The Latent Demand Method

The Latent Demand Method predicts relative potential non-motorized trips based on characteristics of trip origins and destinations and their relative proximity and concentration/dispersion. While the way the method predicts potential bicycle and pedestrian travel is the same, in the interest of clarity the following description presents only the bicycle mode.

Methods of Assessing Non-Motorized Trip Activity

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

Revealed demand

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

Evaluation of Key Bicycle Trip Generators and/or Attractors

Until recently, this method has been the most common method of estimating bicycle and pedestrian travel demand. However, it has two major problems: the limited number of

key bicycle and pedestrian attractors it considers, and the fact that it generally focuses only on attractors – therefore only one end of the trip is considered.

The first problem with this method is that it tends to focus on *key* bicycle and pedestrian trip attractors such as schools, parks, and neighborhood retail centers, and thus only a fraction of the existing and potential trip attractors are represented. In fact, virtually every residence, every business, and every social and service establishment in a study area is a *key* 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 *key* attractors, only one end of the 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 bicycle and pedestrian trip activity (or interchange) between the attractor (park) and generator (population) would be low. Consequently, the method does not account for the bicycle and pedestrian trip interchange reality that exists *among* generators and attractors throughout the Region.

Latent Demand

The method that quantifies both ends of the non-motorized trip as well as considers *all key* generators and attractors in a study area for both existing and potential trips is the *Latent Demand Method*. The *Latent Demand Method* 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 roadway corridors to serve bicycle and/or pedestrian trip activity; among them are Baltimore (MD), Birmingham (AL), Philadelphia (PA), Tallahassee (FL), Tampa (FL), Phoenix (AZ), Scottsdale AZ), Westchester, Rockland & Putnam Cos. (NY), and a growing number of other areas.

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 METHOD

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 and 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 non-motorized modes play a greater role. For example, the distance between trip origins and destinations affects bicycling and walking more dramatically than it does for automobile travel. Additionally, the condition of the bicycling and walking environment affects whether a 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 trip, the carrying, or "payload" capacity plays a role in not only the bicycle and pedestrian travel distances but also whether or not a bicycling or walking trip is even made.

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

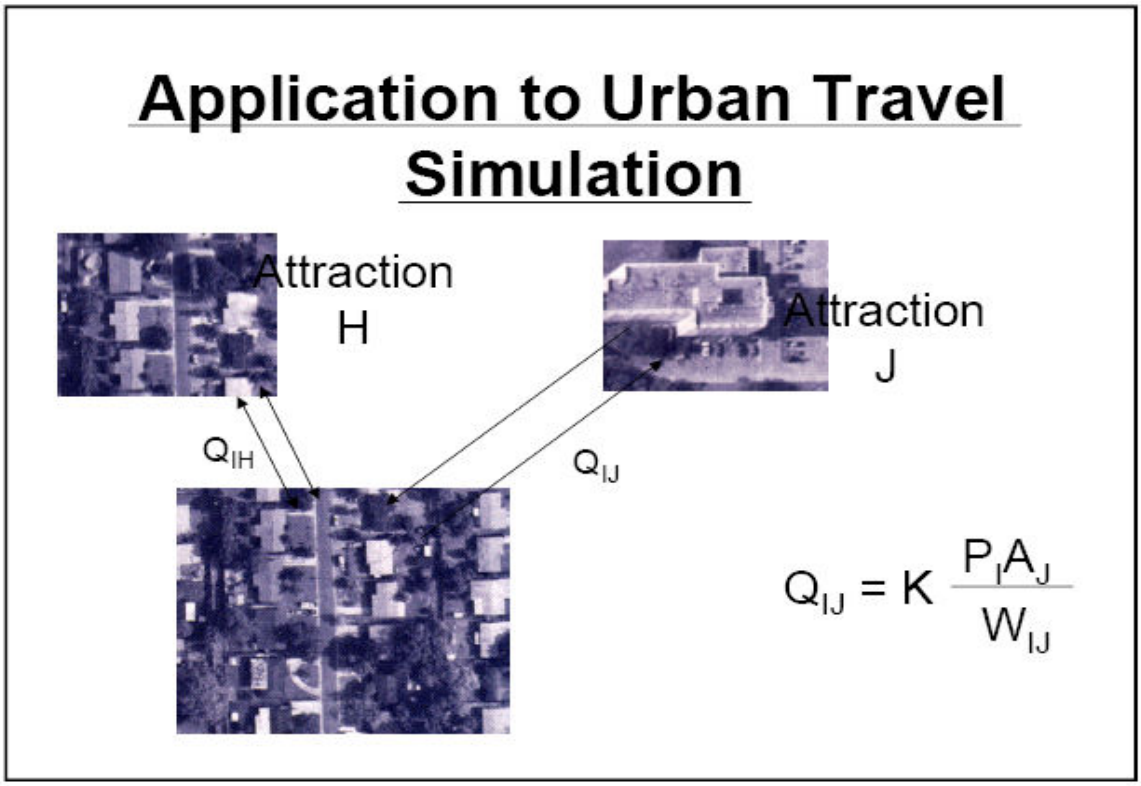


Figure 1 Newton's gravity model as applied to trip interchange.

