Maricopa Association of Governments

Pedestrian Plan 2000

Technical Appendix

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MARICOPA ASSOCIATION of GOVERNMENTS

Maricopa Association of Governments

Pedestrian Plan 2000

Technical Appendix

Prepared for the

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Technical Appendix

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INTRODUCTION

One of the objectives of the Maricopa Association of Governments' (MAG) *Pedestrian Plan 2000* is to determine the types of pedestrian facilities that are appropriate for differing levels of pedestrian activity. A key factor in designing the roadway environment is assessing the relative amount of pedestrian activity that could potentially occur along the roadway. This process of identification and quantification of potential pedestrian trip activity is known as travel demand analysis.

In order to perform a travel demand analysis for the walking mode, a methodology must be employed that recognizes the unique impediments to that mode. Unlike automobile travel, pedestrian travel often does not occur due to a number of impediments, one of which is relatively poor accommodation of pedestrians within the existing transportation network. Consequently, existing pedestrian counts generally do not indicate the level of potential pedestrian trip activity on a roadway network. Therefore, alternative or surrogate measures of assessing pedestrian trip activity are needed.

Methods of Assessing Pedestrian Trip Activity

There are three primary methods of assessing pedestrian trip activity. The first method is documenting *revealed demand*. This measure is accomplished by simply counting the existing number of people walking on the streets. A second method is to identify, map, and *evaluate potential trip generators or attractors*. In practice, this method tends to focus on major pedestrian trip attractors. The third method is to assess the *latent demand* throughout the metro area. Latent demand considers both existing and pent-up pedestrian activity. It also enables planners and engineers to anticipate and plan for future pedestrian travel needs. The following paragraphs briefly describe each of these methods, their advantages and disadvantages.

Revealed demand

This method consists of taking counts of existing pedestrians on the roadways. Its usefulness is limited to areas that already have an extensive sidewalk network that provides an overall high-quality walking environment. This method is not usable for the vast majority of U.S. metro area transportation networks, due to their generally poor pedestrian accommodation.

Evaluation of Pedestrian Trip Generators and/or Attractors

Until recently, this method has been the most common method of estimating pedestrian travel demand. However, it suffers from two major problems: the limited number of pedestrian attractors it considers, and the fact that it generally focuses only on attractors – therefore only one end of the pedestrian trip is considered.

The first problem with this method is that it tends to focus on *major* pedestrian trip attractors such as schools, parks, and retail centers, and thus only a fraction of the existing and potential pedestrian trip

attractors are represented. In fact, virtually every residence, every business, and every social and service establishment in a metropolitan area is a pedestrian trip generator or attractor. Thus this method, in practice, fails to account for that fact.

The method's second shortcoming is directly related to the first. Since the method focuses on major attractors, only one end of the pedestrian trip – the destination, is quantified. This is a problem because the method does not account for the production (or supply) of trips available to that attractor. For example, a particular park may have many amenities, and hence exhibit a high trip attraction rate, but if it is in a rather remote area (i.e., the surrounding population density is very low) the actual pedestrian trip activity (or interchange) between the attractor (park) and generator (population) would be low. Consequently, the method does not account for the pedestrian trip interchange reality that exists *among* generators and attractors throughout the Region.

Latent Demand

The model that quantifies both ends of the walking trip and *all* generators and attractors in a metropolitan area for both existing and potential trips is the *Latent Demand Model.* The *Latent Demand Model* is a logical extension of the second method, and it is rapidly becoming the method of choice for metropolitan areas throughout the United States. Numerous U.S. metro areas are using this method to estimate the potential of the roadway network segments to serve bicycle and/or pedestrian trip activity; among them are Baltimore (MD), Birmingham (AL), Gainesville (FL), Philadelphia (PA), Tallahassee (FL), Tampa (FL), and Westchester County (NY). A similar method is being employed in the *MAG Pedestrian Plan 2000.*

The *Latent Demand Model* is essentially a gravity model, based upon a theory similar to that used in the prevailing four step Urban Transportation Planning System-based travel demand models throughout the United States. The following sections outline its theory and technical application in a Geographic Information System (GIS) transportation planning environment.

THE LATENT DEMAND MODEL

Travel patterns in a metropolitan area are well described by Newton's law of universal gravitation as applied to trip interchanges, which is shown in Figure 1. This relationship essentially says that the amount of trips, regardless of travel mode, between two areas is *directly* related to the number of trip productions (eg. population residences) in one area and the number of trip attractions (eg., workplaces, shopping opportunities, schools, etc.) in the other (destination) area. The relationship also says that impedances (e.g., travel distance and/or time between the areas, conditions of the travel environment, etc.) play a significant role in *reducing* the amount of trips made between those areas.

Walking activity patterns can be described by a similar relationship, see Figure 2. However, unlike those for the automobile travel mode, the impedances to the walking mode play a greater role. For example,

the distance between trip origins and destinations affects walking more dramatically than it does for automobile travel. Additionally, the condition of the walking environment affects whether a walking trip is made and how far, and what route, a person is willing to travel (see Figure 3). Furthermore, depending on the purpose of the walk trip, the carrying, or "payload" capacity plays a role in not only the walk travel distances but also whether or not a walking trip is even made[1].

Impedances are different for different trip purposes. For example, people are typically willing to walk a greater distance to work than they are to simply pick up a food item at a corner convenience store. This phenomenon is reflected in national survey data for three trip purposes, as depicted in Figure 4. Essentially, the trip making probability varies according to the distance between origins and destinations, and it also depends on the purpose of the trip.

The *Model* accounts for the above outlined characteristics of pedestrian travel in a metropolitan area. While it is not a full and rigorous four-step travel demand model, it includes the trip interchange relationship in a gravity model trip distribution analysis but is conducted with a segment-based focus. It models trips according to the four general utilitarian trip purposes identified in the National Personal Transportation Survey (NPTS) shown in Figure 5. The *Latent Demand Model* is an analysis of the entire region, using a segment-based, geographic information system (GIS) algorithm to quantify relative potential pedestrian trip activity.

The *Latent Demand Model* is an effective analysis tool for assessing pedestrian travel demand. It:

- Includes all potential trip generators and attractors
- Quantifies the potential trip interchange between generators and attractors
- Recognizes that different trip types account for differing shares of the total trips
- Estimates the trip making probability of each trip type as a function of distance, and
- Can be employed to assess the latent pedestrian demand for any metropolitan roadway network

Potential pedestrian trip activity is separated into two categories, non-linked trips and linked trips. In brief, non-linked trips are those that can occur entirely by walking (based on NPTS trip purpose/ distances) because the origins (generators) and destinations (attractors) are in close proximity to each other. In the *Latent Demand Mode*, potential non-linked trips represent *latent* trip activity.

Linked trips are those portions of trips whose origins and destinations are so dispersed that travel by automobile (or other modes) is required to arrive in the general vicinity of the attractor. Once in the vicinity of the attractor, the remainder of the trip is made afoot. An example of a linked trip is when a person who takes transit or drives to an area changes mode and walks to different destinations within that area. The *Latent Demand Model* also estimates linked trips in a scenario in which adverse walking conditions are not an impediment to pedestrian trip activity.

[1] Seasonal and environmental factors affect walking travel distances, but in an analysis of roadways within the same metro area, they are not a factor unless they vary *within* the region.

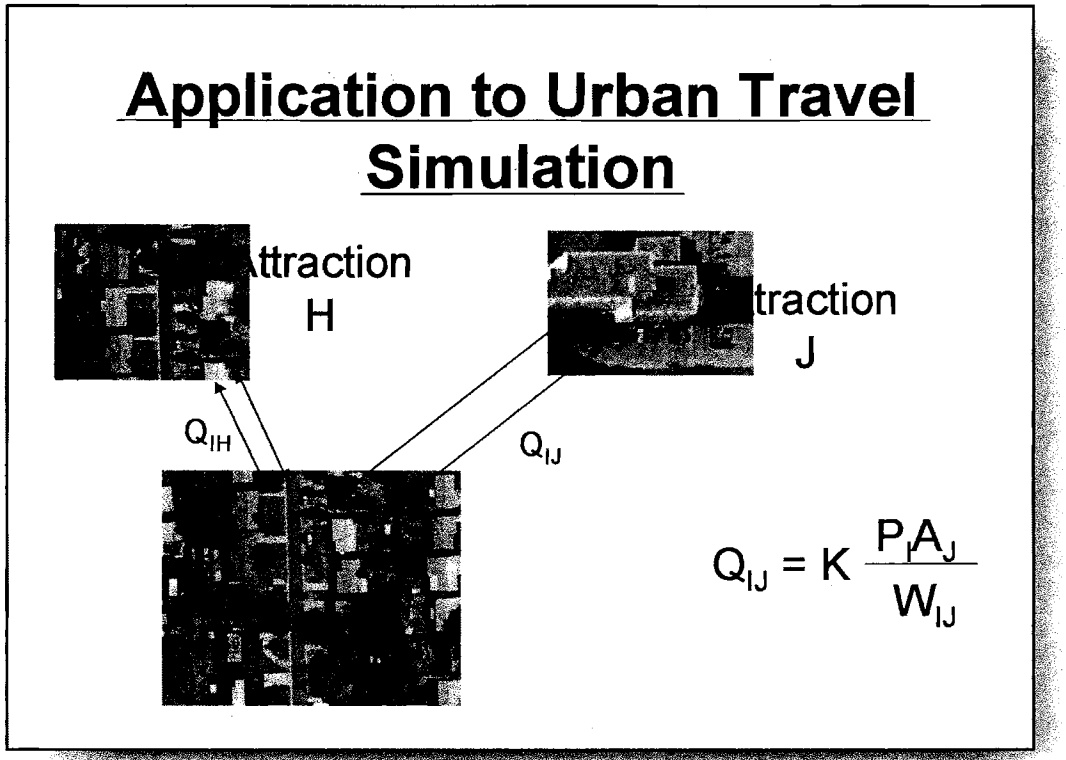


Figure 1 Newton's gravity model as applied to trip interchange.

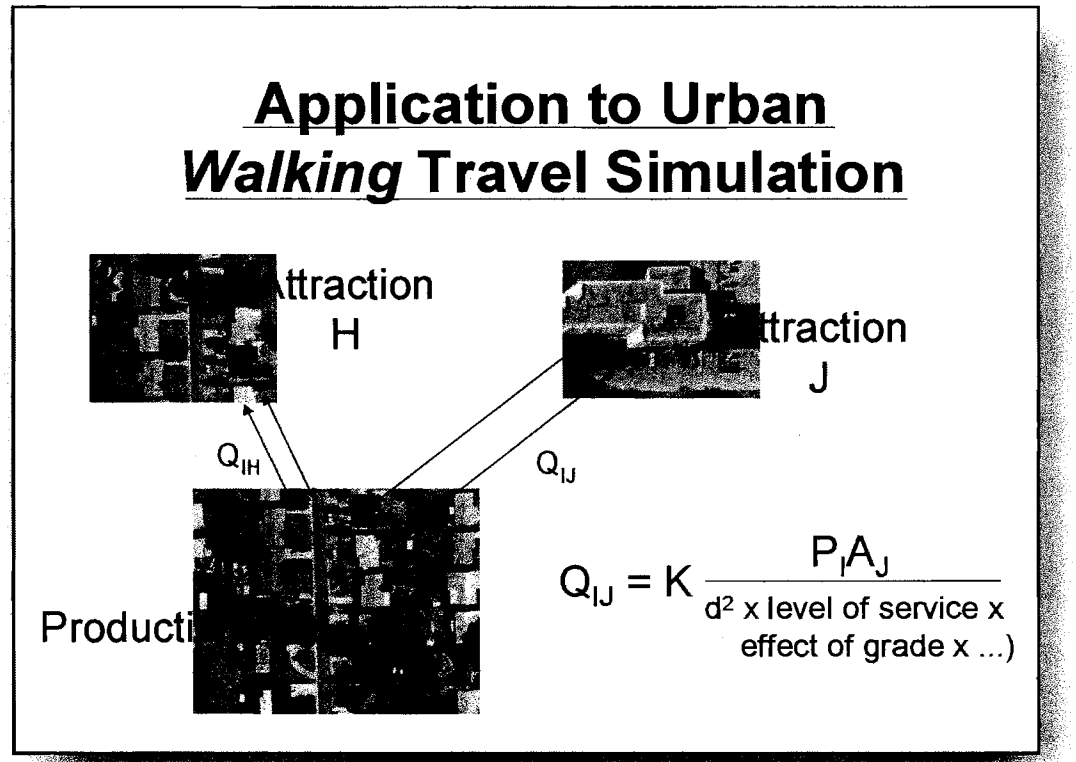


Figure 2 Walking trip interchange relationship.

Figure 3 Roadway conditions have a large effect on walking.

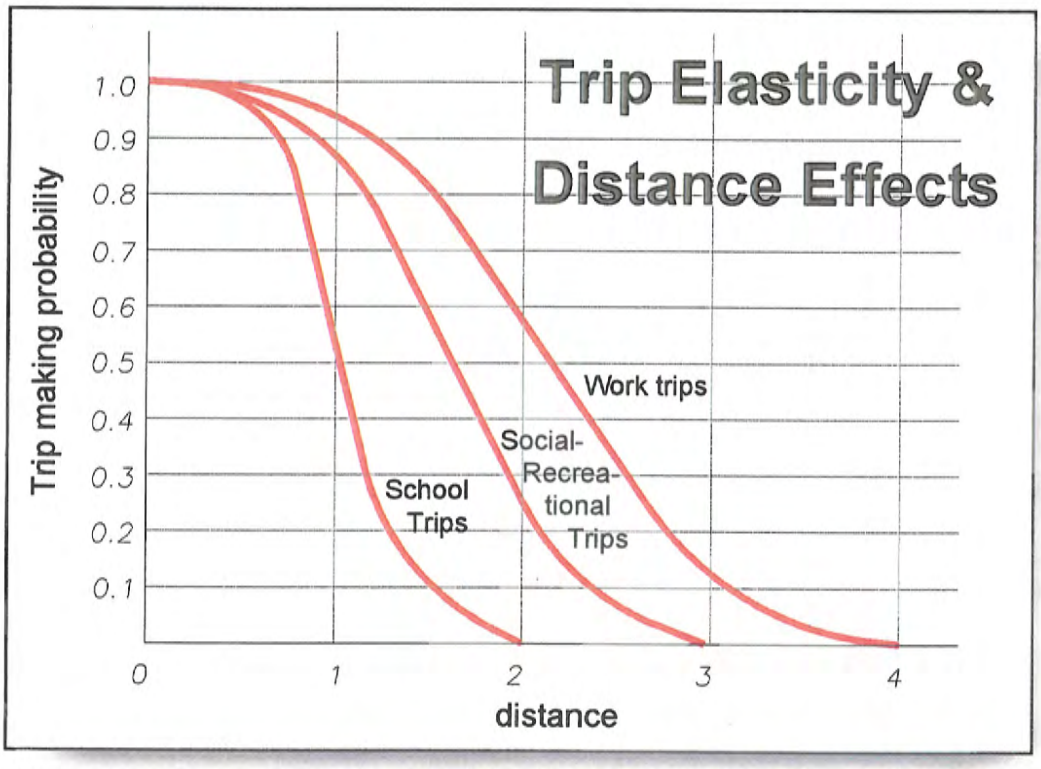


Figure 4 Typical trip making probability (impedance effects) due to distance.

The *Latent Demand Model* identifies and quantifies both categories of trips. The following sections document the modeling processes for both the non-linked trip and linked trip.

Non-Linked Trips

As previously stated, the impedances to walking as a transportation mode play a large role in the probability of a pedestrian trip occurring. One of the significant impedances, the effect of motor vehicle traffic, is assumed not to exist for the purpose of calculating non-linked, or *latent* trips. This assumption is based on the premise that if motor vehicle traffic was not present, the "latent" pedestrian trips would become "revealed" trips.

Latent pedestrian travel activity is directly related to the frequency, magnitude, and proximity of trip generators and attractors to a roadway segment. Figure 6 is a stylized representation of the potential trip activity around a work trip attractor, such as an office complex. The intensity of the shading on the surrounding street network graphically depicts the relative trip activity given that the inbound trips are coming from all directions and that there is no vehicular traffic on the streets. Figures 7 and 8 are stylized representations of this effect around attractors for social/ recreational trips and school trips, respectively.

The *Latent Demand Model* process takes these "snapshots" of the potential trip activity for *all* attractors and generators throughout the metropolitan area and essentially assembles them into a composite, as depicted in Figure 9. The intensity of the shading of the streets within this figure depicts the total relative potential pedestrian trip activity surrounding the generators and attractors. The street segments with the more intense areas of shading represent the areas with the highest potential pedestrian trip activity. Figure 10 shows the mathematical expression of this GIS-based region-wide model.

The following sections describe how the pedestrian travel analysis for the MAG *Pedestrian Plan 2000* is accomplished in a GIS environment.

Generators, Attractors, and Spatial Queries

The first step in the process is to identify those generators (or origins) and attractors (or destinations) that represent the trip ends for the four general trip purposes. Generators are the origin end of the trip and are represented by every residence in the study area. Attractors are every business, school, park and trail, and social and service establishment. The generators and attractors form the foundation of the pedestrian travel demand calculations that the *Latent Demand Model* incorporates.

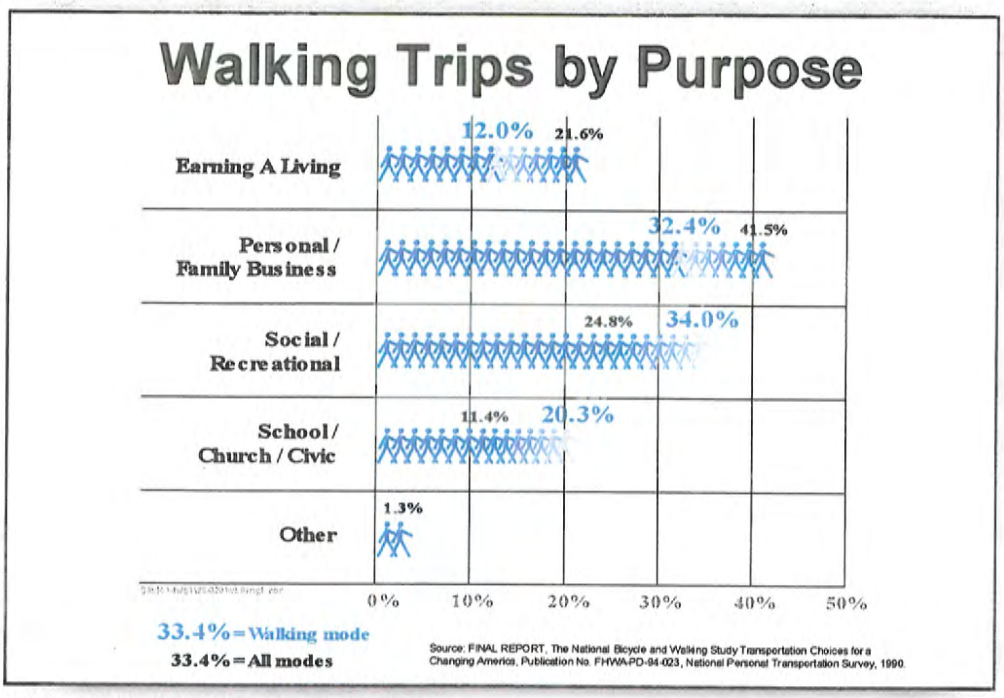


Figure 5 Walking Trips by Purpose.

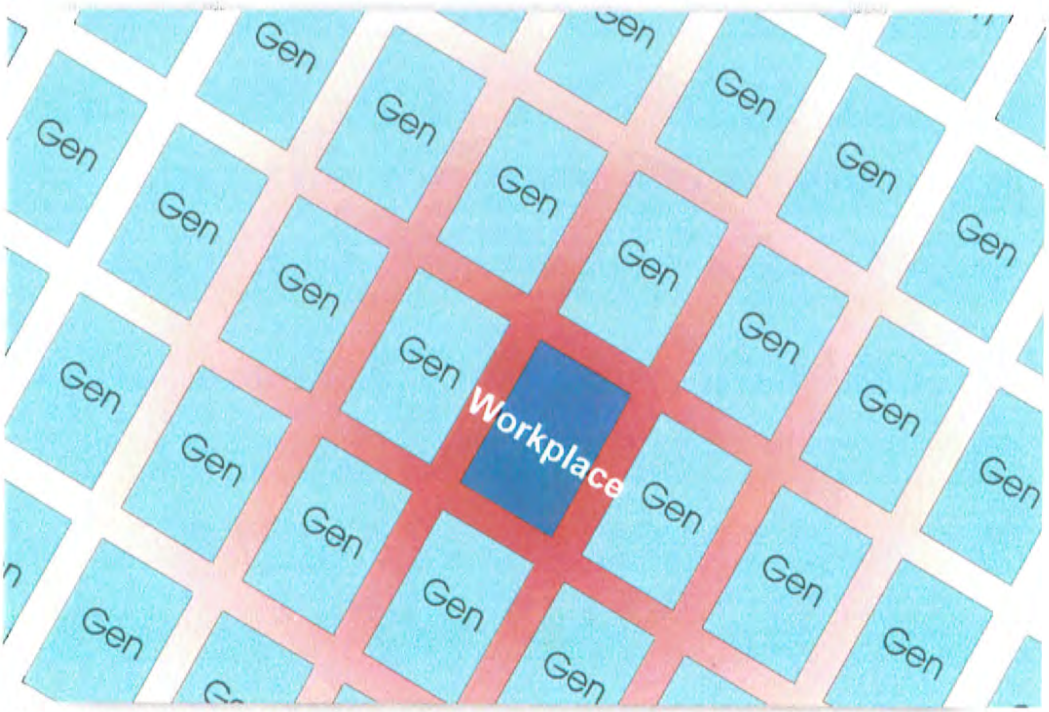


Figure 6 Potential pedestrian trip activity around a work trip attractor.

