COBB COUNTY

BICYCLE AND PEDESTRIAN IMPROVEMENT PLAN

Evaluation Methodology

October 2008

Sprinkle Consulting
Planners+Engineers+Landscape Architects

ON-ROAD NETWORK EVALUATION TECHNIQUES

To prioritize bicycle and pedestrian improvements for the County's on-road network, three evaluative criteria are proposed: existing conditions (bicycle and pedestrian levels of service), demand (latent demand), and public input. The following sections will describe these categories.

Bicycle Level of Service

The Bicycle Level of Service (Bicycle LOS) Model, a bicycling conditions performance measure, is a "supply-side" criterion. It is an objective measure of the bicycling conditions of a roadway which provides an evaluation of bicyclists' perceived safety and comfort with respect to motor vehicle traffic and roadway conditions. This widely used criterion is classified as the quality or level of service (accommodation) for bicyclists that currently exists within the roadway environment. One of the greatest benefits of incorporating Bicycle Level of Service is the indication it provides regarding which network segments have the greatest needs. It uses the same measurable traffic and roadway factors that transportation planners and engineers use for other travel modes. With statistical precision, the *Bicycle LOS Model* clearly reflects the effect on bicycling suitability or "compatibility" due to variations in factors such as roadway width, bike lane widths and striping combinations, traffic volume, pavement surface conditions, motor vehicle speed and type, and on-street parking. This method is not limited to merely assessing conditions: it can serve as an important and effective analytical tool in the identification of restriping candidates, development of street cross-section performance guidelines, and planning of bicycle routes.

After the on-road bicycle network has been evaluated, each segment will have an objective "grade" which measures bicycle accommodation on that section of roadway. For example, a segment without any type of bicycle facility (given other roadway characteristics detailed above) may provide a level of service "D." Using this tool, it is possible to determine how much accommodation benefit would be achieved as a result of improvements. In the above example, adding a designated bike lane might improve the segment's level of service to "B." Through this process, it is possible to objectively and easily see which facilities have the greatest needs relative to the rest of the network.

For more information about the *Bicycle Level of Service Model*, including the model form and the collected data items, please see Appendix A.

Pedestrian Level of Service

Similar to the evaluation procedure used for the bicycle mode, pedestrian level of service is an evaluation of pedestrians' perceived safety with respect to motor vehicle traffic. It identifies the quality of service for pedestrians that currently exists within the roadway environment and provides a measure of facility needs within the County's sidewalk network. The *Pedestrian Level of Service (Pedestrian LOS) Model* will be used for the evaluation of walking conditions. This model is the most accurate method of evaluating the walking conditions within shared roadway environments. It uses the same measurable traffic and roadway factors that transportation planners and engineers use for other travel modes. With statistical precision, the *Pedestrian LOS Model* clearly reflects the effect on walking suitability or "compatibility" due to variations in factors such as roadway width, presence of sidewalks and intervening buffers, barriers within those buffers, traffic volume, motor vehicle speed, and on-street parking.

The *Pedestrian LOS Model* is used by planners and engineers throughout the United States in a variety of planning and design applications. The *Pedestrian LOS Model* can be used to conduct a benefits comparison among proposed sidewalk/roadway cross-sections, identify roadways that are candidates for reconfiguration for sidewalk improvements, and to prioritize and program roadways for sidewalk improvements. As with the *Bicycle LOS Model*, it clearly demonstrates the needs of pedestrian facilities among the County's network segments.

For more information about the *Pedestrian Level of Service Model*, including the model form and the collected data items, please see Appendix B.

Potential Bicycling / Walking Activity and the *Latent Demand Method*

This criterion is a "demand-side" assessment of the relative amount of both potential bicycle and pedestrian travel along a road (or off-road) corridor. In other words, it is an estimate of the relative amount of bicycle and pedestrian activity that would occur along a corridor if facilities were constructed and conditions were excellent. The demand criterion and the *Bicycle LOS/Pedestrian LOS* criterion are complementary. When coupled, they provide a balanced picture of user need and perceived safety. For example, a particular corridor segment may have relatively poor walking conditions but relatively high pedestrian activity potential, perhaps because it is adjacent to an elementary school. Thus, the segment would rank high on the pedestrian priority needs list. Conversely, another segment may have relatively good cycling conditions but relatively low potential bicyclist activity levels (low demand). Therefore, the segment would likely rank low on the priority (improvement) needs list (with all other criteria being equal).

