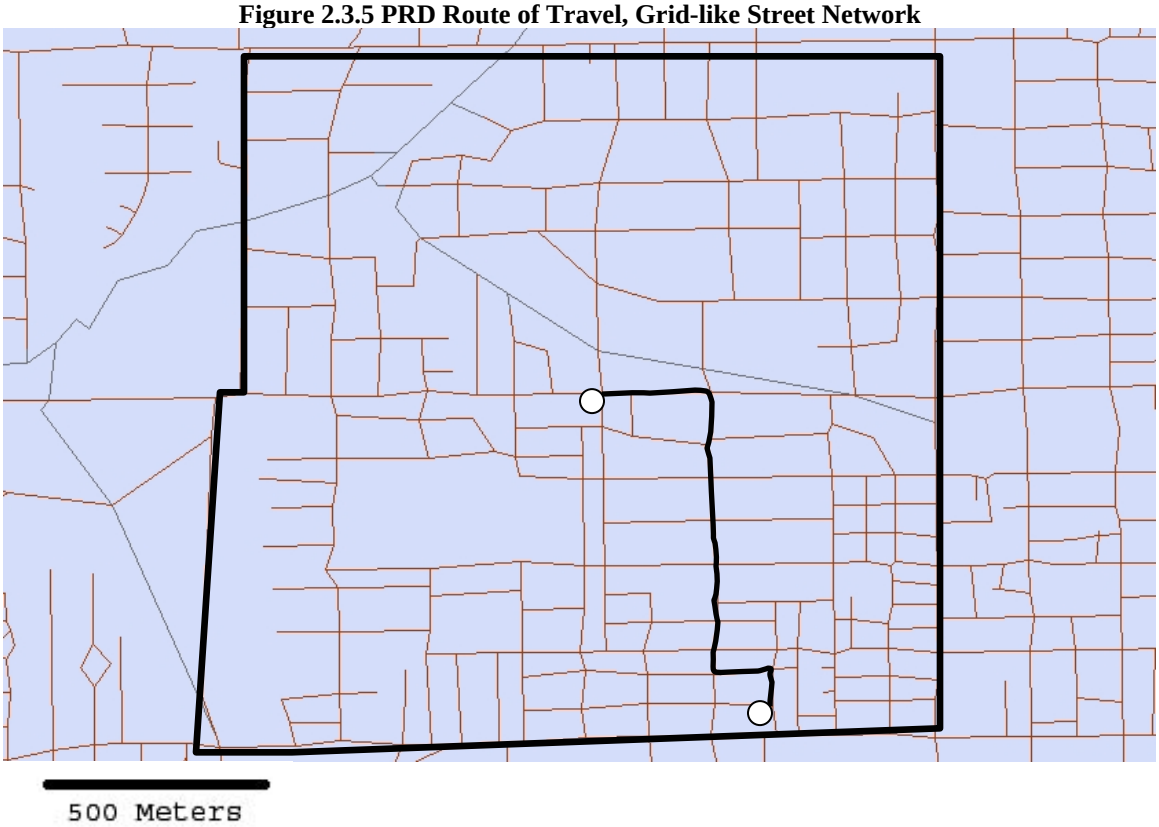
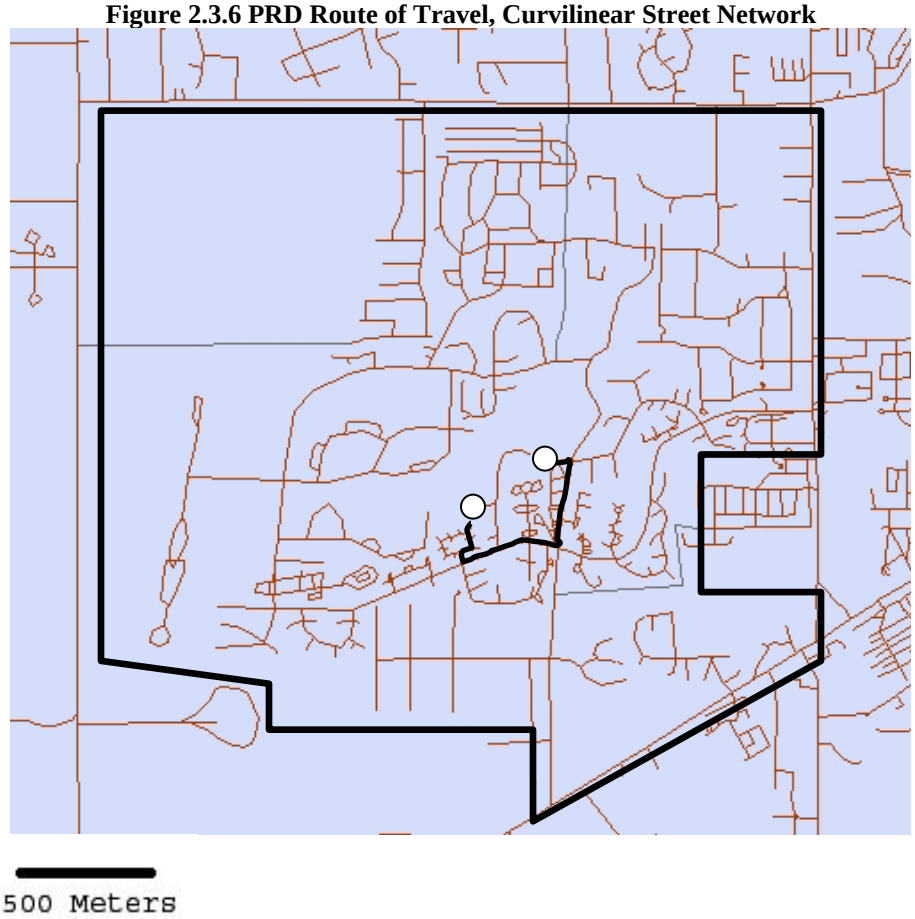


**Figure 2.3.6 PRD Route of Travel, Curvilinear Street Network**




### *2.3.4 Link-Node Ratio*

The link-node ratio is a commonly used method which divides the number roadway segments (links) by the number of points of intersection of two or more roads or any cul-de-sac ends (nodes) to determine a ratio. A perfect grid network has a link-node ratio of 2.5. A generally acceptable range is between 1.4 and 1.8 (OPTB 1999 as quoted in Steiner *et al.* 2000).

As expected, the results from the link-node analysis show a higher level of connectivity with a ratio of 1.45 for the grid network neighborhood. This ratio falls within the acceptable range of 1.4 and 1.8. In contrast, the curvilinear neighborhood falls far below the acceptable range. The results of both neighborhoods for the link-node ratio and three other measures of connectivity are shown in Table 2.3.3.

| Table 2.3.3 Comparison of Results Using Different Methods of Analysis of Connectivity | | | |
|---|---|---|---|
| | **Grid Network Neighborhood** | **Curvilinear Neighborhood** | **Acceptable Range** |
| **Link-Node Ratio** | 1.45 | .87 | 1.4–1.8 |
| **Number of Blocks (per sq. mi)** | 135 | 6.1 | >50 |
| **Average Block Size* (in feet)** | 611 | 1409 | 300–611 |
| **Pedestrian Route Directness** | 1.3 | 2.47 | 1–1.2 |
| * – for random sample of blocks | | | |

## 2.4 Evaluation of Selected Methodologies

### *2.4.1 Number of Polygons*

As mentioned previously, this methodology could be viewed as a proxy for measuring the elements of block length, sidewalk continuity, and number of intersections. With a higher number of polygons within the area, the number of blocks will be greater, there will be sidewalk continuity, and there will also be a greater number of intersections. The advantage of this methodology is its seeming simplicity. However, the method proves to be inaccurate in some situations. While a greater number of blocks could indeed translate into a more direct pedestrian route thus allowing pedestrians to reach their destination more efficiently, the method fails to quantify the directness of that route. An area theoretically could have 50 polygons, however one of the polygons could be very large while the rest of the district has very small polygons. This would mean that a pedestrian must much farther than the accepted distance to reach their destination. While the network in Figure 2.4.1 has more than 50 polygons, a pedestrian traveling from point A to point B would have to travel a substantial distance on the network even though the actual distance is only one block away.

Additionally, another potential problem with this methodology occurs in the delineation of the polygons. In Figure 2.4.1 the pedestrian network is straightforward and there are no questions concerning what are, or are not, polygons. In contrast, complications arise when determining polygons in neighborhoods with a less grid-like street pattern, like the curvilinear street network in the Gainesville discussed earlier. When many cul-de-sacs are present in a small area it can often be difficult to determine where the polygon boundaries are located. Questions also arise as to what is a polygon in a network with curvilinear streets and/or a large number of cul-de-sacs. Because of these complexities, the average city planner may have difficulty in determining the number of polygons per square mile.

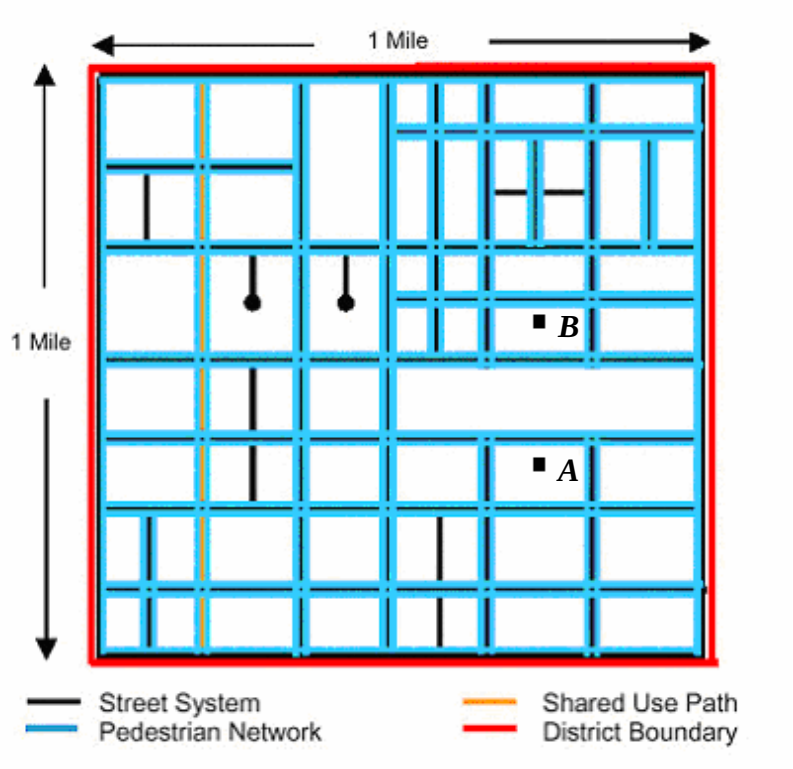



**Figure 2.4.1 Alternative Block Organization**

The polygon method of determining pedestrian connectivity also does not adequately consider the nature of intersections within the district. Intersections are a major impedance factor for determining the connectivity of a network. A successful pedestrian connectivity index should take into account how easy it is for the pedestrian to cross that intersection. This includes the presence of crosswalks, pedestrian signals, and speed of traffic at the intersection among other things.

### *2.4.2 Block Length*

The concept of a maximum block length is a good measure of pedestrian connectivity that can be very useful, especially when used in a proactive manner. This methodology is closely related to the number of polygons per square mile methodology in that its premise is to maximize the number of blocks in an area. This methodology however, does not calculate a connectivity index. Instead, it simply sets a standard for block lengths. This methodology would not be useful in areas that are already developed because it can be extremely difficult to change the block length in residential neighborhoods once they are built. However, when used as a design standard, it could promote networks that have high connectivity.

### *2.4.3 Link-Node Ratio*

The link-node ratio is a commonly used measure that uses intersections and roadway segments to calculate a connectivity measure. While this measure is useful, there is one flaw that is inherent with it. The boundaries of most areas are defined by arterials. When using the link-node ratio, the question arises of whether or not to include segments that begin on the boundary arterials and terminate outside of the study area boundary. If these

are included, the results of the analysis can be drastically different than if they are not included. If this methodology is to be widely used in practice, a standardized methodology needs to be established.

### *2.4.4 Pedestrian Route Directness*

This methodology could prove to be the most accurate of all methodologies because it incorporates block length and intersection locations into the calculation. However, future research is needed in order to determine a more reliable standard of comparison. Two major operational problems are associated with this methodology. First, it is extremely tedious to complete this analysis without using GIS. While theoretically, one could use this with just a map and a ruler, the time involved in completing an analysis would be extensive.

The pedestrian route directness equation is also extremely data intensive. When using a GIS, it is necessary to have points for all major destinations. Once all destinations are inputted, various GIS scripts would be necessary in order to calculate distances. This process requires an in-depth knowledge of GIS which may be beyond the means of most local government planners.

## 2.5 Recommendations

Even though there is a currently a large amount of research about the concept of pedestrian connectivity, there is no current standard that has been agreed upon as being both effective and efficient. Theoretically, there are various methodologies that seem as though they could prove to be both accurate and effective such as the Pedestrian Route Directness equation. However, operationalizing a methodology such as this requires local jurisdictions to have both the access to and knowledge of GIS in order for this to become a standard. It is understood that many local governments do not have the means to perform such an analysis.

It is our recommendation to continue to use the current methodology of number of blocks per square mile in conjunction with the link-node methodology. Both of these methodologies are relatively simple to use with or without GIS and, in fact, they are much less cumbersome to perform by hand using maps rather than a GIS. While many cities throughout the country have implemented the block length methodology for dealing with connectivity, it is our opinion that the current methodology of looking at the number of blocks per square mile is easier to use and reaches the same conclusion. When used in conjunction with the link-node methodology, an even greater measure of connectivity can be achieved.

## 3.0 ACTIVITY CENTERS ALONG A CORRIDOR

Identifying the activity centers and the number of people they serve by alternative modes is very important when trying to grasp the multimodal potential of a proposed district. This section will detail two methodologies to analyze the density and mix of land uses within activity centers. These methodologies will eliminate districts whose activity centers consist of large shopping malls, "big box" stores and other spread out commercial development. These methodologies also help account for smaller-scale specialty development and recreational/cultural land uses.

The first step in defining a MMTD should *not* be to draw the boundary. Instead multimodal activity centers should be defined. Then using the activity centers as the geographic center, the boundary should be drawn based on the service area of alternative modes of transportation.

On the left in Figure 3.0.1 is a MMTD with a good boundary. The mixed use, high density activity centers are located toward the center. The boundary drawn around it lies at the reasonable maximum bicycling distance. This distance is ideally calculated using the actual road layer instead of "as the crow flies". The end result is that all residents within the district boundary have an alternative mode of transportation available to them. Figure 3.0.2 shows a poorly drawn MMTD on the right. It does not have its activity centers at the center of the district. In fact, there are residents of the district who live outside of walking and bicycling distance of the activity centers. This district will do little to promote multimodal behavior, since many people living in the district must continue to rely on automobiles. With a properly drawn MMTD, this area could have strong multimodal potential.

**Figure 3.0.1 – Good MMTD Boundary**

**Figure 3.0.2 – Poor Multimodal Boundary**

This part is divided into four sub-sections. Sub-section 1 takes a close look at the recommended land use table included in the November 2003 version of the MMTD Handbook issued by the Florida Department of Transportation. Sub-sections 2 and 3 describe methodologies to identify mixed use and high density activity centers, respectively. Sub-section 4 discusses planning and policy uses for GIS techniques.

The entire methodology takes approximately 3–5 hours to perform, depending on the processor speed of the computer being used. To perform this methodology, the user will need the following resources:

- ArcGIS 8.x with Spatial Analyst
- Three publicly available scripts:
    - – "Poly to Centroid version 1.1" written by Juan Solorzano
    - – "Nearest Neighbor VBA Macro" written by M. Sawada
    - – "Quadrant Count" written by Tunde Owoola
- Note – All three scripts can be downloaded from http://arcscripts.esri.com. It is easiest to search by the author's name. FDOT has been provided with a copy of all three scripts. All three scripts can be installed into ArcGIS 8.x
- ArcView 3.2
- A GIS parcel layer containing Florida Land Use and Cover Classification System (FLUCCS) codes or at minimum, Parcel Use codes

- A copy of the FLUCCS manual or the GIS-producing agency's Parcel Use table.
- A copy of the MMTD Handbook Land Use table from January 2003 (FDOT 2003b)
- Additional GIS layers to give the user landmarks by which to draw district boundaries, such as major roads or municipal boundaries.
- Statistical Package for Social Scientists (SPSS)or other statistical package

### 3.1 Part A – Land Use Table and Land use Classification Systems

It is important to have a discrete, ordered system of land use classification to ensure that map algebra, diagrams and other information are presented in a clear, easily understood manner. This ordered land use classification system also enhances any GIS analysis. Two land use classification systems are found in nearly every GIS land use layer table; (1) Parcel Use; and (2) the FLUCCS codes.