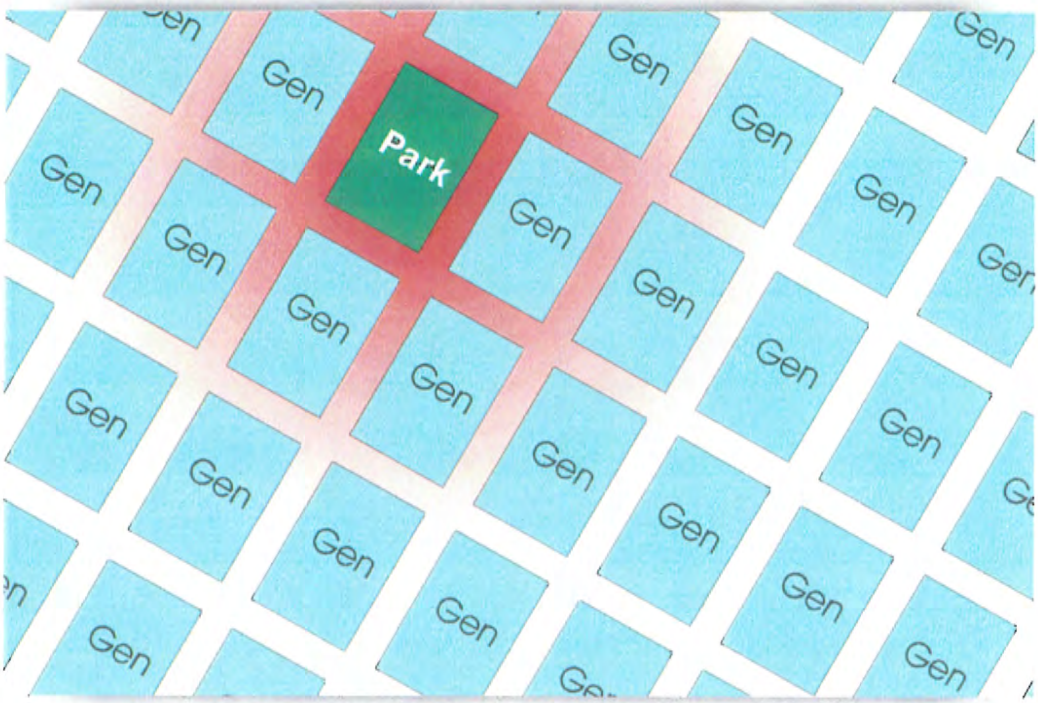


Figure 7 Potential pedestrian trip activity around a social/recreational attractor.

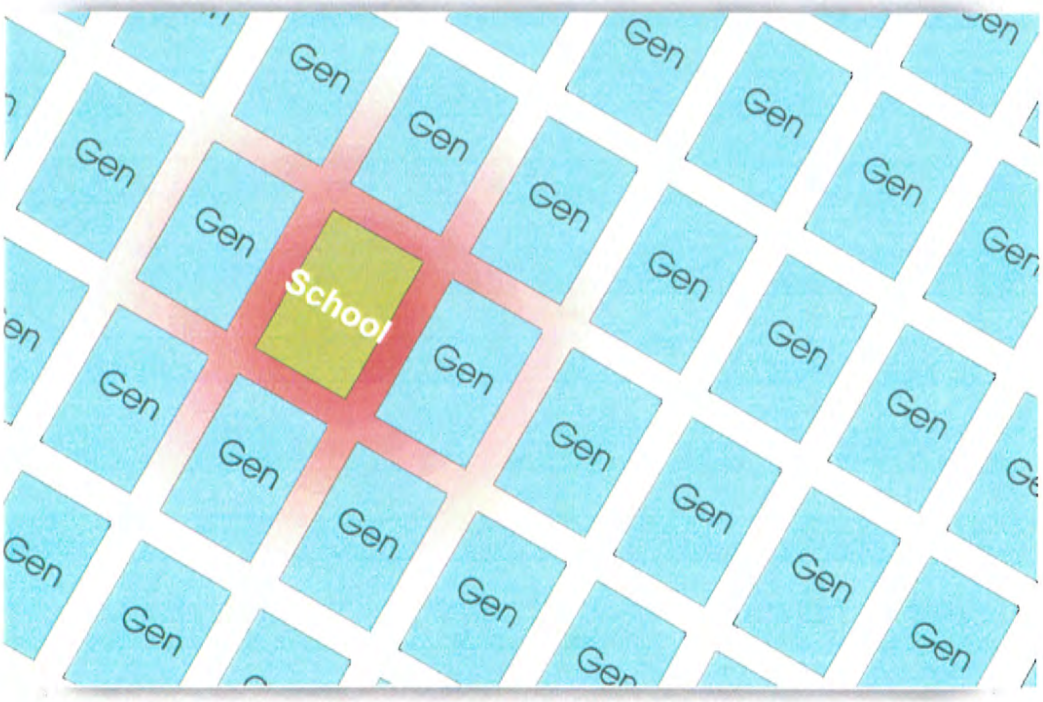


Figure 8 Potential pedestrian trip activity around a school.

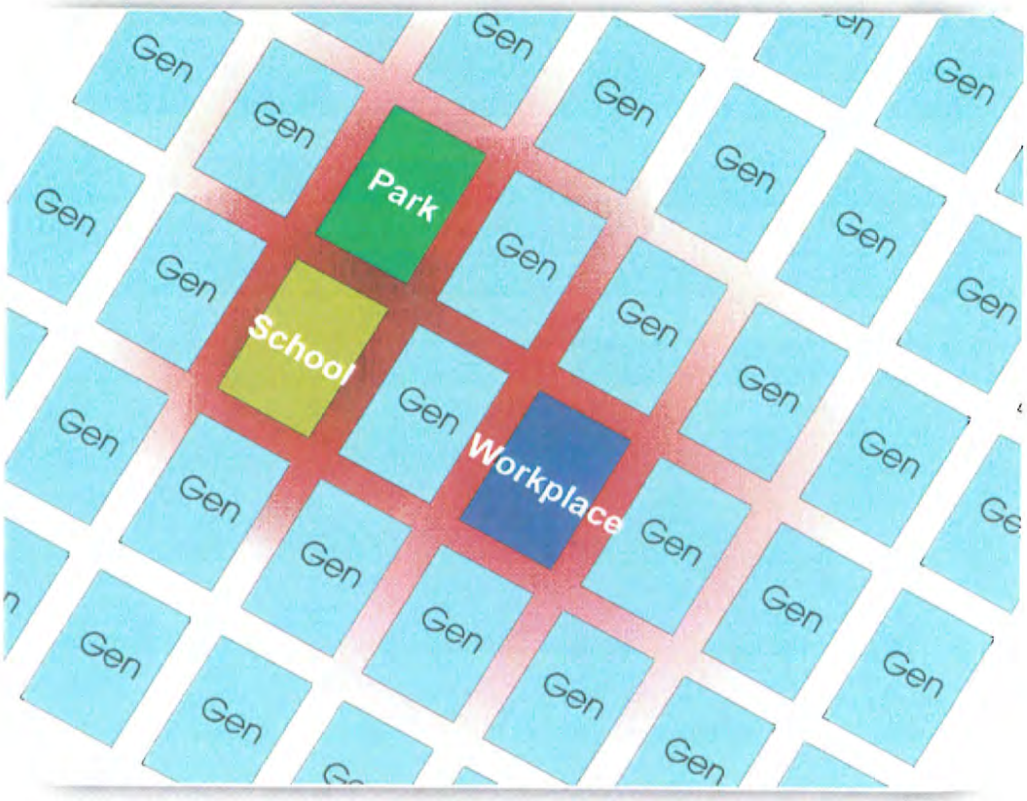


Figure 9 Composite of potential pedestrian trip activity for three types of trip attractors.

$$LDS = \sum_{n=1}^{4} TTS_n \times \frac{\sum_{n=1}^{4}\left(GA_n \times \overline{TG}_n\right)}{\left(GA_n \times \overline{TG}_n\right)} \times \left[\overline{TG}_n \sum_{d=1}^{1} P_{nd} \times ga_n\right]$$

n	= walking trip purpose (e.g., work, personal/business, recreation, school)
TTS	= trip purpose share of all walking trips
GA	= number of generators or attractors per trip purpose
$\overline{TG}$	= average trip generation of attractor or generator
P	= effect of travel distance on trip interchange, expressed as a probability
ga	= number of generators or attractors within specified travel distance range
d	= travel distance range from generator or attractor

Figure 10 The Basic Latent Demand (score) Algorithm.

While the locations of many of the generators and attractors are individually identified, particularly for the school and social-recreational (parks) trip purposes, aggregated data is used for modeling the other trip purposes. For example, while the *Latent Demand Model* quantifies the trip generation of every residence for work trips, it does not use the physical location of every residence within the study area. Rather, the *Model* uses the aggregated population, as found in the Transportation Analysis Zone (TAZ) data from MAG's transportation planning model. Likewise, the work trip and work errand demand analyses are based on TAZ employment data for the trip interchange calculations.

Once the generator and attractor data has been identified and, if necessary, geocoded or "mapped" into the GIS environment, spatial queries are performed around the network road segments. The spatial queries "capture" the data for the calculation of potential trip interchange, between origins and destinations within various travel distance ranges. The travel ranges are established from national survey data as reported in the NPTS study and vary according to trip purpose. Each travel range represents a "buffer", and the buffers are the geographic limits of the spatial queries.

As the spatial queries are performed, their results are used to populate a database. That database is then programmed to calculate the trips within each buffer, per trip purpose. Once all of the trips have been calculated for each buffer around a road segment, they are summed to determine that road segment's *Latent Demand Score*. The road segment represents a corridor area, or "travel shed".

The following sections document, for each of the four trip purposes, the generators and attractors identified, the mathematical relationship between them, and how the spatial queries are performed.

Work (Wk) Trips The generators and attractors used to estimate the potential trip activity for this trip type are the TAZs' population density and TAZ total employment, respectively. The following equation shows the computational form of the spatial queries.

Where:

$$Q_{Wk} = \sum_{d=1}^{n} P_d \times \left[\sum_{z=1}^{n} \left(E_z \times \frac{\rho_z}{E_z} \right) \right] \qquad (1)$$

Q_{Wk} = Total trip interchange potential for work trips
d = Spatial query buffer
n = Total number of buffers
P = Effect of travel distance on trip interchange, expressed as a probability (see Figure 4)
z = TAZ adjacent to roadway segment
E = Total employment within buffer
ρ = Population within buffer

Restriction:

$$\frac{\rho_z}{E_z} \leq 1 \qquad (1a)$$

Figure 11a depicts the three spatial queries performed for work trips. The queries are segment-based which means that the queries/buffers are centered on the individual road segments. The buffer width of each query for this trip type (and indeed all of the trip types) is based on the pedestrian trip distances reported in the NPTS study.

While trips to colleges and universities might be considered as school trips, they are *modeled* as "work trips" due to the similarity of their trip characteristics (primarily trip length and regularity) to work trips. Furthermore, the *generator* for trips to colleges and universities is the same as that for work trips - population. The attractors are the colleges and university locations. Their individual full-time enrollments (FTE's) are used in the calculation of the trip interchange. Equation 2 mathematically describes how this trip interchange is calculated and how the spatial queries account for this information.

$$Q_{C\&U} = \sum_{d=1}^{n} P_d \times \left[\sum_{A=1}^{n} (FTE) \times S \times \frac{\rho_z}{FTE} \right] \qquad (2)$$

Where:

$Q_{C\&U}$ = Total trip interchange potential for college and university trips
d = Spatial query buffer
n = Total number of buffers
P = Effect of travel distance on trip interchange, expressed as a probability (see Figure 5)
A = Number of attractors
FTE = Full-time enrollment of college or university
S = Percent of segment within TAZ
ρ = Population within TAZ

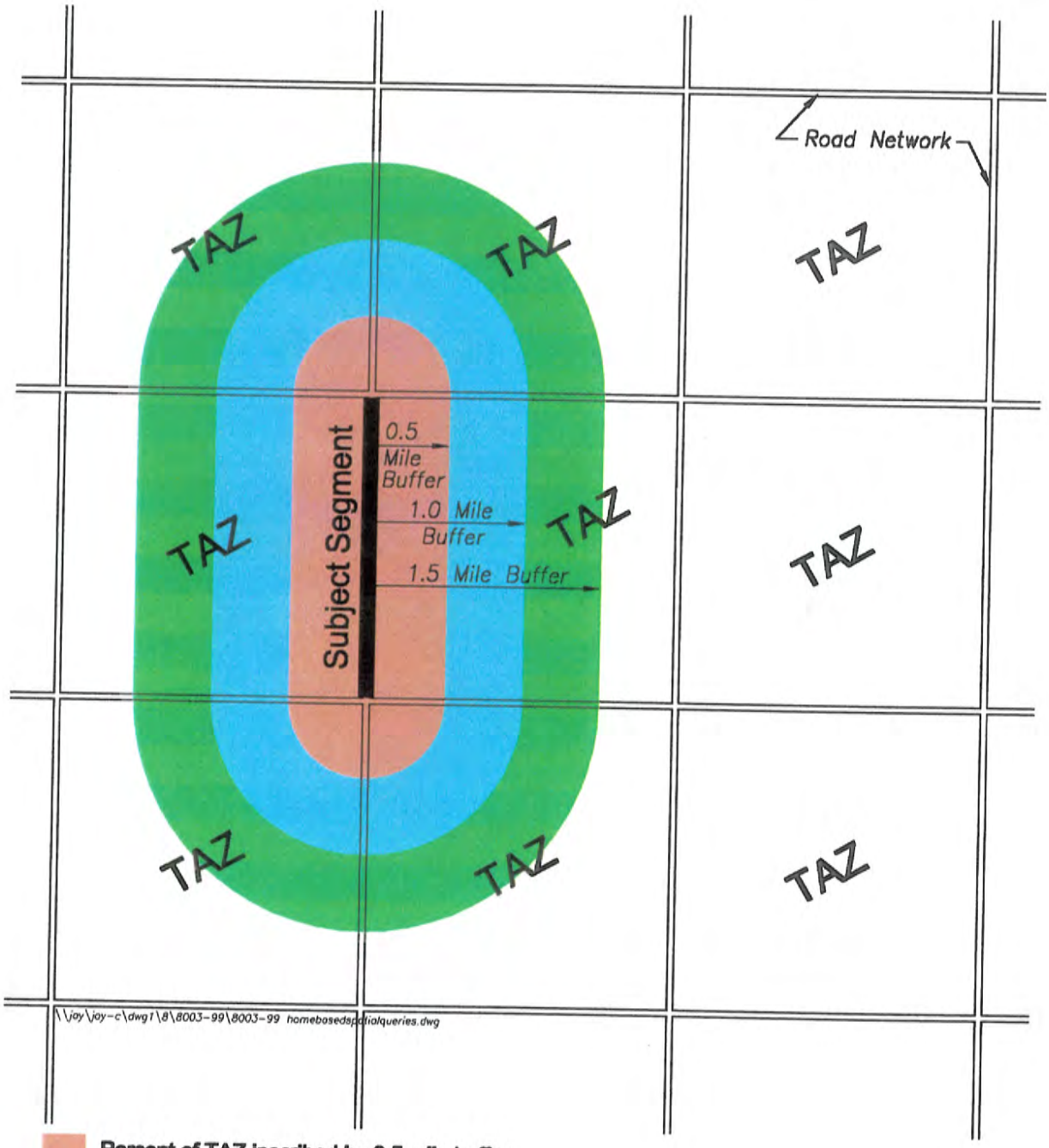
Restriction:

$$\frac{\rho_z}{FTE} \leq 1 \qquad (2a)$$

The spatial queries for college/university trips are performed differently from the other work trips. The

Figure 11a

Work Trip Spatial Queries (Segment-Based)



Percent of TAZ inscribed by 0.5 mile buffer

Percent of TAZ inscribed by 1.0 mile buffer

Percent of TAZ inscribed by 1.5 mile buffer

essential difference is that the spatial queries for colleges and universities are *attractor-based* rather than segment-based. This means that the spatial queries are centered on the individual colleges and universities (see Figure 11b), rather than the segment. As Figure 11b illustrates, the percent of the segment falling within each buffer is used to normalize the segment's trip interchange potential.

Shopping and Errands (SE) Trips As with the work trip, the generator for shopping and errand trips is population. The attractor is total employment per TAZ. The *Latent Demand Modeling* further subdivides this trip type into two categories of shopping and errand trips. The first is work-based errands, or those made by, and between, places of employment. For example, a person who picks up his/her dry cleaning during lunchtime is performing a work-based errand. The second category is home-based errands. An example of a home-based errand is a person going from their residence to a neighborhood store for a carton of milk or video rental.

Equation 3 is the mathematical expression that quantifies these two categories of shopping and errand trips.

$$Q_{SE} = \sum_{d=1}^{n} P_d \times \left[\sum_{z=1}^{n} (E_z + \rho_z) \right] \qquad (3)$$

Where:

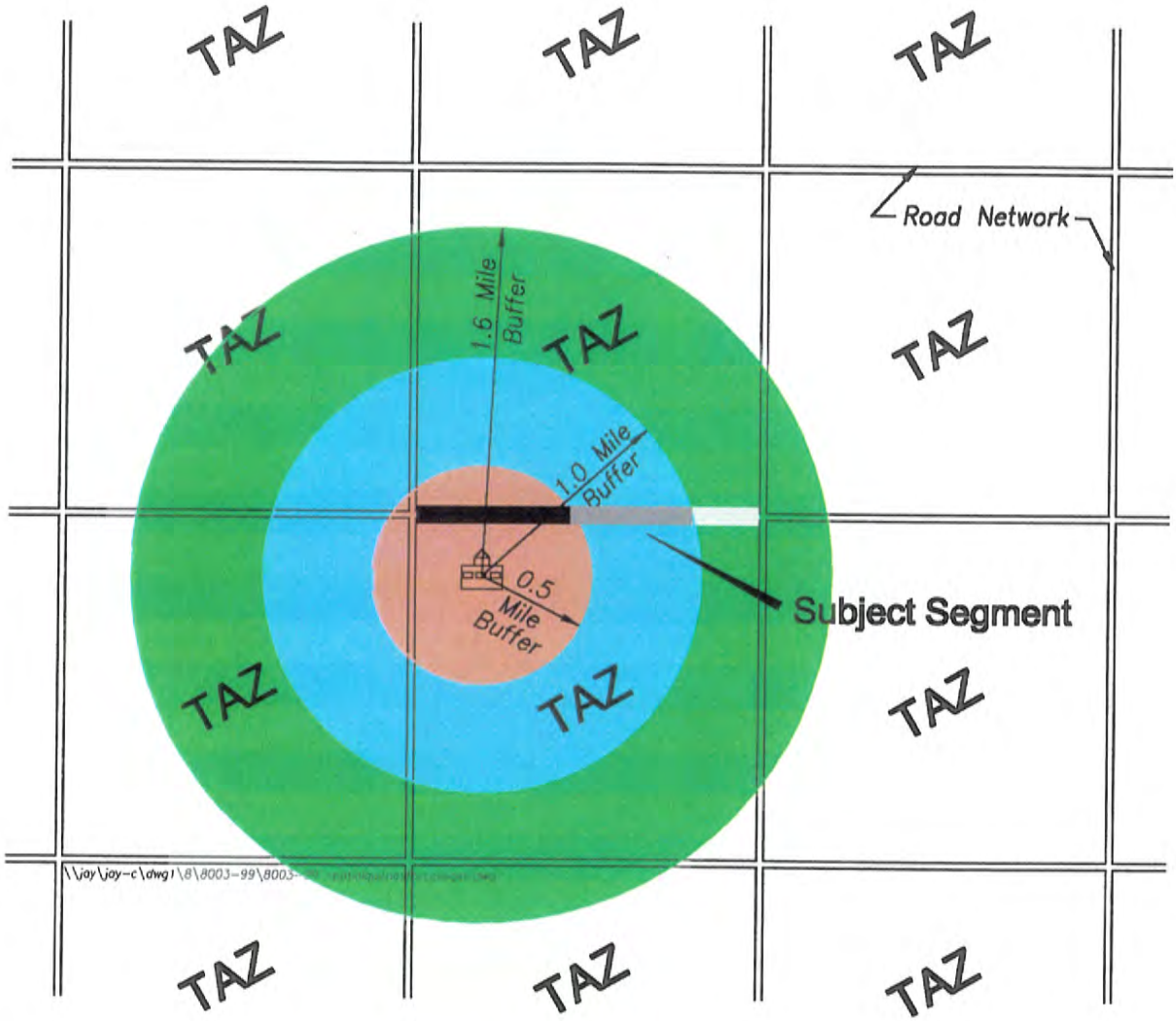
Q_{SE} = Total trip interchange potential for the shopping and errand trips
d = Spatial query buffer
n = Total number of buffers
P = Effect of travel distance on trip interchange, expressed as a probability (see Figure 5)
z = TAZ adjacent to roadway segment
E = Total employment
ρ = Population within buffer

The spatial queries for the shopping and errand trips are segment-based. Figure 12 graphically illustrates the two spatial queries performed for this trip type.