The process of identifying and quantifying potential bicycle and pedestrian trip activity is known as a travel demand analysis. To perform a travel demand analysis for the bicycle and pedestrian modes, a methodology must be employed that recognizes the unique impediments to that mode. Unlike automobile travel, bicycle trsvel and pedestrian travel often do not occur due to a number of impediments, one of which is relatively poor accommodation of bicyclists and pedestrians within the existing transportation network. This is generally the case throughout the Cobb County study network. Consequently, existing bicycle and pedestrian counts generally do not indicate the level of potential bicycle trip activity within a roadway network. Therefore, alternative or surrogate measures of assessing bicycle and pedestrian trip activity are needed.

There are four 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 or walking on the streets. A second method is to identify, map, and *evaluate key bicycle generators or attractors*. In practice, this method tends to focus on major bicycle and pedestrian trip attractors. The third method is the application of field calibrated predictive models that forecast actual user volumes. The final 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. Each of these methods, and their advantages and disadvantages, are described below.

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

Until recently, the evaluation of key bicycle trip generators and/or attractors 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 bicycle and pedestrian 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 bicycle and pedestrian trip attractors are represented. In fact, virtually every residence, every business, and every social and service establishment in a study area is a *key* bicycle and pedestrian trip generator and/or attractor. Thus this method, in practice, fails to account many bicycle and/or pedestrian trips in the study area.

The method's second shortcoming is directly related to the first. Since the method focuses on *key* attractors, only one end of the bicycle/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 bicycle/pedestrian trip activity (or interchange) between the attractor (park) and generator (population) would be low. Consequently, the method does not account for the bicycle/pedestrian trip interchange reality that exists *among* generators and attractors.

Field calibrated predictive models can be used to forecast the actual number of bicyclists and pedestrians that could be expected to use a particular roadway or trail corridor. These methods typically use built environment (land use, transportation facilities), trip (purpose, trip lengths), and/or demographic (populations density, socio-economic variables) characteristics to predict mode choice or recreational demand. The output of these models includes actual forecasted volumes of pedestrians and bicyclists on given corridors.

These predicitive models, while yielding an actual volume of forecasted users, are data collection intensive and are intended for use on a corridor – as opposed to a network level. To date their application on a system wide basis has been labor and/or cost prohibitive.

The method recommended for this Plan, which quantifies both ends of the bicycling and walking 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.

The *Latent Demand Method* is essentially a gravity model, based on a theory similar to that used in the prevailing four-step Urban Transportation Planning System-based travel demand models throughout the United States. The land uses considered in the *Latent Demand Method* are consistent with those that have been field validated with recent research into the predictive mode choice and recreational demand models. The Atlanta Regional Commission used this method in the development of their Bicycle Transportation & Pedestrian Walkways Plan. Appendix C outlines its theory and technical applications in a Geographic Information System (GIS) transportation planning environment.

Prioritization and the Benefit-Cost Index

Once all of the relevant data has been collected, the opportunity exists to create project prioritization lists for the Cobb County study network. The methodology that will be used to prioritize the respective networks is a benefit-cost index, an effective and easy-to-understand method for ranking potential bicycle and pedestrian projects. The benefit-cost index is based upon traditional benefit-cost ratios used in infrastructure planning and programming. It provides an indication of the relative value of improving a transportation facility with respect to other (candidate) transportation facilities.

As an example, the benefits of improving a particular on-road bicycle or pedestrian facility (improvement in level of service, facility demand, and public need based on the results of public input) can be compared against the per mile cost of the potential improvement. Other potential benefits that may be considered include contribution to congestion mitigation, connectivity to activity centers, and advancement of other County goals. After these benefits have been settled upon, we will consult with County staff and the Project Management Team to determine their respective weightings; an example of the resulting benefit-cost index is shown below. This is an important decision because it allows benefits viewed as being most important to more heavily influence the prioritization. Once this process has been carried out for all such facilities, an effective prioritization tool will exist for use by County staff and elected officials.

$$Benefit/Cost\_Index = \frac{XX\% \times \Delta LOS + YY\% \times Latent\_Demand\_Score + ZZ\% \times Other\_Measures}{Unit\_Facility\_Cost}$$

Where:

- ΔLOS = the change to be realized in the segment's Bicycle or Pedestrian Level of Service Score by the implementation of the proposed improvement.
- Latent_Demand_Score = The segment's score from the Latent Demand Method
- Other_Measures = Discretionary values decided by the Project Management Team.
- Unit_Facility_Cost = the per mile cost of the proposed improvement

APPENDIX A:

The Bicycle Level of Service Model

The statistically-calibrated mathematical equation entitled the *Bicycle Level of Service*[1] *Model (Version 2.0)* was used as the foundation of the evaluation. This *Model* is the most accurate method of evaluating the bicycling conditions of shared roadway environments. It uses the same measurable traffic and roadway factors that transportation planners and engineers use for other travel modes. With statistical precision, the *Model* clearly reflects the effect on bicycling suitability or "compatibility" due to factors such as roadway width, bike lane widths and striping combinations, traffic volume, pavement surface conditions, motor vehicles speed and type, and on-street parking.

The *Bicycle LOS Model* is based on the proven research documented in *Transportation Research Record 1578* published by the Transportation Research Board of the National Academy of Sciences. It was developed with a background of over 100,000 miles of evaluated urban, suburban, and rural roads and streets across North America. It has been adopted by the Florida Department of Transportation as the recommended standard methodology for determining existing and anticipated bicycling conditions throughout Florida. Many urbanized area planning agencies and state highway departments are using this established method of evaluating their roadway networks. These include metropolitan areas

[1] Landis, Bruce W. "Real-Time Human Perceptions: Toward a Bicycle Level of Service" *Transportation Research Record 1578*, Transportation Research Board, Washington DC 1997 (see Appendix A).

across North America such as Atlanta GA, Baltimore MD, Birmingham AL, Philadelphia PA, San Antonio TX, Houston TX, Buffalo NY, Anchorage AK, Lexington KY, and Tampa FL as well as state departments of transportation such as, Delaware Department of Transportation (DelDOT), New York State Department of Transportation (NYDOT), Maine Department of Transportation (MeDOT) and others.

Widespread application of the original form of the *Bicycle LOS Model* has provided several refinements. Application of the *Bicycle LOS Model* in the metropolitan area of Philadelphia resulted in the final definition of the three effective width cases for evaluating roadways with on-street parking. Application of the *Bicycle LOS Model* in the rural areas surrounding the greater Buffalo region resulted in refinements to the "low traffic volume roadway width adjustment". A 1997 statistical enhancement to the *Model* (during statewide application in Delaware) resulted in better quantification of the effects of high-speed truck traffic [see the $SP_t(1+10.38HV)^2$ term]. As a result, *Version 2.0* has the highest correlation coefficient ($R^2 = 0.77$) of any form of the *Bicycle LOS Model*.

Version 2.0 of the *Bicycle LOS Model* will employed to evaluate the roads and streets within Cobb County. Its form is shown below:

$$\text{Bicycle LOS} = a_1 \ln(Vol_{15}/L_n) + a_2 SP_t(1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4 (W_e)^2 + C$$

Where:

Vol_{15} = Volume of directional traffic in 15 minute time period

$$Vol_{15} = (ADT \times D \times K_d) / (4 \times PHF)$$

where:

ADT = Average Daily Traffic on the segment or link
D = Directional Factor
K_d = Peak to Daily Factor

PHF = Peak Hour Factor

L_n = Total number of directional *through* lanes
SP_t = Effective speed limit

SP_t = 1.1199 ln(SP_p - 20) + 0.8103

where:
SP_p = Posted speed limit (a surrogate for average running speed)

HV = percentage of heavy vehicles (as defined in the 1994 Highway Capacity Manual)
PR_5 = FHWA's five point pavement surface condition rating
W_e = Average effective width of outside through lane:

where:
$W_e = W_v$ - (10 ft x % OSPA) and $W_l = 0$
$W_e = W_v + W_l$ (1 - 2 x % OSPA) and $W_l > 0$ & $W_{ps} = 0$

$W_e = W_v + W_l$ - 2 (10 x % OSPA) and $W_l > 0$ & $W_{ps} > 0$ and a bikelane exists

where:
W_t = total width of outside lane (and shoulder) pavement
OSPA = percentage of segment with occupied on-street parking
W_l = width of paving between the outside lane stripe and the edge of pavement
W_{ps} = width of pavement striped for on-street parking
W_v = Effective width as a function of traffic volume

and:
$W_v = W_t$ if ADT > 4,000veh/day
$W_v = W_t$(2-0.00025 x ADT) if ADT ≤ 4,000veh/day, and if the street/road is undivided and unstriped

a_1: 0.507 a_2: 0.199 a_3: 7.066 a_4: - 0.005 C: 0.760

(a_1 - a_4) are coefficients established by multi-variate regression analysis.