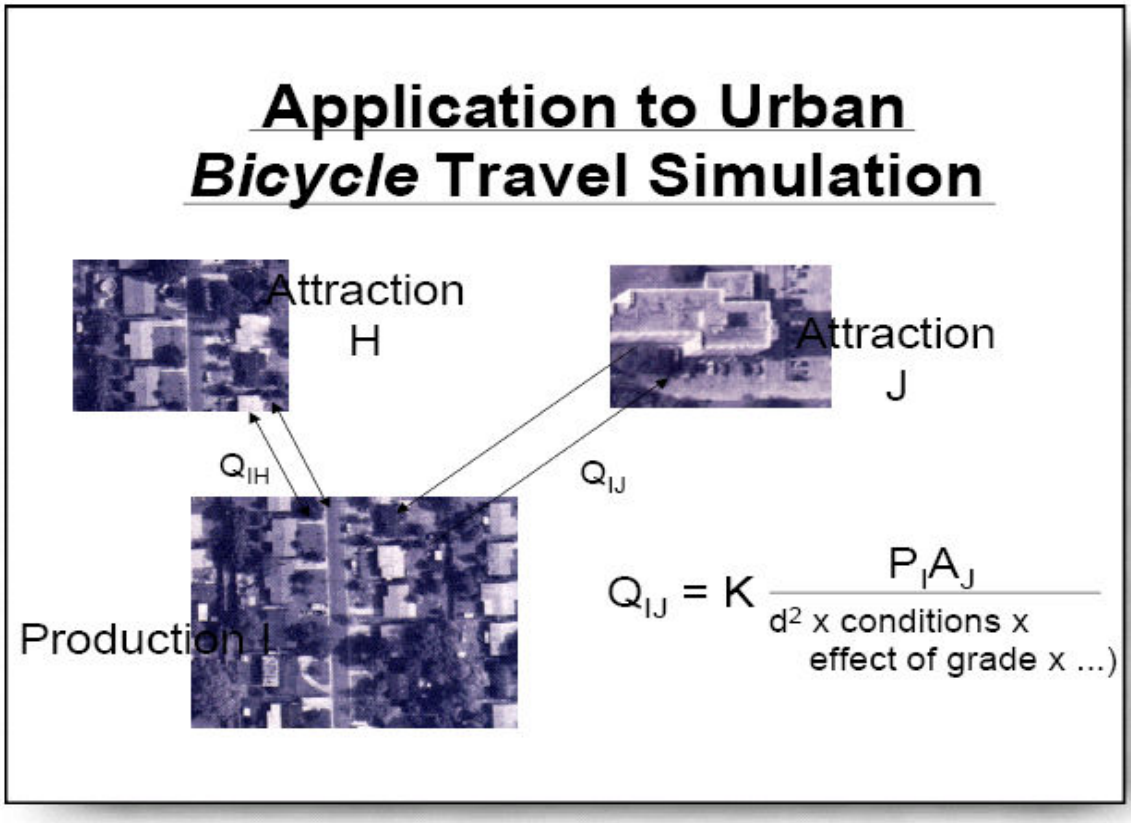


Figure 2 Bicycling trip interchange relationship.

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 and pedestrian travel in an 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 corridor 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 corridor-based, geographic information system (GIS) algorithm to quantify relative potential bicycle trip activity.

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

- Includes all *key* trip generators and attractors
- Quantifies the potential trip interchange between key 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 roadway network

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

Figure 3 Roadway conditions have a large effect on bicycling.

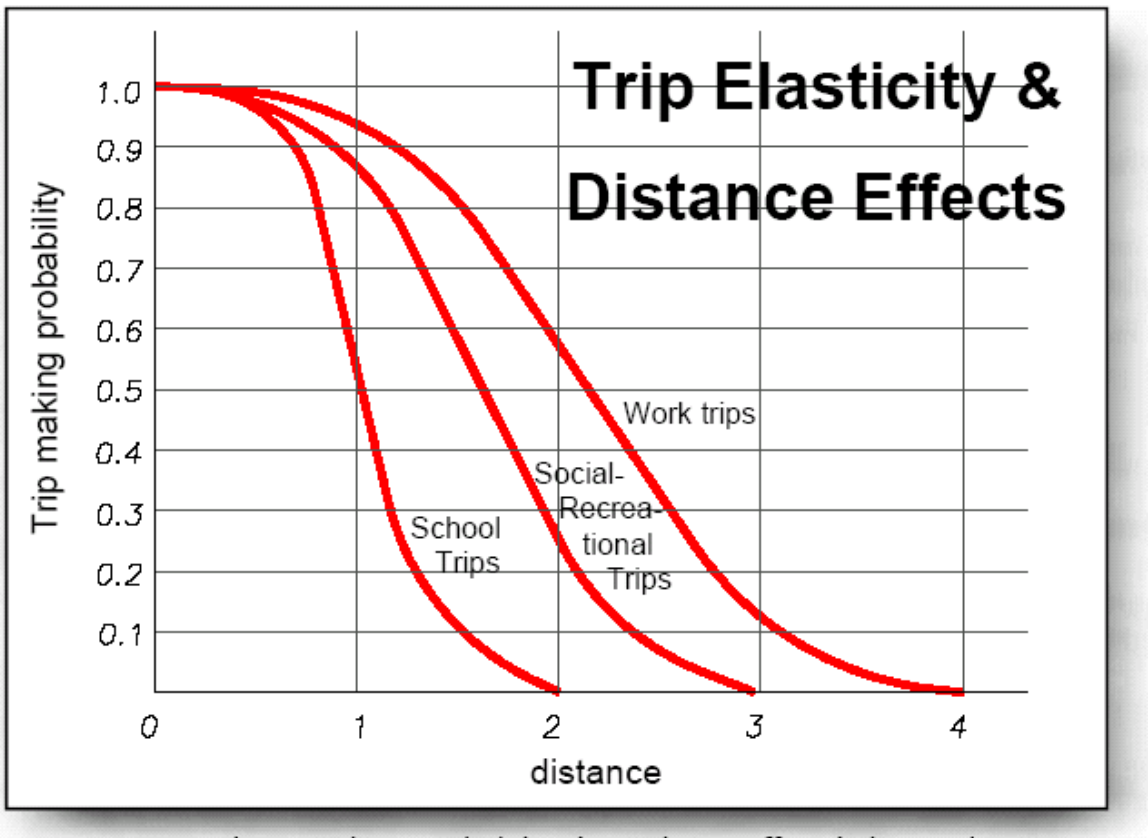


Figure 4 Typical trip making probability (impedance effects) due to distance.

Latent non-motorized 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 Model* process takes these "snapshots" of the potential trip activity for *all key* attractors and generators throughout the study 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 and pedestrian trip activity. Figure 10 shows the basic mathematical expression of this GIS-based region-wide method.

