THE LATENT DEMAND METHOD

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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 reflects that the number of trips, regardless of travel mode, between two areas is *directly* related to the number of trip productions (e.g. 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 shows 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.

Bicycling activity patterns can be described by a similar relationship, see Figure 2. However, unlike those for the automobile travel mode, the impedances to the bicycling mode play a greater role. For example, the distance between trip origins and destinations affects bicycling more dramatically than it does for automobile travel. Additionally, the condition of the bicycling environment affects whether a bicycling 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 bicycle trip, the carrying, or "payload" capacity plays a role in not only the bicycle travel distances but also whether or not a bicycling trip is even made (Seasonal and environmental factors also affect travel distances, but in an analysis of roadways within the same region, they are not a factor unless they vary within the region).

Impedances are different for different trip purposes. For example, people are typically willing to bicycle a greater distance to work than they are to simply pick up a convenience item at a neighborhood store. This phenomenon is reflected in national survey data, as depicted for three trip purposes 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 *Latent Demand Method* accounts for the above outlined characteristics of bicycle 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 United States' National Personal Transportation Survey (NPTS) shown in Figure 5. The *Latent Demand Method* is an analysis of the entire region, using a corridor-based, geographic information system (GIS) algorithm to quantify relative potential bicycle trip activity.

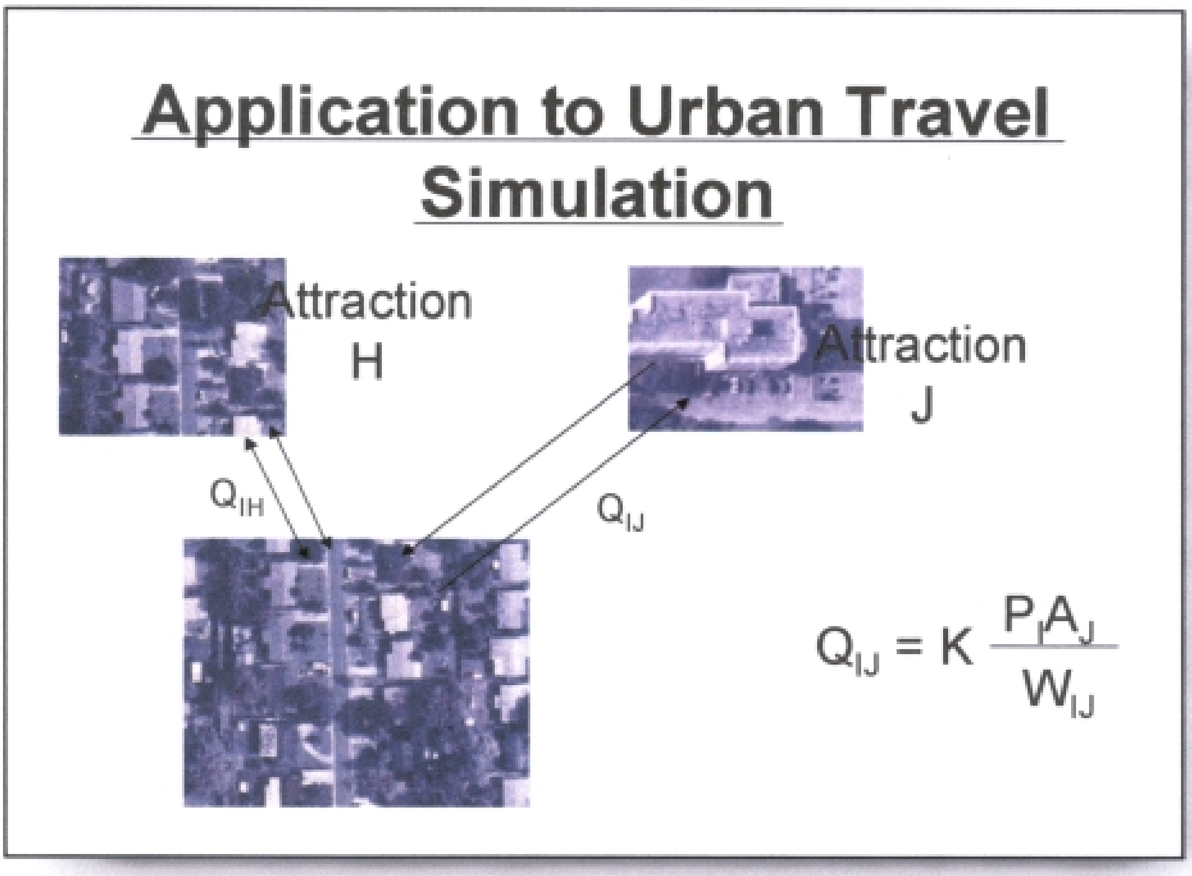


Figure 1 Newton's gravity model as applied to trip interchange.