The *Bicycle LOS* score resulting from the final equation is stratified into service categories "A, B, C, D, E, and F" (according to the ranges shown in Table 1) to reflect users' perception of the road segment's level of service for bicycle travel.

TABLE 1 Bicycle Level-of-Service Categories

LEVEL-OF-SERVICE	BLOS SCORE
A	$\leq$ 1.5
B	$>$ 1.5 and $\leq$ 2.5
C	$>$ 2.5 and $\leq$ 3.5
D	$>$ 3.5 and $\leq$ 4.5
E	$>$ 4.5 and $\leq$ 5.5
F	$>$ 5.5

This stratification is in accordance with the linear scale established during the referenced research (i.e., the research project bicycle participants' aggregate response to roadway and traffic stimuli). The *Model* is particularly responsive to the factors that are statistically significant. An example of its sensitivity to various roadway and traffic conditions is shown in Figure 1.

$$\text{Bicycle LOS} = a_1 \ln(Vol_{15}/L_n) + a_2 SP_t(1+10.38HV)^2 + a_3(1/PR_5)^2 + a_4(W_e)^2 + C$$

a_1: 0.507 a_2: 0.199 a_3: 7.066 a_4: -0.005

C: 0.760

Baseline inputs:

ADT = 12,000 vpd % HV = 1 L = 2 lanes
SP_p = 40 mph W_e = 12 ft PR_5 = 4 (good pavement)

	BLOS	% Change
Baseline Bicycle LOS Score	3.98	N/A

Lane Width and Lane striping changes (T-statistic = 9.844)

W_t	=	10 ft	4.20	6% increase
W_t	=	11 ft	4.09	3% increase
W_t	=	12 ft - - (baseline average) - - - - - - - -	3.98	- - - - no change
W_t	=	13 ft	3.85	3% reduction
W_t	=	14 ft	3.72	7% reduction
W_t	=	15 ft (W_l = 3 ft)	3.57 (3.08)	10%(23%) reduction
W_t	=	16 ft (W_l = 4 ft)	3.42 (2.70)	14%(32%) reduction
W_t	=	17 ft (W_l = 5 ft)	3.25 (2.28)	18%(43%) reduction

Traffic Volume (ADT) variations (T-statistic = 5.689)

ADT	=	1,000	Very Low	2.75	31% decrease
ADT	=	5,000	Low	3.54	11% decrease
ADT	=	12,000	Average - - (baseline average) - -	3.98	- - - - - - no change
ADT	=	15,000	High	4.09	3% increase
ADT	=	25,000	Very High	4.35	9% increase

Pavement Surface conditions (T-statistic = 4.902)

PR_5	=	2	Poor	5.30	33% increase
PR_5	=	3	Fair	4.32	9% reduction
PR_5	=	4 - -	Good - (baseline average) - - - -	3.98	- - - - no change
PR_5	=	5	Very Good	3.82	4% reduction

Heavy Vehicles in percentages (Combined speed and heavy vehicles T-statistic = 3.844)

HV	=	0	No Volume	3.80	5% decrease
HV	=	1 - - -	Very Low - (baseline average) - -	3.98	- - - - - - no change
HV	=	2	Low	4.18	5% increase
HV	=	5	Moderate	4.88	23% increase[a]
HV	=	10	High	6.42	61% increase[a]
HV	=	15	Very High	8.39	111% increase[a]

[a]Outside the variable's range (see Reference *(1)*)

Figure 1: Bicycle LOS Model Sensitivity Analysis

Data Collection / Inventory Guidelines for Future Updates

Following is the list of data required for computation of the *Bicycle LOS* scores as well as the associated guidelines for their collection and compilation into the programmed database.

Average Daily Traffic (ADT)

ADT is the average daily traffic volume on the segment or link. The programmed database will convert these volumes to Vol_{15} (volume of directional traffic every fifteen minutes) using the Directional Factor (D), Peak to Daily Factor (K_d) and Peak Hour Factor (PHF) for the road segment.