Most counties and municipalities have a Parcel Use system. This is usually a 2-digit code system. It is limited to 100 land use categories. There are disadvantages and advantages to using a Parcel Use system. In Table 3.1.1 below, an attempt was made to fit the Alachua County Parcel Use system into the table. The Parcel Use system corresponds reasonably well with the MMTD Handbook land use table. The major disadvantage of the Parcel Use system is that it is not standardized across the state. Every county has a different Parcel Use code system and often they cannot be compared. Another disadvantage of using Parcel Use is that the codes are often not in any discernable order. In Alachua County, Florists/Greenhouses are code 30, while code 31 is the completely unrelated Theaters/Stadiums.[1]

The FLUCCS is set forth by the State of Florida Department of Revenue (DOR) as the official land use classification system for land management in the state. It relies on a 4-tiered number system. The thousands number is the most general, the hundreds place is more specific, the tens place is even more specific, and the single digit describes only one land use. Nearly all GIS-producing government agencies in the state classify land use by the FLUCCS code along with their native classification schemes such as Parcel Use. Further, the FLUCCS system allows us to describe land use on a very specific basis (i.e., "Professional Services" instead of "Light Commercial") that would be the same across the state. This is important, since we are interested in districts that have a high amount of Commercial, but a wide variety of commercial activities. The 4-digit FLUCCS system also fits nicely with the land uses enumerated in the MMTD Handbook. However, most GIS data sources do not use the full 4 digits. Most use 2 digits (i.e., 1700 instead of 1744). By using the methodology described later, we can help solve this problem and get full 4 digit numbers.

[1] Department of Revenue (DOR) codes are similar in structure to parcel use codes because they have two digits and, in some instances, may be share the same values. However, it is preferable to utilize parcel use codes because they account for local variation among local jurisdictions. The DOR code is *not* standard across the state. As shown in section 5, the DOR codes can be used for GIS analysis and are preferable to Water Management District land use data, and many local zoning and land use classifications.

Table 3.1.1 shows the land use table from the MMTD Handbook (FDOT 2003b) along with the corresponding codes for Alachua County's Parcel Use system and the FLUCCS. It is followed by a discussion about each land use type, and recommendations are made about modifying the table in the MMTD Handbook.

**Table 3.1.1 Evaluation of Existing MMTD Land Use Table (Source: FDOT 2003b)**

| Land Use | Multimodal Compatibility | FLUCCS Codes | Alachua Parcel Use Code | Suggestions |
|---|---|---|---|---|
| Office | ■ | 143 | 17–19 | |
| Local Services | ● | ? | ? | |
| Medical Services | ● | 1741–1743 | 73, 74, 85, | Change to "Hospitals/Clinics" |
| Hotel | ■ | 1451 | 35 | Expand to "Tourist Facilities" |
| Restaurants | ■ | 1415 | 21, 22 | |
| Local Shopping | ■ | 1411 | 16 | |
| Regional Shopping | ● | 1411 | 13,15, | |
| Specialty Shopping | ■ | 1411 | none | |
| Convenience Retail | ● | 1414 | 26 (partial) | |
| Gym/Health Club | ● | None | none | Eliminate |
| Recreational/Cultural | ■ | 1441–1448, 1722, 1851, 1881–1882 | 32, 33, 71, 77, 79, 82, | Split into "Recreational" and "Cultural" |
| Day Care | ● | 1780 | none | |
| College/University | ■ | 1711–1712 | 83, 84 | Include primary and secondary schools |
| Government Services | ■ | 1750–1759 | Many | |
| High Density Residential: >7 per acre | ■ | 1300–1369 | Not Defined 03, 04 | |
| Other Residential | ● | 1100–1299 | Not Defined 01, 02, 08 | Make Medium Density its own category |
| ■ Primary Land Use | | ● Supporting Land Use | | |

Office

The code for general offices is the 3 digit code 143x. This code fits the description from the Handbook well. However, please see the "Medical Services" below.

Local Services

This category is not differentiated by Alachua County Parcel Use codes or FLUCCS codes. It will only be possible to set this apart as its own category by a windshield survey.

Medical Services
Medical services should be redesignated as Health Care Facilities. The FLUCCS has a land use code for hospitals, 1741–1743. These codes also include nursing homes and clinics. The name "medical services" implies that medical offices are included. They will fall under "Office" according to the system and most Parcel Use systems.

Hotel
Hotels fall into the FLUCCS category 1451. Other tourist infrastructure may also be of utility in a MMTD. Thus, perhaps this category should be renamed "Tourist Services". If the change was made, it would be defined as 1451–1459.

Restaurants
Restaurants have their own code, 1415.

Local Shopping
Shopping centers have a 4 digit code, 1411. This does not allow for FLUCCS to differentiate between Local and Regional Shopping Centers. Please see the methodology discussed below.

Regional Shopping
Shopping centers have a 4 digit code, 1411. This does not allow for FLUCCS to differentiate between Local and Regional Shopping Centers. Later in this section, a methodology will be described to differentiate the various types of shopping and commercial land uses.

Specialty Shopping
Shopping centers have a 4 digit code, 1411. This does not allow for FLUCCS to differentiate between Local, Specialty, and Regional Shopping Centers. Specialized shopping will fall under the 3 digit code 141x. It is likely that Local Shopping, Regional Shopping and Specialty Shopping will have to be differentiated later in a more qualitative fashion. A methodology to differential shopping centers can be found in section 3.1.2.

Convenience Retail
This category has its own 4 digit code, 1414.

Gym/Health Club
There is no category that fits Gym/Health Club. Probably the closest category is 141x, Retail Goods and Services. It is suggested that this category be merged with Recreation. Codes 1861–1864 (Community Recreational Facilities) include Basketball Courts, Gyms, and Baseball Diamonds. Since FLUCCS differentiates between these uses and "Governmental", this should be a new category. Codes 1810 (Swimming Beaches) and 1841 (Marinas) should also be included.

Cultural/Recreational
Cultural land uses include: 1721 (Churches and Synagogues), 1851 (City Parks), 1881–1882 (Historical Resources),

Day Care
Day Care has its own FLUCCS code, 1780.

College/University
The FLUCCS code 1711 and 1712 represent Colleges/Universities and Vocational Schools respectively. Primary and Secondary schools may also be a supporting use in an MMTD. If so, the codes 1711– 1715 should be used and the category changed to "Education Facilities".

Government Services
All Government Services fall under FLUCCS codes 1751–1758. This category does not include military installations or correction facilities.

High Density Residential
High density residential in all of its manifestations falls under codes 130x–136x. This includes high rise apartments, dense town homes and other facilities.

Other Residential
FLUCCS allows 30 designations of residential land use. Seven of them fall into High Density. It may be of use to consider Medium Density residential separately from "Other Residential". Medium Density Land uses (2–6 Dwelling Units per acre) are designated by codes 120–129. A proposed "Medium Density Residential" category will include single family homes and multiple family units whose density is 2–6 D.U. per acre. Perhaps this should be a complementary land use, while low density should not be considered complementary.

### *3.1.1 Recommended Changes to MMTD Land Use Table*
Table 3.1.2 is the new suggested Land Use Table for inclusion in the MMTD Handbook. This table is derived by fitting land uses into the FLUCCS code system. A discussion on changes made follows the table.

**Table 3.1.2 Suggested MMTD Land Use Table**

| Land Use | Multimodal Potential | FLUCCS Code | FLUCCS Description |
|---|---|---|---|
| Office | ■ | 1430 | General Office |
| **Health Care Facilities** | ● | **1741–1743** | **Hospitals, Clinics, Nursing Homes** |
| **Tourism Facilities** | ■ | **1445**<br>**1451–1459** | **Amusement Parks**<br>**Hotels, Tourist Attractions** |
| Restaurants | ■ | 1415 | Restaurants |
| Local Shopping | ■ | 1411*<br>1413 | Shopping Centers<br>Banking Facilities |
| Regional Shopping | ● | 1411* | Shopping Centers |
| Specialty Shopping | ■ | 1411* | Shopping Centers |
| Convenience Retail | ● | 1414 | Convenience Stores |
| **Recreational** | ■ | **1841**<br>**1851**<br>**1861–1864**<br>**1870** | **Marinas**<br>**Parks**<br>**Outdoor Playing Fields**<br>**Stadiums** |
| **Cultural** | ■ | **1441–1444,**<br>**1446–1448**<br>**1722**<br>**1881–1882** | **Theaters and Museums**<br>**Galleries and Libraries**<br>**Churches and Synogogues**<br>**Historical Resources** |
| Day Care | ● | 1780 | Commercial Day Care |
| **Educational Facilities** | ■ | **1711**<br>**1712**<br>**1713–1715** | **Universities and Colleges**<br>**Vocational Schools**<br>**Elementary through High Schools** |
| Government Services | ■ | 1750–1759 | Governmental Facilities |
| High Density Residential: >7 per acre | ■ | 1300–1369 | High Density Residential |
| **Medium Density Residential: 2–6/acre** | ● | **1200–1299** | **Medium Density Residential** |
| ■ Primary Land Uses | | ● Supporting Land Uses | |

**Bold** – New or altered category explained below
* – Specialty, Regional, and Local Shopping must be differentiated from each other. See Step 9 below for a discussion on making the distinction.

Health Care Facilities
The "Medical Services" category was narrowed so that the title excluded professional medical offices. Only Hospitals, Clinics, and Nursing Homes remain.

Tourism Facilities
The "Hotels" category was expanded to include all tourist facilities. It now includes RV parks, tourist attractions and miscellaneous tourist facilities.

Recreational
The "Cultural/Recreational" category was split into two different categories. Recreational uses now include Marinas, Parks, Stadiums and Outdoor Playing Fields. There are many more recreational land uses listed in the FLUCCS manual. However many of them are not conducive to multimodalism and dense development. These include: Racetracks, Gun Ranges, and Golf Courses.

Cultural
This category arises from the former "Cultural/Recreational" category. It includes indoor recreational activities. These include: theaters, art galleries, libraries, museums, houses of worship, and historical resources.

Educational Facilities
This category is expanded from "Colleges and Universities" to include vocational schools, elementary, middle and high schools.

Medium Density Residential (2–5 Dwelling Units per Acre)
This category is narrowed from "Other Residential". Low Density Residential is not supportive of multimodalism. However Medium Density Residential includes single family housing built on parcels of a half acre and smaller. In order to provide residents with a variety of housing options, single family homes deserve consideration to be included in a MMTD. However they should be of an adequate density. Thus, Low Density Residential is removed from the table.

Eliminated Categories
The following categories were eliminated from the original table:
Gym/Health Club – There are no land use codes for this type of land use.
Local Services – This category is probably covered by Local Shopping because the parcels likely identify the use as retail.
Low Density Housing – Eliminated from "Other Housing" because it is not conducive to multimodalism.

### *3.1.2 Fitting the Systems Together*
To analyze the land use mix, it is important to have a GIS land use layer that is:

Very Discrete – It should display land uses to at least the census block level. Preferably, it should be a parcel layer. These are commonly available from County Property Appraisers, although some may charge a fee for these products. Land Use data from

Water Management Districts should be avoided, since they focus on rural land and are not discrete enough.

Contains a FLUCCS Code Field – If no FLUCCS code field is present, it may stillbe possible to perform the land use mix procedure. However, it will require manipulating the Parcel Use classification system.

Current and Updated – Land uses can and do change due to rezonings, special exceptions, and comprehensive plan amendments. Since we are interested in studying the land use mix of some very closely related uses, it is important that the layer be up to date. Windshield surveys and other field data collection techniques could potentially render the necessary updates if current data cannot be found.

Once the land use layer has been identified, it is time to alter the data table to enter specific land use types. A copy of the local county's Parcel Use code table will be needed. A copy of the FLUCCS manual will also be needed (FDOT 1999). It can also be obtained from the Florida Department of Revenue (DOR) website. The procedure below assumes a basic ability to operate a GIS program.

Step 1
For the proposed MMTD, run several tests in the statistics package of ArcGIS to ensure that the potential area has a satisfactory amount of generalized land uses (Commercial, Industrial, Residential, Recreational, Educational, and Institutional). According to the MMTD Handbook, the district should have three or more significant land uses, so the potential area should have at least three of the six categories listed above. Also ensure that the district is of sufficient size and population. The Handbook states that the district should have at least 5,000 people. If the district passes, proceed to step 2.

Step 2
Query the FLUCCS field for all records with code 1400 and promote (or sort ascending) them to the top of the table.

Step 3
Scroll over to the Parcel Use field. Get the Parcel Use code from the first record. Now query the selected set for that parcel use codes and promote all of those values. All of the FLUCCS codes equal to precisely 1400 will be reclassified according to their, more specifically designated, parcel use codes.

Step 4
Match the Parcel Use code to the reference table supplied by the county. Now match the land use's name to its corresponding land use name in the FLUCCS manual. Refer to the appendix on page 63. Record the 4-digit FLUCCS code.

Step 5
Start editing in ArcGIS. For all records that were selected in steps 2 and 3, replace the FLUCCS column with the new 4-digit FLUCCS code. For example, if you have 10

records that have Parcel Use code 24 (Insurance Company Offices) and FLUCCS code 1400, you will replace the FLUCCS code for all 10 records with code 1430 (Professional Offices).

Step 6
Clear the selection. Repeat from step 2 until no FLUCCS codes in the1400 remain. The newly recoded values will fall below the remaining 1400 codes after they are promoted.

Step 7
Repeat the process for FLUCCS codes equal to 1700. DO NOT recode Military (173x), Correctional (176x) or Other Institutional (177x) since these land uses are not listed in the MMTD Handbook as promoters of multimodalism.

Step 8
Repeat the process for all FLUCCS codes equal to 1800.

All of the land uses listed on the table fall into the general land use codes 1200 (Medium Density Residential), 1300 (High Density Residential), 1400 (Commercial), 1700 (Institutional) and 1800 (Recreational). It is not necessary to become more specific about the Residential codes. Now you have a very discrete data set.

Step 9 – Differentiating Types of Shopping Centers
To accomplish this task, you will need either a) A Parcel Use system that is very specific about the type of shopping center; b) Local knowledge of the shopping centers; or c) A windshield survey of the parcels in question.

– Query the data table for FLUCCS Code 1411 (Shopping Centers)
– Starting at Step 2 above, recode shopping centers using the following codes:

2701 Regional Shopping Centers
2702 Local Shopping Centers
2703 Specialty Shopping Centers

Note – These codes do not have corresponding land uses in the FLUCCS system. This is why we are able to use them here.

– Fill in each parcel using local knowledge or windshield survey. Recode each parcel with the codes listed above.

### 3.2 Part B – Dissimilarity Index to Identify Mixed Use Activity Centers

In a "Dissimilarity Index" (Weston 2002), we use a rasterized land use layer and compare each cell to those around it. The raster layer is composed of thousands of equally sized blocks, each one called a cell. The entire map is covered by these cells. Each cell can contain only one piece of information, but some cells may represent "no data." The cells in our land use layer each contain one FLUCCS land use code.

The Neighborhood Statistic tool is a standard function of the Spatial Analyst extension of ArcGIS 8.x. The Neighborhood Statistic tool is often used to compare image signatures in satellite imagery, however we are adapting it to analyze land use. In this test the Neighborhood Statistic tool will take each cell in the map and compare it to the 48 cells that surround it. The output will be a new raster layer. The cells in the new layer will record how many different MMTD land uses there are around each cell.

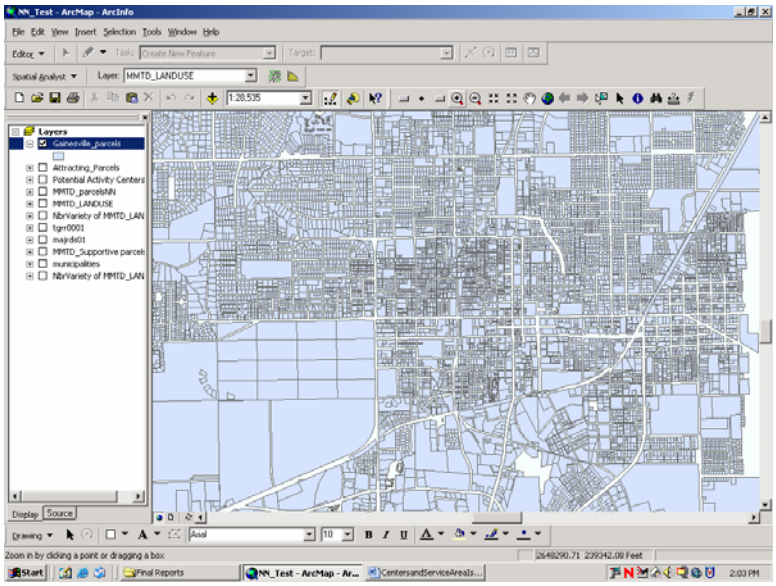


**Figure 3.2.1 All Parcels Used for Dissimilarity Analysis**

The parcels that have FLUCCS codes that correspond to the MMTD-supportive land use table are selected. A GIS file of all parcels is shown is Figure 3.2.1 above. After selecting only the MMTD-supportive parcels, the view is quite different. Figure 3.2.2 below shows only MMTD-supportive parcels.