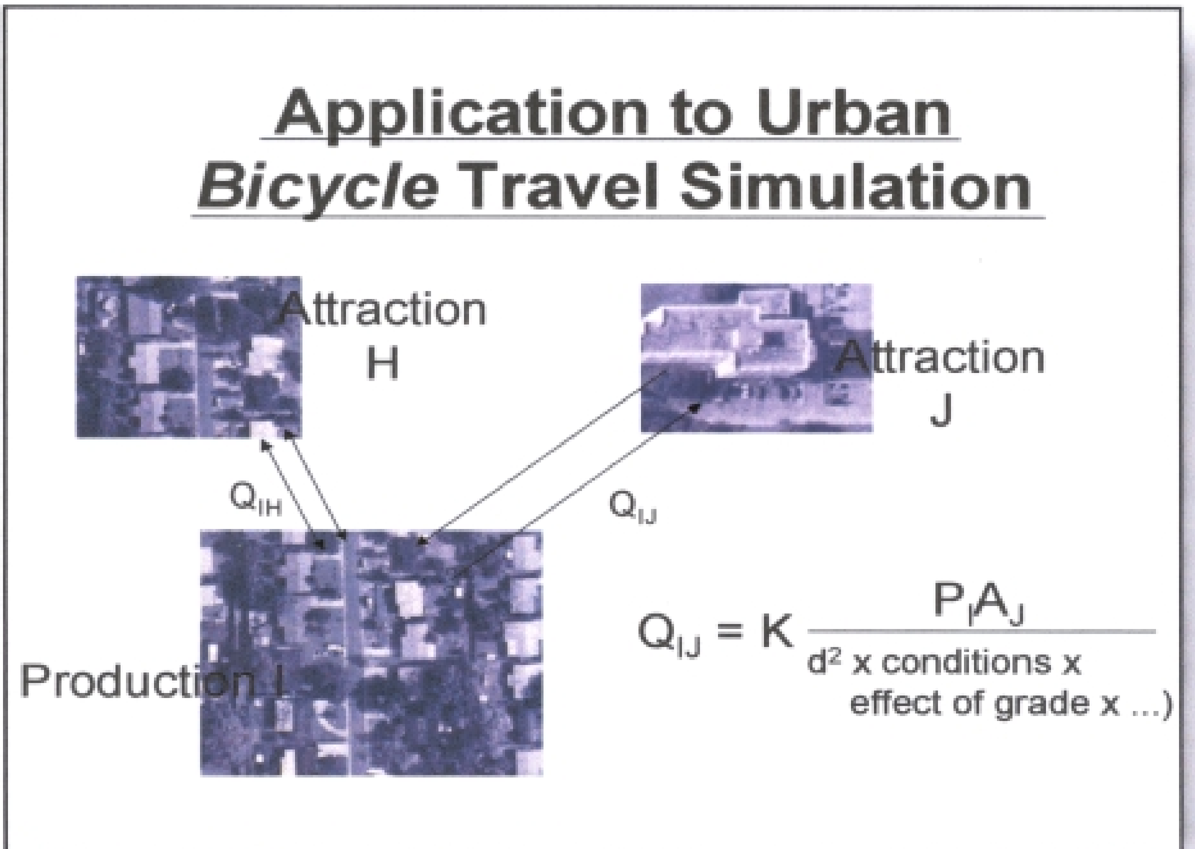


Figure 2 Bicycling trip interchange relationship.

Figure 3 Roadway conditions have a large effect on bicycling.

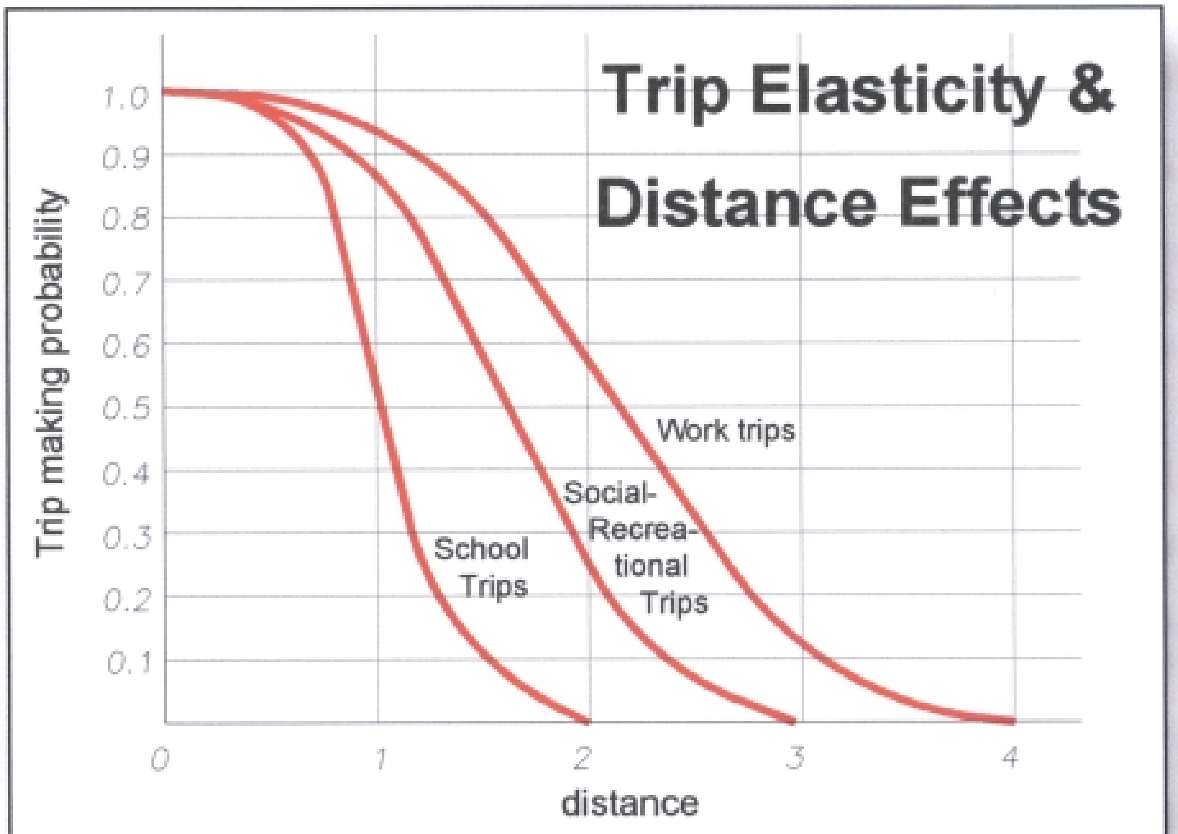


Figure 4 Typical trip making probability (impedance effects) due to distance.