The following sections describe how the bicycle travel demand analysis would be performed for a non-specific study area in a GIS environment.

Generators, Attractors, and Spatial Queries

The first step in the process is to identify the *key* 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.

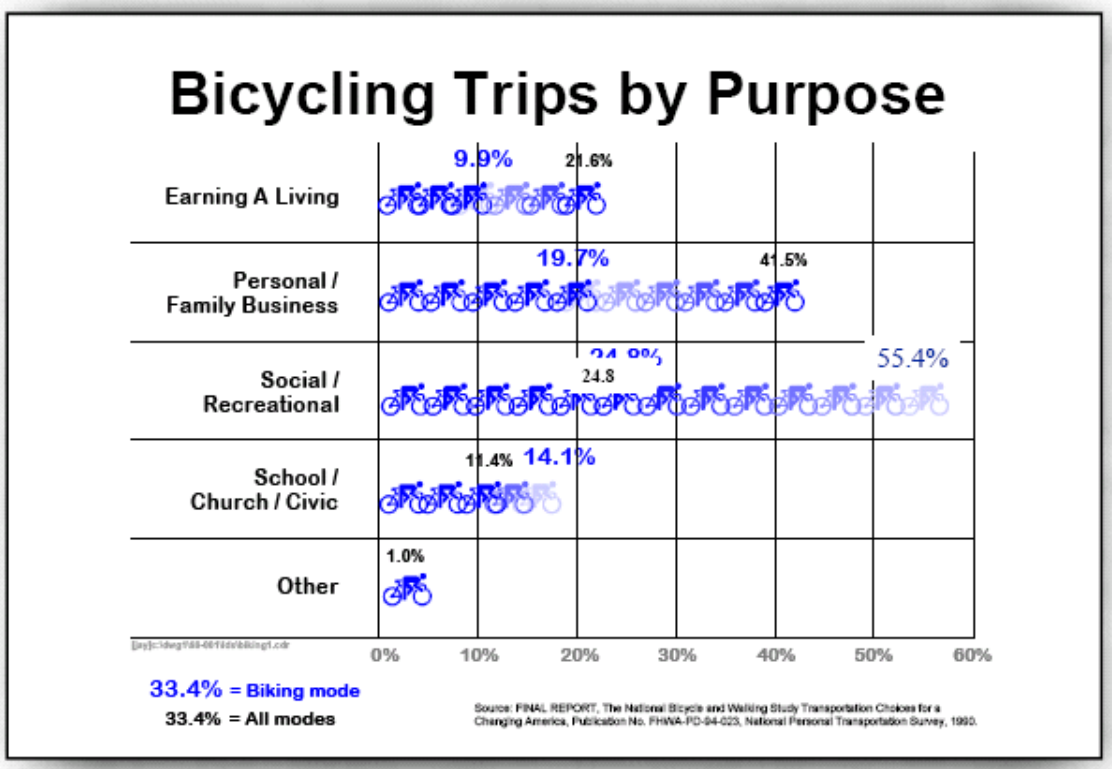


Figure 5 Bicycling Trips by Purpose.

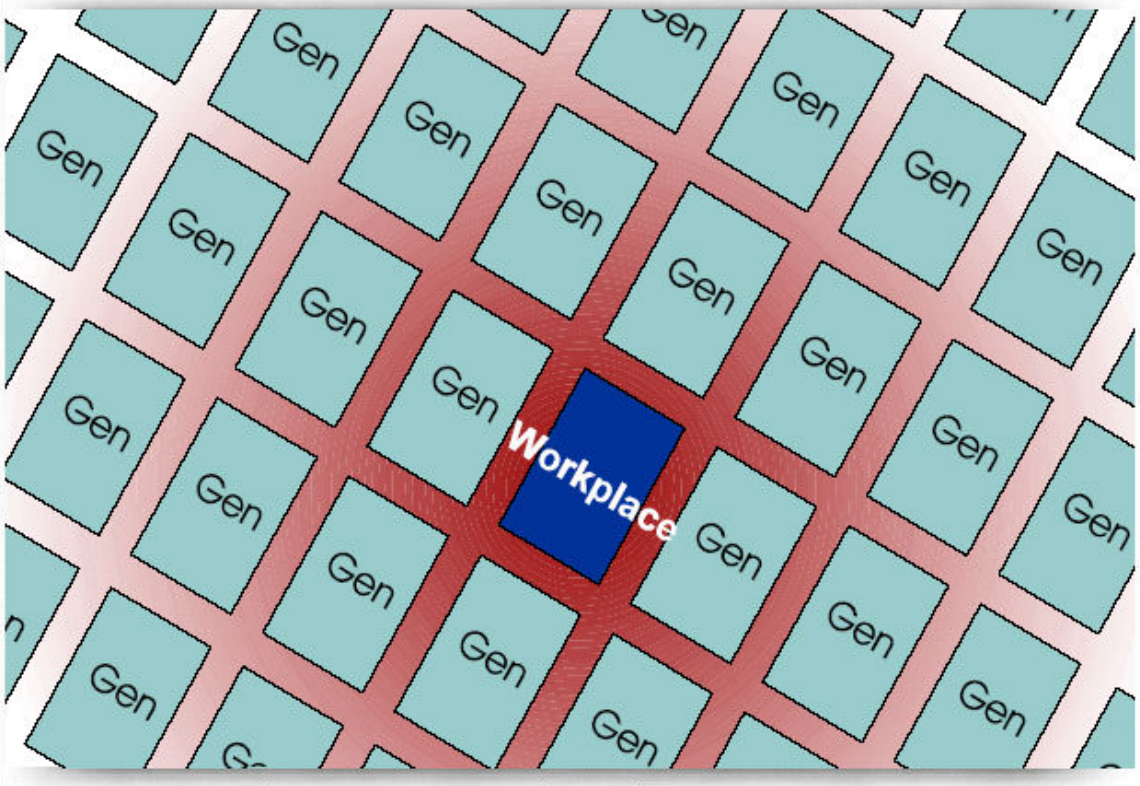


Figure 6 Potential trip activity around a work trip attractor.