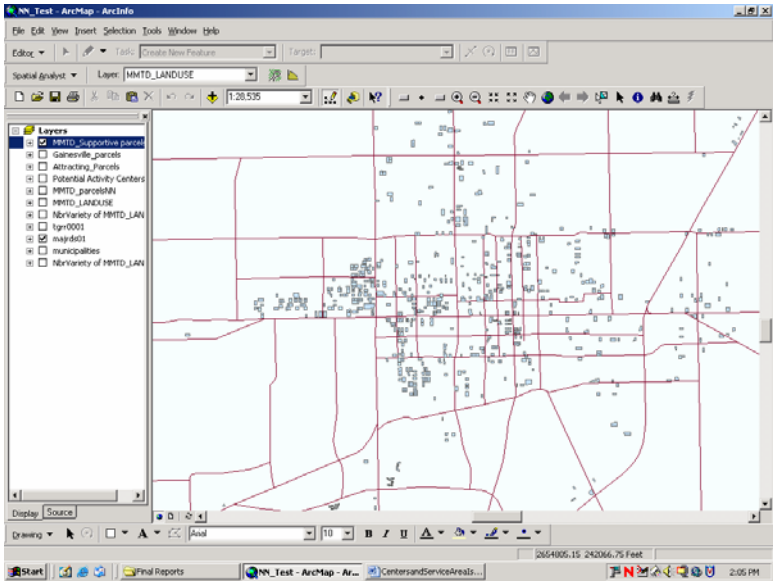



**Figure 3.2.2 MMTD Supportive Parcels**

After the MMTD-supportive parcels have been selected, we will convert the vector parcel data to raster format. In raster format, ArcGIS will break the parcel map into thousands of equally sized blocks. Each block will adopt the land use code which constitutes the majority of its area as shown in Figure 3.2.3 below. The blocks that do not lie above an MMTD-supported parcel will adopt the value "No Data". To convert to raster, open the Spatial Analyst menu, and select Convert/Features to Raster. Set the cell size as 31 square meters (approximately ¼ acre). Set the "value" to the land use code.

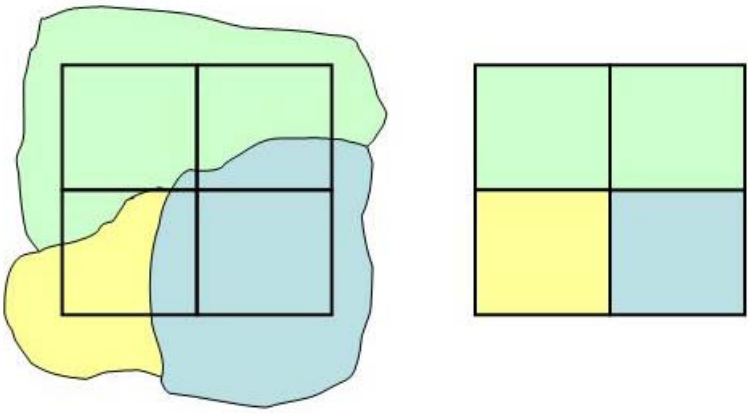


**Figure 3.2.3 Converting Vector Data to Raster**

Figure 3.2.4 below demonstrates a raster land use layer. The map has been broken down into small, equally sized blocks. The blocks are colored according to their land use code.

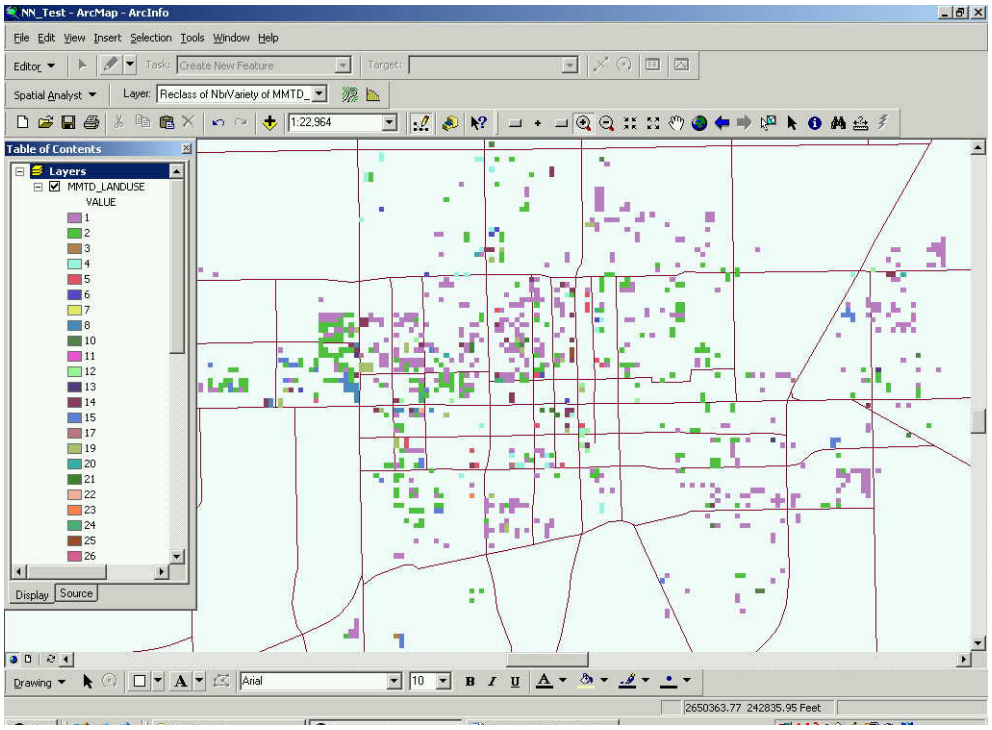



**Figure 3.2.4 Rasterized MMTD Supportive Parcels Ordered by Land Use Code**

Each cell has 8 cells that border it (including those that touch only at the corner). Outside that are 16 more cells. A third ring of cells has 24. Thus there are a total of 48 cells within 3 rings (about ¼ mile) of every cell in the raster layer. The Dissimilarity Index compares the FLUCCS codes of all the cells within a quarter mile square. Each unique FLUCCS code will be given one point. The maximum point score is 48.

In Figure 3.2.5 below, titled "Dissimilarity Comparison," two cells have been analyzed for the purposes of explanation. Each box represents 3 rings around a center cell. The box on the left will earn a point score of 1, because the center cell is the only MMTD-supportive land use. The box on the right will earn a point score of 4 because there are four land uses within the study area. In the box on the right, there are 4 cells colored brown (high density residential), one blue (office), one dark green (governmental) and one light blue (convenience retail). Note that the dissimilarity index counts the brown cells only one time, because it is analyzing the *variety* of land uses.

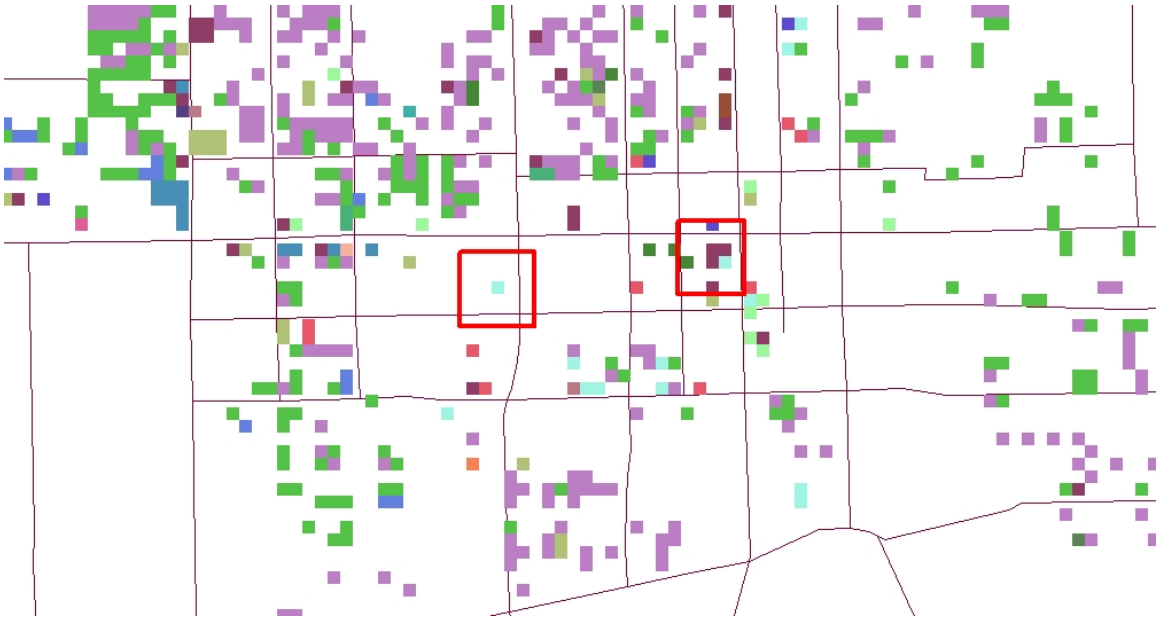


**Figure 3.2.5 Dissimilarity Comparison**

The methodology below walks the user through the entire process, beginning with a simple parcel map. At the end of the process, ArcGIS will render a map displaying the land use mix.

Step 1
Using the full parcel layer, select the land use codes that correspond to the MMTD-supportive land use table from the MMTD Handbook. Create a new layer of the parcels that match the MMTD table. Save the new layer.

Step 2
Convert the selected parcel layer to raster. Using the Spatial Analyst toolbar, select Convert/ Features to Raster. Set the cell size at 31 square meters (1/4 acre). Set the Value to the FLUCCS code or Parcel Use code. When Spatial Analyst is creating the new raster, it will break the map up into ¼ acre squares. Each square will take the value of the land use underneath it. In the case where two land uses are present in one ¼ acre cell, spatial analyst will assign the value of the land use that occupies the greatest amount of space.

Step 3
Bring up the Neighborhood Statistics dialog box from the Spatial Analyst menu.

Step 4
Set the "Input Data" to the land use raster layer that was created from the parcel layer.

Step 5
Make sure the "Field" is set to Value. Change the "Statistic Type" to Variety. Make sure "Neighborhood" is set to Rectangle.

Step 6

Under "Neighborhood Settings", make sure the "Units" are set to Cell. Both the height and the width should be 3.

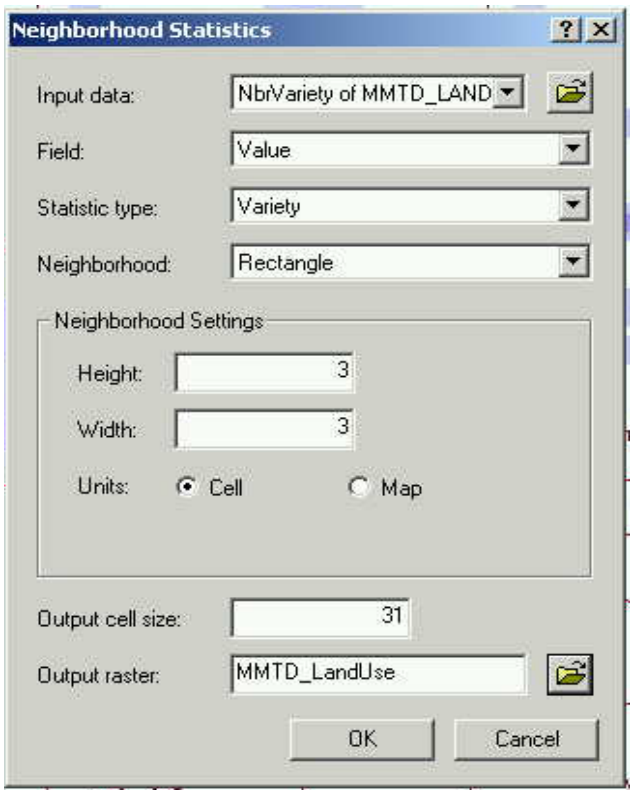



**Figure 3.2.6 Neighborhood Statistics Dialog Box**

Step 7

Change the Output Cell size to 31 square meters (the same as the land use raster). Give your output file a name, and hit OK (See Figure 3.2.6).

After running the methodology above, the user should have a view that looks similar to Figure 3.2.7. The software has looked at the parcel use codes of the 48 cells surrounding each cell and counted the unique values. Areas with a robust mix of land uses are presented as darker colors.

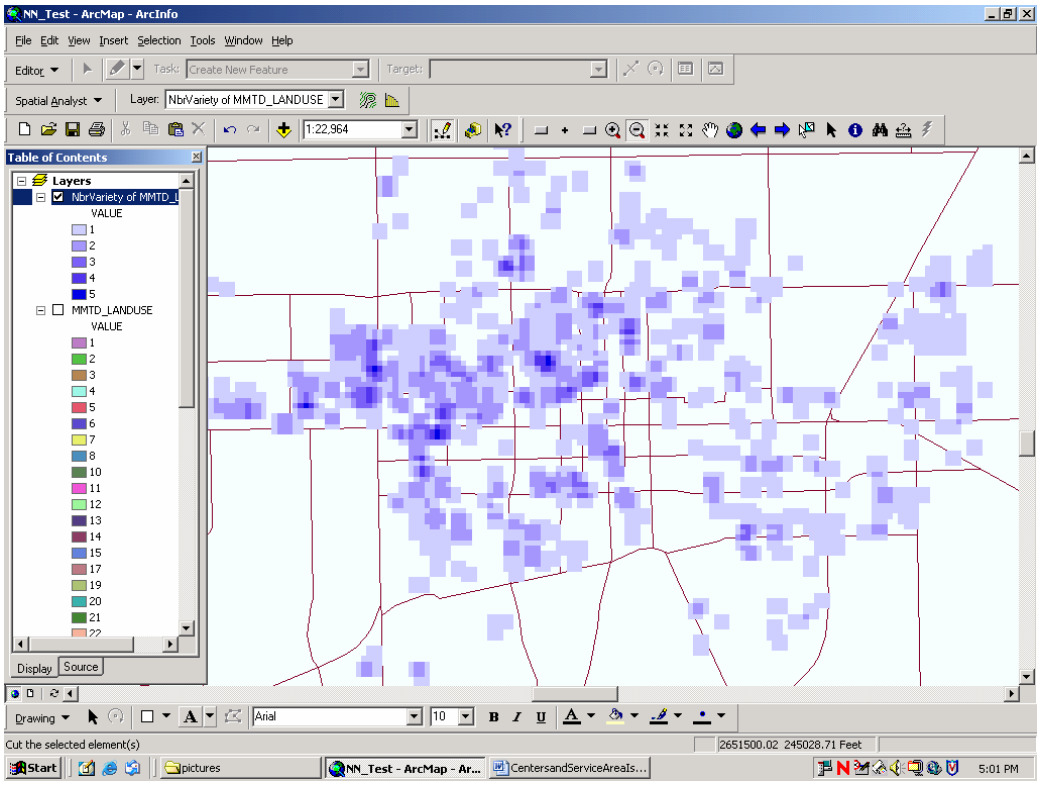



**Figure 3.2.7 Variety of Land Uses – End Result of Neighborhood Statistics Tool**

The areas where there is a robust variety of land uses will stand out on the newly created raster layer. The next step is to identify those areas as activity centers. The user must "eyeball" the activity centers by grouping areas of high land use mix. The user should create a vector layer of activity centers and draw polygons (i.e., digitize) around the areas with a strong land use mix. An image below (See Figure 3.2.8) shows an example of digitized activity centers.

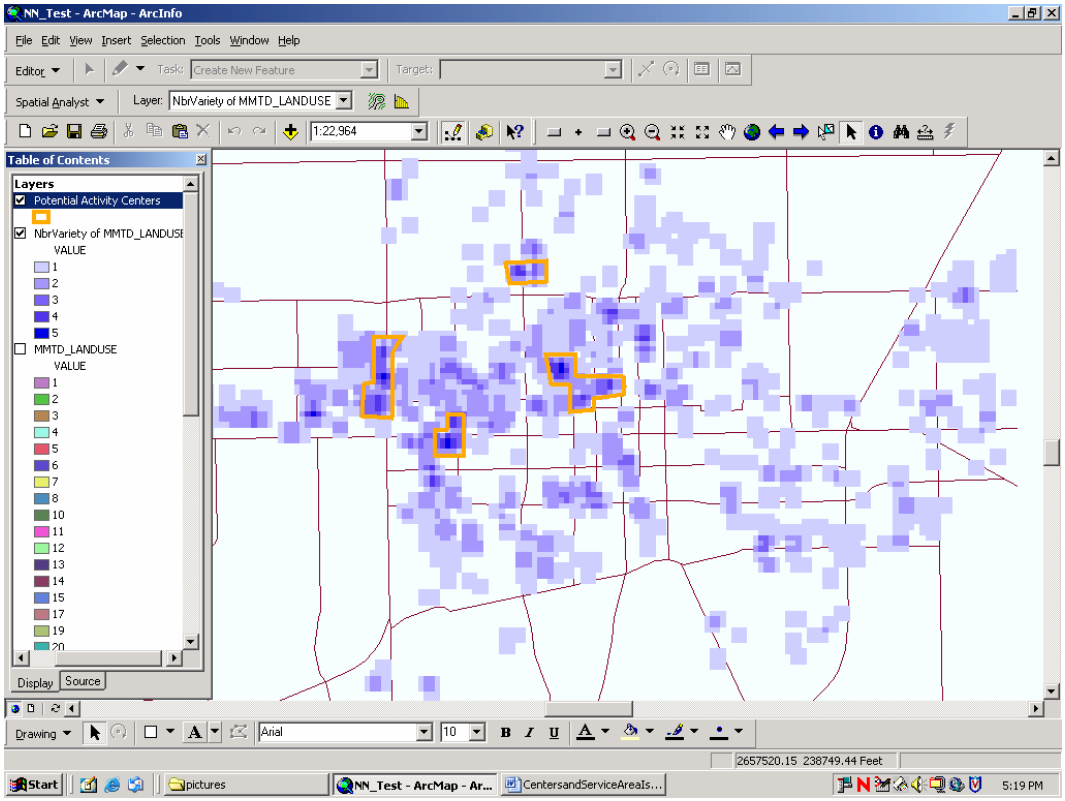



**Figure 3.2.8 Activity Centers with Strong Land Use Mix**

Once the user has identified high levels of mixed use, it is possible to quantify the exact number of land uses found in each activity center. While quantifying the number of land uses is useful to know, it is not a required portion of the Dissimilarity test. This is done using the Zonal Statistics function of Spatial Analyst. The Zonal Statistics tool will render the variety of land uses within a given zone (See Figure 3.2.9). In this case, the zones are the digitized activity centers the user just created. The original land use raster should be used for the "Value Raster". This will allow Spatial Analyst to count the varieties of land use codes within the potential activity centers.