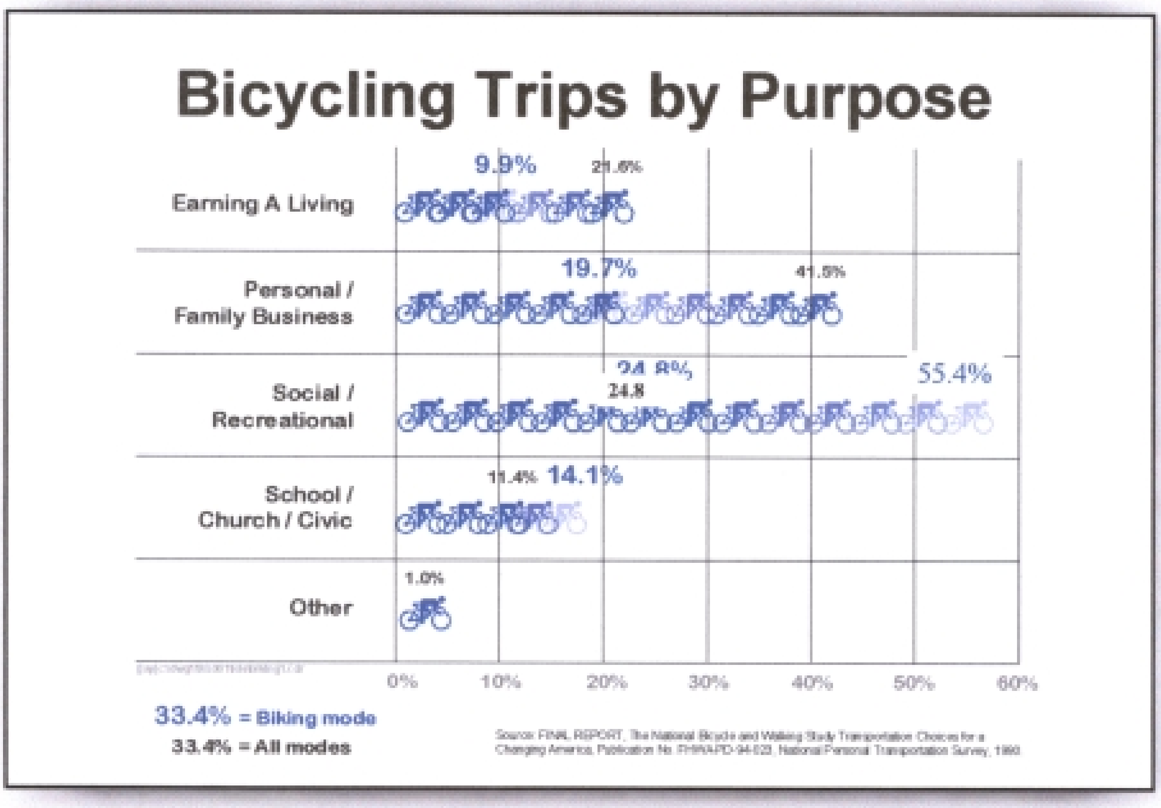


Figure 5 Bicycling Trips by Purpose.

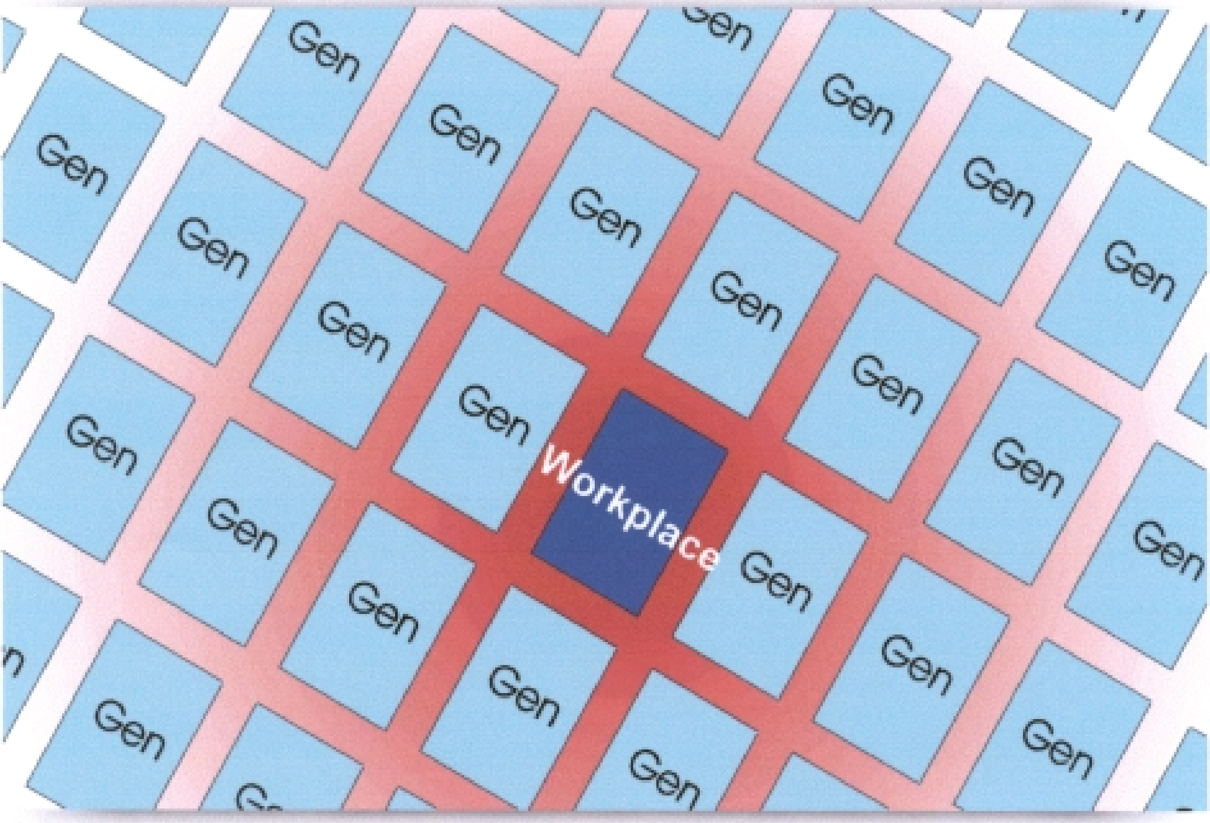


Figure 6 Potential trip activity around a work trip attractor.

The *Latent Demand Method* is an effective analysis tool for assessing bicycle 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 demand for any metropolitan roadway network

As previously outlined, the impedances to bicycling as a transportation mode play a large role in the probability of a bicycle 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” bicycle trips would become “revealed” trips.

Latent bicycle 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 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 Method* 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 bicycle trip activity surrounding the generators and attractors. The street segments with the more intense areas of shading represent the corridor areas with the highest potential bicycle trip activity. Figure 10 shows the basic mathematical expression of this GIS-based region-wide model.

Generators, Attractors, and Spatial Queries

The first step in the process is to identify the generators and attractors 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 the destination end and are represented by every business, school, park and trail, and social and service establishment. The generators and attractors form the foundation of the bicycle travel demand calculations that the *Latent Demand* method follows.