School (Sc) Trips The locations of elementary, middle and high schools are the attractors for this trip type. Since students living within a two-mile radius of a school are generally not eligible to use the school transportation system, they are considered potential walkers. This two-mile radius constitutes a transportation exclusion zone for which potential pedestrian trip activity is measured. Equation 4 mathematically expresses the calculation of potential school trips. Average school enrollment for the entire school district is the base quantity used in determining potential trips.

Figure 11b

Spatial Queries for Colleges and Universities (Attractor-Based)



Percent of TAZ inscribed by 0.5 mile buffer

Percent of TAZ inscribed by 1.0 mile buffer

Percent of TAZ inscribed by 1.6 mile buffer

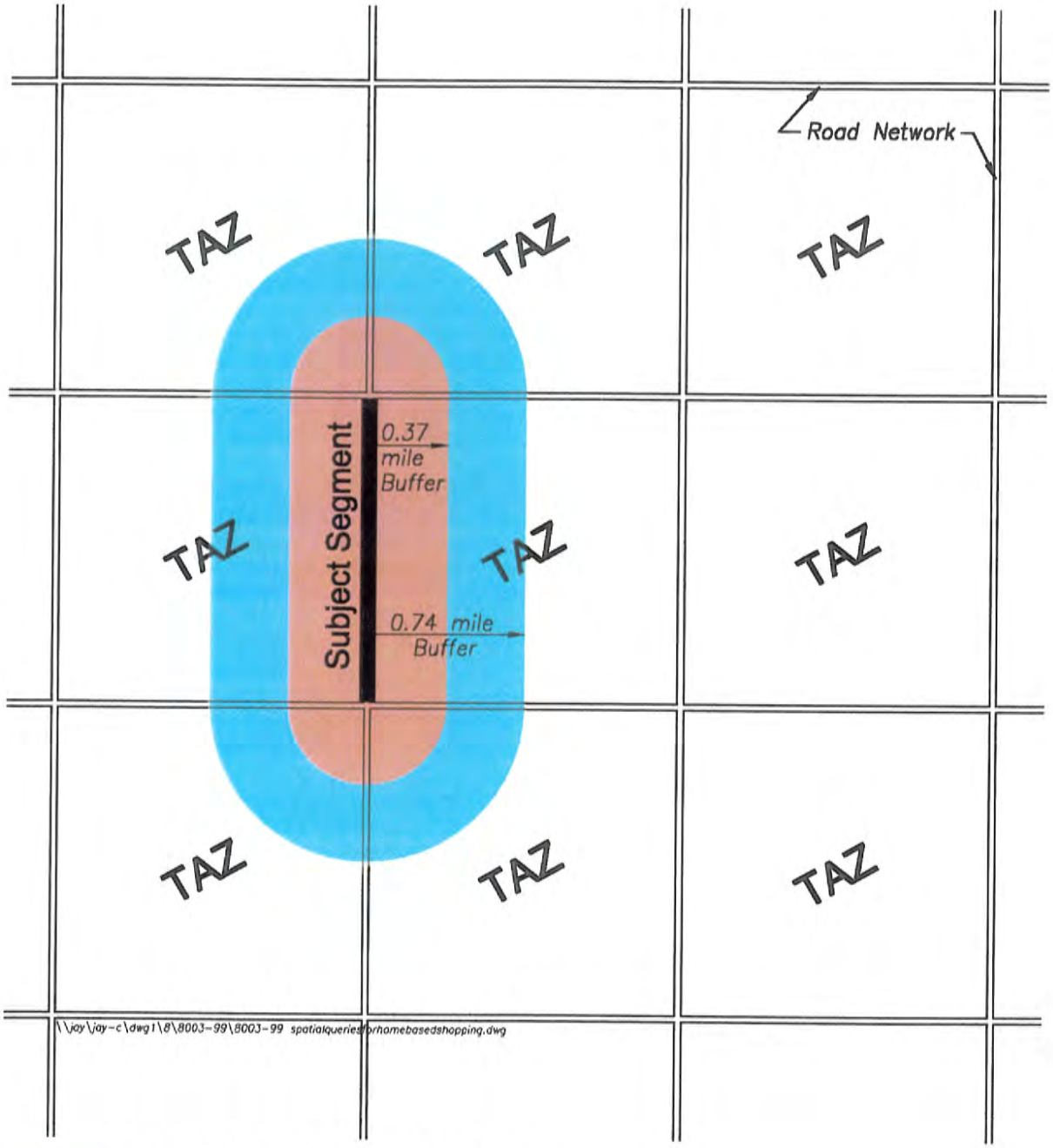
% of Segment inscribed in 0.5 Mile Buffer

% of Segment inscribed in 1.0 Mile Buffer

% of Segment inscribed in 1.6 Mile Buffer

Figure 12

Spatial Queries for Shopping and Errands (Segment-Based)



Percent of TAZ inscribed by 0.37 mile buffer

Percent of TAZ inscribed by 0.74 mile buffer

$$Q_{Sc} = \sum_{d=1}^{n} P_d \times \left[\sum_{A=1}^{n} (2 \times ASE \times S) \right] \qquad (4)$$

Where:

Q_{Sc} = Total trip interchange potential for home-based school trips
d = Spatial query buffer
n = Total number of buffers or TAZ's
P = Effect of travel distance on trip interchange, expressed as a probability (see Figure 5)
A = Number of attractors
ASE = Average school enrollment
S = Percent of road segment within buffer

As with colleges and universities, the spatial queries for this trip type are attractor-based. Figure 13 illustrates the two spatial queries performed for this trip type, and how the percent of the road segment falling within each "buffer" is likewise calculated.

Recreational and Social (RS) Trips Public parks, trail heads, and trails are the attractors used for the recreational and social (RS) trip purpose demand assessment. The total trips associated with these attractors are given in equation 5, below.

$$Q_{SRC} = \sum_{d=1}^{n} P_d \times \left(T_t + \frac{\rho_z}{T_t} \right) \qquad (5)$$

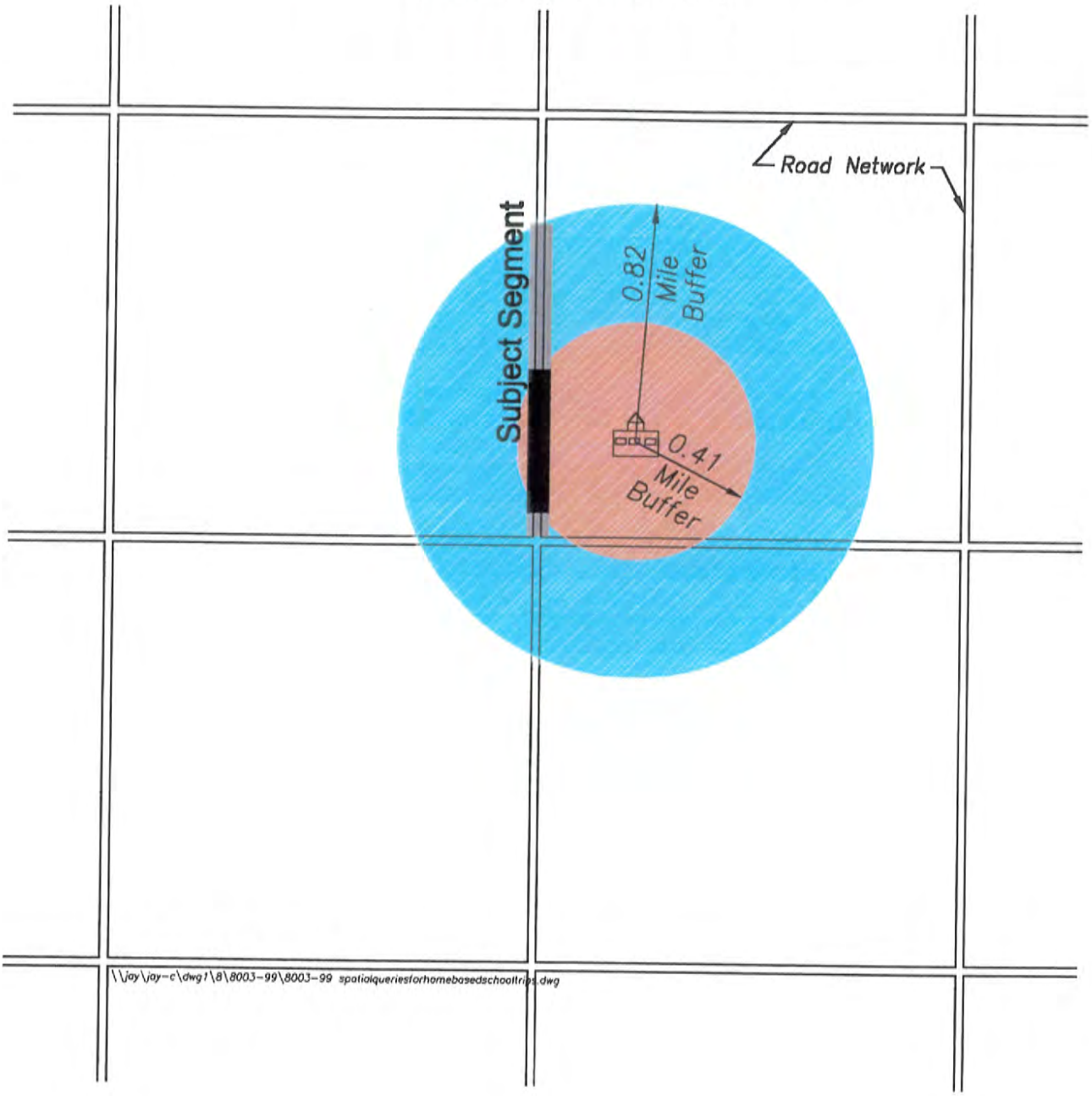
Where:

Q_{SRC} = Total trip interchange potential for social/recreational trips
d = Spatial query buffer
n = Total number of buffers or TAZ's
P = Effect of travel distance on trip interchange, expressed as a probability (see Figure 5)
T_t = Total number of park & trail head trips (or Q_{parks}) + total number of urban trail trips (or Q_{trails})
ρ = Population within buffer

As shown above, T_t is separated into two categories of recreational and social trips: parks & trail heads and urban trails. The reason for separating urban trails from the parks and trail-heads lies in how the spatial queries are performed. An urban trail is, in effect, a linear park. Therefore, the spatial query is performed from the trail itself to describe the portion of the road segment proximate to that portion of the trail. Thus, the spatial queries for urban trails are attractor-based, whereas the spatial queries for parks and trail-heads are segment-based. The following paragraphs document the trip calculations for each category.

Figure 13

Spatial Queries for School Trips (Attractor-Based)



Percent of TAZ inscribed by 0.41 mile buffer

Percent of TAZ inscribed by 0.82 mile buffer

% of Segment inscribed in 0.41 Mile Buffer

% of Segment inscribed in 0.82 Mile Buffer

Prior to performing spatial queries on parks and trail-heads, the parks were stratified into three categories; major parks, staffed parks, and minor parks. The reason: the "attractiveness" of different types of parks. For example, a park that has ball fields and a swimming pool generally attracts more users than a park of equal size with fewer amenities. Accordingly, the trip attraction for the former will be higher than that for the latter. A definition of each park type along with its associated trip generation follows:

- Major Parks (and Trail Heads) – these are characterized as parks that have regularly programmed events and large, staffed events. Trip generation = 2,058 trips. [This is based on an average major park size of 688 acres multiplied by a Trip Generation Rate of 2.99 trips per acre.]
- Staffed Parks – these typically have intermittently programmed events and staffed events. Trip generation = 313 trips [This is based on an average major park size of 16.3 acres multiplied by a Trip Generation Rate of 19.15 trips per acre.]
- Minor parks – these generally do not have programmed events nor do they have staffed events. Trip generation = 11 trips [This is based on an average major park size of 6.9 acres multiplied by a Trip Generation Rate of 2.23 trips per acre.]

Due to their trip attraction potential, trail-heads are considered major parks, and are assigned the same trip generation. The quantification of trip interchange for parks and trail heads is shown in Equation 5a, below.

$$Q_{parks} = \sum_{c=1}^{4}\left(\sum_{A=1}^{n} A \times TG\right) \qquad (5a)$$

Where:

Q_{Parks} = Total trip interchange potential for park and trail head trips
c = Categories of parks
A= Number of attractors
n = Total number of buffers
TG = Trip generation rate

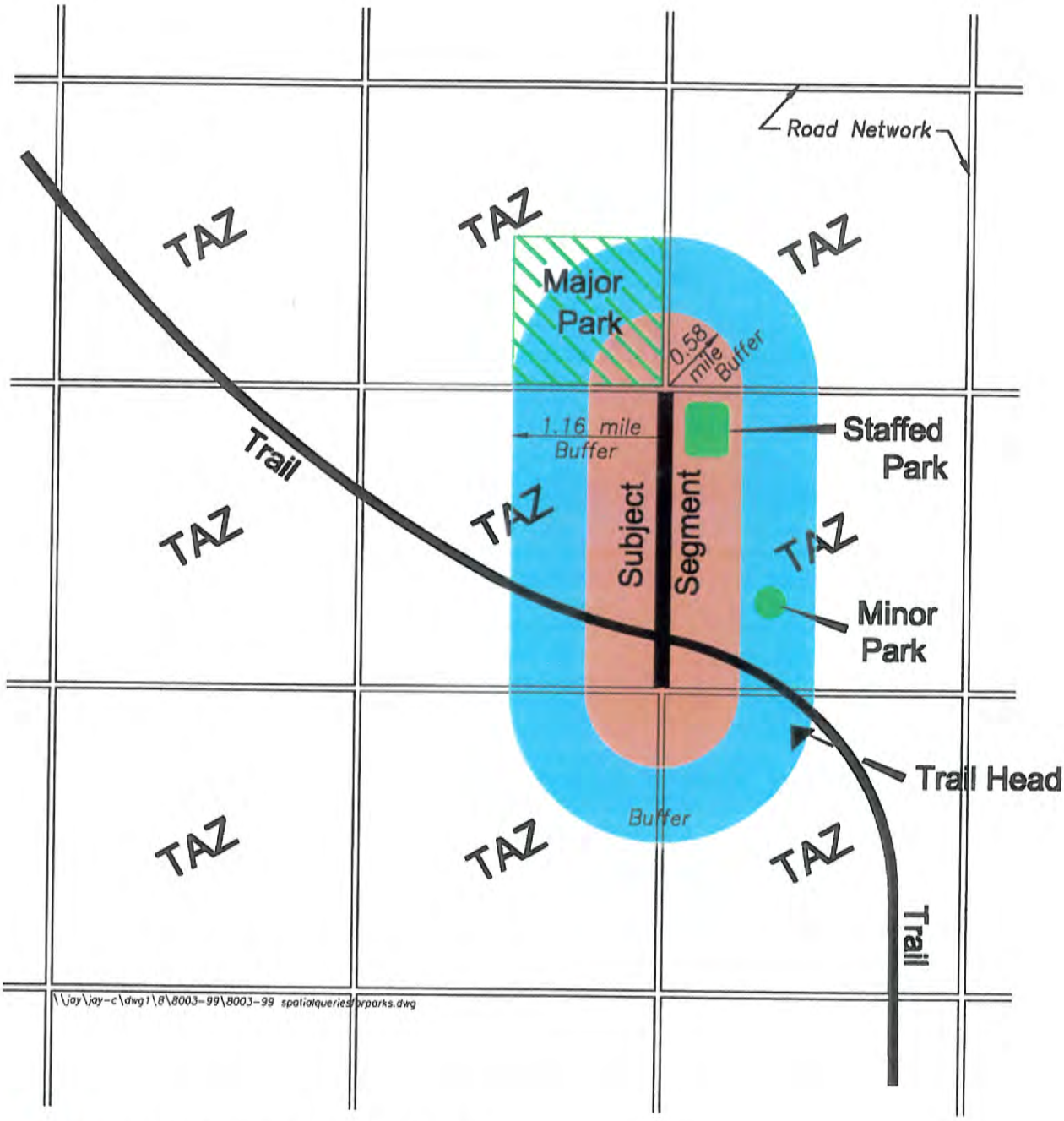
Figure 14a is a graphic representation of the segment-based spatial queries used for the park and trail head latent demand analysis.

As previously described, quantification of the travel demand associated with trails has been separated from parks and trail heads due to the fact that the spatial queries are attractor-based, or more appropriately centered on the trail itself. The generator used in the trip interchange calculation for this category is once again the population surrounding the subject road segment. The trip generation used for the calculation is 313 trips, which is based on the trail acreage multiplied by its associated trip generation rate. In the case of trails, the trip generation rate is 19.15 trips per acre.

Equation (5b) represents the calculation of potential trip activity for trails:

Figure 14a

Spatial Queries for Parks and Trail Heads (Segment-Based)



Percent of TAZ inscribed by 0.58 mile buffer

Percent of TAZ inscribed by 1.16 mile buffer

$$Q_{trails} = \sum_{A=1}^{n} S \times TG \qquad (5b)$$

Where:

Q_{Trails} = Total trip interchange potential for trail trips
A = Number of attractors
n = Total number of buffers
S = Percent of segment within buffer
TG = Trip generation rate

Figure 14b depicts the two spatial queries performed for this trip purpose, which are attractor-based.

Putting it Together: The Total of Non-Linked Trips

The sum of the individual trip purposes for each roadway corridor, when multiplied by their associated trip share from the NPTS study, is the *Non-Linked Trips Latent Demand Score* for that roadway corridor. The mathematical expression for this is given by Equation 6.

$$LDS = \sum_{n=1}^{4} (Q_n \times TTS_n) \qquad (6)$$

Q= Total number of potential non-linked trip interchanges calculated by spatial queries, per trip purpose
n = Pedestrian trip purpose (e.g., work, personal/business, recreation, school)
TTS = Trip purpose share of all pedestrian trips (calculated using NPTS data[2])

The tabular results of the non-linked latent demand analysis for each road corridor within the Project study network is in the Final Report document of the *MAG Pedestrian Plan 2000.* The regional ranking results for both base year (1995 data file) and future (Year 2020) are depicted graphically on the maps within the Final Document of the *MAG Pedestrian Plan 2000* (Section 4).

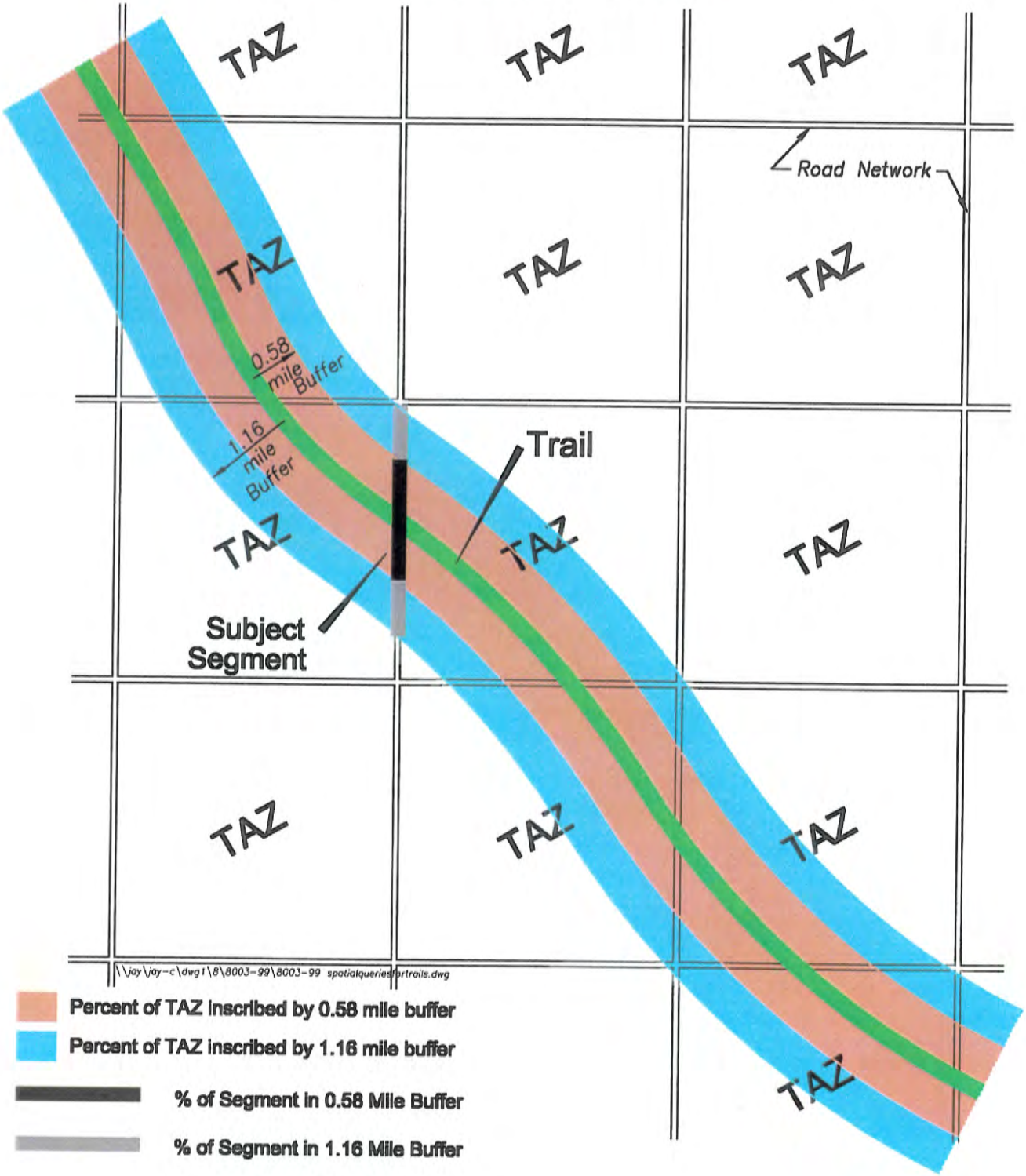
Linked Trips

As previously stated, linked trips account for a significant portion of the existing pedestrian activity on the MAG network today. The majority of linked trips are represented by two of the trip purposes identified in the NPTS study, work trips and shopping and errand trips. While these trips consist of a vehicular travel link and a walking link, only the walking link is quantified for the *MAG Pedestrian Plan 2000.* The following paragraphs detail how this link is quantified.