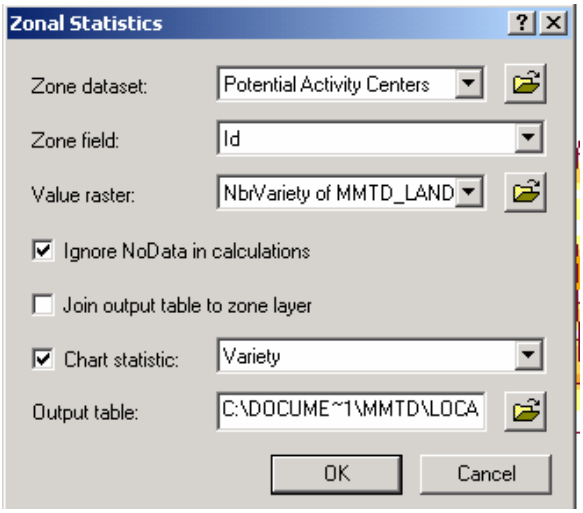



**Figure 3.2.9 Zonal Statistics Dialog Box**

The output of the Zonal Statistics is a bar graph showing the variety of land uses within the potential activity center. Table 3.2.1 was derived over a series of test runs. Compare the number of land uses in the left column with the multimodal potential in the right column. Activity centers that qualify as poor should be discarded.

| **Table 3.2.1 Neighborhood Statistic Interpretation** | |
|---|---|
| Number of Land Uses | Activity Center Mixture/MMTD Potential |
| 1–4 | Poor |
| 5–10 | Good |
| 11–49 | Excellent |

### 3.3 Part C – Spatial Statistics to Identify Dense Activity Centers

Another measure of the magnitude of activity centers is their density. Previously, the measures used to describe the density of an area were limited to measures such as: people per acre, floor area ratio and employment per acre. No measure exists that takes into account the spatial density. Nor is there a measure that describes only the density of specific land uses. This section will use GIS and two spatial statistics tests to define and describe activity centers in terms of the density of the desired land uses in a MMTD.

The first step is to create points at the geographic center of each parcel that is a MMTD-supportive land use. From the Parcel shapefile, select the parcels with the appropriate land use codes. Now we will create the points at the center. The easiest way to create these points is to use the "Poly to Centroid version 1.1" script written by Juan Solorzano. It is also possible to get the centroid points by copying them from a coverage file inside ArcCatalog.

Two important filters are applied to the parcels by creating points at the geographic center. When points are created on MMTD-supportive parcels, their relation to each other can be studied in greater depth. Since only one point is created for each parcel, an "activity center" consisting of large parcels will stand out as less dense than one with small parcels. Large parking lots, "big box" stores and shopping malls are high *intensity* land uses, but since their parcels are large, they are considered low *density* by these statistical tests.

The screenshot below titled "MMTD-Supportive Parcel Centroids" shows the center points of MMTD-Supportive Parcels and the outlines of the potential activity centers from the dissimilarity test (See Figure 3.3.1). The potential activity centers do not encompass the densest areas of points.

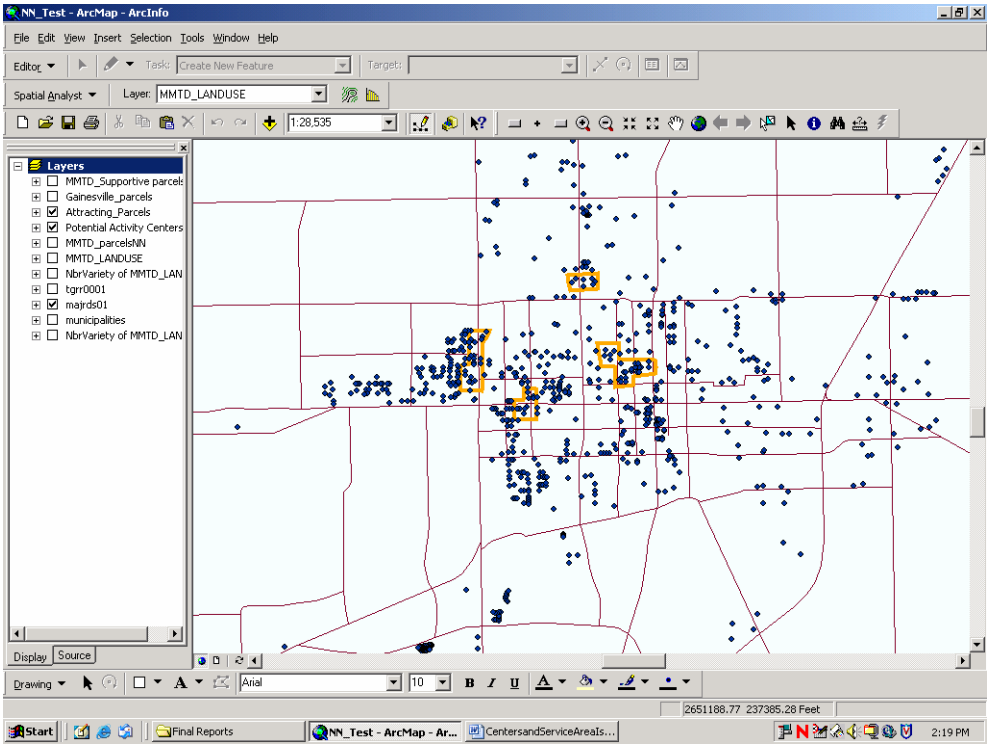



**Figure 3.3.1 MMTD-Supportive Parcel Centroids**

The potential activity centers can be expanded to cover adjacent points (See Figure 3.3.2). This creates activity centers that are *both* dense and mixed use. New activity centers should not be created. Instead only modify old ones. An example is shown in the screenshot below. It may be helpful to not include medium-density housing when creating points. Medium-density housing is the most common MMTD-supportive land use, and the presence of these points may make the view too crowded.

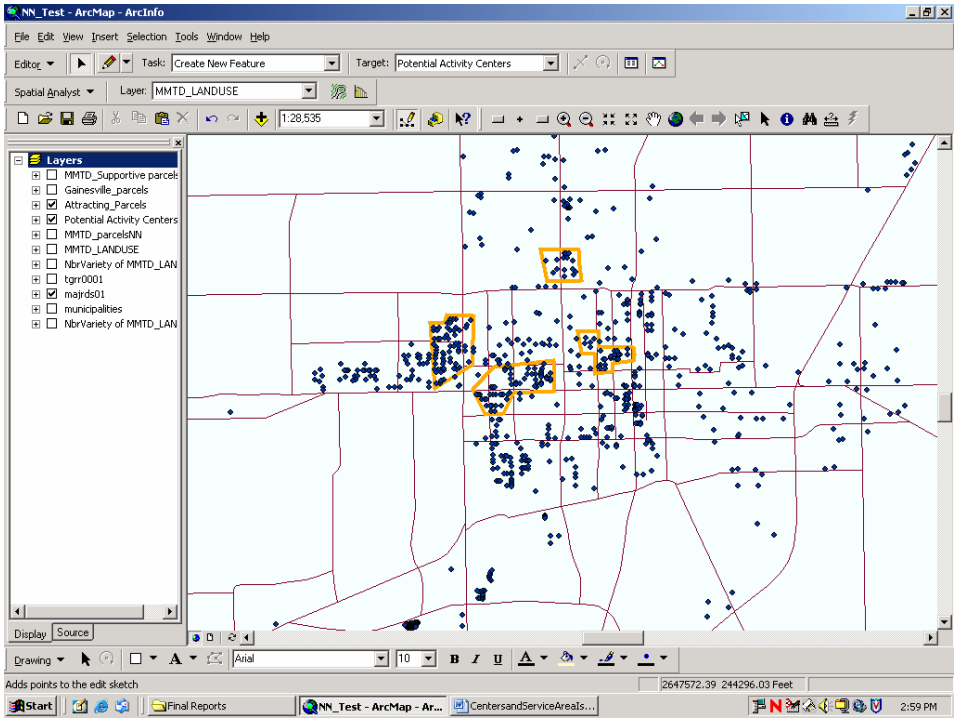



**Figure 3.3.2 Expanded Activity Centers**

### *3.3.1 Drawing the District Boundary*

The orange polygons now represent our activity centers (See Figure 3.3.2). As discussed in the introduction, we want our activity centers to lie at or near the geographic center of the Multimodal Transportation District. The district boundary should closely match the reasonable service area of alternative modes. To get a rough outline of the district, buffers will be drawn at ½ mile and 1 mile intervals around the identified activity centers to represent the maximum walking and bicycling distance (See Figure 3.3.3).

The blue ring represents the maximum walking distance from the activity centers, while the red ring represents the maximum bicycling distance from the activity centers. This method does not take into account road network or pedestrian facilities factors; it simply draws a straight line or "crow fly" distance buffer. These factors are discussed in depth in Sections 2 and 4 of this paper

For the purposes of the spatial statistics tests, the bicycling buffer is the extent of the district. Later on, the area served by transit can be added to the final district boundary.

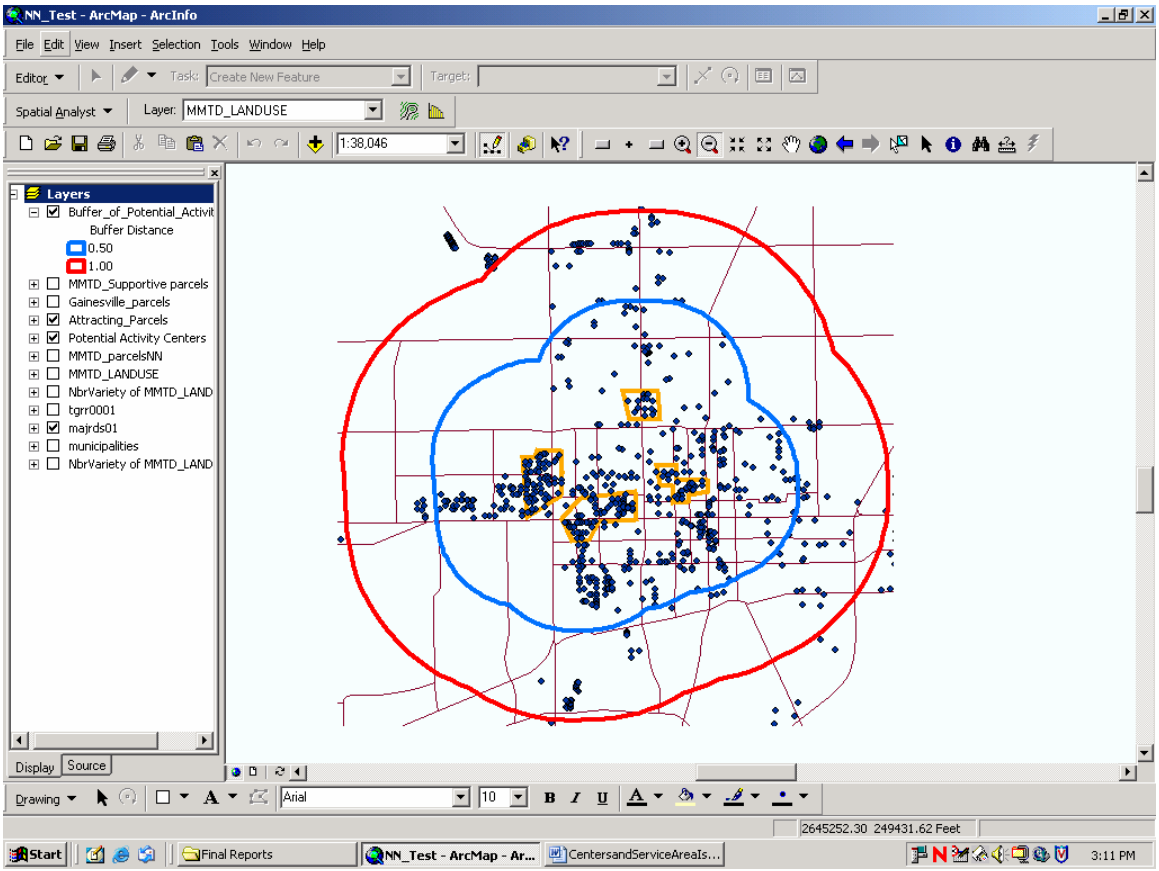



**Figure 3.3.3 Buffers Around Activity Centers**

3.3.1.1 Statistical Test #1 – Poisson Point Pattern Distribution Test

The first step for this statistical test is to select the points that lie within the bicycling distance buffer and create a new shapefile with those points.

In a Poisson Point Pattern Distribution test, points are analyzed in a map to determine if they are randomly distributed or organized in some sort of clustering pattern. This test will alert the user as to whether the district displays enough clustering to be called an activity center. The study area is overlaid with a grid of square cells (or quadrants), and the number of points that fall within each cell is tabulated. Figure 3.3.4 demonstrates a grid overlaid on a set of points.

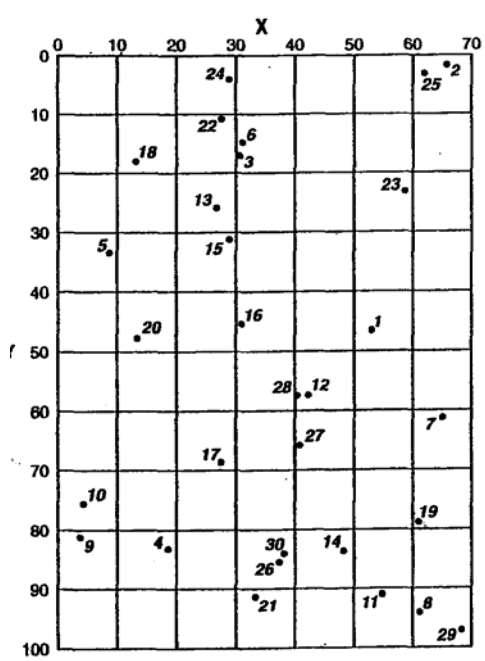



**Figure 3.3.4 Grid Applied to a Point Map**
Source: Burt, James and Gerald Barber. *Elementary Statistics for Geographers 2nd Ed.* 1996

A frequency distribution of the number of cells with a given number of points is complied. For example, if there are 100 cells in the view, Table 3.3.1 could be derived.

**Table 3.3.1 Frequency Distribution of Number of Cells by the Number of Points**

| Number of Points | # of Cells with that Number |
|---|---|
| 0 | 61 |
| 1 | 23 |
| 2 | 12 |
| 3 | 3 |
| 4 | 1 |

This frequency distribution will be statistically compared with a standard distribution known as a Poisson Distribution. The Poisson Distribution assigns probabilities to rare occurrences over time or space. The Poisson Distribution is described by the equation:

$$p(x) = \frac{e^{-\lambda}\lambda^{x}}{x!}$$

Where e is the inverse of the natural logarithm, x is the frequency class, and lambda ($l$) = (Number of points in the view) / (Number of Quadrants). Lambda is only calculated once, and acts as a constant in each calculation.

Fortunately, most of this process is automated. To perform the Point Pattern Distribution Test, use the script titled "Quadrant Count" written by Tunde Owoola. Note that this

script only functions in ArcView 3.x. This script will automate several of the time consuming tasks of performing the test. The script will:

a) Count the total number of points in the view
b) Examine the view and determine how many squares or "quadrants" it should be cut into. It does this using a complicated equation that based on the area.
c) The script will calculate Lambda (l) by dividing the total number of points by the number of cells.
d) Count the number of cells with zero points and add that number to the frequency table.
e) Count the number of cells with one point and add that number to the frequency table. The counting process is repeated up to a frequency of 100.

The script will create a Microsoft Excel output file of the frequency table. This Excel file should be imported to the Statistical Package for the Social Sciences (SPSS) statistical software program or other similar programs. Using SPSS, a Kolmogorov-Simirnov (or K-S) test will be run to compare the frequency distribution to the Poisson distribution. A K-S test creates an output number known as the D-statistic. If the D-statistic is greater or less than 1.96, the district is assumed to present a clustering of MMTD-supported land uses. This test proves that the points observed are dense (and clustered) enough to be called activity centers.

3.3.1.2 Statistical Test #2 – Nearest Neighbor Analysis

A nearest-neighbor statistic describes the average distance between points. The distance from each point to its nearest neighbor is measured and a statistical test interprets the mean distance between points to the expected mean distance. This test was originally developed to measure natural phenomena such as plant species and soil pH. However it is also useful for measuring man-made phenomena.