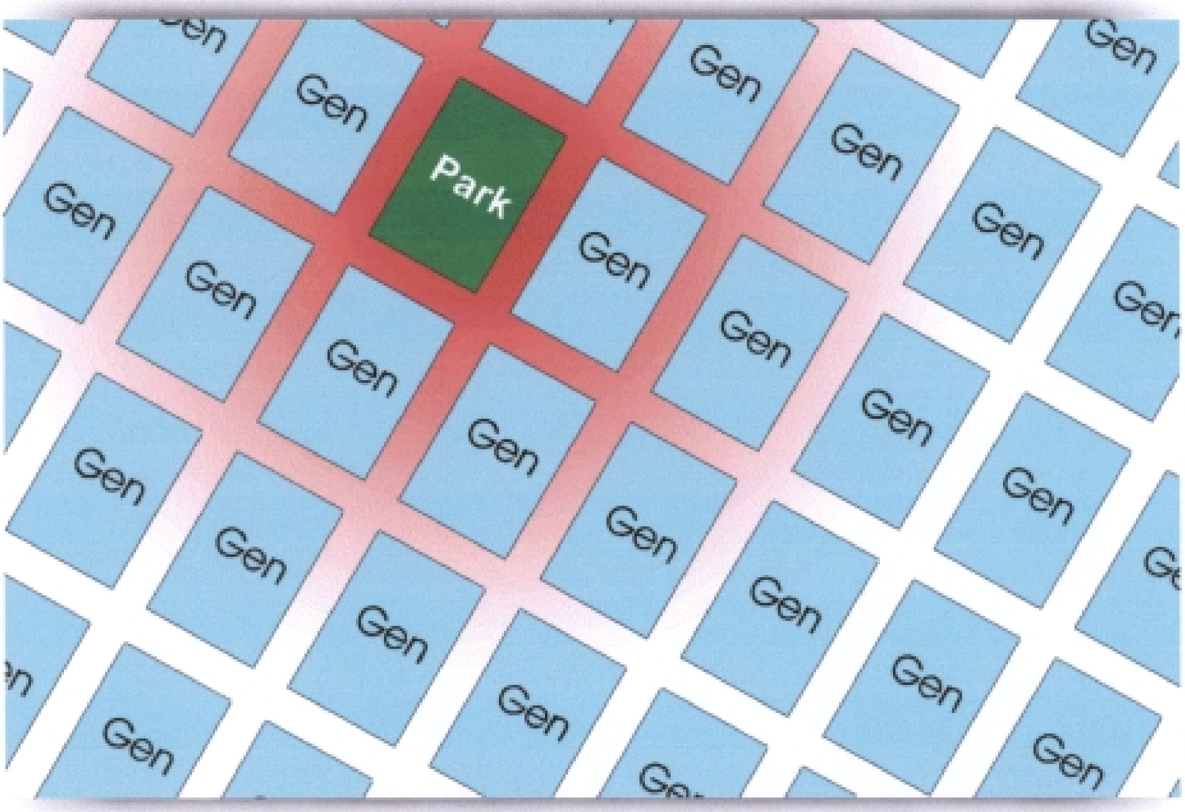


Figure 7 Potential trip activity around a social/recreational attractor.

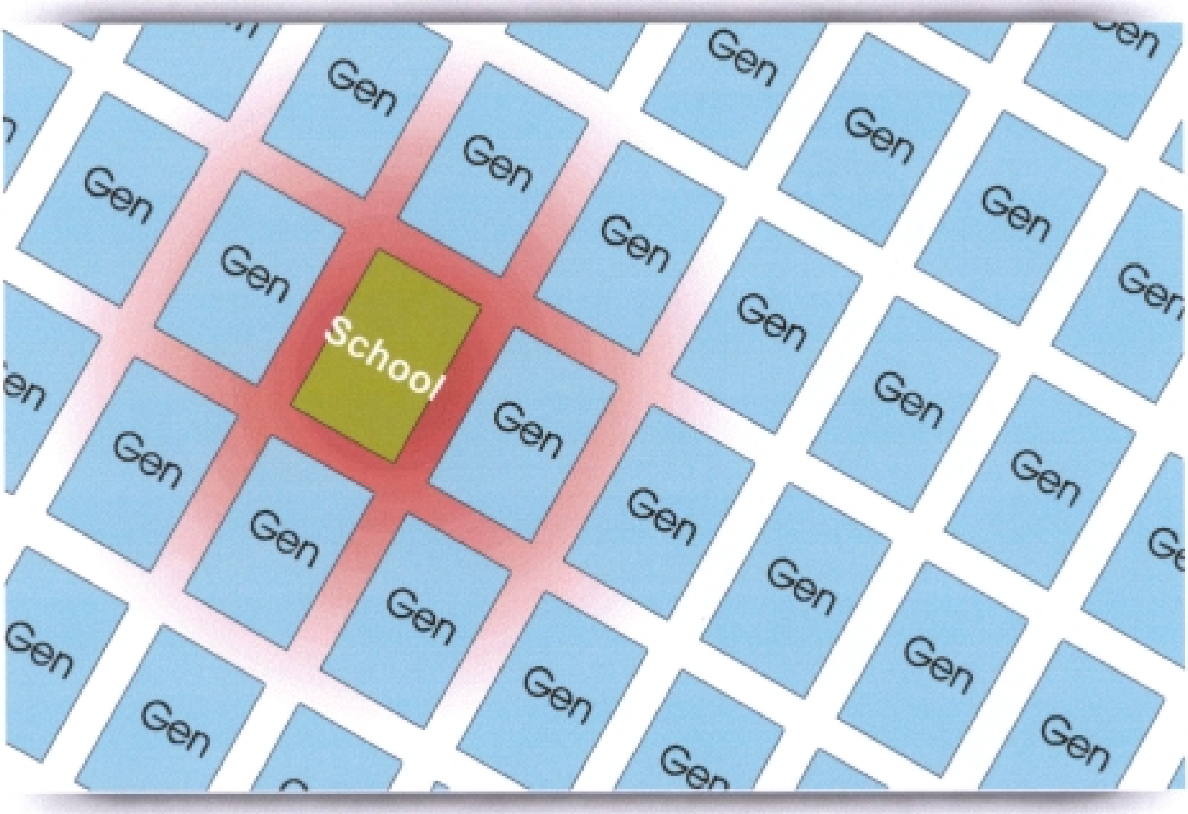


Figure 8 Potential trip activity around a school.