[2] Trip share not applied to colleges and university trips

Figure 14b

Spatial Queries for Trails / Linear Parks (Attractor-Based)



Since employment is the measure used to quantify the "trip attraction" for both work trips and shopping/ errand trips, it is logical to use this same measure in the quantification of linked trips. The linked trip analysis uses a variation of this measure, *employment density*, to describe existing relative pedestrian trip activity levels.

Employment density is used rather than gross employment because density is a truer indicator of the concentration of business and retail establishments within the travel corridor represented by a road segment. For example, a TAZ in a downtown area and one in a suburban area may have the same number of employees; however, the one in the downtown area is likely smaller and thus has a higher employment density. Also, business and retail establishments in downtown areas are generally located immediately adjacent to the sidewalk, whereas those in a suburban area are generally set back well off the right-of-way line, thereby reducing their accessibility to pedestrians.

Equation 7 represents the mathematical representation of the above along with the spatial query performed.

$$Q_{linked} = \sum_{z=1}^{n} \frac{E}{a} \qquad (7)$$

Where:

Q_{linked} = Total pedestrian trips for linked trips
z = TAZ adjacent to roadway segment
n = Total number of buffers
E = Employment of TAZ within buffer
a = Area of TAZ within buffer

One segment-based spatial query is performed for this analysis, as illustrated in Figure 15.

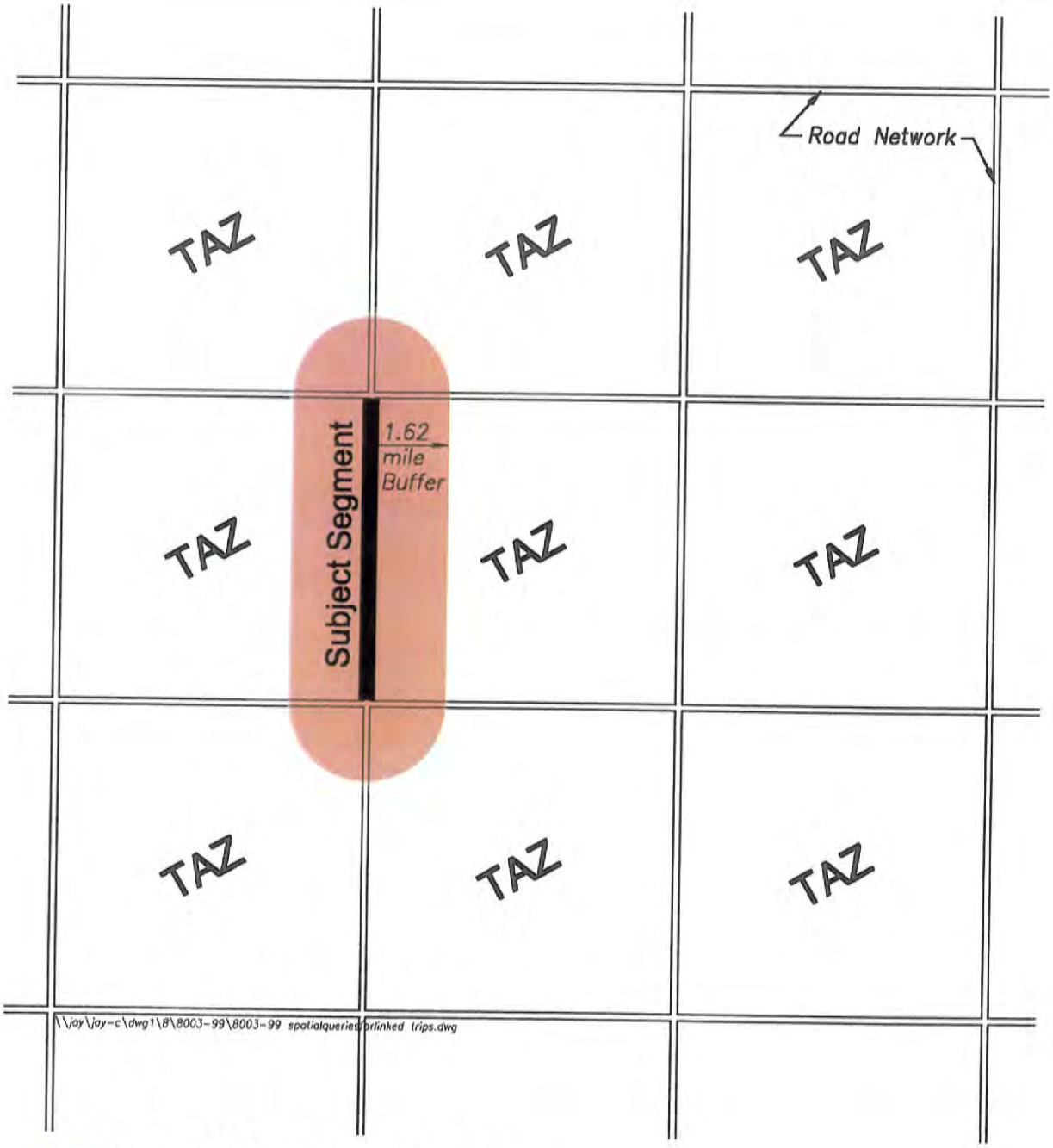
The tables in the Final Report document of the *MAG Pedestrian Plan 2000* also reflect the results of the linked trip analysis. The maps in the Final Report document pockets graphically depict these results for the current (1995 data file) conditions as well as for the future (Year 2020) conditions.

Latent Demand: Composite Results

The results of the non-linked trip analysis and the linked trip analysis reveal differing levels of pedestrian activity among the road segments for the different land use, or planning horizons. These different activity levels beg the question, "Which set of results should be used?" It is recommended that, of the analyses performed, the highest level of activity indicated on any of the maps for a particular road corridor is the one that should be used to represent the roadway corridor. The reason for this is as

Figure 15

Spatial Queries for Linked Trips (Segment-Based)

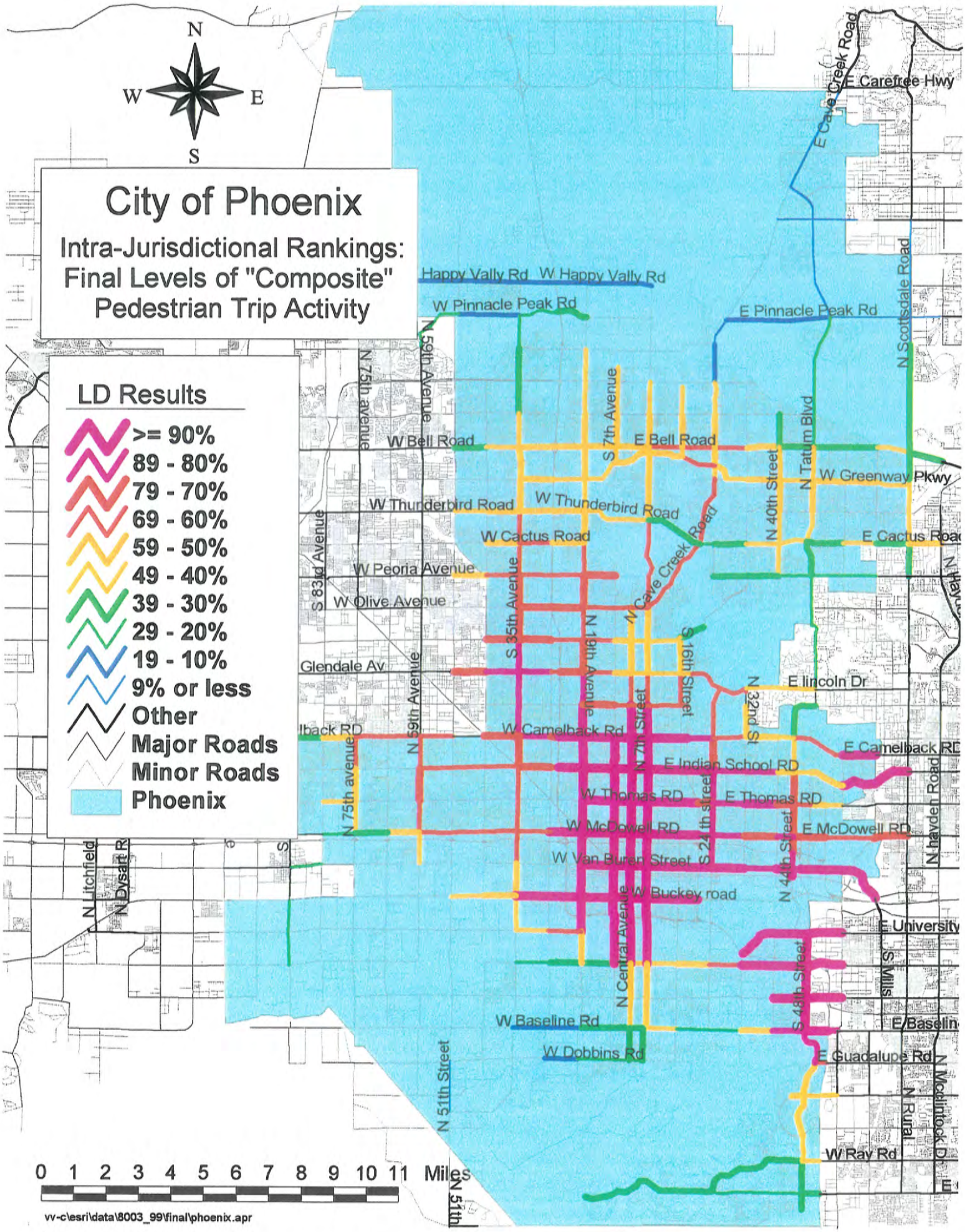


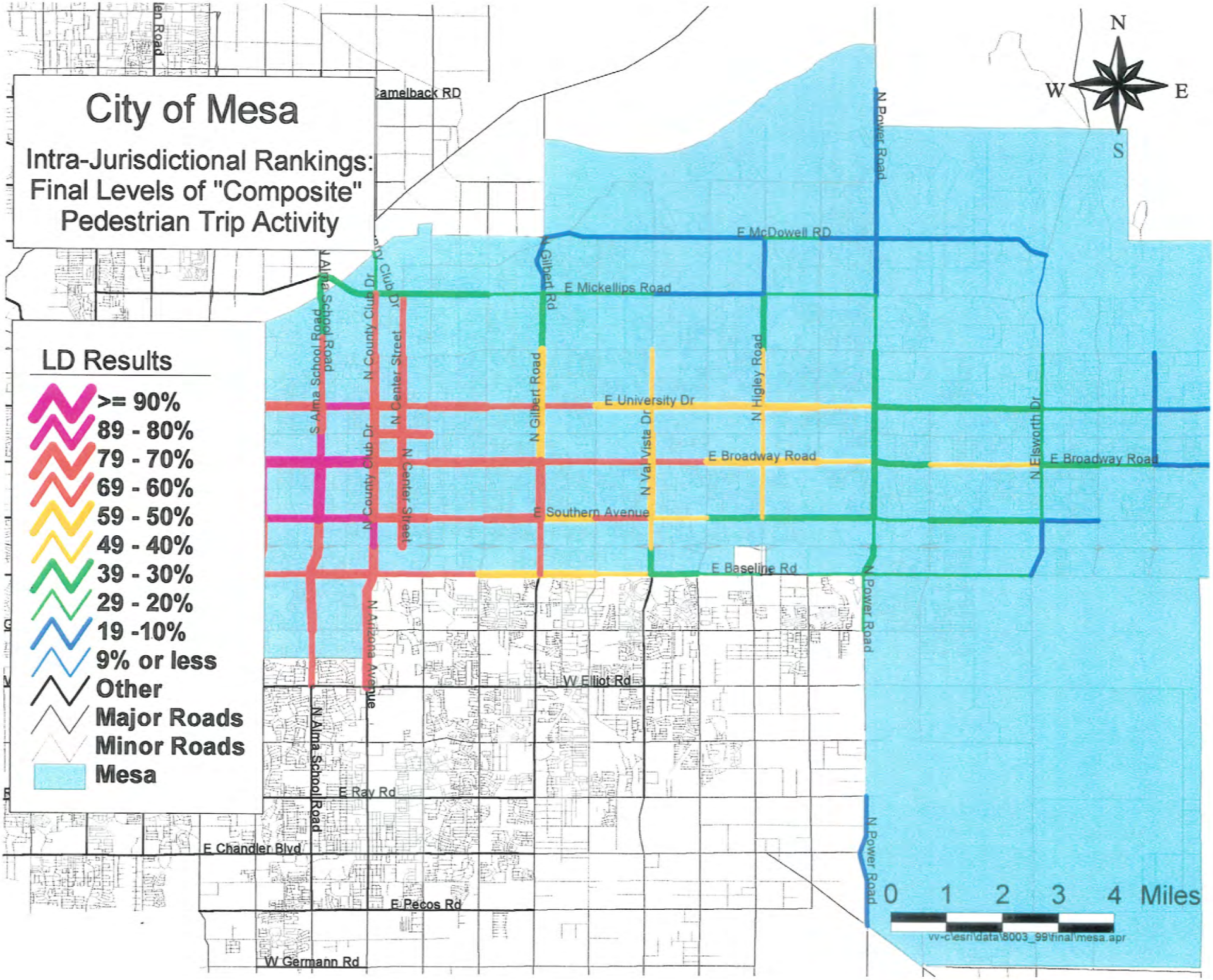
Percent of TAZ inscribed by 1.62 mile buffer

follows: the *minimum* amount of activity that should be planned for in the selection of facility types for a particular roadway is represented by the *maximum* amount of activity within the corridor, either existing or potential, whether in the present or future. Map Figure 4-8 in the *MAG Pedestrian Plan 2000* Final Report document depicts the highest level of activity per roadway corridor. This composite of the latent demand analyses represents the pedestrian activity areas, or districts recommended for use in the selection of facility types (Section 5 of the *MAG Pedestrian Plan 2000* Final Report document).

Intra-Jurisdictional Rankings

The following maps have been developed for the individual jurisdictions' use in determining how their roadway corridor areas compare amongst themselves. **The levels of (composite) potential pedestrian activities should not be classified into the *regional* districts**. Maps have been produced only for jurisdictions who have at least ten roadway corridor segments analyzed.


City of Phoenix
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
LD Results
>= 90%
89 - 80%
79 - 70%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
29 - 20%
19 - 10%
9% or less
Other
Major Roads
Minor Roads
Phoenix
N
S
E
W
Happy Vally Rd
W Happy Vally Rd
W Pinnacle Peak Rd
E Pinnacle Peak Rd
E Carefree Hwy
E Cave Creek Road
N Scottsdale Road
N 59th Avenue
N 75th avenue
W Bell Road
E Bell Road
S 7th Avenue
N Tatum Blvd
W Greenway Pkwy
W Thunderbird Road
N 40th Street
W Cactus Road
E Cactus Road
S 83rd Avenue
W Peoria Avenue
W Olive Avenue
S 35th Avenue
N 19th Avenue
N Cave Creek Road
S 16th Street
Glendale Av
E lincoln Dr
N 32nd St
W Camelback Rd
E Camelback RD
N 7th Street
E Indian School RD
W Thomas RD
E Thomas RD
S 24 th street
W McDowell RD
E McDowell RD
N hayden Road
W Van Buren Street
N 44th Street
W Buckey road
E University
N Litchfield
N Dysart R
N Central Avenue
S 48th Street
S Mills
W Baseline Rd
E Baselin
W Dobbins Rd
E Guadalupe Rd
N Rural
N Mcclintock D
N 51th Street
W Ray Rd
0 1 2 3 4 5 6 7 8 9 10 11 Miles
vv-c\esri\data\8003_99\final\phoenix.apr