The Nearest Neighbor Test is a comparison between the expected mean distance and the observed mean distance. To get the observed distance, the distance between each point and its closest neighbor is measured. Note that point B's closest neighbor may be point A, but Point A's closest neighbor is not necessarily point B. The distances are averaged to get the observed mean distance. To get the expected mean distance, use the following equation.

$$R(\text{expected}) = \sqrt{(\#\text{ of points})} / (\text{Area})$$

The statistic **R** describes the ratio between the observed mean distance and the expected mean distance. The R-statistic can range from 0 to 2.149. A completely random distribution will have an R-statistic of 1. Thus the R-statistic can be used on a sliding scale to describe the strength of clustering found (Barber and Burt 1996).

The existence of large parcels often means homogenous land use, large parking lots and low density. The Nearest Neighbor Statistic will recognize the wider spatial distribution and alert us to districts that display these characteristics. The Nearest Neighbor Test will interpret the *nature* of the clustering found during the Poisson Nearest Neighbor Test.

The major advantage of the Nearest-Neighbor Statistic is that it interprets the results. Unlike the Point Pattern Distribution, the Nearest-Neighbor Analysis goes beyond accepting or rejecting hypotheses. Nearest-Neighbor Analysis can describe the clustering characteristics of the points. The test interprets five possible clustering patterns as shown in the stylized images in Figure 3.3.5:

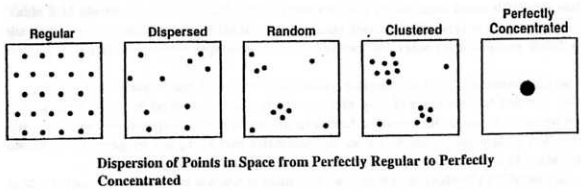



**Figure 3.3.5 Dispersion Patterns**
Source: Burt, James and Gerald Barber. *Elementary Statistics for Geographers 2nd Ed.* 1996

The point patterns range from perfectly regular (or repelled) to perfectly concentrated. Since we are looking at MMTD-supportive land uses, the Nearest Neighbor Analysis will help us describe the spatial arrangement of activity centers and alternative-mode producing land uses.

The five possible distributions of points correspond to recognizable development patterns. They also can help distinguish between the three types of Multimodal Districts: Urban Centers, Regional Centers and Town Centers. The MMTD Handbook lays out different criteria for each type of district, and the Nearest Neighbor Test will help distinguish one from the other. In general, the higher the R-statistic, the better multimodal potential for the district. Below is a discussion of each possible class as defined by the Nearest Neighbor Test.

Regular – Regular (or Repelled) dispersions, the points are found at regular intervals from each other. Thus, the variance and standard deviation of the Nearest Neighbor Statistic will be very small or zero. *The R-Statistic will be at or near zero.* This land pattern is highly unlikely to be found, and if it was, there is no multimodal potential.

Dispersed – A dispersed point pattern is one where *the R-statistic is less than 0.8.* A Dispersed land pattern is most likely found in a low density residential setting with few trip attracting land uses. The only points that are found represent parks and neighborhood-serving retail. A Dispersed land pattern is not supportive of multimodalism.

Random – In a random point pattern, *the R-statistic will range between 0.8 and 1.2.* A Random land pattern is characteristic of suburban strip-style development. Large parking lots and a linear pattern would make the distance between points very large. A Random land pattern is in general not supportive of multimodalism, however the presence of transit could mitigate this.

Clustered – In a clustered point pattern, *the R-statistic falls in the range 1.2–1.8*. Since the points are clustered in several areas, the mean distance is reduced considerably. The standard deviation remains somewhat elevated because the clustering is not perfect and there are outlying points. A Clustered land pattern describes the existence of one or more activity centers. Town Center or Regional Center MMTDs will present a clustered land pattern. Town Center MMTDs will usually be in the lower end of the range. A Clustered land use pattern is in general supportive of multimodalism.

Concentrated – A concentrated distribution describes one or more dense activity centers. *The R-statistic is in the upper range, between 1.8 and 2.1*. An R-statistic above 2.1 essentially means that the points are all concentrated at one point in space, which is physically impossible, particularly when discussing land uses. There are few if any outlying points. An "Urban Center" MMTD will usually present a concentrated land use pattern. This land use pattern is very supportive of multimodalism.

To perform the test, run the "Nearest Neighbor VBA Macro" written by M. Sawada. Set the boundary to the bicycling distance buffer. The script will produce a window showing the statistics important to this test. The dialog box after the script has run is shown in Figure 3.3.6 below. Refer to the two important pieces of data for calculating the R-statistic: Average distance (Avg. dist.) and Observed Distance (Exp. avg.). Use the "Corrected" figures, since those figures are corrected to account for "edge effects" where points lie close to the boundary.

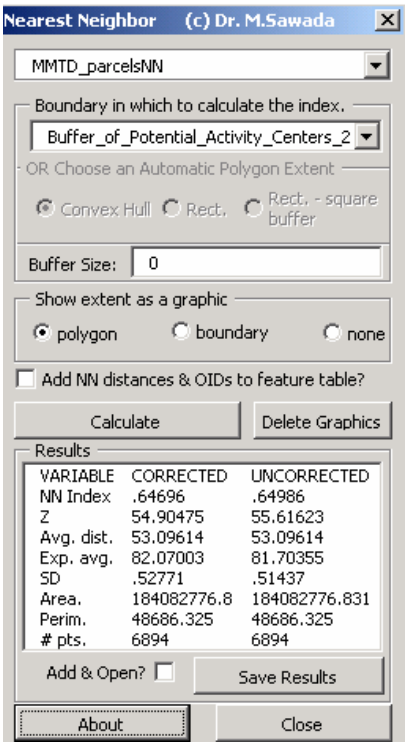


**Figure 3.3.6 Nearest Neighbor Script**

Using the equation R = (Expected Distance) / (Observed Distance), enter the numbers created by the script: R = (82.07) / (53.1), therefore R = 1.55. Referring to the discussion above, the analyzed district is Clustered. Therefore we can also assume it is a Town Center or Regional Center Multimodal Transportation District.

## 3.4 Part D – Defining the Multimodal Service Area and the MMTD Boundary

### *3.4.1 Existing Conditions*

Currently in the MMTD Handbook, reference is made to the ability of activity centers to be accessible by alternative modes. The Pedestrian, Bicycle and Transit Level of Service measures give us a glimpse the overall condition of alternative mode transportation within an area. However, we do not currently have a measure of the number of people each activity center or corridor serves at that level of service.

By defining our activity centers and then drawing a buffer around them (ideally based upon the street network), we can calculate the number of dwelling units and people who reside within a reasonable walking distance of each activity center. This procedure can be repeated for bicycling distance, transit access and other appropriate measures.

Figure 3.4.1 shows the multimodal service areas around two activity centers. In this case, the activity centers are downtown Miami and the University Medical Center. Buffers have been drawn around the activity centers to show the areas that each mode serves. The walkable area is shown at ½ mile. The bicycling area is shown at 1 mile. Finally, the transit area (in this case, the Metrorail and Metromover lines) is shown as a ½ mile walk from the transit line.

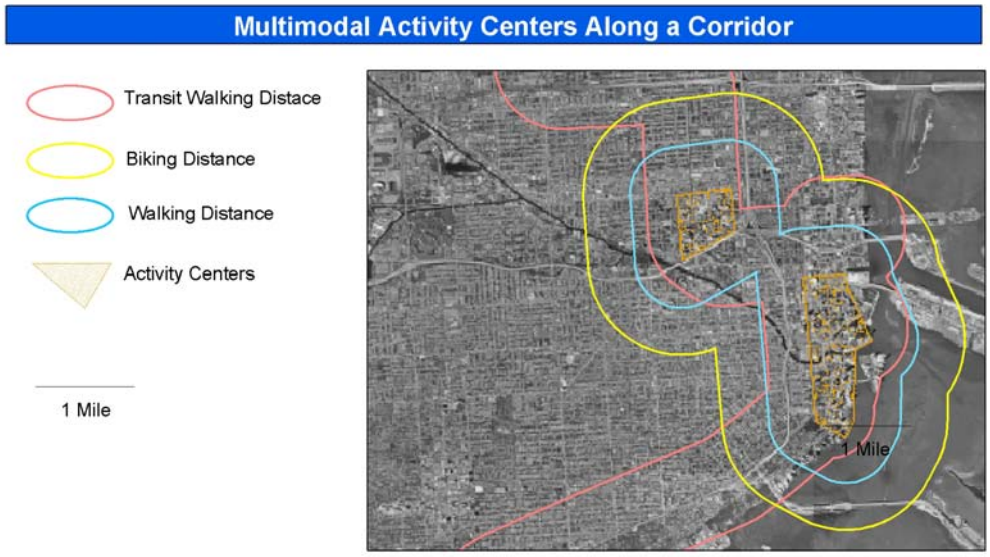



**Figure 3.4.1**

In previous parts of this paper, methodologies have been described to identify and quantify high density, mixed use activity centers within a potential MMTD. Using these methods, we can identify the rough boundary of the activity center and use that boundary to look at the number of residents who have the opportunity to reach that activity center by alternative modes.

The statistical function of ArcGIS will be used to calculate the number of acres of each type of residential land use. Use the "Select by Location" function to select all of the residential parcels whose centers lie within the buffer. This will supply us with the number of acres of different types of residential land uses located within ½ mile of the activity center along the existing road network.

The Metadata of the parcel layer or the FLUCCS manual will reveal the density of the residential units. Table 3.4.1 shows the FLUCCS guidelines for each density type:

**Table 3.4.1. Allowable Densities for Residential FLUCCS Codes**

| Density Type (FLUCCS code) | Allowed Dwelling Units Per Acre |
|---|---|
| High (1300–1399) | 6 to 20 |
| Medium (1200–1299) | 2–5 |
| Low (1100–1199) | Less than 2 |

Some parcel layers may contain guidelines that are more specific. In cases where there is a range, the average value should be taken.

One last piece of data is needed to calculate the number of people within walking distance of our activity centers. The Census Bureau publishes the average household size for every geographic boundary down to the census block. It is best to use the smallest geographic unit possible, to account for local variation across a neighborhood.

We will use the following equations to calculate the number of people served within walking distance:

(# of People in High Density) = (Acres of High Density) * (Dwelling Units Per Acre, High Density) * (Avg. Household Size)

(# of People in Medium Density) = (Acres of Medium Density)* (Dwelling Units Per Acre, Medium Density) * (Avg. Household Size)

(# of People in Low Density) = (Acres of Low Density)* (Dwelling Units Per Acre, Low Density) * (Avg. Household Size)

(Total Number of People) = (# High) + (# Medium) + (# Low)

The number of people living within the district is an important factor because the MMTD Handbook recommends that 5,000 people live within the district bounds.

We can also use this methodology to analyze the full development potential of the district. By using the allowed zoning classifications of the parcel, we can determine the maximum population capacity of the district provided there are no amendments to the zoning ordinance.

### *3.4.2 Other Related Considerations*

**Transit Access**

Using the route map of the local transit system, the routes that intersect the activity center are selected. The buffer is then drawn from the entire length of the route at ¼ mile, which is generally accepted as reasonable walking distance to transit. We can then determine how many people live within a single transit connection (no line change) of the activity center. The district boundary can also be modified to include areas served by transit.

**Access to more than one activity center**

Once buffers are drawn, we can select the areas where buffers overlap. We can then calculate the number of people who live within walking distance, bicycling distance, or a single transit connection of two or more activity centers.

**Walkability/Bicycability between multiple activity centers**

After buffers are drawn, any activity centers that lie within the buffer of another activity center can be considered within reasonable walking distance of each other.

**Persons served by alternative modes**

Probably the most valuable is the statistic that comes of this is the "Persons served by alternative modes" which is simply the number of people within transit access, walking distance and bicycling distance. If this number exceeds 5,000, we likely have a viable MMTD and its rough boundary defined.

**Drawing the Multimodal Transportation District Boundary**

People living and working in the areas underneath the buffers have access to two or more modes for transportation to an activity center. All land in a MMTD should have access to two or more modes of transportation (including automobiles). Figures 3.4.2 and 3.4.3 show two activity centers in the Brickell area of South Miami along the US 1 corridor. The alternative mode service areas are also shown.

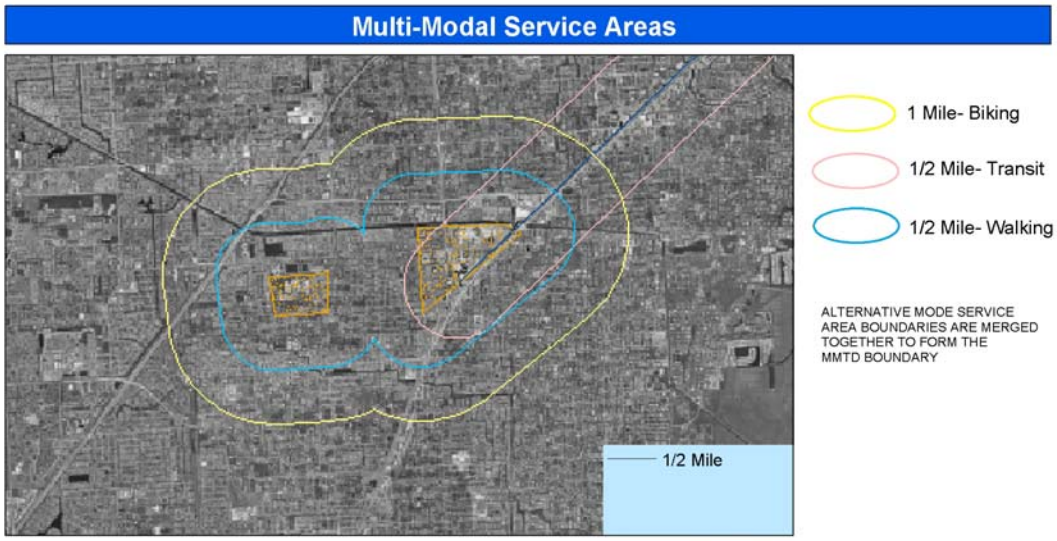



**Figure 3.4.2**

By tracing around the alternative mode service area, we draw the Multimodal Transportation District boundary in Figure 3.4.3.

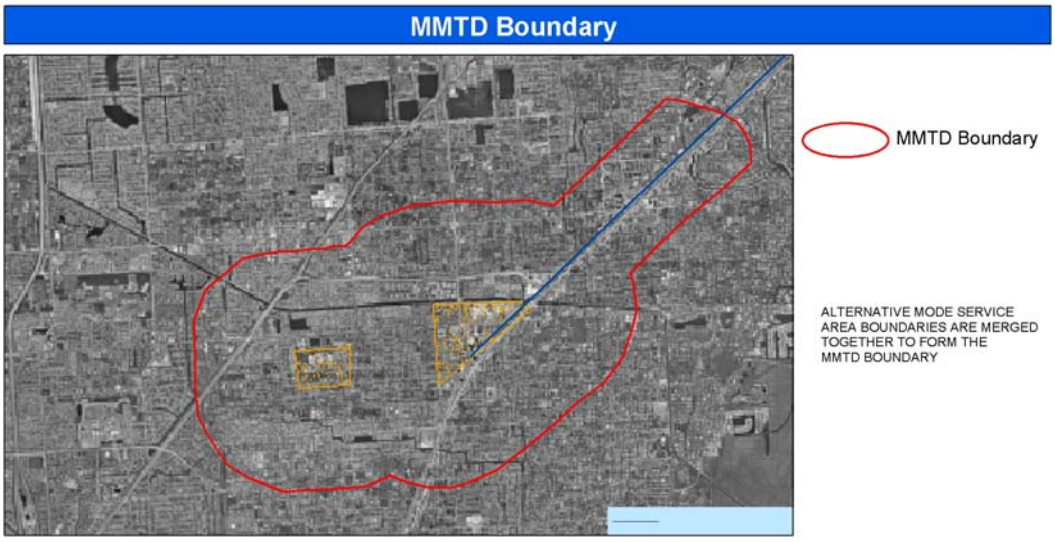



**Figure 3.4.3**

### 3.5 Limitations

The user must be aware of several limitations of the methodologies in this section. First, the Point Pattern Distribution test must be performed in ArcView 3.2, while the rest of the methodologies require ArcGIS 8.x. The script developed for Section 4 of the paper also requires ArcView 3.2, so the program will be used in at least two sections of this methodology. Second, the buffers and distances described in this section do not take into account the road network distance. Instead distances are shown "as the crow flies". It is

best to use road network distance whenever possible, however tools to analyze the road network are not fully developed for ArcGIS 8.x. Section 4 of this paper describes the development of a tool to analyze road network distance. Lastly, some of the methodologies in this section require a level of subjectivity from the user. Users should possess local knowledge to ensure that subjectivity does not cause important MMTD land uses to be excluded from activity centers or the district altogether.

### 3.6 Conclusion

Following this methodology, the user can define activity centers and a rough district boundary based upon the spatial distribution of MMTD-supportive land uses. After doing some simple GIS calculations, the user would be presented with:

– The locations and extent of high density, mixed use activity centers. This would eliminate more suburban-style areas that do not lend themselves to multimodalism.

– A rough boundary of the entire district. The boundary is based on the area where residents have access to alternative modes to reach activity centers. The boundary can be moved slightly to include land uses valuable in an MMTD such as hospitals or schools.

– The land area of the district based on the service area of alternative modes of transportation. This statement is made with the assumption that all areas inside of a MMTD should have reasonable access to alternative modes of transportation. Once we buffer around our activity centers the actual path of the roads and trails, we will know which residents have an option to travel to the activity centers by modes other than the automobile.