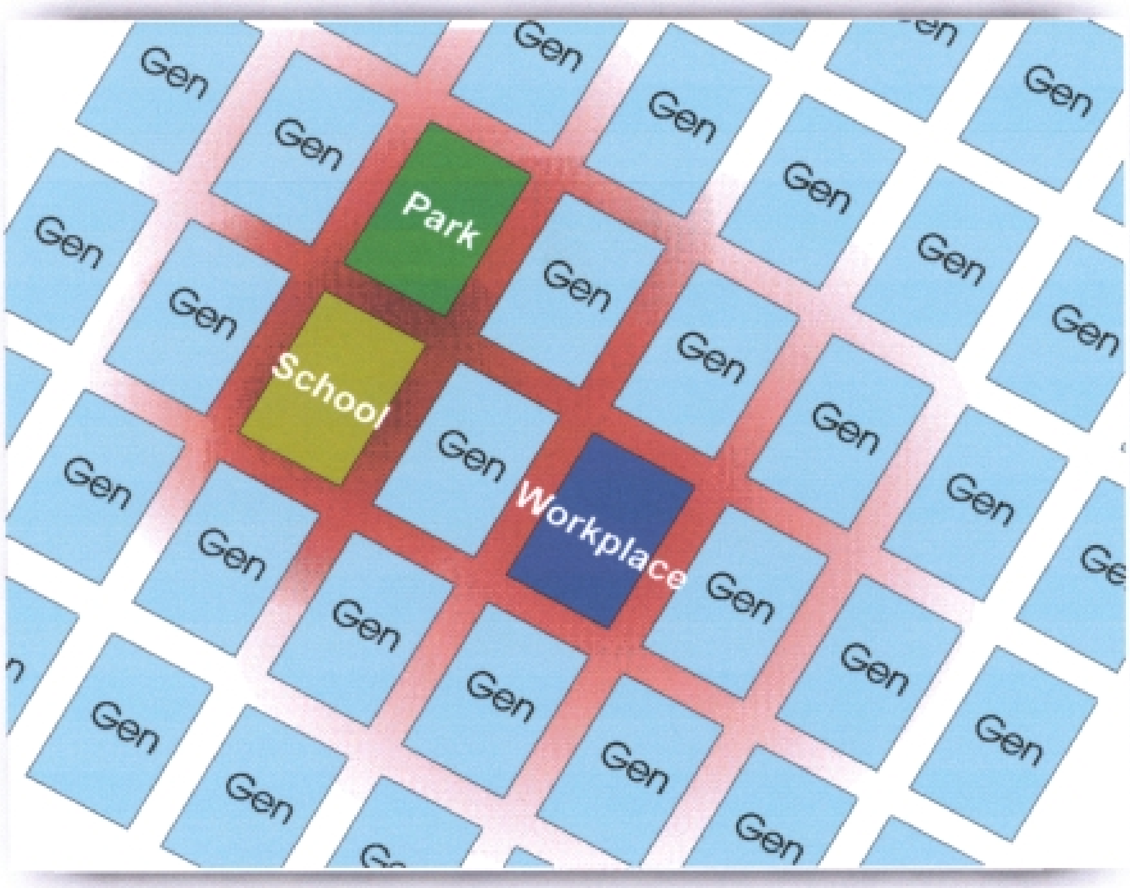


Figure 9 Composite of potential trip activity for three types of trip attractors.

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

n	= bicycle trip purpose (e.g., work, personal/business, recreation, school)
TTS	= trip purpose share of all bicycle 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 <u>range</u> 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 Method* 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 *Method* uses the aggregated population, as compiled in the Transportation Analysis Zone (TAZ) data from the regional transportation planning model. Likewise, the work trip and work errand demand analyses are based on TAZ employment data.

Once the generator and attractor data has been identified and geocoded or "mapped" into the GIS environment, spatial queries are performed around the network road corridors. 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 corridor, they are summed to determine the Corridor's *Latent Demand*. The road segments, are used to represent 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:

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

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
r = Population within buffer

Restriction:

$$\frac{\rho_z}{E_z} \leq 1 \tag{1a}$$

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 bicycle 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 with work trips (primarily trip length and regularity). 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.