City of Mesa
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
LD Results
>= 90%
89 - 80%
79 - 70%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
29 - 20%
19 -10%
9% or less
Other
Major Roads
Minor Roads
Mesa
N
W
E
S
Camelback RD
N Power Road
E McDowell RD
E Mickellips Road
N Gilbert Rd
N Alma School Road
N County Club Dr
N Center Street
N Higley Road
E University Dr
N Val Vista Dr
E Broadway Road
N Elsworth Dr
E Southern Avenue
E Baseline Rd
N Arizona Avenue
W Elliot Rd
E Ray Rd
E Chandler Blvd
E Pecos Rd
W Germann Rd
0 1 2 3 4 Miles
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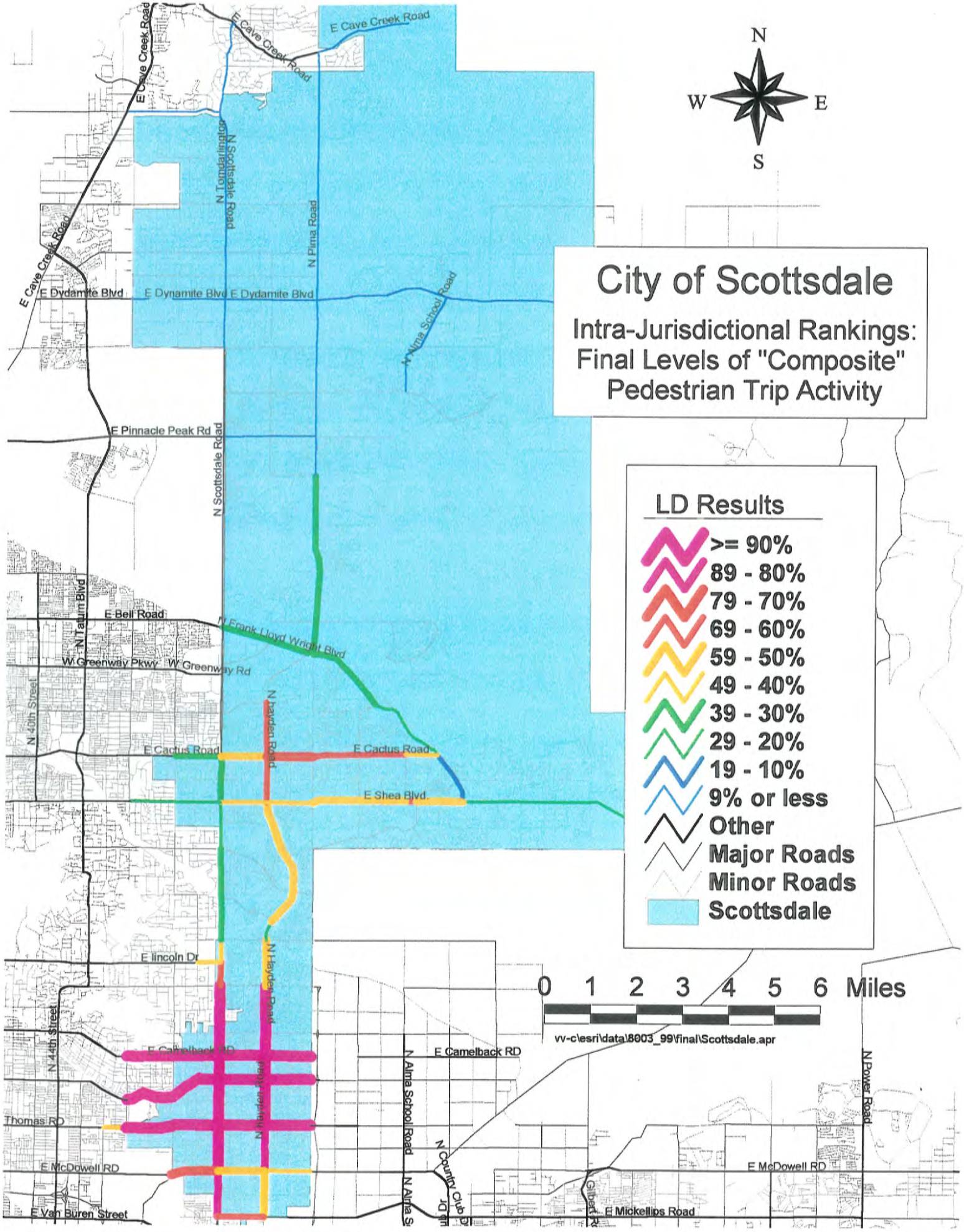
City of Scottsdale
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
N
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LD Results
>= 90%
89 - 80%
79 - 70%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
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19 - 10%
9% or less
Other
Major Roads
Minor Roads
Scottsdale
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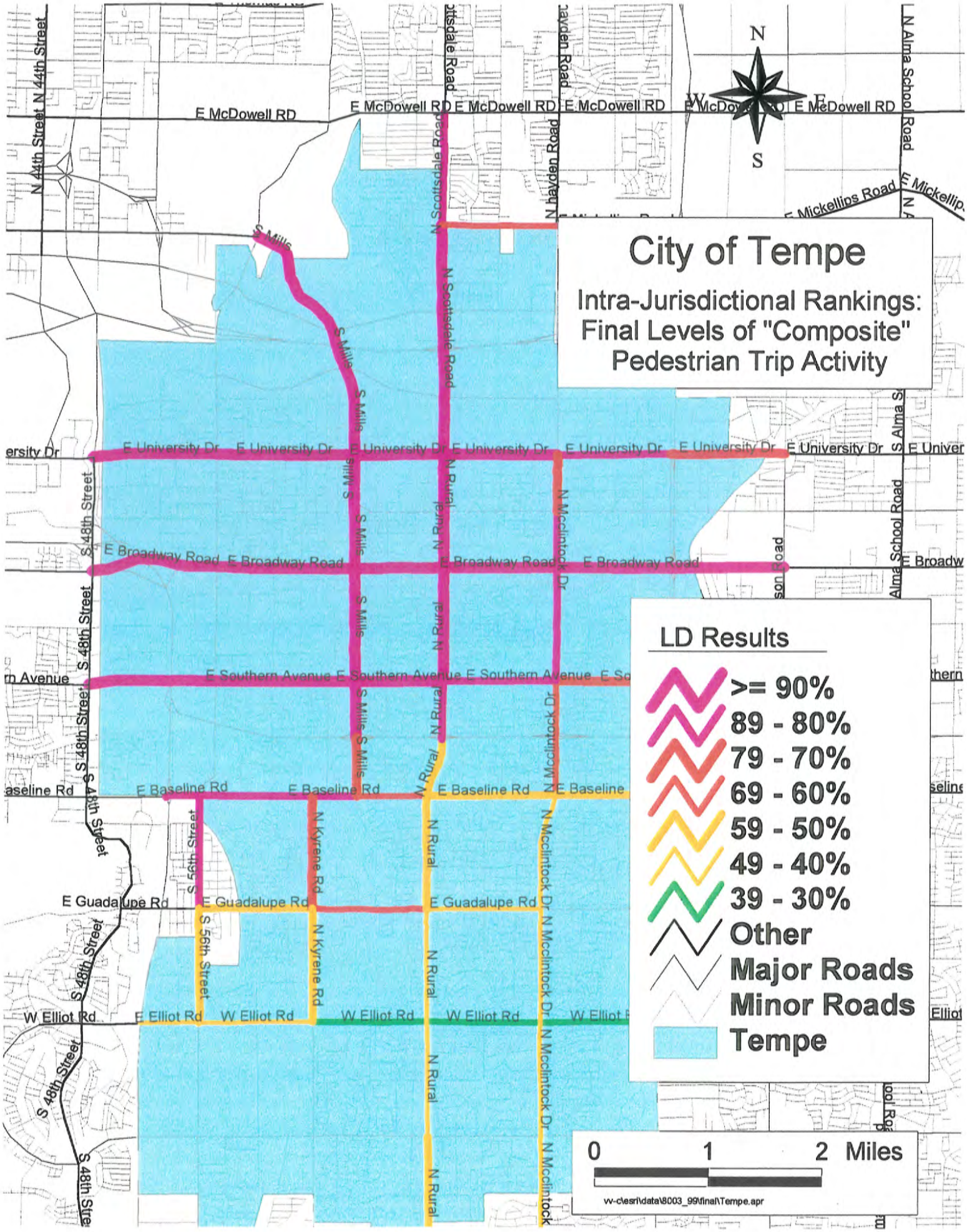
E Cave Creek Road
E Dynamite Blvd
E Pinnacle Peak Rd
N Scottsdale Road
N Pima Road
N Alma School Road
N Tatum Blvd
E Bell Road
N Frank Lloyd Wright Blvd
W Greenway Pkwy
W Greenway Rd
N 40th Street
N hayden Road
E Cactus Road
E Shea Blvd.
E lincoln Dr
N Hayden Road
N 44th Street
E Camelback RD
Thomas RD
E McDowell RD
E Van Buren Street
N Alma School Road
N Country Club Dr
E Mickellips Road
N Power Road


City of Tempe
Intra-Jurisdictional Rankings: Final Levels of "Composite" Pedestrian Trip Activity
LD Results
>= 90%
89 - 80%
79 - 70%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
Other
Major Roads
Minor Roads
Tempe
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E McDowell RD
N 44th Street
N Scottsdale Road
N Hayden Road
N Alma School Road
E Mickellips Road
S Mills
E University Dr
E Broadway Road
S 48th Street
N Rural
N Mcclintock Dr
E Southern Avenue
E Baseline Rd
S 56th Street
N Kyrene Rd
E Guadalupe Rd
W Elliot Rd
E Elliot Rd
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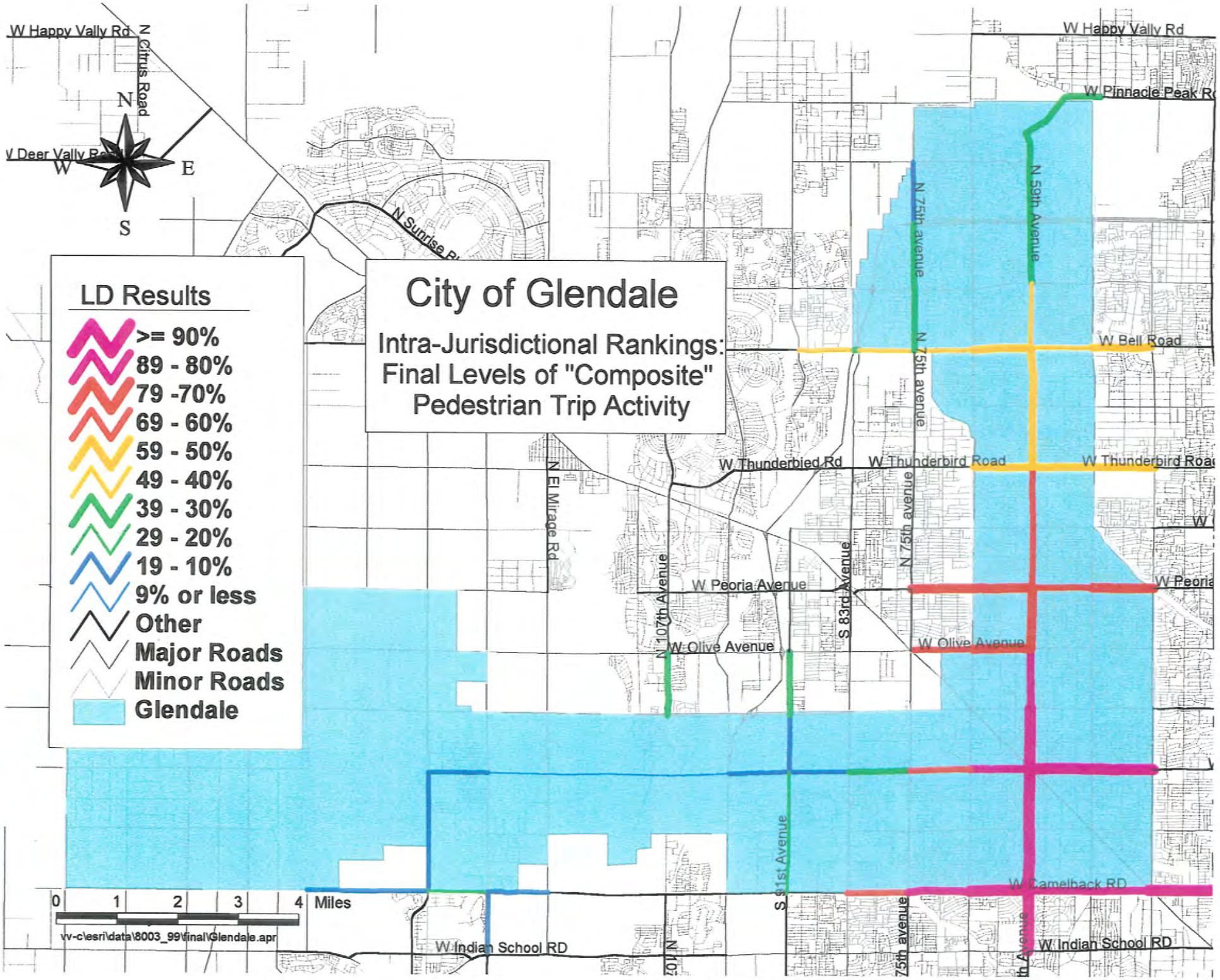
City of Glendale
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
LD Results
>= 90%
89 - 80%
79 -70%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
29 - 20%
19 - 10%
9% or less
Other
Major Roads
Minor Roads
Glendale
N
S
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W
0 1 2 3 4 Miles
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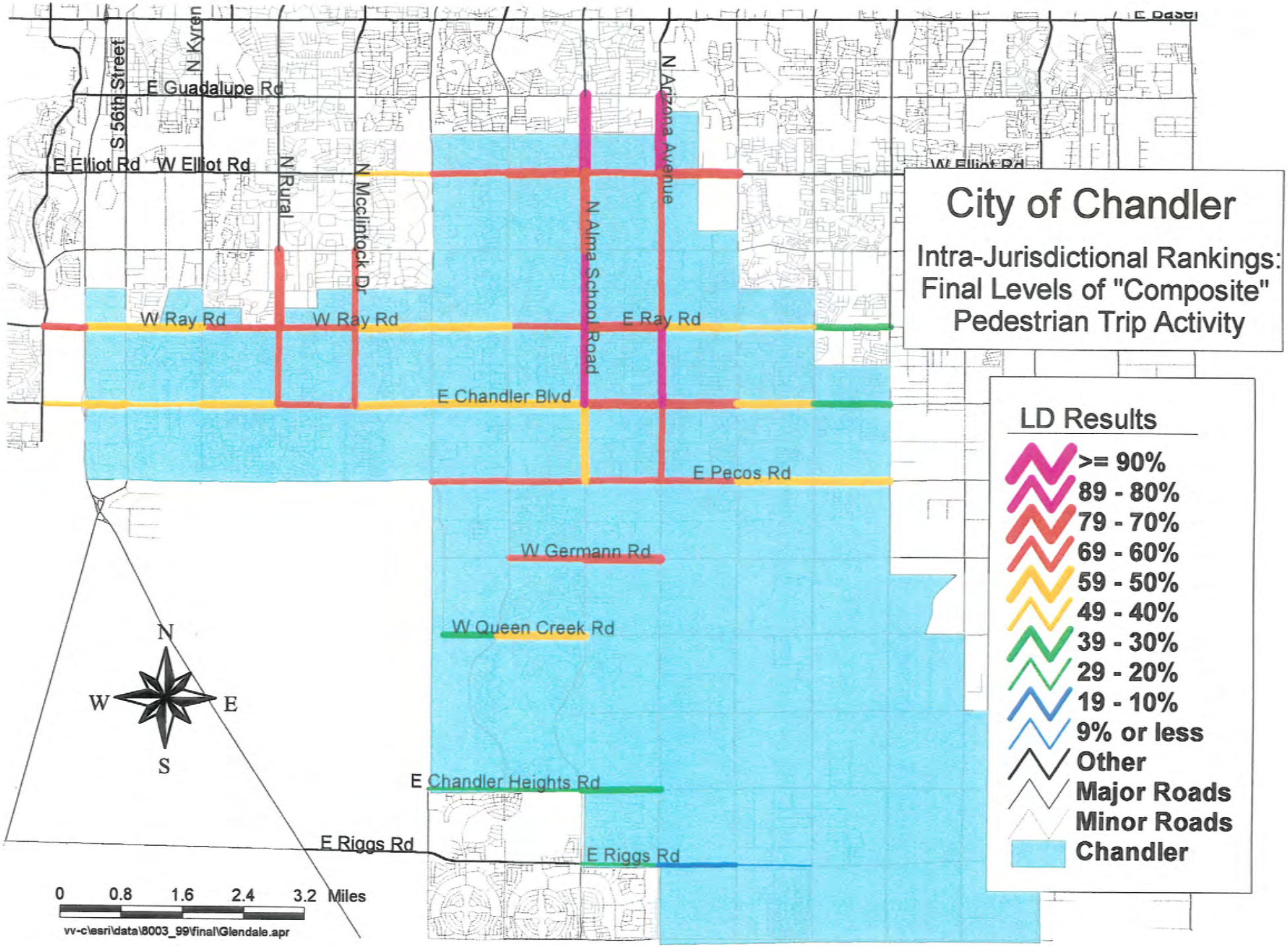
W Happy Vally Rd
N Citrus Road
W Deer Vally Rd
N Sunrise
W Happy Vally Rd
W Pinnacle Peak Rd
N 59th Avenue
N 75th avenue
W Bell Road
W Thunderbied Rd
W Thunderbird Road
W Thunderbird Road
N El Mirage Rd
N 107th Avenue
W Peoria Avenue
S 83rd Avenue
W Olive Avenue
W Olive Avenue
S 91st Avenue
W Camelback RD
W Indian School RD
W Indian School RD