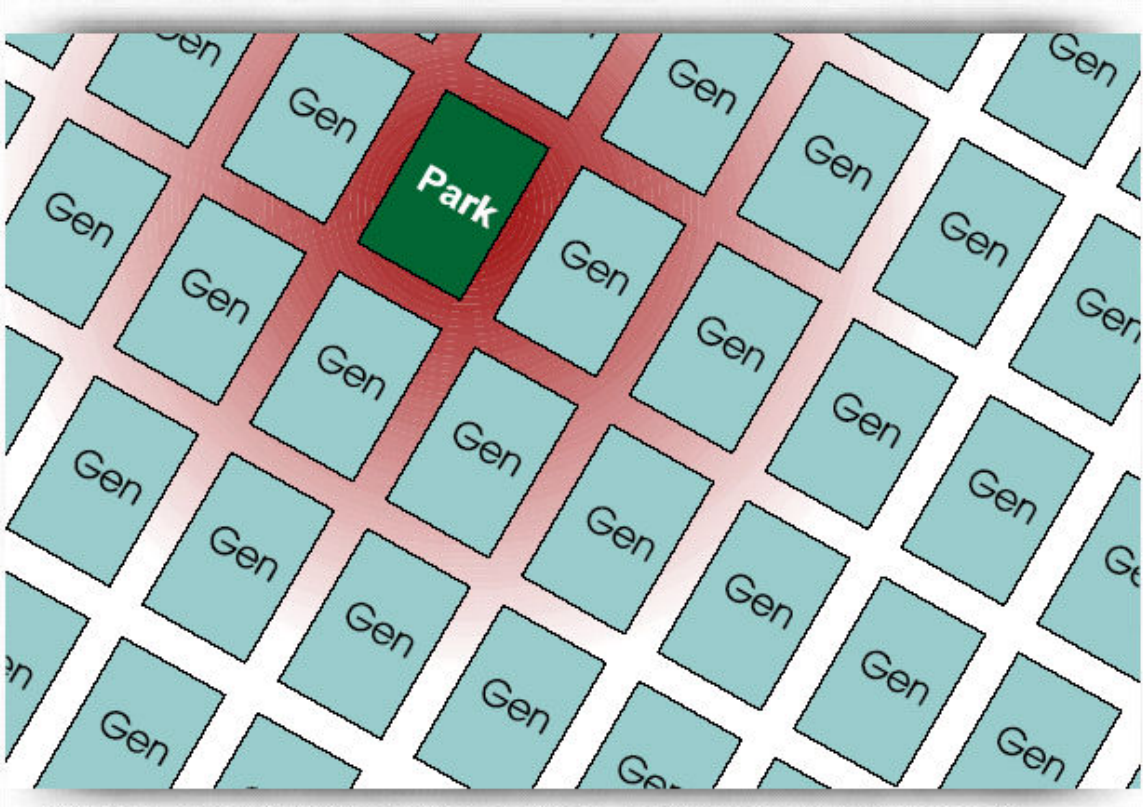


Figure 7 Potential trip activity around a social/recreational attractor.

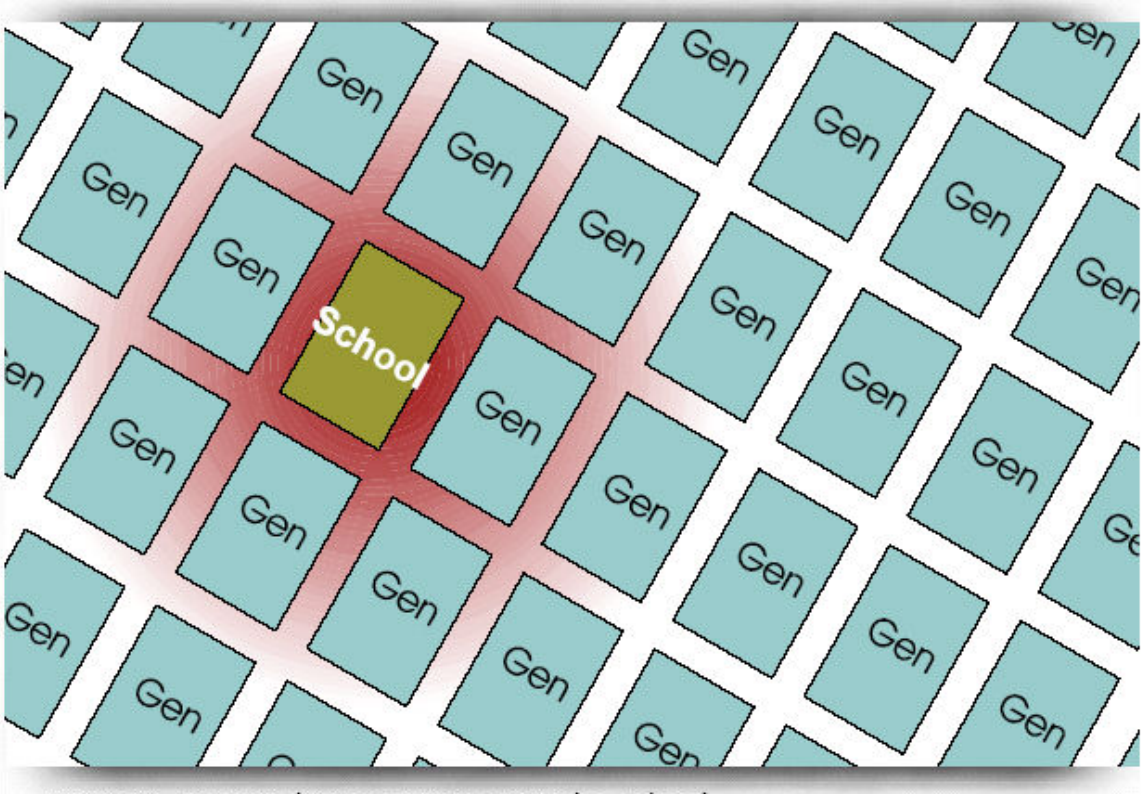


Figure 8 Potential trip activity around a school.