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

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
r= Population within TAZ

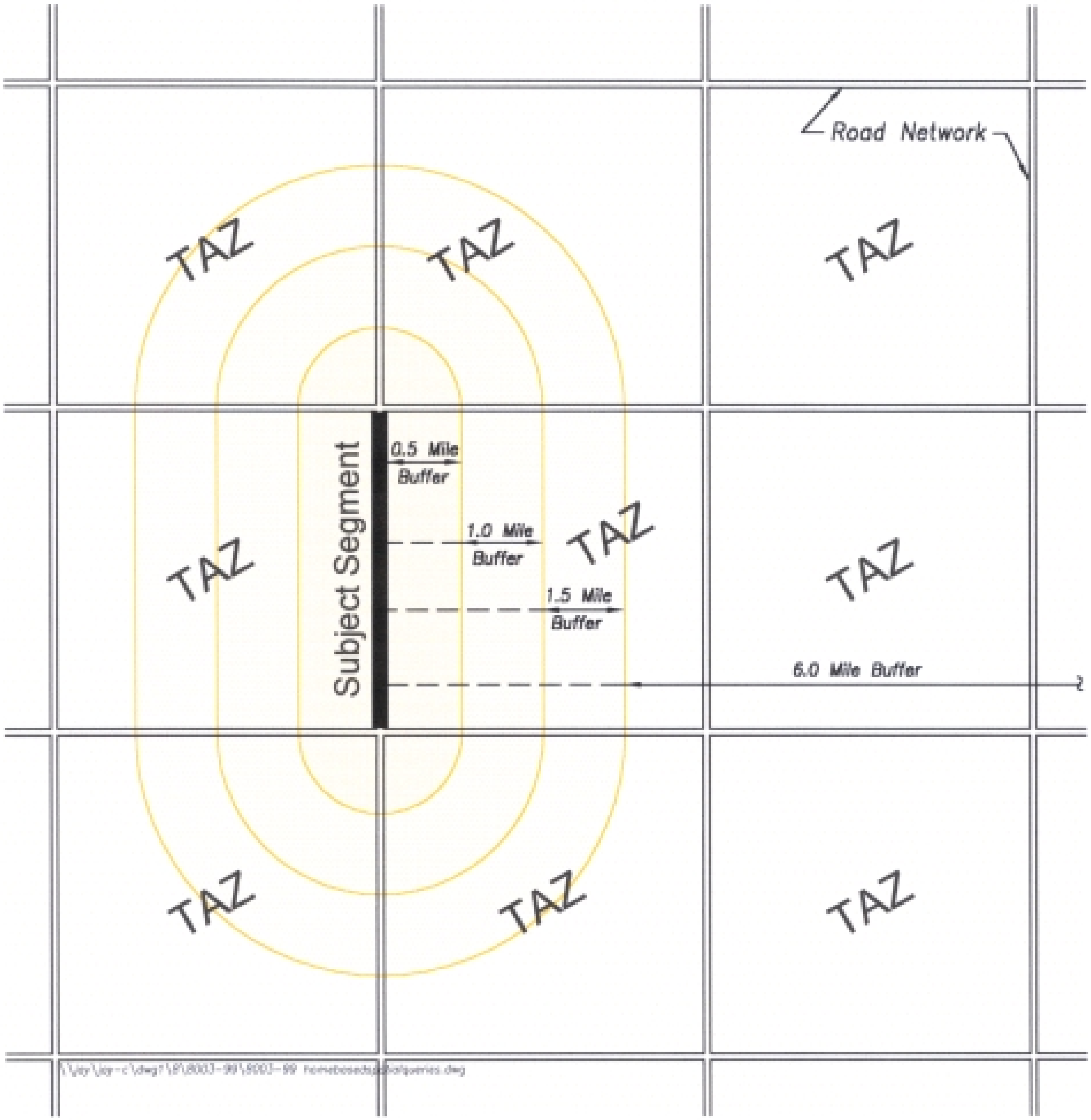
Restriction: *(2a)*

$$\frac{\rho_z}{FTE} \leq 1$$

The spatial queries for college/university trips are performed differently from the other work trips. The essential difference is that the spatial queries for colleges and

Figure 11a

Bicycle 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

Percent of TAZ inscribed by up to 6.0 mile buffer 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 corridor. As Figure 11b illustrates, the percent of the corridor falling within each buffer is used to normalize the corridor'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 Method* 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.

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

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
- r= 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 bicyclists. This two-mile radius constitutes a transportation exclusion zone for which potential bicycle 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)

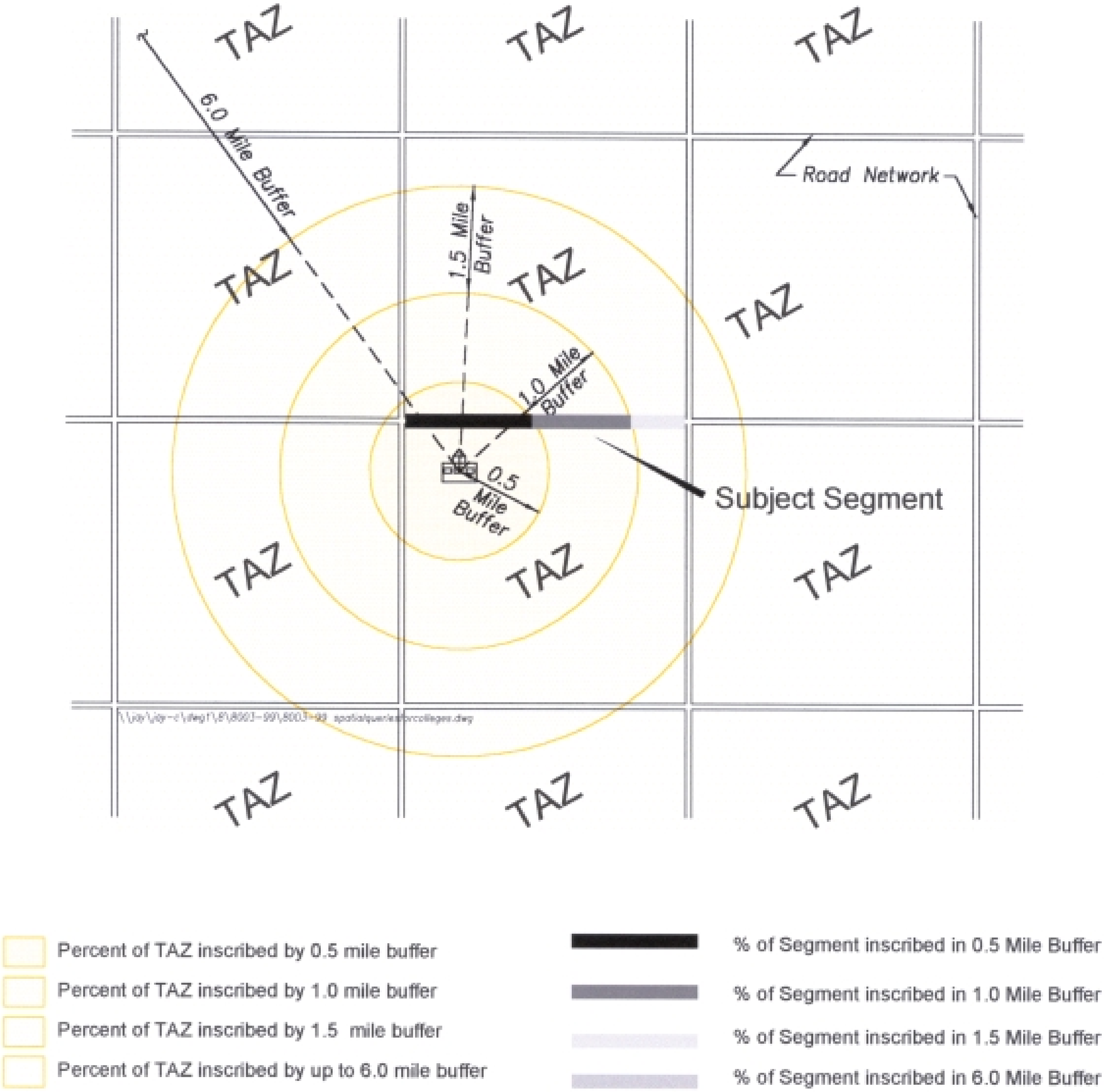
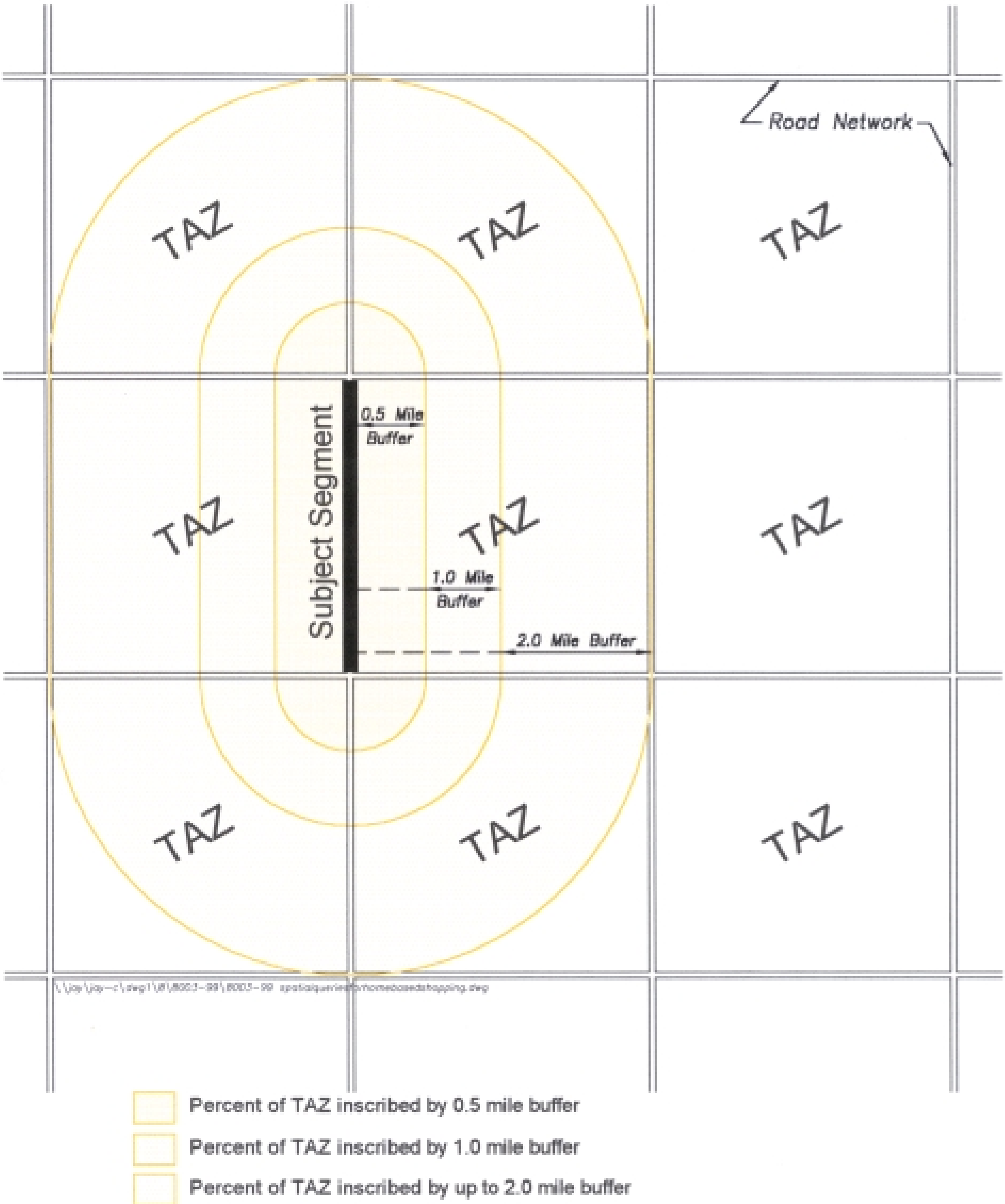