– The approximate population of the proposed MMTD. We will calculate the approximate number of people who live within walking, bicycling or transit distance of the activity centers.

– The type of district (Urban Center, Regional Center, Town Center). A different set of standards are applied to each activity center type in the MMTD Handbook.

All of the above factors are requirements set out in the MMTD Handbook. Further, it gives planners and city officials a methodology to create a boundary for the district that is based on access to alternative modes, rather than simply trying to fit the right number of people and land into a boundary. The urban form of the district will consist of high density mixed use activity centers and the “hinterland” that they serve, along with alternative mode transportation connections that bring the hinterland into connection with the center.

## 4.0 MEASURING LAND USE CONNECTIVITY USING AN ARCVIEW SCRIPT

### 4.1 Introduction

The MMTD Handbook is the most comprehensive tool to date in Florida's effort to reconcile the good intentions of concurrency management with the unintended consequences of sprawl and constriction of urban cores. Prior methodologies such as Transportation Concurrency Exception Areas (TCEAs) and Transportation Concurrency Management Areas (TCMAs) have embraced the idea that multimodal transportation planning, land use planning, and urban design can compensate for poor automobile level of service (LOS); however, the analytical tools available when these measures were drafted did not feasibly allow a quantifiable nexus to be drawn between the land use and transportation planning sides of the equation. As such, the language of the TCEA and TCMA legislation is largely nominative and lacks merit as a planning tool because the data and analysis necessary for implementation is not defined as a part of the enabling legislation.

Conversely, the MMTD Handbook sets out numerous quantifiable measures designed to ensure the automobile LOS exemption afforded a district does not adversely affect access to economic, leisure, and other activities within the district. While the Handbook does not explicitly address external to internal trips or external to external trips impacted by the MMTD, the provision for regional inter-modal access and the exclusion of FIHS facilities tacitly address these concerns. Regarding internal transportation considerations, the Handbook introduces a wealth of measures to ensure adequate population, employment, and intensity and organization of land use are in place or accommodated in the Future Land Use Plan. Likewise, the Multimodal Areawide LOS methodologies codified in the Florida Department of Transportation's (FDOT) 2002 Quality/Level of Service Handbook (FDOT 2002) provide quantitative measures to define the quality and coverage of the multimodal transportation network.

Although the MMTD Handbook measures the provision of multimodal transportation options and concentration of land uses within a proposed district, one critical element remains: a method of linking the transportation network to the land use map capable of quantifying real network access between specific land uses, activity centers, and transit facilities. The following chapter will describe a modest tool developed within the commonly available ArcView 3.2 GIS software package capable of constructing an accessibility matrix between MMTD land uses based on LOS-weighted network distance. After discussing the purpose of the MMTD Accessibility Analyst and the usefulness of its outputs, this chapter will present an installation and users' manual as well as a summary of basic enhancements which could extend the usefulness of the tool.

### 4.2 Accessibility Analyst Overview

The MMTD Accessibility analyst tool is an Avenue script which exists as part of an ArcView3.x project file. Avenue is a proprietary object-oriented programming language used to customize the ArcView software platform. Although the analysis process necessary to produce the accessibility matrix product can be conducted manually using ESRI's Network Analyst extension, the number of individual steps and iterative nature of

the necessary tasks makes a manual process undesirable. Conversely, the Accessibility Analyst script allows an areawide analysis to be conducted with a minimum of user input in a few minutes time. This efficiency allows multiple alternative land use and transportation network scenarios to be tested and compared with relative ease once the basic input data has been developed. Accessibility Analyst does require the ArcView Network Analyst extension to operate.

The basic objective of the Accessibility Analyst tool is to develop a quantitative link between an MMTD's land use map and multimodal transportation network. The basis for this analysis is the assumption that a local government's transportation planning obligation is to provide access to economic and other functions—not necessarily via the automobile mode. As such, the measure of Level of Service, replete with empirically validated formulas, is a proxy for the true impact of successful transportation planning—access between dissimilar land uses.

As with any effort to quantify the connection between land use and transportation, it is important to understand that while the analytical tools are well developed, the data inputs are less than perfect. For the purpose of this analysis, the necessary land use input is a GIS parcel map with land use attribution and land use specific trip-length threshold attribution. The transportation network necessary to run the Accessibility Analyst tool is a roadway centerline layer preferably attributed with bicycle and pedestrian Level of Service data. Necessary preprocessing tasks will be discussed in the Users' Manual section of this chapter. Presently, the Accessibility Analyst tool measures access to transit, but can not accommodate access between land uses using the transit mode due to the complexities of route timing, directions, and transfer criteria. This limitation will be discussed in greater detail in the Future Enhancement section of this chapter. Currently, access to transit is measured by regarding transit stops as land use features.

Accessibility Analyst functions by iteratively employing Network Analyst's *Service Area* tool to propagate a travel path from each land use parcel along the transportation network out to a maximum allowable cost. The accumulation of cost is a function of the network length weighed by modal LOS. The maximum cost for a given land use is predefined by the user and embedded in the input table. This feature recognizes the idea that the oft quoted ¼ mile pedestrian trip length may be appropriate for a quart of milk but does not necessarily apply to all trip purposes. Although the Accessibility Analyst cannot intuitively reconcile both origins and destinations in expressing trip purpose, the users' ability to both set district-wide land use trip-length thresholds and then modify trip lengths for specific uses and areas provides a degree of flexibility in modeling real world behavior.

In the example described by Figure 4.2.1, below, basic trip-length thresholds are defined in a simple look-up table. Next the input land use layer attribute table is modified through manual GIS overlay analysis to select parcels which are within a Central Business District area and parcels where census data suggests transit dependency is high. These two subsets of parcels are then loaded with trip-length weighting factors which, when combined with the basic trip-length table, provide a modified trip length suitable

for input into the Accessibility Analyst. Naturally, in the absence of well developed trip-length weighting factors, default distances may be used.

**Figure 4.2.1: Trip Length Adjustment**

Basic Trip Length Table

| Land Use | Trip Length (ft) |
|---|---|
| Res | 1,320 |
| Com | 1,600 |
| Svc | 1,400 |

+

| Parcel ID | Land Use | Central Business District Adj. | Transit Dependent Adj. |
|---|---|---|---|
| 00001 | Res | 1.00 | 1.50 |
| 00002 | Res | 1.25 | 1.00 |
| 00003 | Com | 1.00 | 1.50 |
| 00004 | Svc | 1.00 | 1.00 |
| 00005 | Com | 1.25 | 1.00 |
| 00006 | Res | 1.25 | 1.00 |
| 00007 | Svc | 1.25 | 1.00 |

=

| Max Trip Length (ft) |
|---|
| 1,980 |
| 1,650 |
| 2,400 |
| 1,400 |
| 2,000 |
| 1,650 |
| 1,750 |

In addition to manually defined input land use table trip-length thresholds, the Accessibility Analyst program also requires a network cost field to be defined. ArcView Network Analyst defaults to the network's length attribute, however, to model the impacts of modal LOS, it is recommended that network length be weighted based on segment's LOS score. Similar to the trip length example, Figure 4.2.2 shows how such a weighting scheme may be employed such that roadway segments with poor modal LOS incur a higher cost (decrement the trip-length threshold more quickly) than segments with good LOS. As with trip-length thresholds, this report does not purport to recommend LOS-based network cost weights. Rather, the Accessibility Analyst tool simply allows such weights, as defined by other studies, to be factored in to an MMTD's accessibility matrix calculation. Likewise, because FDOT's multimodal LOS equations lack the ability to define bicycle and pedestrian LOS for minor roadways for which traffic volume and speed data are not readily available, a default network cost should be assigned to these facilities, perhaps on the basis of sidewalk availability and lane width.

**Figure 4.2.2: Modal LOS Network Cost Weighting**

| LOS | Weight |
|---|---|
| A | 0.600 |
| B | 0.750 |
| C | 1.000 |
| D | 1.125 |
| E | 1.250 |
| F | 1.500 |
| Off Network | 1.000 |

+

| Feature ID | Feature Length | LOS Score |
|---|---|---|
| 00001 | 286 | A |
| 00002 | 446 | C |
| 00003 | 54 | E |
| 00004 | 388 | C |
| 00005 | 302 | B |
| 00006 | 504 | B |
| 00007 | 583 | A |
| 00008 | 782 | D |
| 00009 | 100 | F |
| 00010 | 746 | F |
| 00011 | 483 | B |

=

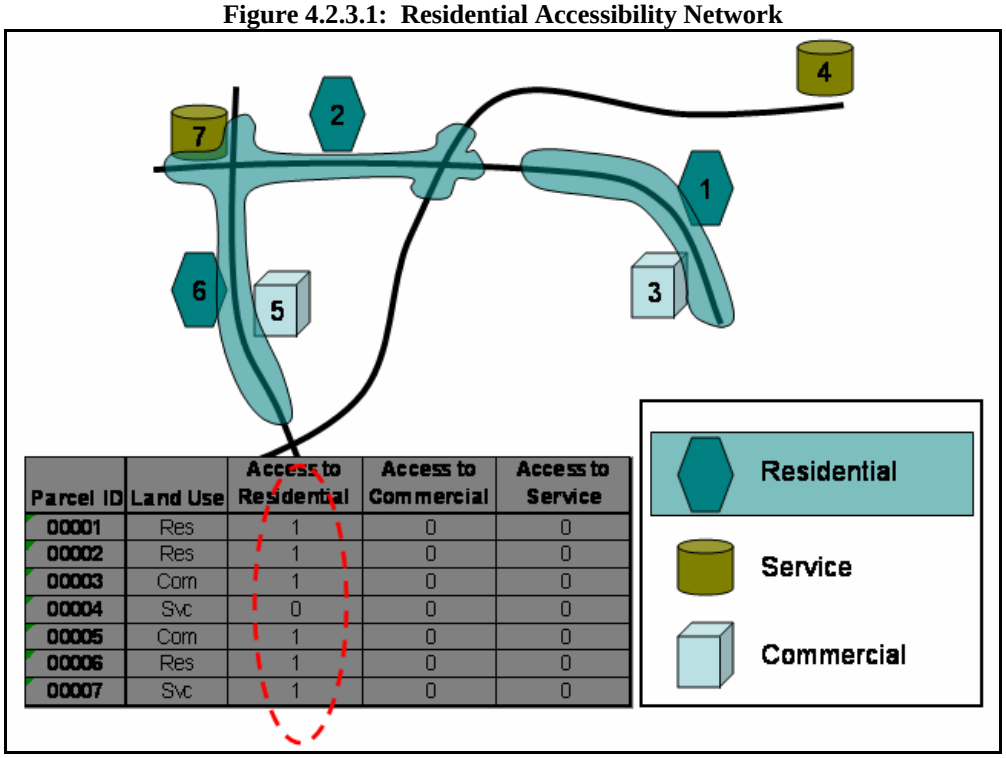
| Cost |
|---|
| 171.6 |
| 446.0 |
| 67.5 |
| 388.0 |
| 226.5 |
| 378.0 |
| 349.8 |
| 879.8 |
| 150.0 |
| 1119.0 |
| 362.3 |

Once trip-length thresholds and network costs have been assigned to the land use input layer and network input layer respectively, Accessibility Analyst cycles through each

land use category found in the input land use layer and propagates a network service area outward from each land use feature. After buffering the network service area at a user-defined distance, those parcels within the buffer are selected and written to a temporary table. When each unique land use category has been processed the resulting series of temporary tables is compiled to determine which land uses each individual parcel accesses.

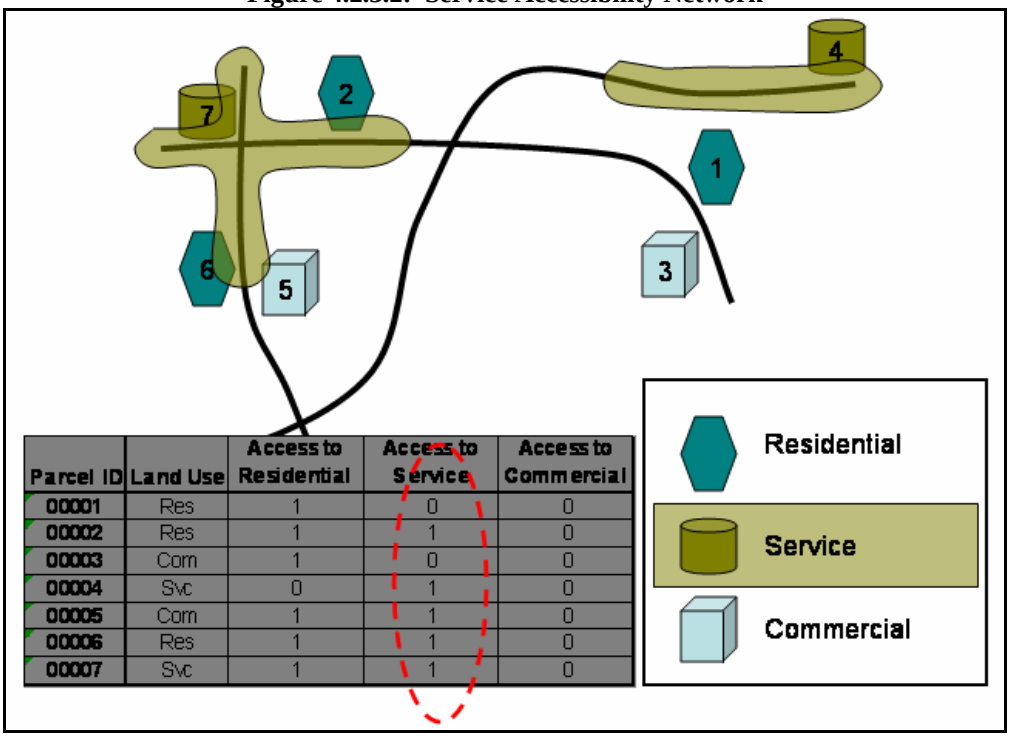
This process, illustrated in Figures 4.2.3.1 to 4.2.3.3, presently results in a yes or no answer for each input layer parcel such that a "1" indicates that the parcel has access to at least one parcel of the land use type listed in the column header and a "0" indicates that no unit of the land use column header is accessible. When the output table is initialized, all values are set to "0". It is anticipated that future versions of Accessibility Analyst will allow the user to summarize each parcel's accessibility options by such measures as: "Count", "Sum_Area", "Sum_Assessed Value" and other numerical data available in the parcel database. This sort of analysis will provide a measure of diversity to the Accessibility Analyst's output; however a simple "yes" or "no" will suffice as a proof of concept.

**Figure 4.2.3.1: Residential Accessibility Network**



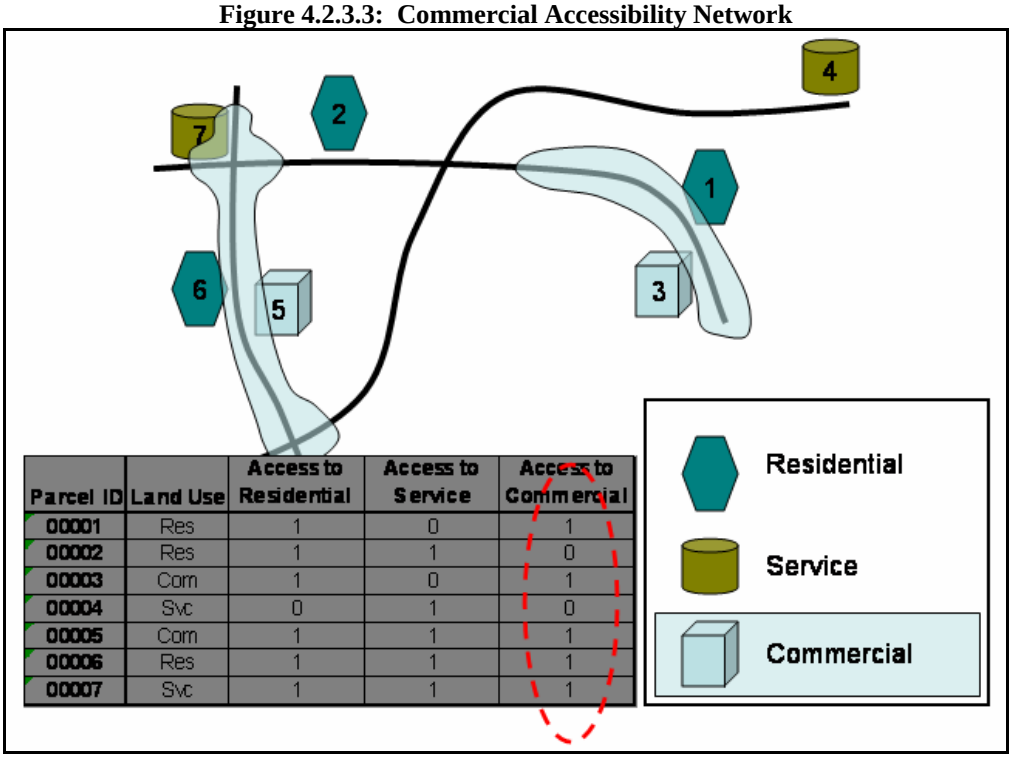

| Parcel ID | Land Use | Access to Residential | Access to Commercial | Access to Service |
|---|---|---|---|---|
| 00001 | Res | 1 | 0 | 0 |
| 00002 | Res | 1 | 0 | 0 |
| 00003 | Com | 1 | 0 | 0 |
| 00004 | Svc | 0 | 0 | 0 |
| 00005 | Com | 1 | 0 | 0 |
| 00006 | Res | 1 | 0 | 0 |
| 00007 | Svc | 1 | 0 | 0 |

**Figure 4.2.3.2: Service Accessibility Network**




| Parcel ID | Land Use | Access to Residential | Access to Service | Access to Commercial |
|---|---|---|---|---|
| 00001 | Res | 1 | 0 | 0 |
| 00002 | Res | 1 | 1 | 0 |
| 00003 | Com | 1 | 0 | 0 |
| 00004 | Svc | 0 | 1 | 0 |
| 00005 | Com | 1 | 1 | 0 |
| 00006 | Res | 1 | 1 | 0 |
| 00007 | Svc | 1 | 1 | 0 |

**Figure 4.2.3.3: Commercial Accessibility Network**




| Parcel ID | Land Use | Access to Residential | Access to Service | Access to Commercial |
|---|---|---|---|---|
| 00001 | Res | 1 | 0 | 1 |
| 00002 | Res | 1 | 1 | 0 |
| 00003 | Com | 1 | 0 | 1 |
| 00004 | Svc | 0 | 1 | 0 |
| 00005 | Com | 1 | 1 | 1 |
| 00006 | Res | 1 | 1 | 1 |
| 00007 | Svc | 1 | 1 | 1 |

Once the intermediate output table depicting individual parcel access has been constructed, the Accessibility Analyst tool summarizes the rows by land use category and averages the "1" and "0" values in the table. This process, shown in Figure 4.2.4 creates the Accessibility Matrix table which illustrates the percentage of land use units for each

land use type row which have access to at least one unit of land use type column. In the example below, 2/3 of Residential units access at least one Service land use, but only 1/2 of Commercial units access at least one service land use.