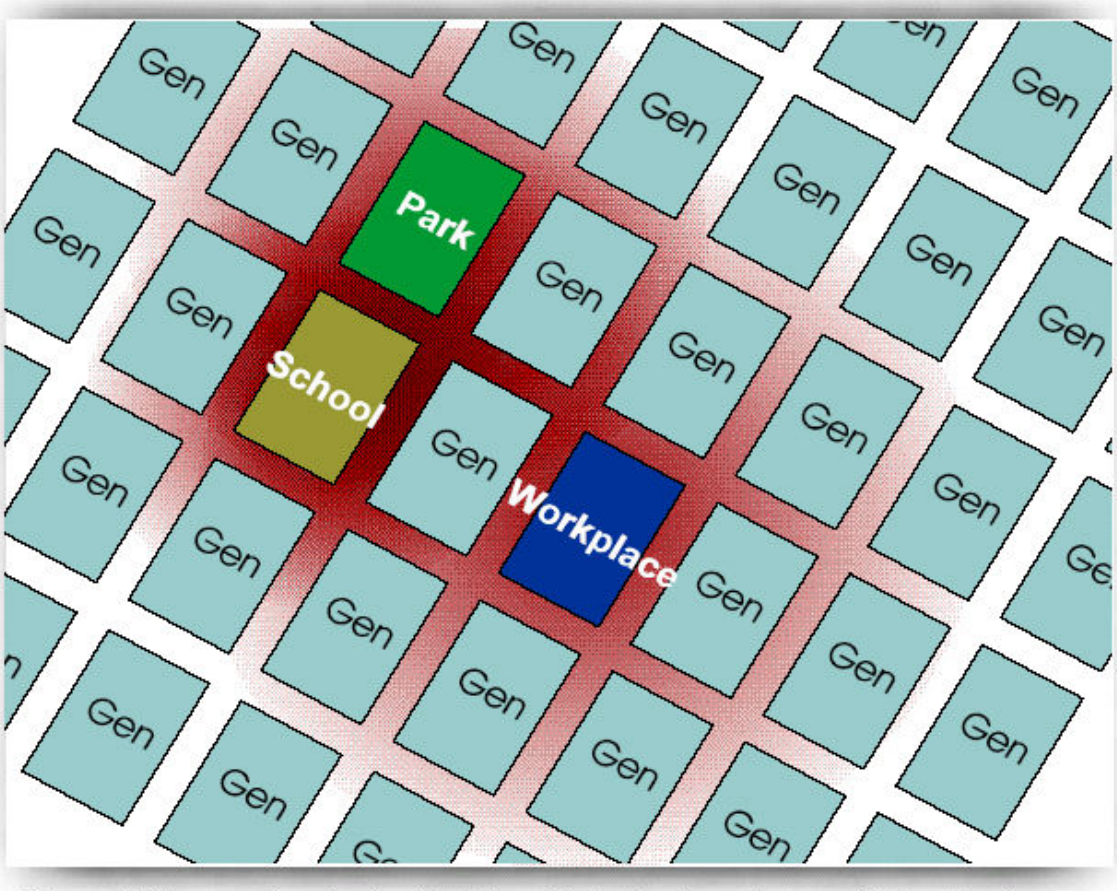


Figure 9 Composite of potential trip activity for three types of trip attractors.

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

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 range from generator or attractor

Figure 10 The Basic Latent Demand (score) Algorithm.

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 and pedestrian travel demand calculations that the *Latent Demand* method follows.

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 Traffic Analysis Zone (TAZ) data from the local jurisdiction.

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. 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.

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

Where:

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 network segment

E = Total employment within buffer

r = Population within buffer

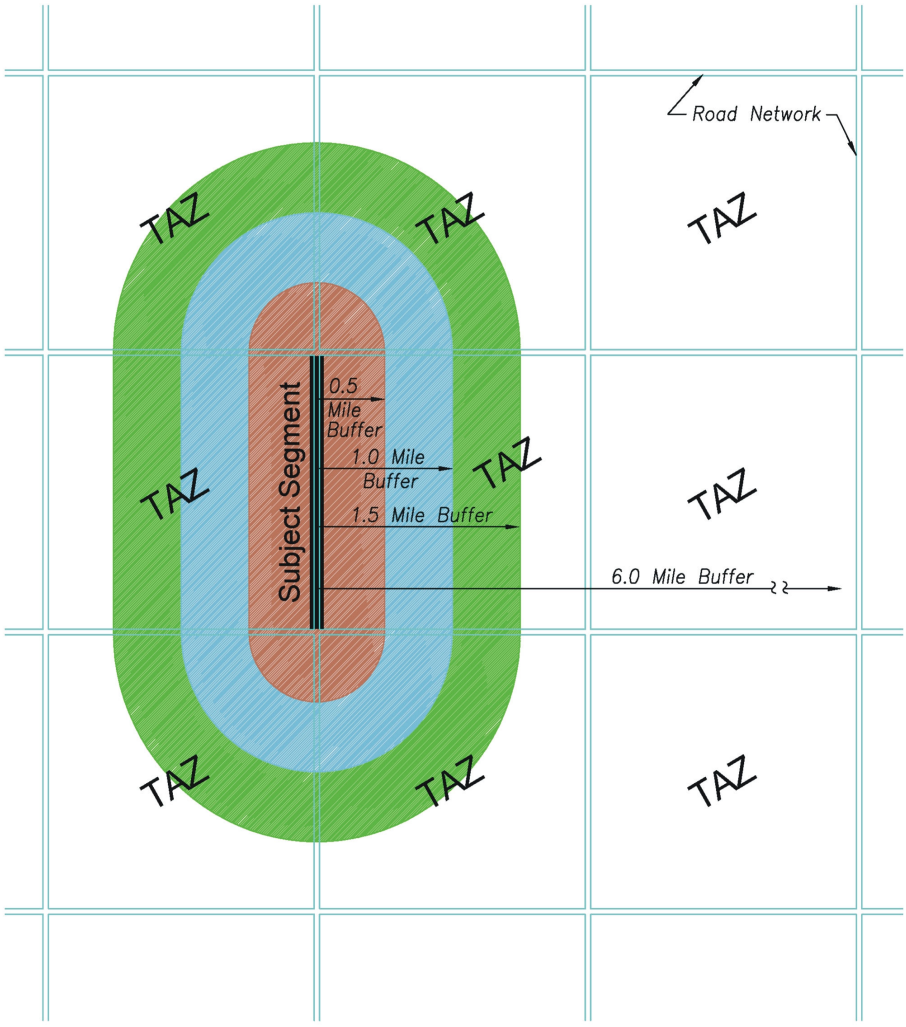
Restriction:

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

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 network 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.

Figure 11a

Work Trip Spatial Queries
(Segment-Based)



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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.

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

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:

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

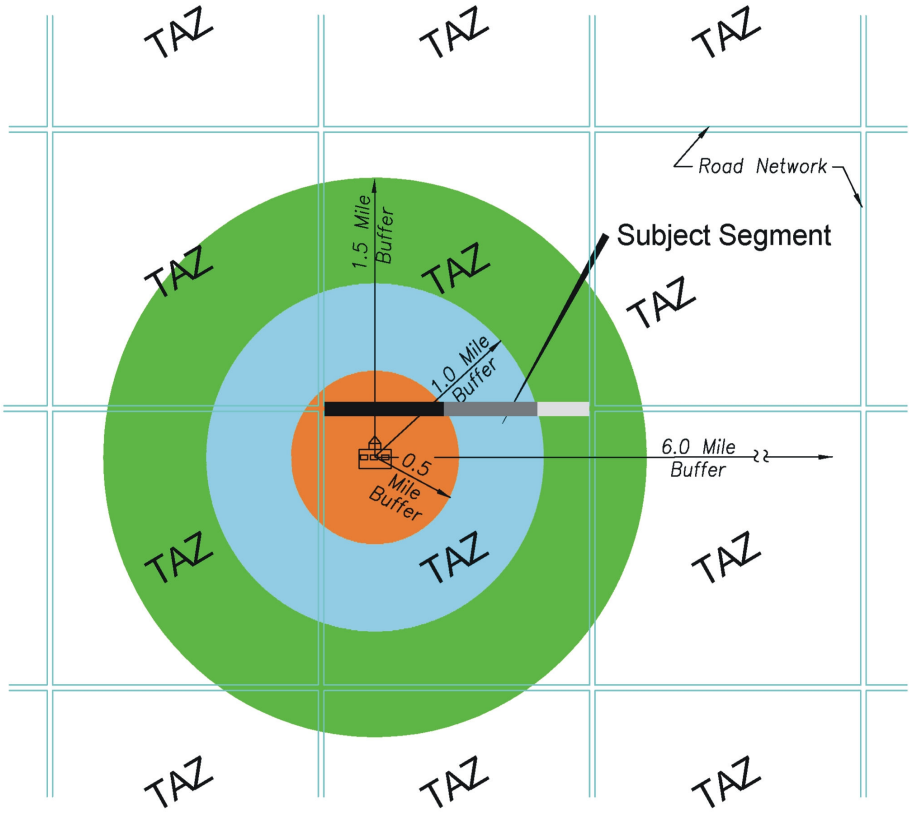
The spatial queries for college/university trips are performed differently from the other work trips. The essential difference is that the spatial queries for colleges and universities are *attractor-based* rather than segment-based. This means that the spatial queries are centered on the individual 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.

Figure 11b

Spatial Queries for Colleges and Universities (Attractor-Based)



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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

% of Segment inscribed in 0.5 Mile Buffer

% of Segment inscribed in 1.0 Mile Buffer

% of Segment inscribed in 1.5 Mile Buffer

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

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

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

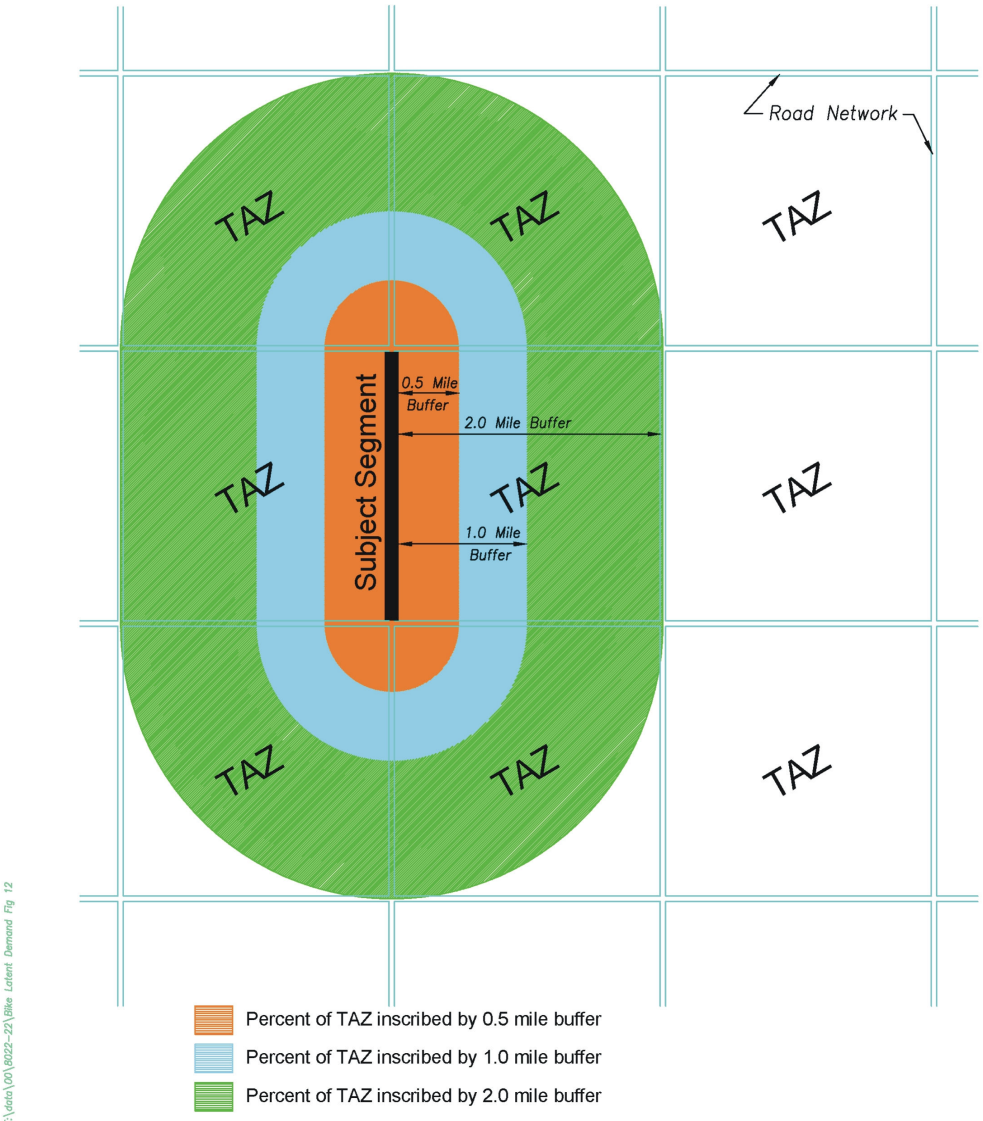
Restriction:

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

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.

Figure 12

Spatial Queries for Shopping and Errands (Segment-Based)



School (Sc) Trips The locations of elementary and middle schools are the attractors for this trip type. Since students living within a one-mile radius of a school are generally not

eligible to use the school transportation system, they are considered potential bicyclists and pedestrians. This one-mile radius constitutes a transportation exclusion zone for which potential bicycle and 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.

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

Where:

Q_{Sc} = Total trip interchange potential for home-based school trips

d = Spatial query buffer

n = Total number of buffers or TAZs

P = Effect of travel distance on trip interchange, expressed as a probability (see Figure 5)

A = Number of attractors

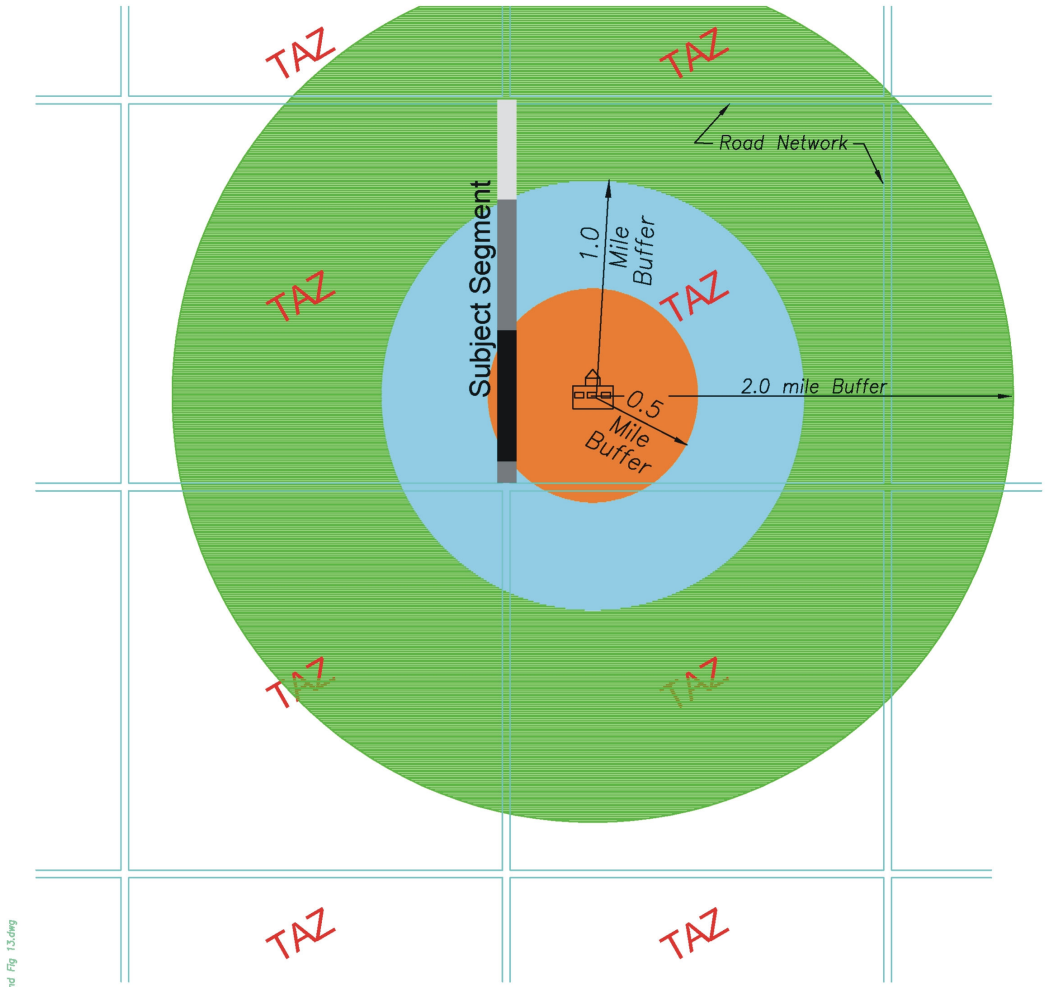
ASE = Average school enrollment

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 transportation network segment falling within each "buffer" is likewise calculated.