City of Chandler
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
LD Results
>= 90%
89 - 80%
79 - 70%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
29 - 20%
19 - 10%
9% or less
Other
Major Roads
Minor Roads
Chandler
E Guadalupe Rd
S 56th Street
N Kyren
E Elliot Rd
W Elliot Rd
N Rural
N Mcclintock Dr
N Alma School Road
N Arizona Avenue
W Ray Rd
W Ray Rd
E Ray Rd
E Chandler Blvd
E Pecos Rd
W Germann Rd
W Queen Creek Rd
E Chandler Heights Rd
E Riggs Rd
E Riggs Rd
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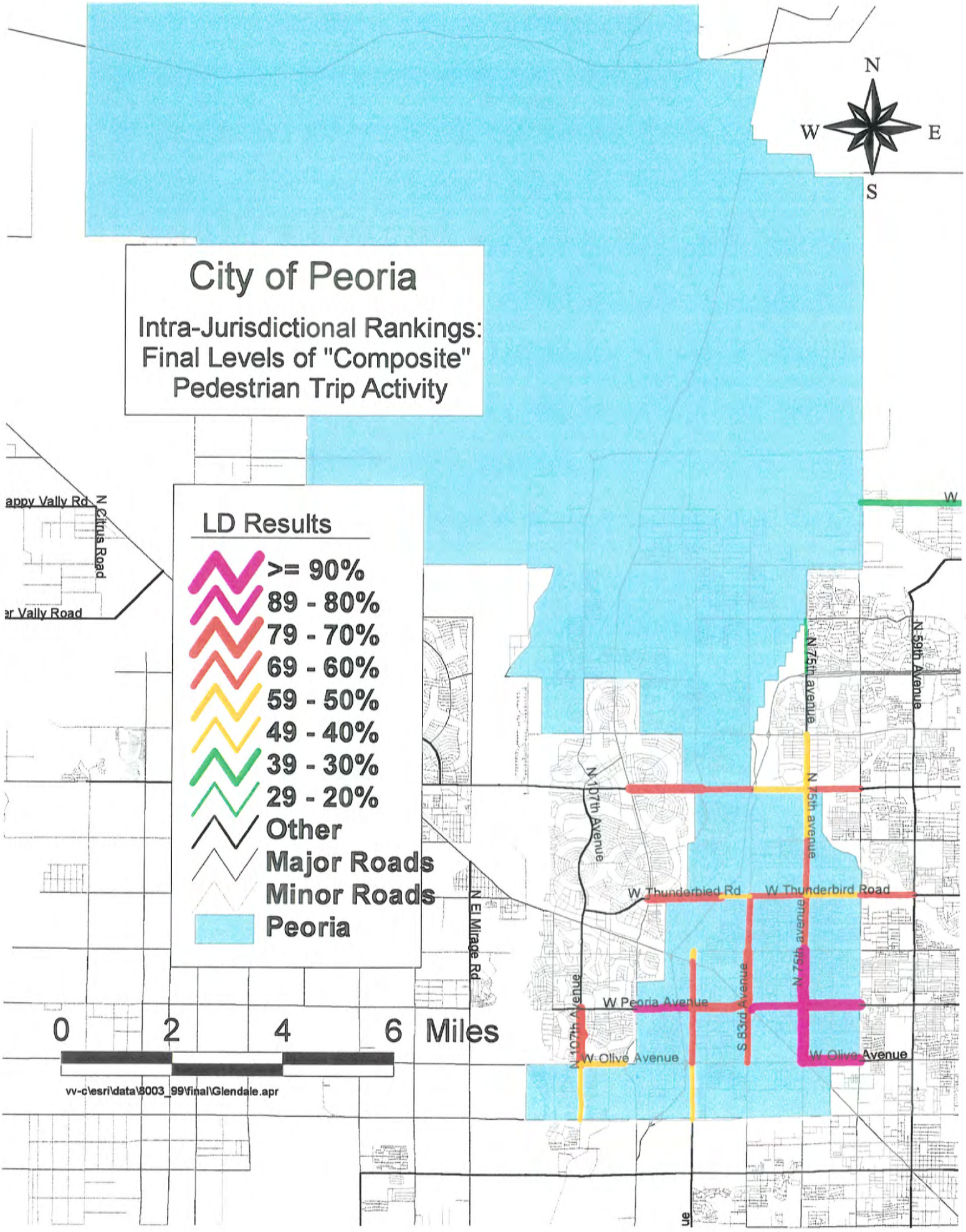
City of Peoria
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
LD Results
>= 90%
89 - 80%
79 - 70%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
29 - 20%
Other
Major Roads
Minor Roads
Peoria
0 2 4 6 Miles
N
W
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S
appy Vally Rd
N Citrus Road
er Vally Road
N 59th Avenue
N 75th avenue
N 107th Avenue
W Thunderbird Rd
W Thunderbird Road
N El Mirage Rd
W Peoria Avenue
S 83rd Avenue
W Olive Avenue
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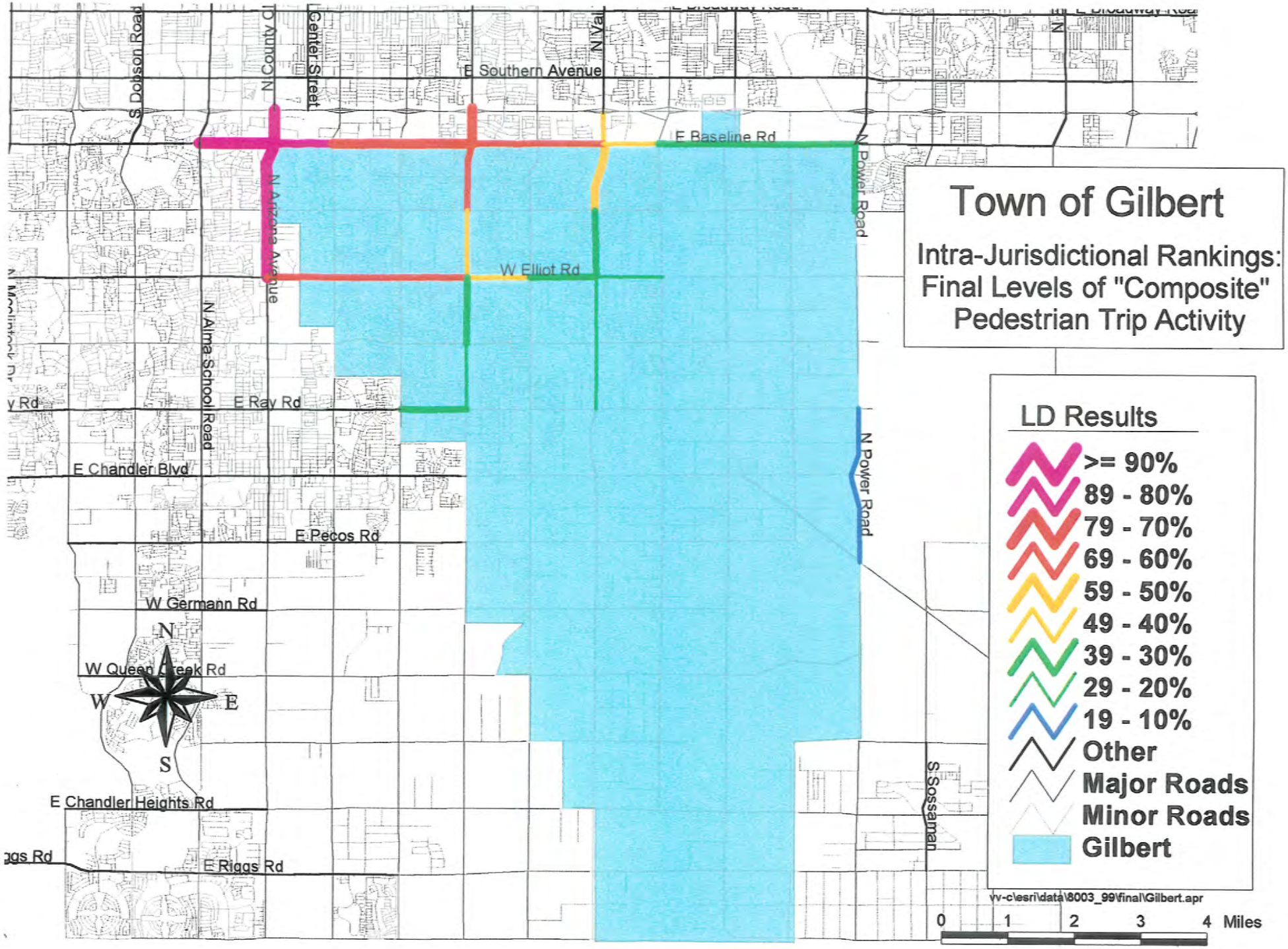
Town of Gilbert
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
LD Results
>= 90%
89 - 80%
79 - 70%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
29 - 20%
19 - 10%
Other
Major Roads
Minor Roads
Gilbert
E Southern Avenue
E Baseline Rd
W Elliot Rd
E Ray Rd
E Chandler Blvd
E Pecos Rd
W Germann Rd
W Queen Creek Rd
E Chandler Heights Rd
E Riggs Rd
S Dobson Road
N County Ct
Center Street
N Arizona Avenue
N Alma School Road
N Power Road
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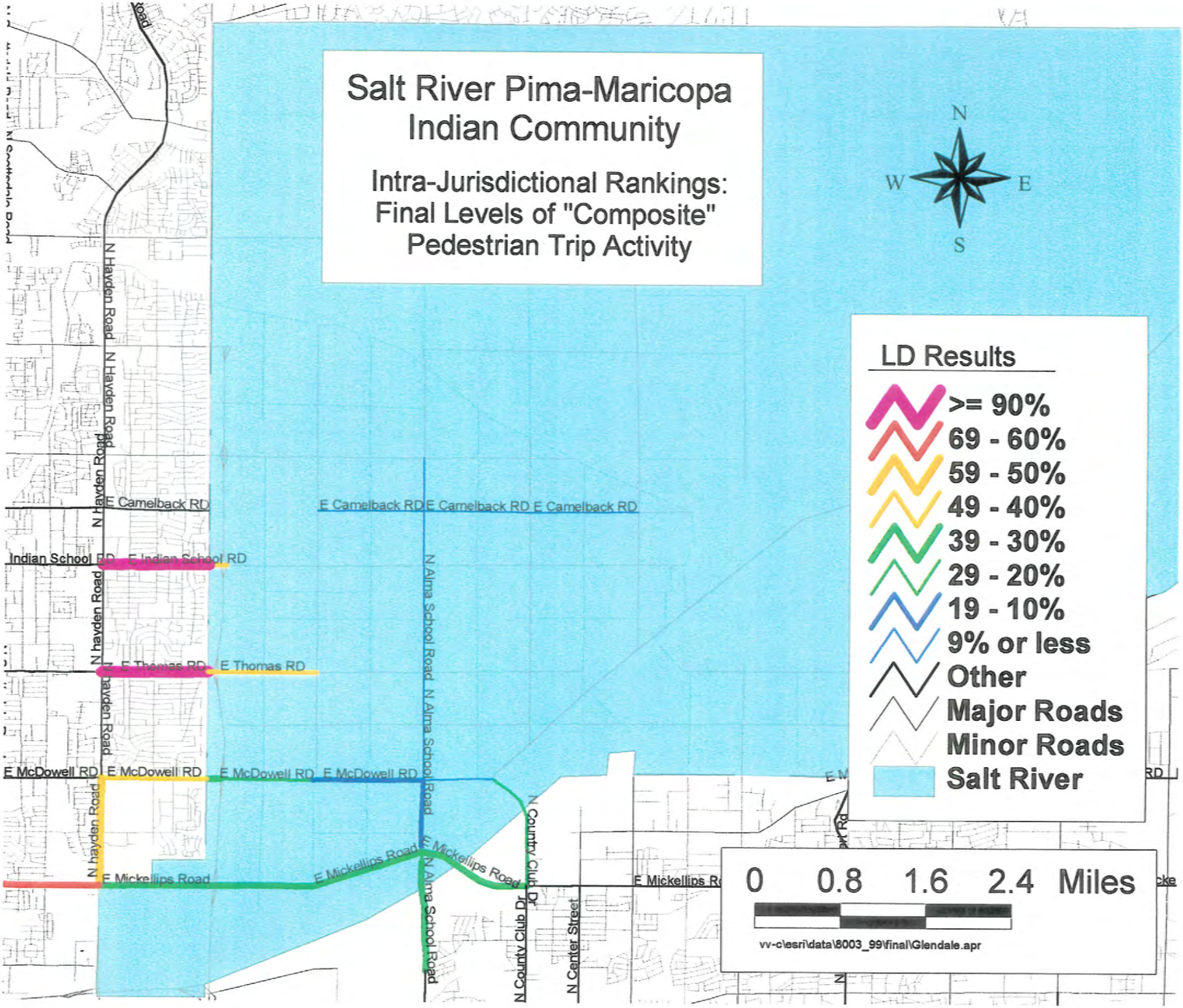
Salt River Pima-Maricopa Indian Community
Intra-Jurisdictional Rankings: Final Levels of "Composite" Pedestrian Trip Activity
N
W
E
S
LD Results
>= 90%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
29 - 20%
19 - 10%
9% or less
Other
Major Roads
Minor Roads
Salt River
0 0.8 1.6 2.4 Miles
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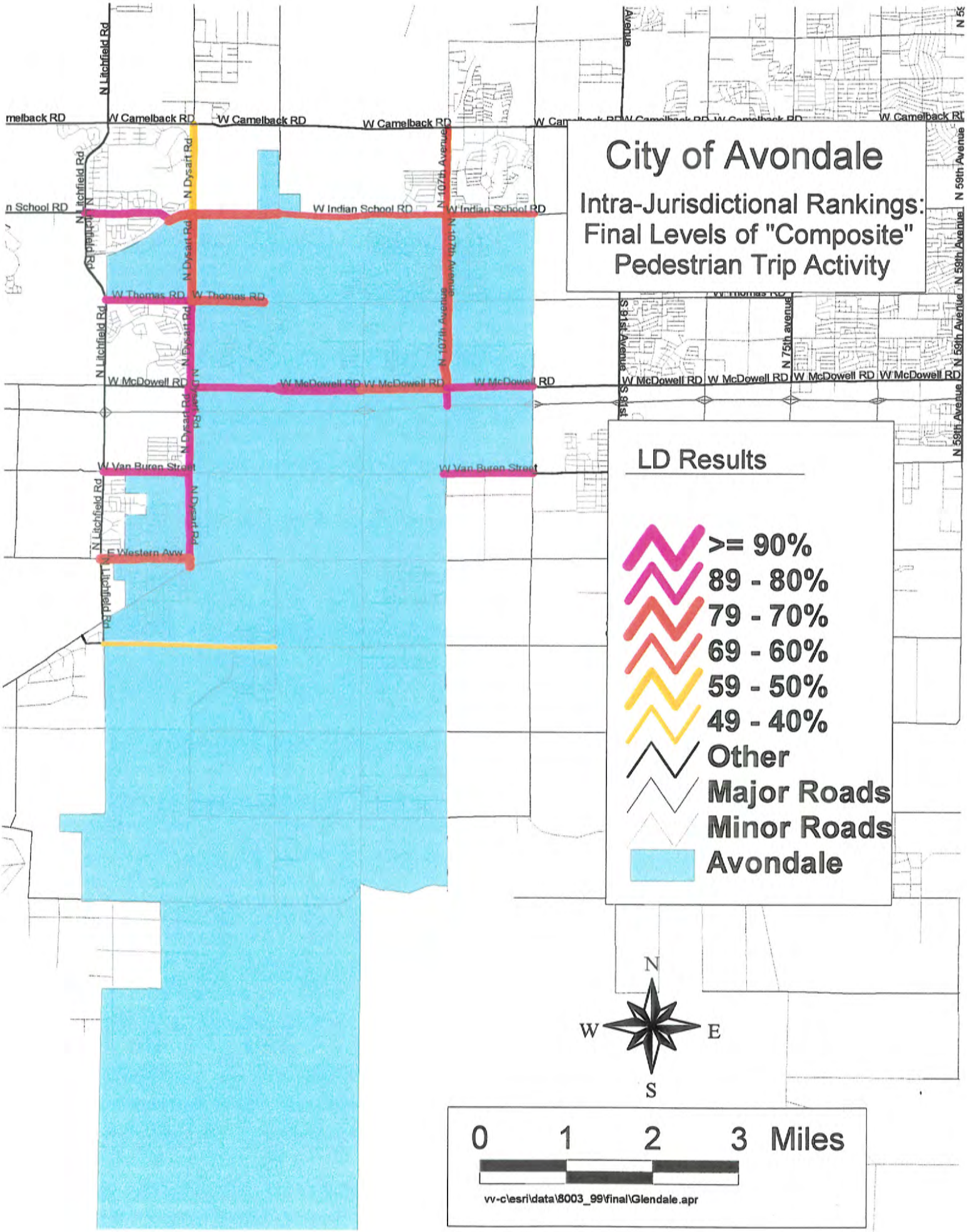
N Hayden Road
E Camelback RD
E Camelback RD E Camelback RD E Camelback RD
Indian School RD
E Indian School RD
N Alma School Road
E Thomas RD
E McDowell RD
E Mickellips Road
N County Club Dr
N Center Street


City of Avondale
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
LD Results
>= 90%
89 - 80%
79 - 70%
69 - 60%
59 - 50%
49 - 40%
Other
Major Roads
Minor Roads
Avondale
W Camelback RD
W Indian School RD
W Thomas RD
W McDowell RD
W Van Buren Street
E Western Ave
N Litchfield Rd
N Dysart Rd
N 107th Avenue
N 75th avenue
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S 81st Avenue
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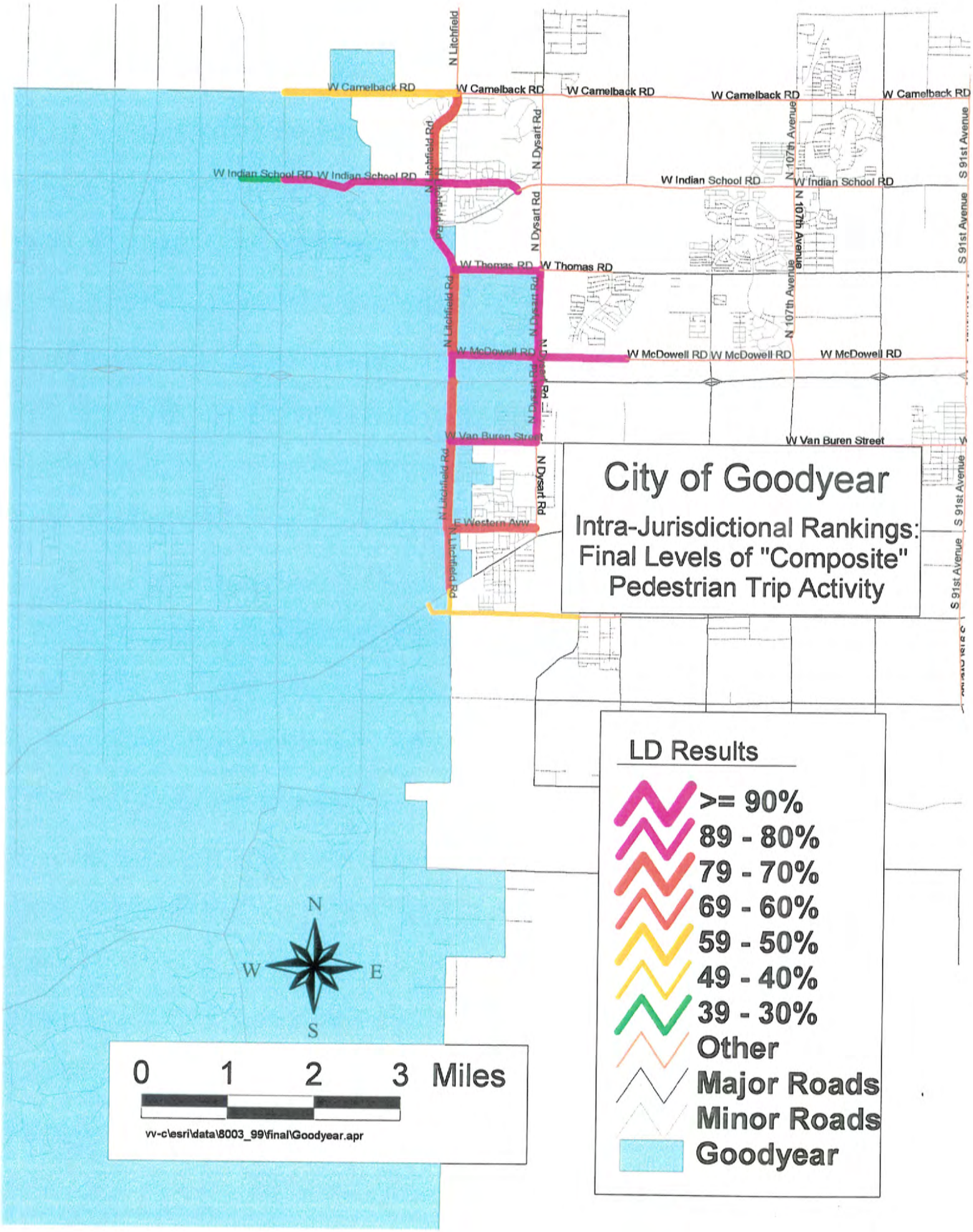
City of Goodyear
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
LD Results
>= 90%
89 - 80%
79 - 70%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
Other
Major Roads
Minor Roads
Goodyear
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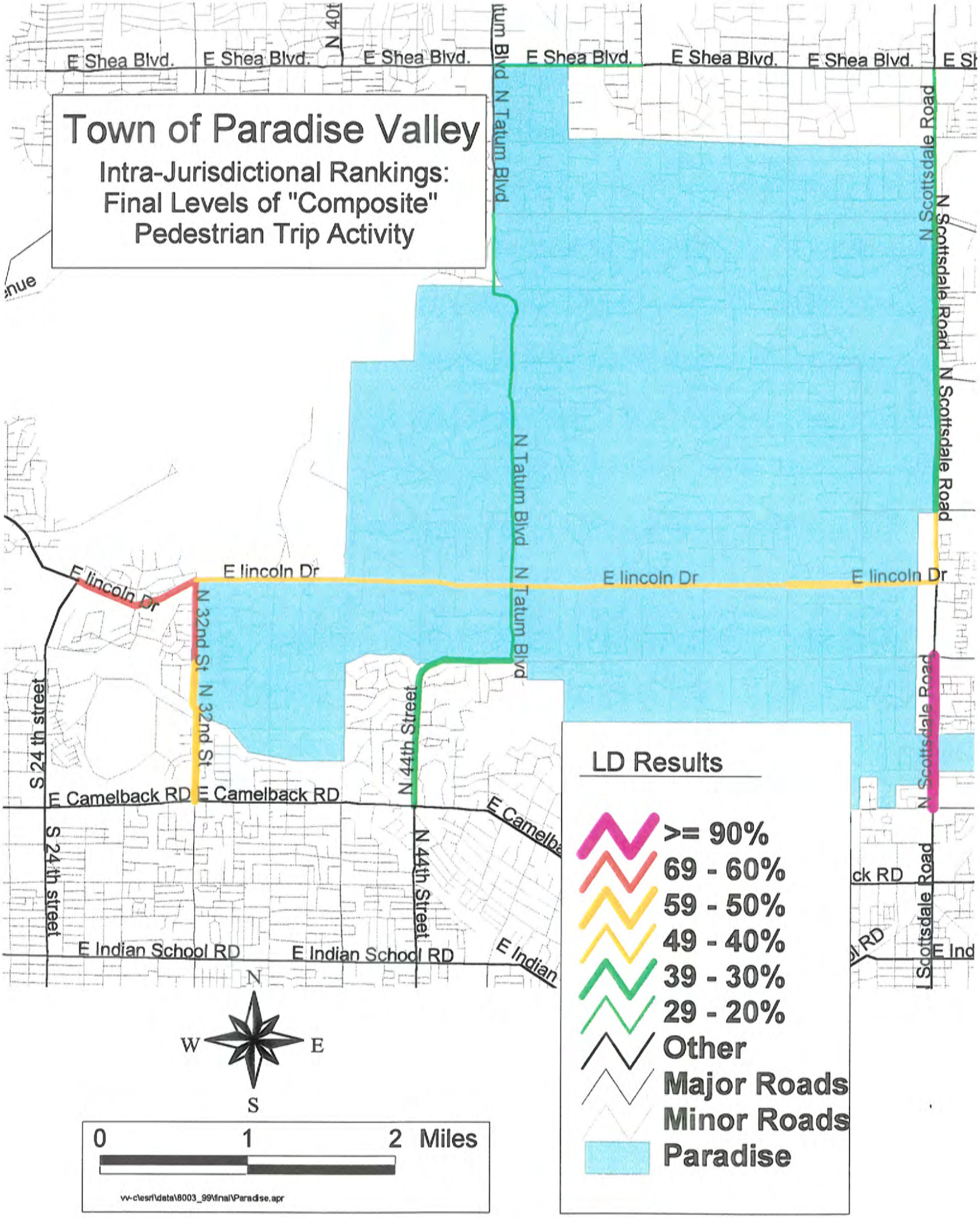
W Camelback RD
W Indian School RD
W Thomas RD
W McDowell RD
W Van Buren Street
E Western Ave
N Litchfield
N Litchfield Rd
N Dysart Rd
N 107th Avenue
S 91st Avenue


Town of Paradise Valley
Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity
E Shea Blvd.
N Tatum Blvd
N Scottsdale Road
E lincoln Dr
N 32nd St
S 24 th street
E Camelback RD
N 44th Street
E Indian School RD
LD Results
>= 90%
69 - 60%
59 - 50%
49 - 40%
39 - 30%
29 - 20%
Other
Major Roads
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Paradise
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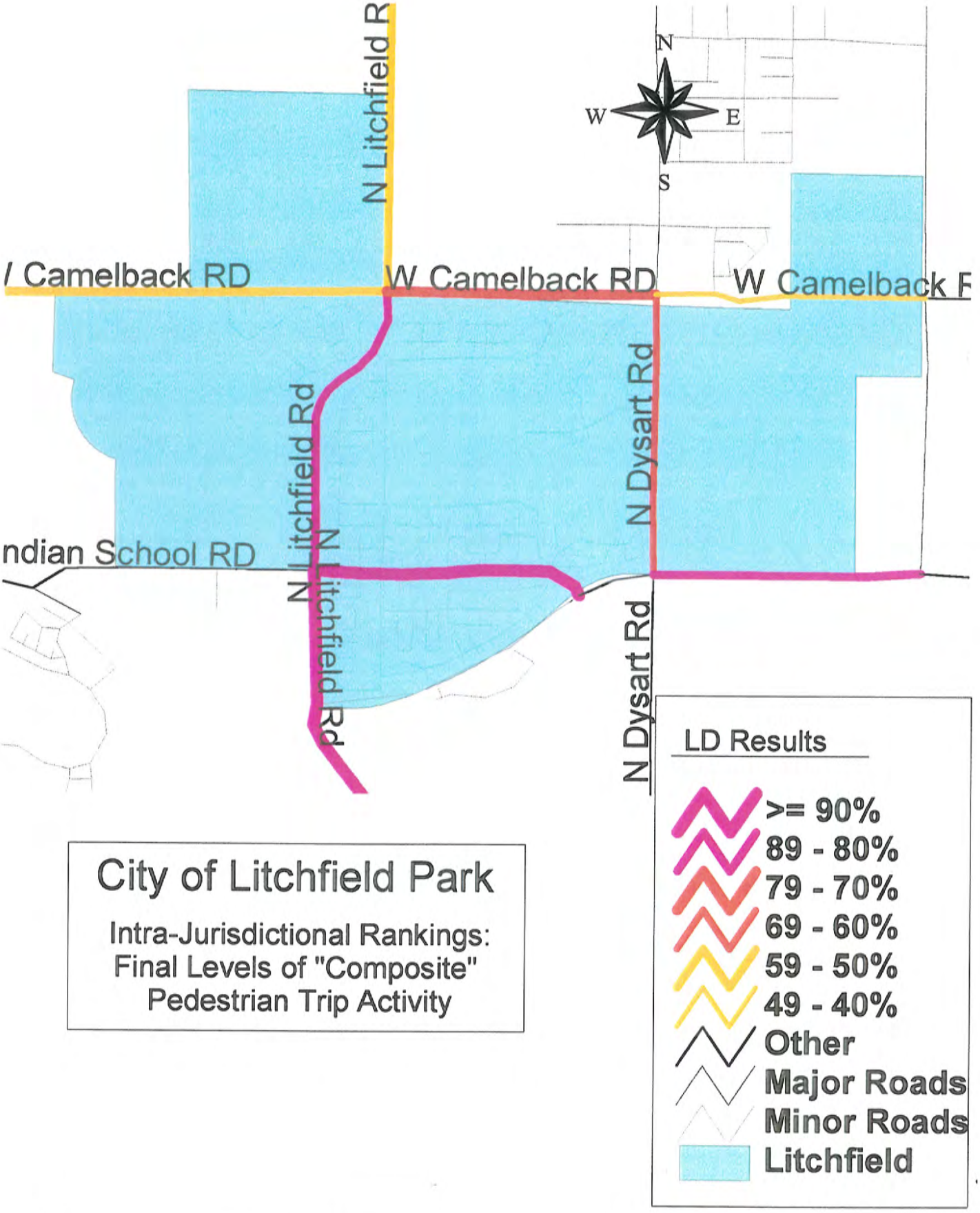