**Figure 4.2.4: Accessibility Matrix**

| Parcel ID | Land Use | Access to Residential | Access to Service | Access to Commercial |
|---|---|---|---|---|
| **00001** | Res | 1 | 0 | 1 |
| **00002** | Res | 1 | 1 | 0 |
| **00003** | Com | 1 | 0 | 1 |
| **00004** | Svc | 0 | 1 | 0 |
| **00005** | Com | 1 | 1 | 1 |
| **00006** | Res | 1 | 1 | 1 |
| **00007** | Svc | 1 | 1 | 1 |

| Land Use | Access to Residential | Access to Service | Access to Commercial |
|---|---|---|---|
| **Residential** | 100% | 67% | 67% |
| **Commercial** | 100% | 50% | 100% |
| **Service** | 50% | 100% | 50% |

Albeit simple, this analytical product allows easy comparison of alternative MMTD transportation and land use plans, affords the ability to model benefit cost in transit stop placement/routing, and most importantly, provides a single quantitative measure that can be used to compare different MMTDs. Using Department of Revenue Codes (DOR), existing land use classes can be defined to a considerable degree of specificity without the need for field data collection. Use of DOR codes also provides a statewide standard classification of land uses for MMTD compliance. Although limited to 254 land use categories by the DBFVI file format, more detailed land use data inputs may be used to refine an analysis and potentially serve to conduct market catchment studies in a non-automobile oriented environment.

## 4.3 Accessibility Analyst Users' Manual

The MMTD Accessibility Analyst Users' Manual is divided into three sections:

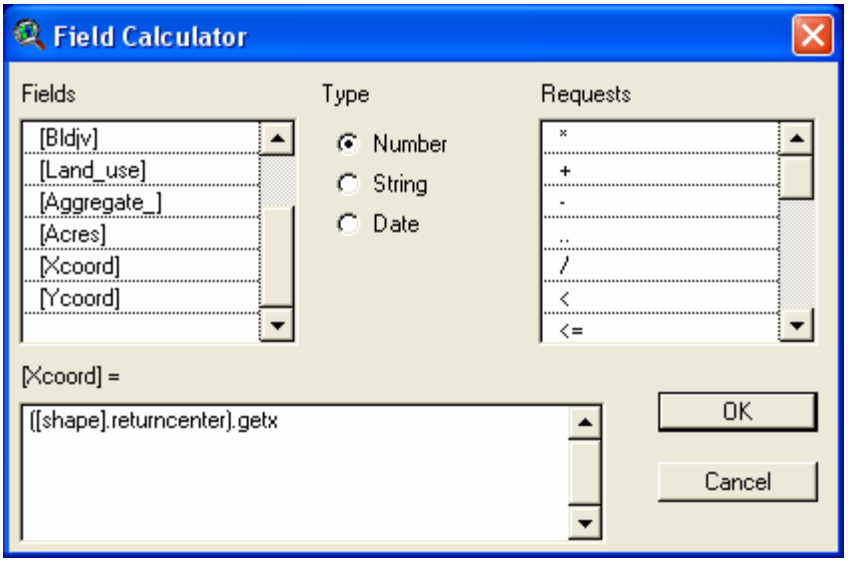
- **Input File Preparation**
- **Program Installation**
- **Program Operation**

### *4.3.1 Input File Preparation*

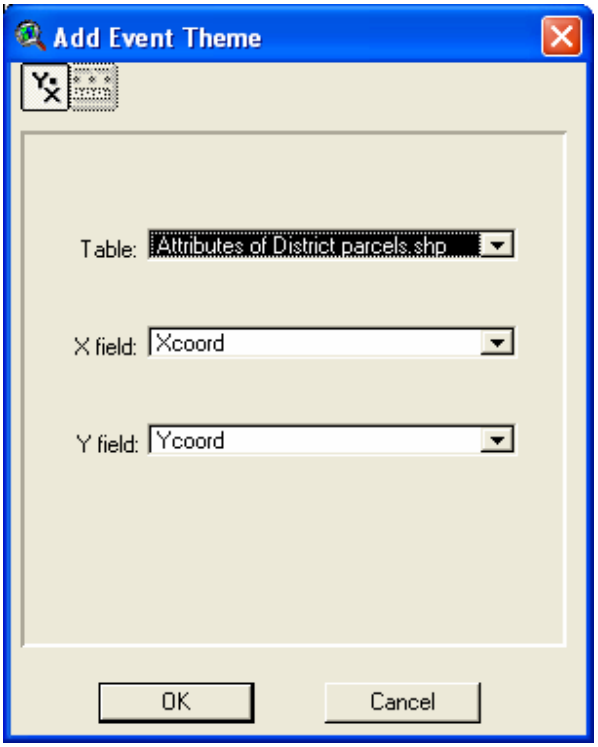
As described in the overview above, Accessibility Analyst requires two input shapefiles to operate—a network shapefile and a land use shapefile. The following will describe the tasks necessary to build basic data and also explain some techniques which may be used to expedite analysis using weighted LOS and land use destination-based trip data.

1. **Land Use Layer Preparation** – Accessibility Analyst is built around the Network Analyst Service Area tool. As such, it requires the input land use layer to be a Point shapefile and it is necessary to define the maximum trip length for each parcel point prior to running Accessibility Analyst. Because the trip length can be accessed through a table join, it is more efficient when running multiple analyses with alternative trip length thresholds to convert the parcel polygons to points before embedding trip length attributes. In order to perform index and relationship functions between temporary output tables, the Land Use Layer must also be embedded with a unique sequential record ID field where the first record in the attribute table is noted as record "1". By using an indexed ID number, Accessibility Analyst is able to operate more efficiently than would be possible by a non-unique/sequential key field. The field in the Land Use Layer designating Land Use may be named anything except for "LU" as this text string is used elsewhere in the program.
2. 
   a. **Add Record ID field to Land Use Layer Attribute Table**
      i. Open the attribute table in ArcView 3.x
      ii. TABLE → START EDITING
      iii. EDIT → ADD FIELD: [FieldName], String, Default Length
      iv. TABLE → STOP EDITING, SAVE EDITS
      v. Open the Land Use Layer.DBF file in Excel
      vi. Populate the Record ID field with sequential, unique values starting at "1"

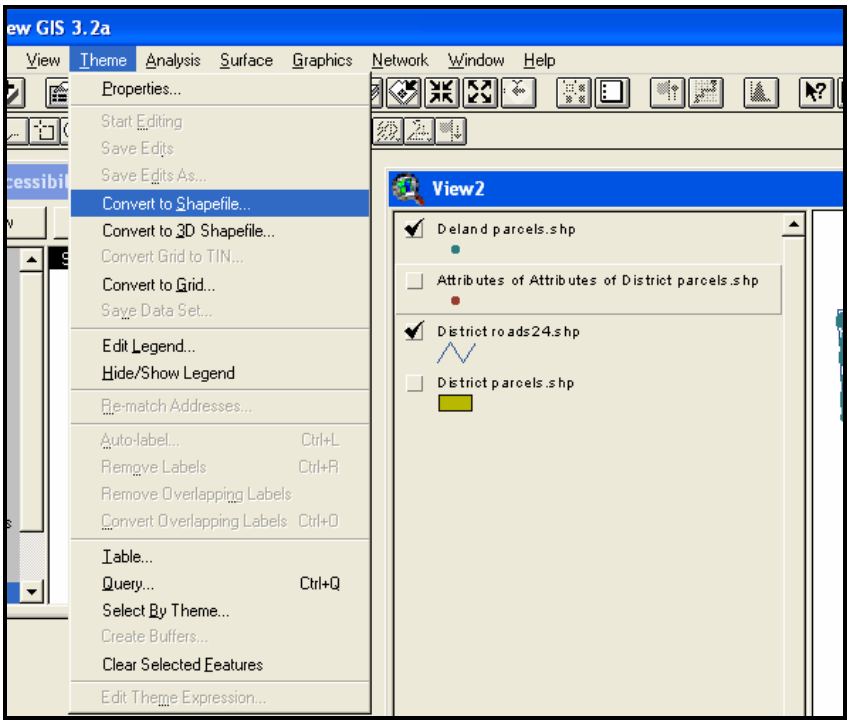
   b. **Convert Parcel (Land Use) Polygon Layer to Point Shapefile**
      i. Open the Land Use Layer Attribute Table in ArcView 3.x
      ii. TABLE → START EDITING
      iii. EDIT → ADD FIELD: "XCOORD", Number, > 2 Decimals
      iv. EDIT → ADD FIELD: "YCOORD", Number, > 2 Decimals
      v. Select "XCOORD" Column in DBF and activate Field Calculator



vi. Repeat for YCOORD substituting ".getx" for ".gety"
vii. TABLE → STOP EDITING, SAVE EDITS
viii. With VIEW as the Active Window and VIEW → ADD EVENT THEME




ix. Select the new Point Event theme and THEME → CONVERT TO SHAPEFILE



c. **Establish Land Use Trip-Length Threshold**
   i. Open the Land Use Layer attribute table in ArcView 3.x and select the Land Use trip length threshold group field. This could be either the Land Use field or perhaps a land use group field
   ii. Use the Summarize tool to produce a table of unique land use groups
   iii. Select the new Summary Table and TABLE → START EDITING
   iv. EDIT → ADD FIELD: [FIELDNAME], Number, 0 decimals
   v. Use the EDIT tool to input land use group-based maximum trip costs
   vi. Repeat as desired
   vii. TABLE → STOP EDITING → SAVE EDITS
   viii. Join Summary Table to Land Use Point Table
      1. Select Land Use Group Field in Summary Table
      2. Select Land Use Group Field in Land Use Table
      3. Click on Join Button to link the Land Use Group-based trip length thresholds to the Land Use Input Table

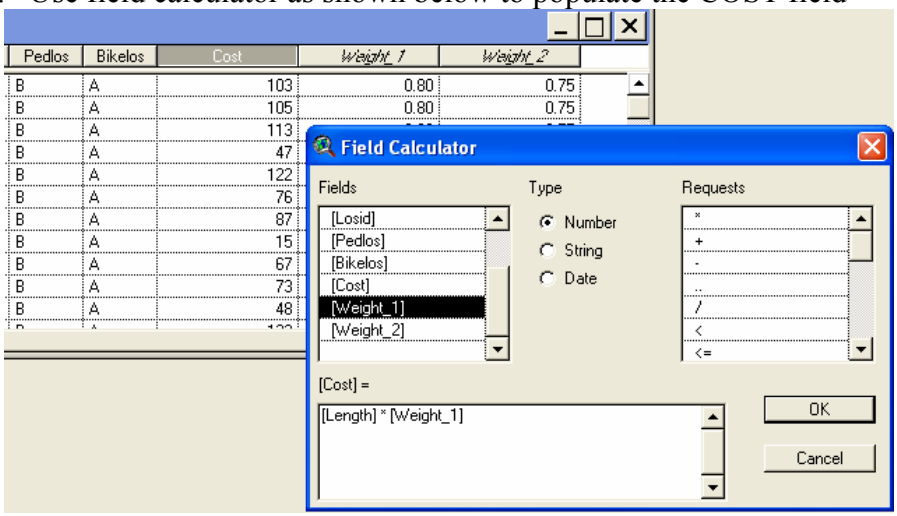
3. **Network Layer Preparation –** Accessibility Analyst requires a polyline shapefile to serve as a network upon which access between land uses may be evaluated. For the purposes of this demonstration a centerline network is employed. Alternately, a left/right offset sidewalk or Bicycle Lane/LOS network could be employed. It is important to understand that while more easily available, a centerline network does not evaluate differences in LOS for each side of the street, nor does it impose any penalty on mid-block crossing. Conversely, a left/right offset network is considerably more difficult to develop in that intersection and mid-block crossing cost line segments must be fused into the network and attributed according to the pedestrian intersection and mid-block crossing models and the bicycle intersection crossing model. Disregarding the need to incorporate intersection crossing into a realistic accessibility model, the following steps are necessary to prepare a centerline shapefile with LOS attribution for use in the Accessibility Analyst script:

   a. **Clean Network Shapefile (Optional) –** If ArcINFO is available, it is recommended to convert the network shapefile to a coverage and perform a CLEAN operation to resolve any unintended gaps in the network. Please be aware that performing a CLEAN operation on left/right offset network with complex intersection features may remove critical network details. Depending on CLEAN settings, intentional network breaks may be fused accidentally. Because MMTD networks are usually limited to a few square miles, a good visual inspection is often feasible and may be the best approach to ensure network integrity

   b. **Add LOS-Based COST field –** Network analyst only considers certain field names when selecting a COST field for the network. Cost refers to number of units decremented against the trip threshold length as the

service area path is propagated from each land use feature. The default cost item is the <line length> however purpose-built network costs may be used so long as they adhere to a fixed set of field names. For the Accessibility Analyst Project, the allowable field name should be "COST". Populating the COST field requires the following steps:

i. Build Cost Weight Table in Excel or ArcView
ii. Join Cost Weight Table to Network attribute table similar to 1.c.viii above
iii. Add Cost field (must be named "COST") as in 1.a.i – iv above
iv. Use field calculator as shown below to populate the COST field



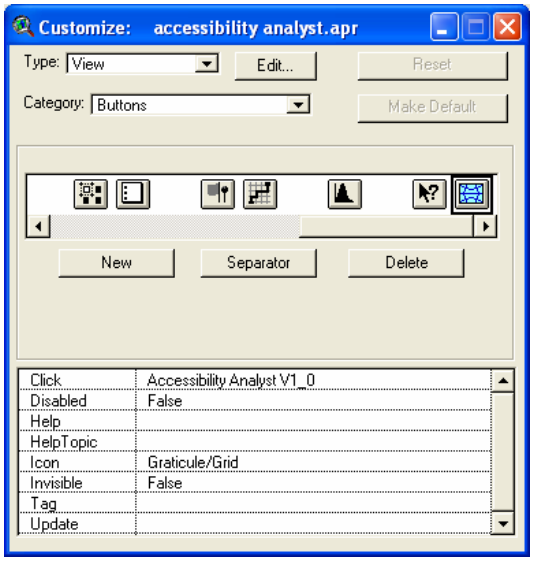

### *4.3.2 Program Installation*

In order for Accessibility Analyst to function, ArcView 3.2a or 3.3 and ArcView Network Analyst V1.0 must be installed and operational on the users' computer. Because Accessibility Analyst is an Avenue Script, it is not installed per se. Rather the .APR project must be opened and loaded with the necessary land use and network files. Multiple versions of each file may be loaded into the same Accessibility Analyst .APR within the same VIEW or in separate VIEWs. Accessibility Analyst dynamically builds output and temporary files based on the input land use layer's characteristics, so no template databases need be installed.

In addition to opening the Accessibility Analyst APR and adding Land Use and Network Data, it is also possible to copy and paste the Accessibility Analyst script into existing ArcView APR files. This is accomplished by a simple cut and paste operation as follows:

1. In the PROJECT window, select SCRIPTS and open the Accessibility Analyst Script
2. Swipe the text in the script editor
3. Paste the text into a blank script editor in the new APR
4. Make sure Network Analyst is loaded into the new APR extension set.