Figure 12

Spatial Queries for Shopping and Errands (Segment-Based)



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

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, 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.

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

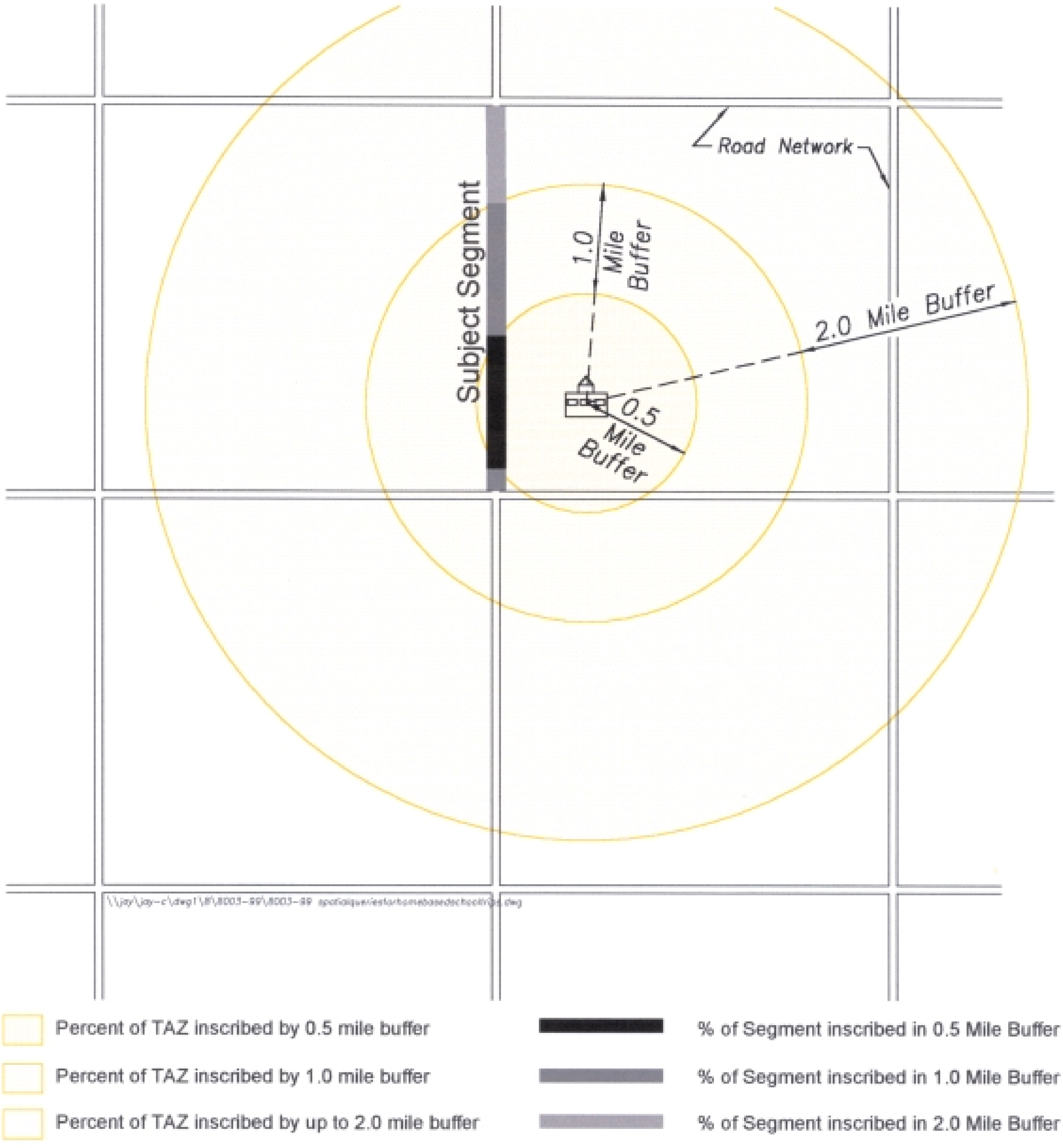
Where:

- 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 trips (or Q_{parks}) + total number of urban trail trips (or Q_{trails})
- r= Population within buffer

As shown above, T_t is separated into two categories of recreational / social trips: parks 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 outward from the trail to quantify the portion of the study segment proximate to the trail. Thus, the spatial queries for urban trails are attractor-based, whereas the spatial queries for parks are segment-based. The following paragraphs document the trip calculations for each category.

Figure 13

Spatial Queries for School Trips
(Attractor-Based)



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 = 3,058 trips. [This is based on an average major park size of 309.41 acres multiplied by a trip generation rate of 2.28 trips per acre.]
- Staffed Parks – these typically have intermittently programmed events and staffed events. Trip generation = 375 trips [This is based on an average staffed park size of 82.97 acres multiplied by a trip generation rate of 4.57 trips per acre.]
- Minor parks – these generally do not have programmed events nor do they have staffed events. Trip generation = 28 trips [This is based on an average minor park size of 17.46 acres multiplied by a trip generation rate of 1.59 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.

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

Where:

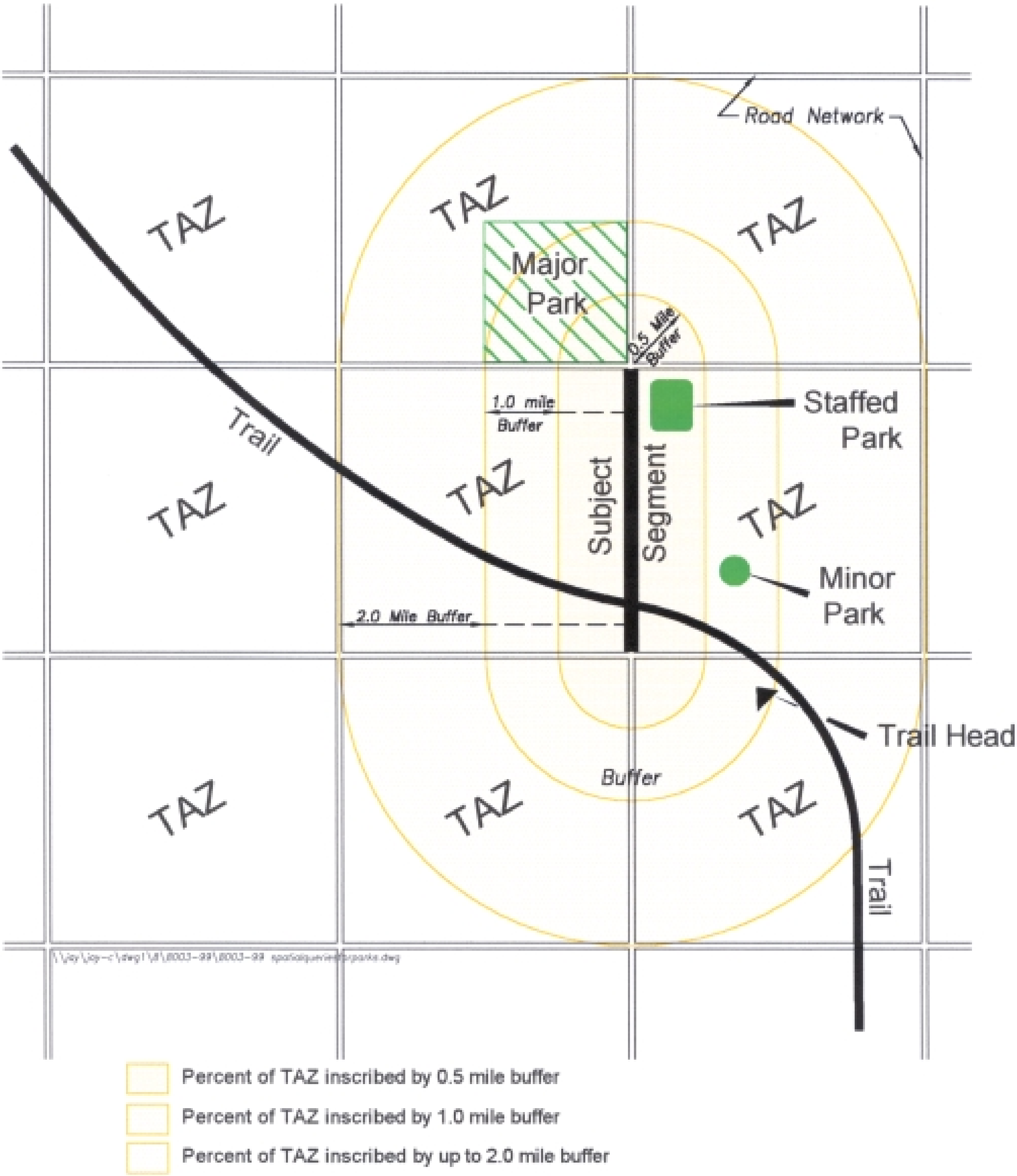
Q_{Parks} = Total trip interchange potential for park and trail head trips
c = Categories of parks
A= Number of attractors
n = Total number of buffers
TG = Trip generation rate

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 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 375 trips (same as staffed park).

Figure 14a

Spatial Queries for Parks
(Segment-Based)



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

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

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 Potential Bicycle Trips

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

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

Q= Total number of potential bicycle trip interchanges calculated by spatial queries, per trip purpose
n = Bicycle trip purpose (e.g., work, personal/business, recreation, school)
TTS = Trip purpose share of all bicycle trips (calculated using NPTS data)

Figure 14b

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