City of Litchfield Park

Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity

0 1 2 Miles

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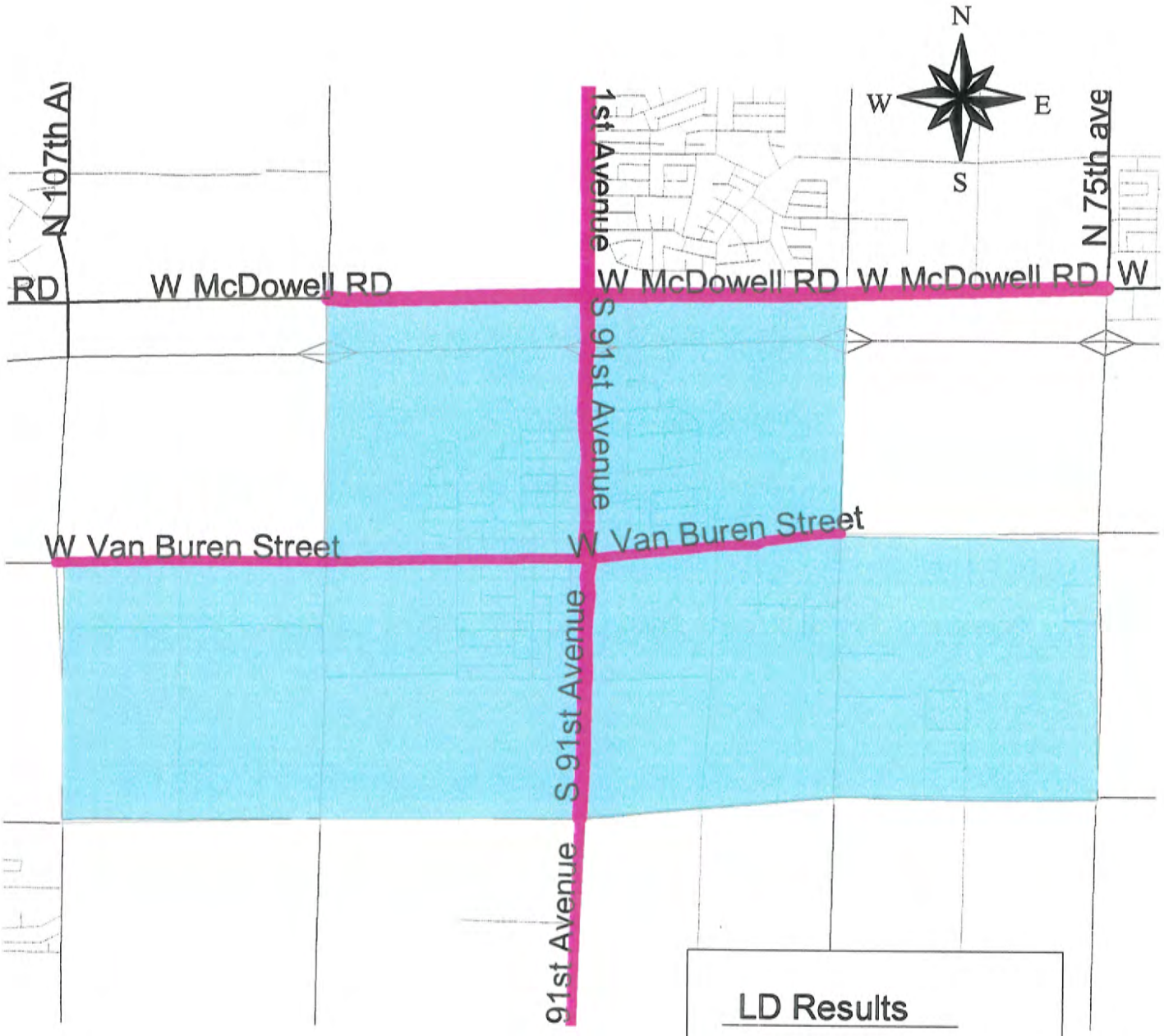

City of Tolleson

Intra-Jurisdictional Rankings:
Final Levels of "Composite"
Pedestrian Trip Activity

LD Results

- >= 90%
- 89 - 80%
- Other
- Major Roads
- Minor Roads
- Tolleson

0 1 2 Miles

vv-c:\esri\data\8003_99\final\Paradise.apr

The Roadside Pedestrian Conditions Model

INTRODUCTION

In recent years there have been initiatives in metropolitan areas throughout the United States to create more "livable communities". Characteristic of these efforts is the reintroduction of bicycle lanes and sidewalks to the streetscapes, complete with street furniture, generous landscaping, pedestrian-scaled lighting, and other features making the public right-of-way more inviting for people to travel by bicycle or on foot. The transportation planning and engineering community has attempted to provide analysis and design methods to help create these "livable streets".

While tremendous gains have been made in the bicycle transportation analysis and planning field; little progress has been made for the pedestrian travel mode. Evaluating the performance of a roadway link for the walking mode is complex compared to that for the motor vehicle. Whereas operators of motor vehicles are largely insulated in their travel environment, the pedestrian is relatively unprotected. The pedestrian, while traversing the roadside environment, is subjected to a multitude of factors significantly affecting his/her feeling of safety, comfort, and convenience. These factors may be classified under three general performance measures describing the roadside pedestrian environment; sidewalk capacity, quality of the walking environment, and the pedestrian's perception of safety with respect to the presence of motor vehicles.

PERFORMANCE MEASURES FOR THE PEDESTRIAN

The first performance measure, *sidewalk capacity*, was developed in the early 1970's by Fruin *(1)*. His method, as formalized in the *Highway Capacity Manual (2)*, is the only established method of quantifying sidewalk capacity. However, this performance measure is limited in its applicability: it only evaluates conditions for an existing (or planned) sidewalk and then only from the perspective of "walking space" or effective sidewalk width available to the pedestrian. Additionally, it cannot be used to prioritize roadways for sidewalk construction. This is an important limitation. Typically, less than 20% of the collector and arterial network of U.S. metropolitan areas have sidewalks. Furthermore, less than 3% have pedestrian activity levels that can be effectively measured by Fruin's capacity method.

Currently, there is no established measure for the *quality*, or enjoyment aspect of the walking environment. Several walking advocates as well as researchers have proposed various measures of the *total quality* of the walking experience. Their measures include numerous qualitative assessments relating to the pedestrian's *enjoyment* of the walking experience (e.g., convenience of the walking experience and the perception of personal security). The "Walkability Audit" developed by advocate Dan Burden is one example of a comprehensive approach. Published works by Sarkar *(3,4)*, Khisty *(5)*, Dixon *(6)*, Crider *(7)*, and others are examples of methods that include a mixed combination of some of the factors of all three performance measures. However, most of these methods require the presence of a sidewalk to be applicable. And, while the qualitative measure of a pedestrian's enjoyment of the walking experience is important to provide a complete picture of the walking environment and to design an "inviting"

sidewalk, it is a separate measure of effectiveness and must be developed separately from the sidewalk capacity or safety perception measures.

The third measure, perceived safety (with respect to the presence of motor vehicles) has not been quantified as a stand-alone performance measure. This measure is the subject of this section. Focusing on the roadside walking environment, the factors most cited as affecting pedestrians' sense of safety include: lateral separation, barriers, and buffers between pedestrians and motor vehicle traffic, motor vehicle volume and composition, effects of motor vehicle travel speed, driveway frequency and access volume.

The perception of safety is a qualitative measure of effectiveness recognized by the *1994 Highway Capacity Manual*. The *Manual* states (on pages 1-4 and 1-5), *"The concept of level-of-service uses qualitative measures that characterize operational conditions within the traffic stream and their perception by (the facility users)...descriptions of individual levels of service characterize these conditions in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience" (underlines added) for the facility type."* With respect to measures of effectiveness, the *Manual* states, *"For each type of facility, levels of service are defined on the basis of one or more operational parameters that best describe operating quality (underlines added) for the facility type" (2).* Thus is the direction of the (measure of effectiveness) modeling effort.

As can be seen, two of the three performance measures (capacity and quality of the walking experience) have been established and developed, respectively. Therefore, what is missing from the description of the walking environment is a calibrated, transferrable model that objectively quantifies "the perceived safety of pedestrians" using measurable traffic and roadway variables. The model described in this technical appendix provides a stable supply-side measure of walking conditions to aid in the priority ranking of roadway segments for sidewalk construction. In addition, it allows for merging pedestrian facility programming into the mainstream of metropolitan area transportation planning. Furthermore, the model evaluates traffic calming measures and streetscape designs for their effectiveness in improving the walking environment.

STRUCTURE OF THE MODEL

The *Roadside Pedestrian Conditions (RPC) Model* outlined herein is a measure of effectiveness which quantifies the roadway and motor vehicle traffic conditions that affect pedestrians' sense of safety in the walking environment. It was developed from a background of applications in six U.S. urban areas constituting over 2,000 miles of roadway. The model design is objective, transferable, and applicable at the project, corridor, and network levels. It uses common, measurable traffic and roadway variables for economy of data collection, accuracy, and reliable and repetitive application. The methodology is a link analysis; it does not include intersection analysis, as there are existing (and proposed – in HCM 2000) methods in Chapter 13 of the *Highway Capacity Manual* to perform that function. It evaluates walking

conditions *regardless* of the presence of a sidewalk.

The following process was employed to develop the initial *RPC* methodology: 1) identify factors that are relevant, 2) establish the optimal configuration of the factors (or combinations thereof), and 3) determine the coefficients for each of the terms through a step-wise multivariable regression analysis of ninety-six (96) observations in the Tampa, Florida metropolitan area. Further development of the *Model's* form and coefficients using a more robust sample of observations (2,700+) is planned for the Spring of 2000.

Model Terms

The "long list" of factors influencing pedestrians' sense of safety within the roadway corridor was confirmed by group consensus considering the aforementioned research and modeling efforts. This group consisted of transportation planners, traffic engineers, travel demand modelers, roadway design engineers, land use planners, planning commissioners and citizen advocates in the Tampa, Florida metropolitan area. The factors included:

1) Lateral separation between pedestrians and motor vehicle traffic
2) Presence of physical barriers and buffers
3) Outside (motor vehicle) lane volume
4) Effect of (motor vehicle) speed
5) Driveway access frequency and volume

Model Terms

All five of these factors describe the walking environment alongside the roadway. Each model factor and its associated variables are discussed in detail below.

Lateral Separation

The proximity of pedestrians to motor vehicle traffic in a shared right-of-way is a primary factor in pedestrians' sense of safety. In general, as the lateral separation (LS) increases, the pedestrian's comfort, or sense of safety, also increases (see Figure 1).

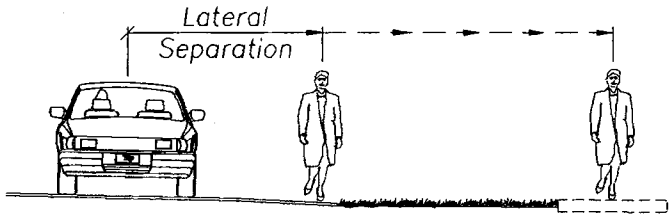

Figure 1 Effect of Lateral separation

The presence of a vertical, non-traversable curb increases the sense of protection, hence safety (see Figure 2). It is anticipated that the effect of vertical separation is more pronounced when the walking path is close to traffic and the effect diminishes as the lateral separation increases.

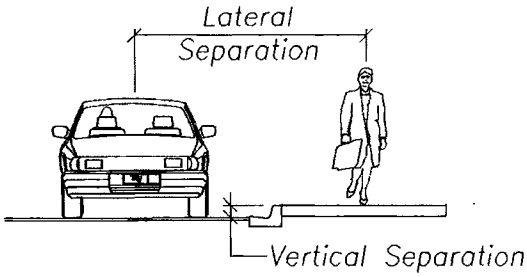

Figure 2 Effect of Vertical Separation

When a barrier such as on-street parking, a line of trees, or a roadside swale is present between motor vehicle traffic and the pedestrian, the pedestrians' sense of protection, hence safety is improved (see Figure 3). Increased frequency of parked cars, trees, or an increase in the depth of the intervening roadside swale further improves the sense of safety.

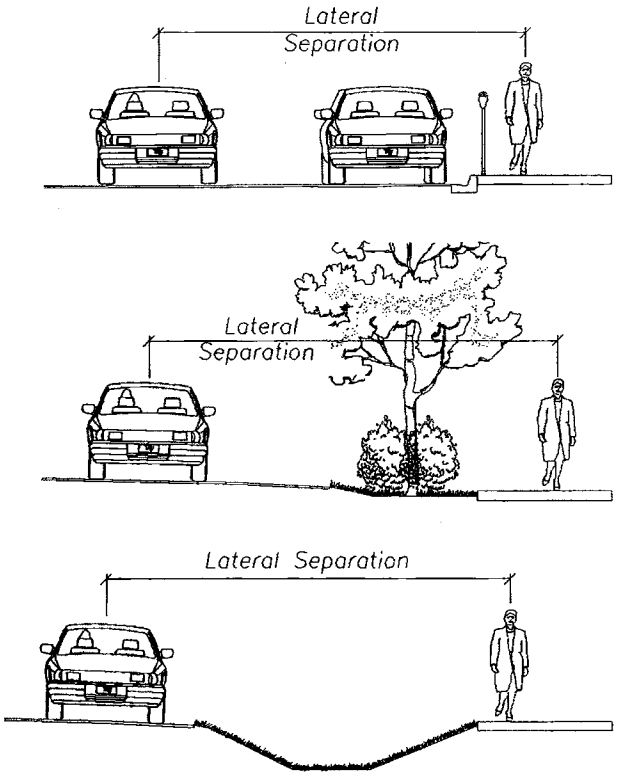

Figure 3 Effect of Vertical Barriers

The mathematical expression that reflects these effects of lateral separation, barriers, and buffers is as follows:

$$LS = \frac{(W_t + W_l)}{2} + (K_p)\%OSP + (K_b)BW + \frac{(K_g)SW}{2} \qquad (1)$$

Where:

W_t = Total width of outside lane and shoulder (meters/feet)
W_l = Width of shoulder (meters/feet)
K_p = On-street parking coefficient
%OSP = Percent of segment with on-street parking
K_b = Vertical barrier coefficient (varies with tree spacing in the buffer)
= $40(T_s)^{-0.67}$ when $T_s < 200$ feet
= 1.0 when $T_s > 200$ feet

where:

T_s = Center to center tree spacing in feet in the buffer
BW = Buffer width (distance between edge of pavement and sidewalk, meters/feet)
K_g = Grade separation coefficient
SW = Width of sidewalk (meters/feet)

The values of coefficients K_p, K_b and K_g are estimated at this point in the development of the *RPC* model. As stated earlier, when the *Model* is calibrated with a larger number of observations, their final values (and perhaps the mathematical form of the terms themselves) will be confirmed.

Examples of how the term "Lateral Separation" quantifies the different scenarios are illustrated in the cases below.

a) CASE I (barrier/buffer): There are three general barrier/buffer scenarios. The first two are illustrated in Figure 4 which shows a non-curbed x-section with a vertical barrier (trees or a swale) situated in a horizontal buffer between the travel lane and sidewalk. Note that there is no on-street parking, therefore the %OSP term equals zero. Thus for these two scenarios, the lateral separation factor is given by:

$$LS = \frac{(W_t + W_l)}{2} + (K_b)BW + \frac{(K_g)SW}{2} \qquad (2)$$

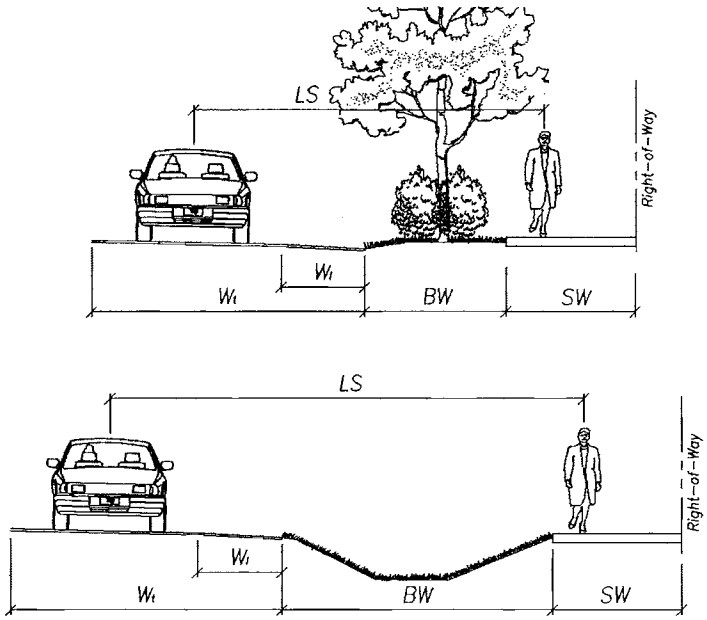

Figure 4a Lateral Separation as Affected by Vertical Barriers

The third barrier/buffer scenario is illustrated in Figure 4b. In this example, on-street parking provides a barrier. Note that there is no buffer, therefore the BW term equals zero. Thus, the lateral separation factor is quantified by:

$$LS = \frac{(W_t + W_l)}{2} + (K_p)\%OSP + \frac{(K_g)SW}{2} \qquad (3)$$

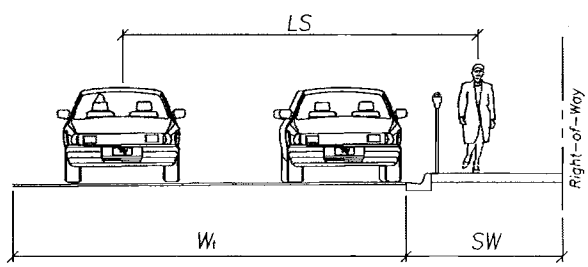

Figure 4b Lateral Separation as Affected by On-Street Parking

b) <u>CASE II (curbed x-section)</u>: In this case, there is no on-street parking. Likewise there are no vertical

barriers between the pedestrian and motor vehicles other than the non-traversable curb. Figure 5a illustrates the scenario of a sidewalk separated from the motor vehicle travel lane by a grass buffer strip. The lateral separation factor is therefore described by:

$$LS = \frac{(W_t + W_l)}{2} + (K_b)BW + \frac{(K_g)SW}{2} \qquad (4)$$

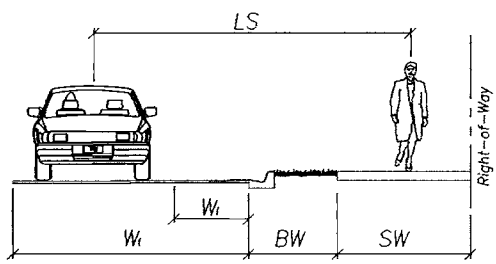

Figure 5a Lateral Separation - Typical Residential X-Section

Figure 5b illustrates the scenario of a sidewalk without an intervening buffer strip. The lateral separation for this situation is given by:

$$LS = \frac{(W_t + W_l)}{2} + \frac{(K_g)SW}{2} \qquad (5)$$

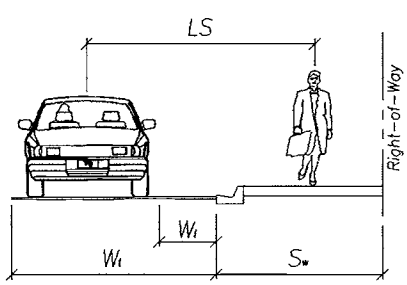

Figure 5b Lateral Separation - Typical Urban X-Section

a) CASE III (non-curbed x-section): In this case, there is neither on-street parking nor a curb. Three scenarios illustrate this case. Figure 6a depicts a sidewalk separated by a wide horizontal

buffer. The lateral separation for this example is calculated by:

$$LS = \frac{(W_t + W_l)}{2} + (K_b)BW + \frac{(K_g)SW}{2} \qquad (6)$$

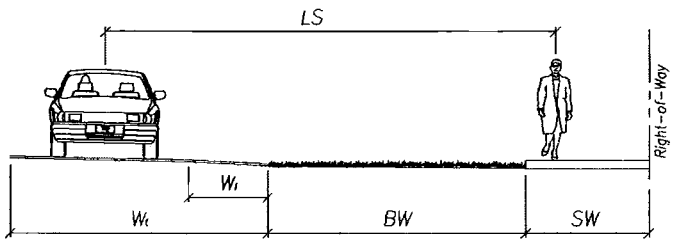

Figure 6a Lateral Separation as Affected by Wide Buffer

Figure 6b depicts the example of a pedestrian walking on the shoulder adjacent to the travel lane. It is assumed that the pedestrian walks in the center of the shoulder and moves to the outside edge of the shoulder as traffic approaches. Note that the only variables that remain are W_t and W_l. Thus, the lateral separation is simplified to:

$$LS = \frac{(W_t + W_l)}{2} \qquad (7)$$

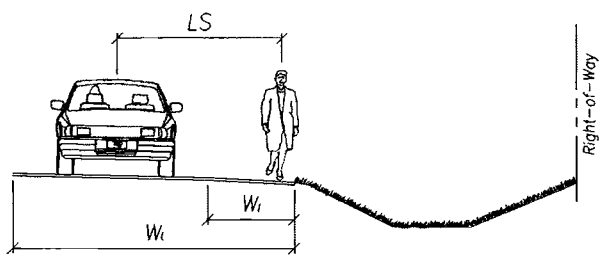

Figure 6b Lateral Separation - Wide Shoulder/Outside Lane

Figure 6c depicts the scenario of a pedestrian walking along the edge of the travel lane due to the lack of a paved shoulder or sidewalk. It is assumed that the pedestrian steps off of the pavement and onto the grass shoulder and walks there as traffic approaches/passes. Note that the only variable that remains is W_t. The lateral separation is therefore given by:

$$LS = \frac{W_t}{2} \qquad (8)$$

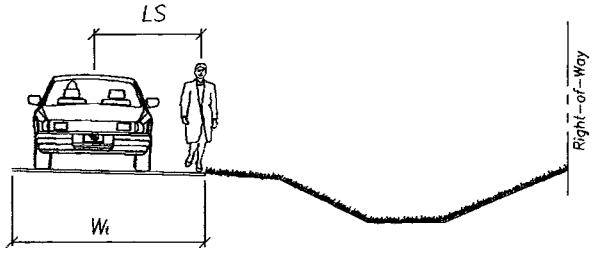

Figure 6c Lateral Separation - No Shoulder

This section introduced the factor of Lateral Separation and its mathematical expression. The next sections describe the remaining two factors of the current version of the *RPC* model.