5. From the PROJECT window select CUSTOMIZE from the PROJECT Menu and set Type to VIEW, Category to BUTTONS, select New, and brose to [Accessibility Analyst Script Name] in the UPDATE setting

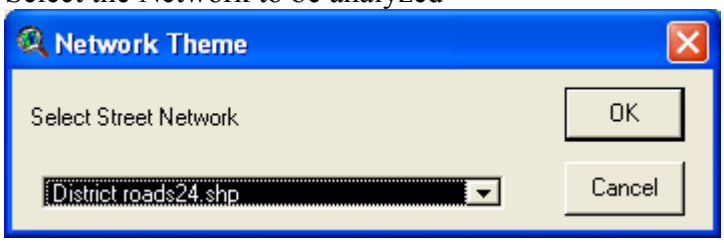



### *4.3.3 Run Program*

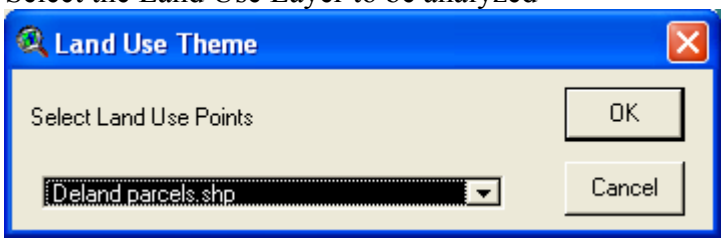
1. Click on the VIEW which contains the network(s) and land use layer(s) to be evaluated

2. Press the Accessibility Analyst button on the View Toolbar.

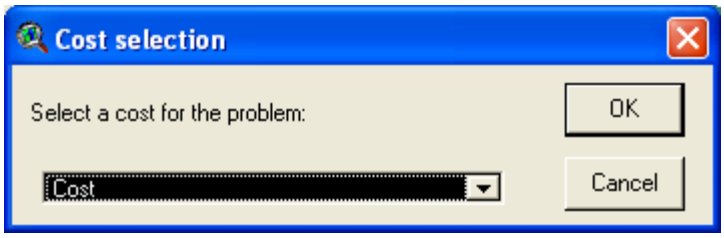
3. Select the Network to be analyzed



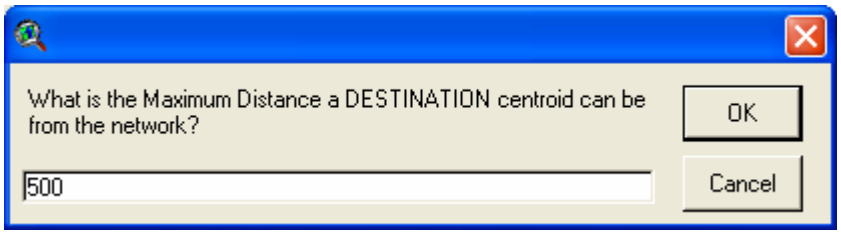

4. Select the Land Use Layer to be analyzed



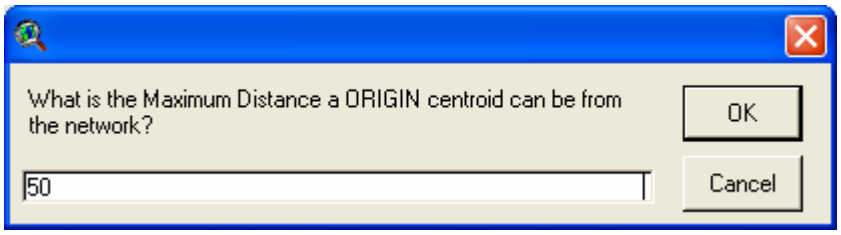

5. Select the Network Cost field – This is the field defined during the file preparation process as segment length * LOS weighting factor.




6. Define a Destination network search tolerance – this is the maximum allowable distance a parcel centroid may be from a network segment. Define a small search tolerance to eliminate big-box retailers and a large search tolerance to include all parcels in the analysis. Be aware that a parcel centroid will always take the shortest distance to the network and this distance is not included in the trip-length threshold.




7. Define an Origin buffer tolerance – this is the maximum distance a parcel centroid can be from the network and still be selected as having access to whichever land use is currently being processed.

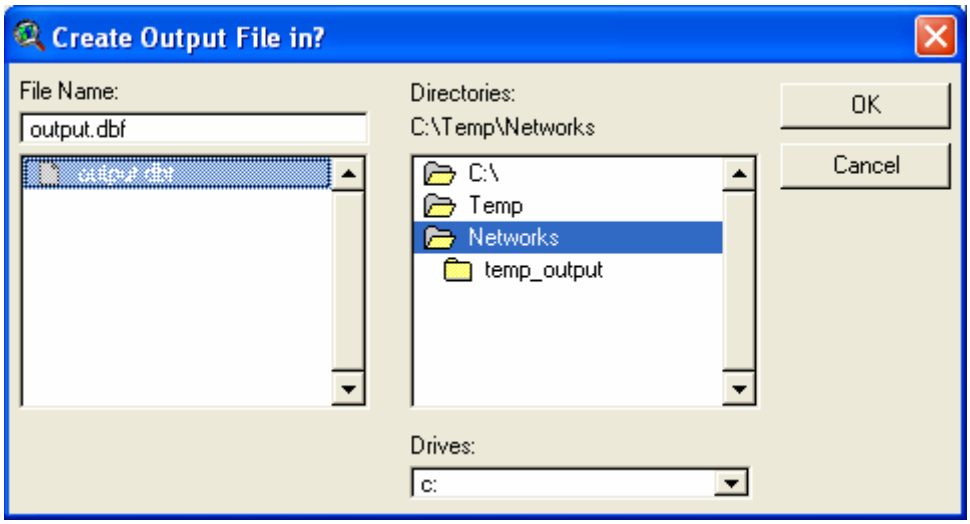



8. Define the Land Use field in the Land Use Layer – In the sample problem, aggregate land use (Commercial, Service, Single Family, Multi-Family, etc…) is used, however any field containing not more than 254 unique values may be selected for the Land Use Field.

9. Define the Record ID field – This is a index field built into the land use table which is used to link temporary output tables. The values in this field must start at "1" and be a continuous series with no duplicates.

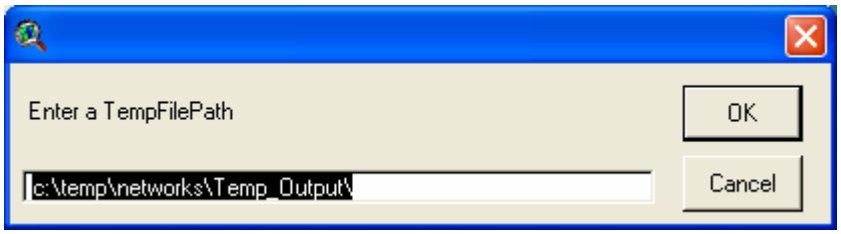
10. Define the Land Use Trip Length Threshold

11. Define Intermediate Output file name and path – As discussed in the Overview and referenced as the first table in Figure 4.2.4, Accessibility Analyst first creates an intermediate output table which records whether each parcel has access to each unique land use class. This table may be overwritten and ignored, but it may also be linked to the Land Use Layer using the Record ID field and then used for analysis purposes such as generating a thematic map of a selected land use (low income multi-family residential perhaps) with access to transit stops.




12. Define a Temp File Path – Accessibility Analyst generates two temporary shapefiles for each unique land use class: a network polyline shape and a network service area polygon shape. These may be overwritten or stored permanently to

help analyze and Q/C different network/land use alternative evaluations. The temp folder must exist prior to executing this step.




13. Go Get a Cup of Coffee – For large study areas, Accessibility Analyst can require up to 15 minutes on a moderately fast desktop using local files. Although in a well-developed MMTD, one would expect a minimum of single family housing, elimination of this land use category from trial runs can reduce processing time to 1 – 2 minutes.

14. Load Output.Dbf and Accessibility Summary.Dbf Tables into the Project and Review Data. – TABLES → ADD → BROWSE

### 4.4 Future Enhancements

As with any software product, Accessibility Analyst can grow and adapt as needs change. Some potential additions or modifications to the program have been identified below:

- User Defined Summary Table – Presently Accessibility Analyst summarizes the "Output" table based on average. This results in a percent rating for each land use intersection such that ##% of the land use in Row R has access to at least one unit of the land use in Column C. By allowing the user to designate the summarize method, or include multiple summarize values in the Accessibility Analyst GUI, the program could show the total number of units of land use C accessed by land use R or the sum of the assessed values.
    - Reasons against this enhancement are the existing summarize tool provided as part of ArcView 3.2 that performs the above functions and is relatively easy to use.

- User Defined Land Use Class Exclusion – As noted in 4.3.3, the Accessibility Analyst can take a long time to run, especially when processing a prolific land use category such as Single Family Residential. Currently, land use exclusions must be managed by removing unwanted land uses from the input layer. To avoid this tedious process, Accessibility Analyst could be enhanced with an optional user dialog to allow specific land uses to be excluded from a given run. Additionally, Accessibility Analyst could be made to save land use templates for future analyses using the same land use input layer format.
    - No significant reasons against

- Intermediate Output Table (Parcel Specific) Count and Summarize Functions – The Output table is particularly useful in producing thematic maps

illustrating which parcels have access to a particular land use, however, the current format of the output table provides only a yes/no answer and so does not measure the diversity of land use accessed by a given parcel. The output table could therefore be modified by the user, similar to the Accessibility Summary table, to show the number of units of a particular land use accessed by a given parcel. Likewise, the sum of value, acreage, or any other numerical land use attribute could be calculated.

  - No significant reasons against

- Automatically Generate Parcel Polygon Center Points – To reduce the need for preprocessing, Accessibility Analyst could automatically generate a temporary centroid layer from the input land use polygon layer.
  - Reasons against include increased processing time for each run.

- Automatically Generate Record ID – Because Record IDs need to be unique and sequential, edits to the input land use table without subsequent reconstruction of the Record ID field could cause problems with the Accessibility Analyst application. To avoid this and limit user preprocessing, Accessibility Analyst could calculate a unique sequential field prior to running.
  - Reasons against are the elimination of reverse compatible joining of the intermediate output table to older versions of the input land use polygon layer for thematic mapping using the Record ID field as a key.

- User Defined Parameter Memory – When several variations of a land use or network input file are to be analyzed sequentially, reproducing the set-up parameters accurately can become time consuming and irritating. The ability to store multiple sets of set-up parameters for a given APR would allow the user to select from list of parameters rather than manually set parameters for each report run
  - No significant reasons against

- Snap Centroids to Network and record snap distance as part of network cost calculation – This feature would replace Steps 4.3.3-6 (Define a Destination Network) and 4.3.3-7 (define an Origin buffer tolerance) and would solve many of the issues associated with measuring access to large parcels. Prior to running Accessibility Analyst, a separate program would calculate the closest distance from each parcel centroid to the multimodal network layer and record that distance in land use layer while re-locating the point to a position directly on the network. The off-set distance would then be added to the cost threshold for that point and then be used to penalize accessibility for parcels with large set-back distances. Off-set distances could be manually reviewed to identify parcels with high off-sets which could then be manually edited based on ground-truthing or review of aerial imagery. An alternate strategy would add a centroid connector to the network layer itself linking the parcel

centroid and the network. This method would best capture true network distance pending accurate verification of centroid locations with respect to building set-backs.

- The Reasons against primarily include the complexity of the programming task including whether such functionality is possible using an Avenue script.

**4.5 Conclusion**

The Accessibility Analyst ArcView script provides an automated methodology for evaluating land use integration based on measured network conditions. By providing a parcel specific and areawide summary of access between land use types, Accessibility Analyst helps to establish the probability that an individual may execute their economic and recreational trips using alternate modes of transportation. Because land use classifications may be standardized across multiple jurisdictions, Accessibility Analyst will allow comparison of potential MMTD districts and aid in establishing statewide implementation standards.

For the full functionality of Accessibility Analyst to be implemented, two important research areas must be investigated:

1. Establishment of LOS-based cost-distance weighting factors
2. Establishment of trip length based on land use types

Additionally, use of Left/Right sidewalk and bicycle lane networks will require integration of intersection crossing difficulty in the network cost factors. Although the full functionality of Accessibility Analyst is not useable in lieu of this research, it may be used as a bootstrap to validate accessibility models which attempt to distill appropriate input factors.

Finally, it must be noted that although Accessibility Analyst attempts to work with raw parcel and centerline data, appropriate care must be given to network continuity and centroid connection schema to ensure that realistic trip paths are being modeled.

## 5.0 SIMPLIFIED METHODOLOGIES FOR APPLICATION OF THE MMTD HANDBOOK

With the increasing availability of GIS, the process by which analysis is performed and maps are produced has become relatively easy. Extending the use of GIS to evaluate a potential area for designation as a MMTD allows the user to save large amounts of time and energy in addition to facilitating the production of maps useful for public presentations. However, because GIS is not readily available to every jurisdiction in Florida, it is necessary to develop methodologies for implementing the Handbook using non-GIS techniques. This prospect poses a unique problem in analyzing MMTDs. Most of the techniques defined in the MMTD Handbook can be accomplished without the use of GIS. The purpose of this section is to provide guidance on additional simplified methodologies for analyzing the multimodal potential of areas that meet the basic criteria for development of a MMTD.

### 5.1 Complementary Mix of Land Uses

The first criterion for designating an MMTD is to have the presence of a complementary mix of land uses. Three criteria are used to determine if a complementary mix of land uses is present according to the Handbook. These include an appropriate scale of development, complementary mix of land uses and transit and pedestrian-friendly design.

In order for an area to be considered of the appropriate scale, it should have a minimum residential population 5,000, a 2:1 ratio of population to jobs and provision of scheduled transit service.

The first step in gathering this information is to delineate the boundaries of the MMTD. To accomplish in a manner that will easily allow for the collection and dissemination of data, it is helpful to choose the area according to census tracts. Census tracts are small, relatively permanent statistical subdivisions of a county. Census tracts contain between 2,500 and 8,000 people and are designed to be homogeneous with with respect to population characteristics, economic status, and living conditions. Census tract data contain a variety of population and employment data, which is why they are useful when analyzing demographics of a MMTD. In order to determine land-uses, a parcel or zoning map can be utilized. It is required that each MMTD have at least three significant land uses, such as retail, office, residential, hotel/motel, entertainment, cultural or recreational that are all mutually supporting.

If an area for the MMTD has already been chosen, the boundaries can be modified in to coincide with the boundaries of census tracts.

Determining if a potential MMTD possesses transit and pedestrian-friendly design can be accomplished by simple observation as well as by using the checklists in the Handbook. After the MMTD boundary has been determined, a site inventory that lists all of the land uses in the MMTD should be compiled. After land uses are determined, the individual can utilize the land-use compatibility matrix in the Handbook to determine what characteristic of development the area falls under (i.e. Urban Center, Regional Center or Traditional Town or Village).

*Data Requirements*

- Simple Map
- Census Tract data
- Physical Observation
- Parcel or zoning map

**5.2 Appropriate Density and Intensity of Land Uses**

In order to calculate density and intensity of the proposed area, it is necessary to determine the overall acreage of the area. This will allow for the determination of residential units per acre as well as employees per acre. As long as a general map of the area is available with a scale bar, then the total area in miles can be converted to acres. Population and employment data can be used in determining the total population and jobs to population ratio can be divided by the total number of acres to produce a per acre number for both residential land use and commercial land use. Once again, the population and employment data can be obtained using census block data. Additionally, if traffic analysis zone (TAZ) data is available, then this data can be used also.

In order to determine the organization of land-uses in the potential MMTD, a zoning or parcel map can be used. Once a central intersection is identified, a ½-mile and ¼-mile buffer can be drawn on the map (using crow-fly, or air, distance from a single point) to identify all parcels within the buffer area. Because MMTDs should be organized around a central core, this technique will reveal exactly what parcels are located with a ½ and ¼-mile proximity to the central core. The area bound by the ¼-mile buffer should possess a mixture of land-uses that commercial, residential and retail. Between the ¼ and ½-mile buffer may have lower densities but should include residential, retail and community land-uses.

This same technique can be used to identify the organization of land-uses along corridors in the potential MMTD. In this instance, a corridor is identified which is usually an arterial that bisects the potential MMTD. Once the corridor is identified, a buffer can be drawn around it in order to determine the extent of land-uses with proximity to the corridor. A map showing parcels should be used for this evaluation. This may include the property appraiser's map or land use or zoning map. Land-uses should be distributed along the corridor in such a way that the densities and intensities should promote transit. Higher densities should be located within walking distances to activity centers along the corridor. These activity centers are best located at key crossings of perpendicular routes, which are generally minor arterials or collectors, or transit service routes.

*Data Requirements*

- Census Block Data
- TAZ Data (if available)
- Parcel map (or zoning, current land use, future land use)

### 5.3 Network Connectivity

The criterion of network connectivity is one that can be easily calculated. The only necessary piece of information is a map that shows the streets (i.e. network) that are located in the potential MMTD. This map can either be a printed map or one that is hand drawn. After the network is determined, polygons are drawn over the complete network. These polygons could be considered blocks. In order to calculate the network connectivity of the area, an individual should simply use the map to count the number of closed polygons in the network. If the number of polygons per square mile is 50 or greater then it is considered to have good network connectivity.

This same principle is to be applied to the pedestrian and bicycle network as well as any shared paths. By doing this, one can calculate the network connectivity for each mode of transportation. See the discussion in the network connectivity section of this report for additional information on the other methods of measuring connectivity and their GIS requirements.

*Data Requirements*

- Simple street/bicycle/pedestrian network map with scale bar

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