Figure 13

Spatial Queries for School Trips (Attractor-Based)



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Recreational and Social (RS) Trips Public parks and urban multi-use pathways (i.e., 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.

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

Where:

Q_{SRC} = Total trip interchange potential for social/recreational trips

d = Spatial query buffer

n = Total number of buffers or TAZs

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}) r= Population within buffer

Prior to performing spatial queries on parks and trail-heads, parks are stratified (with the assistance of Town staff and County staff) 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 more passive park of equal size with fewer amenities. Accordingly, the trip attraction rate for the former will be higher. A definition of each park type along with its associated trip generation follows:

- Major Parks – these are characterized as parks that have regularly programmed events and large, staffed events. Trip generation is calculated by multiplying the trip generation rate of 4.57 trips per acre by the each major park's size.]
- Staffed Parks – these typically have intermittently programmed events and staffed events. Trip generation is calculated by multiplying the trip generation rate of 2.28 trips per acre by each staffed park's size.]

· Minor parks – these generally do not have programmed events nor do they have staffed events. Trip generation is calculated by multiplying the trip generation rate of 1.59 trips per acre by each minor park's size.]

The quantification of trip interchange for parks is shown in Equation 5a, below.

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

Where:

Q_{Parks} = Total trip interchange potential for park and trail head trips

c = Categories of parks

A= Number of attractors

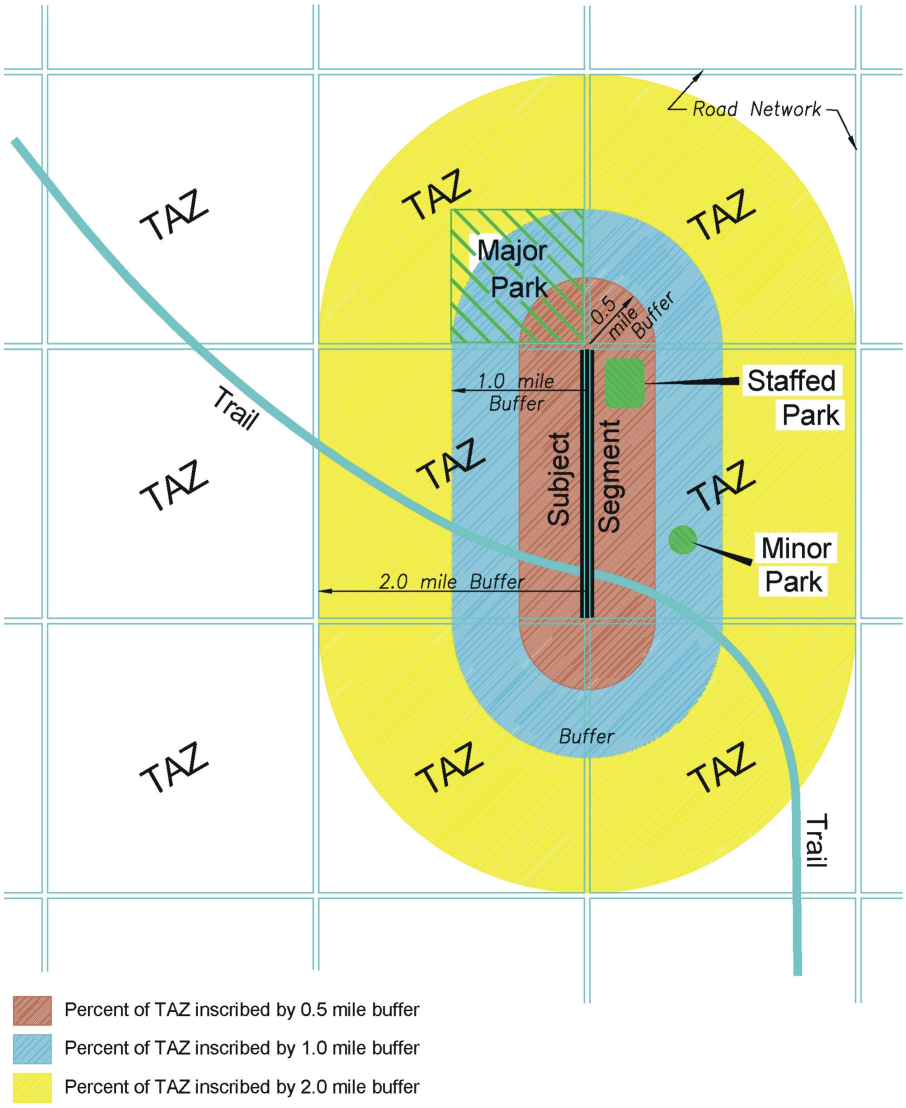
n = Total number of buffers

TG = Trip generation rate

Figure 14a is a graphic representation of the segment-based spatial queries used for the parks' latent demand analysis.

Figure 14a

Spatial Queries for Parks (Segment-Based)



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Access To Transit The attractors are transit routes, modified by the number of buses that serve each route daily. Equation 6 represents the calculation of potential trip activity.

$$Q_{transit} = \sum_{R=1}^{n} T$$

Where:

R = Transit route

n = Total number of transit routes

T = number of bus/transit trips

ANALYSIS AND RESULTS

Using the study network, the TAZ demographic and employment data, and the mapped trip attractors and/or generators, all corridor segments are analyzed according to the aforementioned method. After populating the database with the results from the spatial queries (all trip types), the values are ranked on a 100% scale for each trip purpose, with 100% representing the highest percentage of *Latent Demand*. The segments are sorted in descending order based on the highest *Latent Demand* score (LDS) of all trip types for that segment and are stratified by jurisdiction. The following equation shows the general computations calculating the final 100% *Latent Demand* score for each network study segment:

$$LDS = \text{Max. Value} \left[\overline{TG}_n \sum_{d=1}^{1} P_{nd} \times ga_n \right]_1^5$$

n = walking trip purpose (e.g., work, personal/business, recreation, school)

$\overline{TG}$ = 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