Outside Lane Volume

The frequency of motor vehicles passing pedestrians, represented by the outside lane volume, is also found to be a significant factor. As passing frequency increases, the pedestrians' feeling of safety decreases. Outside lane volume is calculated by the following:

$$\text{Outside Lane Volume} = \frac{\text{ADT}}{\text{L}} \qquad (9)$$

where:
ADT = Average daily traffic (for road or street)
L = Total number of (thru) lanes (for road or street)

Effect of Speed

Similarly, the speed of motor vehicle traffic affects pedestrians' sense of safety. As speed increases, pedestrian discomfort increases. This is reflected in the following equation [borrowing the form from the *Bicycle Level of Service (8)* equation, which not only considers the speed of motor vehicles, but also the wind blast effect of trucks and other heavy vehicles]:

$$\text{Effect of Speed} = S_p[1+(10.38 \times \text{HV})]^2 \qquad (10)$$

where:
S_p = Posted Speed (kph/mph)
10.38 = Wind blast envelope multiplier for heavy vehicles
HV = Proportion of heavy vehicles

Driveway Access Frequency and Volume

In the transverse environment, uncontrolled vehicular movement (i.e., roadway access) presents an interaction hazard to the pedestrian using a shared right-of-way. This transverse feature represents a similar "turbulence" or hazard to the pedestrian as to motor vehicle operators, which has been acknowledged in recent highway access management policy development *(9)*. Accordingly, as the number of driveways increases, a corresponding decrease in the perceived safety to the pedestrian is expected. Affecting this perception of safety is the volume of vehicles accessing the driveways.

The five factors discussed above; lateral separation, presence of barriers and buffers, outside lane volume, effect of speed, and driveway access frequency and volume are considered the *primary* factors affecting pedestrians' sense of safety. As such, they form the basis for the *Roadside Pedestrian Conditions* model and have been combined in the following equation:

$$\begin{aligned} RPC = {} & a_1 f(LS) + a_2 f(ADT, L) + a_3 f(Speed, TrafficMix) + \\ & a_4 f(\text{Driveway Access Vol., Freq.}) + a_n f(x_n) + \ldots C \end{aligned} \qquad (11)$$

MODEL CALIBRATION

The researchers conducted a step-wise regression analysis using ninety-six (96) observations of roadway conditions within the Tampa, Florida roadway network. Numerous variable transformations and combinations were tested. Table 1 shows the best model form and it's terms' coefficients and T-statistics that resulted from the testing. The correlation coefficient (R^2) of the best-fit model is 0.85 (see Figure 7 for a plot of predicted versus mean observed *RPC* values). The coefficients are statistically significant at the 95 percent level. Thus, the following *Model* was developed:

$$RPC = a_1 \ln(LS) + a_2 \ln\left(\frac{ADT}{L}\right) + a_3 S_p [1 + (10.38 \times \%HV)]^2 + C \qquad (12)$$

The *RPC Model* equation was tested for statistical significance at the 95% level. The fifth factor, "driveway access frequency and volume", while included in the step-wise regression analysis, was found to be significant only at the 90% level thus it has not been included in the current *RPC Model*.

Findings and Applications

The initial result of this research is the development of a reliable, statistically calibrated model suitable for application in US metropolitan areas. Table 2 may be used as a basis for stratifying the model scores into pedestrian level of service classes. The *RPC Model* provides a stand-alone measure of a

roadway's performance with respect to pedestrian's perception of safety. It can be used to rank (from a supply-side perspective) roadway sections for sidewalk construction. Further, this measure, when coupled with the *capacity* (Fruin) measure and the *quality* performance measure (e.g. a Dan Burden-style "Walkability Audit" to assess the enjoyment and convenience of the walking experience in the case of an existing sidewalk) "completes the picture" of the roadside walking environment.

TABLE 1 Model Coefficients and Statistics

	Coefficients	T-statistics
Model Terms	Model 1.0	Model 1.0
Lateral Separation (LS):		
ln(LS)	- 1.94	- 10.62
Motor Vehicle Volume:		
ln(ADT/L)	0.63	5.04
Speed and MV type:		
S_p [1 + (10.38 x %HV)]^2	0.02	2.04
Constant	2.62	2.72
Model Correlation (R^2)	0.85	

TABLE 2 Level of Service Categories

Level-of-Service	Model Score
A	≤ 1.5
B	> 1.5 and ≤ 2.5
C	> 2.5 and ≤ 3.5
D	> 3.5 and ≤ 4.5
E	> 4.5 and ≤ 5.5
F	> 5.5

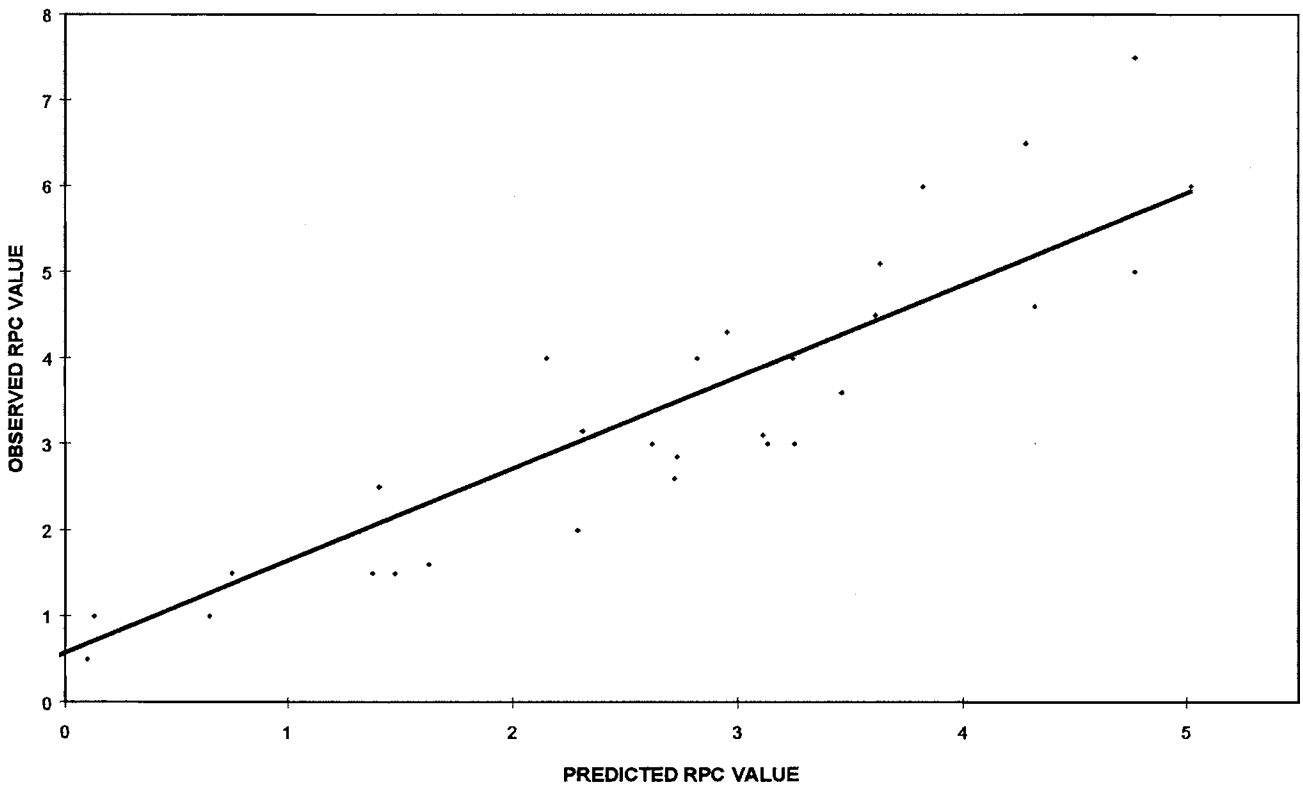

Figure 7 Residual plot of predicted and standardized residuals

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Sample MAG Roadway Evaluations

Walking Conditions Evaluation

Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
7th Avenue	Osborn Road	Indian School Road	30,000	3	5	D	35	11.0	0.0	0.0	0	U	0.0	0	5.0	100	100	4.75	E

7th Avenue north of Osborn Road, view toward the north.

ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
W_l = Width of paving between the outside lane stripe and the edge of pavement, if any
W_{ps} = Width of pavement occupied by on-street parking
OSP = Percentage of segment with occupied on-street parking
U/R = Curbed (urban) or open shouldered (rural)

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Walking Conditions Evaluation

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Existing Conditions																			
7th Avenue	Thomas Road	Osborn Road	30,000	3	5	D	35	12.0	0.0	0.0	0	U	0.0	0	5.0	100	100	4.65	E

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HV = Estimated percentage of trucks
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U/R = Curbed (urban) or open shouldered (rural)

7th Avenue north of Thomas Road, view toward the north.

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MAG Pedestrian Plan 2000

Walking Conditions Evaluation

Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
16th Street	Glendale Avenue	Northern Avenue	20,000	3	5	U	40	12.0	0.0	0.0	0	U	0.0	0	6.0	100	100	4.41	D

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ADT = Average Daily Traffic on the segment or link
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L = Total number of through lanes
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SP_p = Posted Speed Limit
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U/R = Curbed (urban) or open shouldered (rural)

16th Street between Glendale Ave. and Northern Ave., view northwest toward the Arizona Canal.

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Existing Conditions																			
20th Street	Camelback Rd.	Indian School Rd.	*20,000*	3	2	U	35	16.0	3.5	0.0	0	U	0.0	0	5.0	100	100	4.41	D

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ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
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W_{ps} = Width of pavement occupied by on-street parking
OSP = Percentage of segment with occupied on-street parking
U/R = Curbed (urban) or open shouldered (rural)

20th Street between Camel Back Road and Indian School Road.

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Existing Conditions																			
64th Street	Thomas Road	McDowell Road	14,000	3	4	D	35	16.0	4.0	0.0	0	U	0.0	0	5.0	100	100	3.71	D

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ADT = Average Daily Traffic on the segment or link
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U/R = Curbed (urban) or open shouldered (rural)

64th Street north of McDowell Road, view toward the south.

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Existing Conditions																			
Bell Road	Del Web Blvd.	99th Avenue	31,000	3	6	D	35	12.0	0.0	0.0	0	U	0.0	0	0.0	100	100	5.74	F

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ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
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OSP = Percentage of segment with occupied on-street parking
U/R = Curbed (urban) or open shouldered (rural)

Bell Road between Del Web Blvd. and 99th Ave..

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Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
Central Avenue	McDowell Road	Thomas Road	33,000	3	5	D	35	12.0	0.0	0.0	0	U	10.0	20	7.0	100	100	1.21	A

Central Avenue north of McDowell Road, view toward the south at the Phoenix Art Museum.

ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
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Existing Conditions																			
Dobson Road	Ray Road	Warner Road	23,000	3	4	D	45	14.0	0.0	0.0	0	U	8.0	100	6.0	100	100	3.20	C

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ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
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Dobson Road north of Ray Road, view toward the north.

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Walking Conditions Evaluation

Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
Elliot Road	Rural Road	McClintock Road	29,000	3	6	D	45	12.0	0.0	0.0	0	U	4.0	100	8.0	100	100	3.59	D

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ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
W_l = Width of paving between the outside lane stripe and the edge of pavement, if any
W_{ps} = Width of pavement occupied by on-street parking
OSP = Percentage of segment with occupied on-street parking
U/R = Curbed (urban) or open shouldered (rural)

Elliot Road east of Rural Road, view toward the east.

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Walking Conditions Evaluation

Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
Galvin Parkway	Salt River Drive	Washington Street	11,000	3	6	D	45	12.0	0.0	0.0	0	U	4.0	0	8.0	100	100	3.29	C

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U/R = Curbed (urban) or open shouldered (rural)

Galvin Parkway south of Salt River Dr., view toward the south.

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Walking Conditions Evaluation

Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
Galvin Parkway	Van Buren St.	Salt River Drive	11,000	3	6	D	45	13.0	0.0	0.0	0	U	8.0	0	8.0	100	100	2.87	C

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L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
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W_{ps} = Width of pavement occupied by on-street parking
OSP = Percentage of segment with occupied on-street parking
U/R = Curbed (urban) or open shouldered (rural)

Galvin Parkway south of Van Buren Street, view toward the north.

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Walking Conditions Evaluation

Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
Indian School Rd.	Squaw Peak Pkwy.	24th Street	43,000	3	5	U	40	11.5	0.0	0.0	0	U	0.0	0	5.0	100	100	5.11	E

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HV = Estimated percentage of trucks
L = Total number of through lanes
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SP_p = Posted Speed Limit
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W_{ps} = Width of pavement occupied by on-street parking
OSP = Percentage of segment with occupied on-street parking
U/R = Curbed (urban) or open shouldered (rural)

Indian School Road between Squaw Peak Pkwy. And 24th Street, view to the west.

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Walking Conditions Evaluation

Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
McClintock Road	Ray Road	Warner Road	25,000	3	4	D	45	16.0	4.0	0.0	0	U	5.0	100	6.0	100	100	3.43	C

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ADT = Average Daily Traffic on the segment or link
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SP_p = Posted Speed Limit
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U/R = Curbed (urban) or open shouldered (rural)

McClintock Road south of Warner Road, view toward the south.

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Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
Litchfield Road	I-10	McDowell Road	10,000	3	6	D	45	12.0	0.0	0.0	0	U	8.0	0	8.0	100	100	2.85	C

Litchfield Road between I-10 and McDowell Rd., view toward the south.

ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
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Walking Conditions Evaluation

Road Name	From	To	Traffic Data Volume ADT (vpd)	Traffic Data Tks. HV (%)	Lanes (L) Th #	Lanes (L) Con	Spd. SP_p (mph)	Width of Pavement W_t (ft)	Width of Pavement W_l (ft)	Width of Pavement W_{ps} (ft)	% OSP	Cross Sec. C/S (U/R)	Avg. Buffer Width (ft)	Tree Spacing in Buffer (ft on ctr)	Swalk Width SWT (ft)	% Sidewalk Coverage SW Left	% Sidewalk Coverage SW Right	Ped. Cond. (RPC) Value	Ped. Cond. (RPC) Grade
Existing Conditions																			
McDowell Road	Central Avenue	7th Street	30,000	3	6	D	35	12.0	0.0	0.0	0	U	6.0	30	8.0	100	100	2.11	B

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McDowell Road east of Central Ave., view toward the east.

ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
W_l = Width of paving between the outside lane stripe and the edge of pavement, if any
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Walking Conditions Evaluation

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Existing Conditions																			
Mill Avenue	Washington St.	University Drive	25,000	3	4	D	*45*	24.0	11.0	0.0	0	U	6.0	0	8.0	100	100	2.98	C

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ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
W_l = Width of paving between the outside lane stripe and the edge of pavement, if any
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U/R = Curbed (urban) or open shouldered (rural)

Mill Avenue south of Washington St., view toward the north.

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Existing Conditions																			
Osborn Road	7th Avenue	Central Avenue	16,000	3	4	D	35	12.0	0.0	0.0	0	U	0.0	0	5.0	100	100	4.39	D

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Osborn Road east of 7th Ave., view toward the east.

ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
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Walking Conditions Evaluation

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Existing Conditions																			
Ray Road	Dobson Road	Alma School Road	25,000	3	6	D	45	12.0	0.0	0.0	0	U	12.0	200	6.0	100	100	3.15	C

Ray Road east of Dobson Road, view toward the east.

ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
W_l = Width of paving between the outside lane stripe and the edge of pavement, if any
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Existing Conditions																			
Rural Road	Elliot Road	Warner Road	23,000	3	6	D	45	13.0	0.0	0.0	0	U	6.0	60	8.0	100	100	2.77	C

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U/R = Curbed (urban) or open shouldered (rural)

Rural Road south of Elliot Road, view toward the south.

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Existing Conditions																			
Salt River Drive	Galvin Parkway	Desert Drive	*4,000*	3	2	U	*30*	15.0	0.0	0.0	0	U	6.0	0	8.0	100	100	2.48	B

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L = Total number of through lanes
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SP_p = Posted Speed Limit
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Salt River Drive west of Galvin Pkwy., view toward the west.

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Existing Conditions																			
Scottsdale Road	Double Tree Ranch	Shea Boulevard	53,000	3	6	U	35	12.0	0.0	0.0	0	U	0.0	0	7.0	100	100	4.58	E

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ADT	=	Average Daily Traffic on the segment or link
HV	=	Estimated percentage of trucks
L	=	Total number of through lanes
Con	=	Configuration of the road segment
SP_p	=	Posted Speed Limit
W_t	=	Total width of outside lane (and shoulder) pavement
W_l	=	Width of paving between the outside lane stripe and the edge of pavement, if any
W_{ps}	=	Width of pavement occupied by on-street parking
OSP	=	Percentage of segment with occupied on-street parking
U/R	=	Curbed (urban) or open shouldered (rural)

Scottsdale Road between Double Tree Ranch and Shea Blvd.

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Walking Conditions Evaluation

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Existing Conditions																			
Thomas Road	7th Avenue	6th Avenue	29,000	3	5	D	35	13.0	0.0	0.0	0	U	0.0	0	5.0	100	100	4.55	E

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Thomas Road east of 7th Ave., view toward the east.

ADT = Average Daily Traffic on the segment or link
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L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
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Existing Conditions																			
Thomas Road	6th Avenue	Central Avenue	29,000	3	5	D	35	14.0	0.0	0.0	0	U	12.0	0	5.0	100	100	3.12	C

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L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
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U/R = Curbed (urban) or open shouldered (rural)

Thomas Road west of 5th Ave., view toward the east.

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Existing Conditions																			
Warner Road	McClintock Road	Price Road	23,000	3	4	D	45	21.0	8.0	0.0	0	U	6.0	0	8.0	100	100	3.12	C

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ADT = Average Daily Traffic on the segment or link
HV = Estimated percentage of trucks
L = Total number of through lanes
Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
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W_{ps} = Width of pavement occupied by on-street parking
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U/R = Curbed (urban) or open shouldered (rural)

Warner Road west of McClintock Road, view toward the east.

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Existing Conditions																			
Washington Street	Priest Drive	48th Street	13,000	3	6	D	45	13.0	0.0	0.0	0	U	20.0	20	8.0	100	100	0.00	A

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ADT = Average Daily Traffic on the segment or link
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Con = Configuration of the road segment
SP_p = Posted Speed Limit
W_t = Total width of outside lane (and shoulder) pavement
W_l = Width of paving between the outside lane stripe and the edge of pavement, if any
W_{ps} = Width of pavement occupied by on-street parking
OSP = Percentage of segment with occupied on-street parking
U/R = Curbed (urban) or open shouldered (rural)

Washington Street west of Priest Dr., view toward the northeast.

For assistance or more information contact:
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