Percent Heavy Vehicles (HV)

Percent HV is the percentage of heavy vehicles (as defined in the *2000 Highway Capacity Manual*).

Number of lanes of traffic (L)

L reflects the total number of *through* traffic lanes of the road segment and its configuration. (e.g., D = Divided, U = Undivided, OW = One-Way, S = Center Turning Lane). The programmed database will convert these lanes into directional lanes. The presence of continuous right-turn lanes should be noted in the comments field. In the other direction it will be noted in the comments if there is a different number of through lanes.

Posted Speed Limit (S_p)

S_p is recorded as posted.

W_t total width of pavement

W_t is measured from the center of the road, yellow stripe, or (in the case of a multilane configuration) the lane separation striping to the edge of pavement or to the gutter pan of the curb. When there is angled parking adjacent to the outside lane, W_t is measured to the traffic-side end of the parking stall stripes.

Width of pavement is the pavement striped for on-street parking (W_{ps})

W_{ps} is recorded only if there is parking to the right of a striped bike lane. If there is parking on two sides on a one-way, single lane street, W_{ps} is reported as the combined width of the striped parking.

Width of paving between the outside lane stripe and the edge of pavement (W_l)

W_l is measured from the outside lane stripe to the edge of pavement or to the gutter pan of the curb. When there is angled parking adjacent to the outside lane, W_l is measured from the outside lane stripe to the traffic-side end of the parking stall stripes.

OSPA %

OSPA% is the estimated percentage of the segment (excluding driveways) along which there is occupied on-street parking at the time of survey. Record each side separately. If the parking is allowed only during off-peak periods and parking restrictions change widths and laneage, indicate the geometric changes in the comments field. Note: Indicate any “angled parking” in the comments field.

Pavement Condition (PC)

PC is the pavement condition of the motor vehicle travel lane according to the FHWA’s five-point pavement surface condition rating shown below in Figure 2.

Designated Bike Lane

A “Y” is coded if there is a bike lane on the segment, otherwise “N” is entered.

Comments

If there is any noticeable difference in the above parameters between two directions (north/south or east/west) on a roadway segment, the data will be recorded for the other direction in the comments field along with the direction. All special conditions and assumptions made during the data collection on the segment will be reported in the comments field.

RATING	PAVEMENT CONDITION
5.0 (Very Good)	Only new or nearly new pavements are likely to be smooth enough and free of cracks and patches to qualify for this category.
4.0 (Good)	Pavement, although not as smooth as described above, gives a first class ride and exhibits signs of surface deterioration
3.0 (Fair)	Riding qualities are noticeably inferior to those above; may be barely tolerable for high-speed traffic. Defects may include rutting, map cracking, and extensive patching.
2.0 (Poor)	Pavements have deteriorated to such an extent that they affect the speed of free-flow traffic. Flexible pavement has distress over 50 percent or more of the surface. Rigid pavement distress includes joint spalling, patching, etc.
1.0 (Very Poor)	Pavements that are in an extremely deteriorated condition. Distress occurs over 75 percent or more of the surface.

Source: U.S. Department of Transportation. Highway Performance Monitoring System-Field Manual. Federal Highway Administration. Washington, DC, 1987.

Figure 2: Pavement Condition Description

Appendix B:

The Pedestrian Level of Service Model

Similar to the evaluation procedure used for the bicycle mode, this is an evaluation of pedestrians' perceived safety with respect to motor vehicle traffic. It identifies the quality of service for pedestrians that currently exists within the roadway environment. This section of the report documents the methodology that will be employed by *Sprinkle Consulting, Inc.* to evaluate the walking conditions, or "level of service" that currently exists on the roadway segments within Cobb County. This section documents the additional data requirements, data collection and compilation guidelines (other than the items listed in the bicycle portion) and results of the evaluation.

The *Pedestrian Level of Service (Pedestrian LOS) Model Version 2.0* was used for the evaluation of walking conditions. This model is the most accurate method of evaluating the walking conditions within shared roadway environments. It uses the same measurable traffic and roadway factors that transportation planners and engineer's use for other travel modes. With statistical precision, the *Model* clearly reflects the effect on walking suitability or "compatibility" due to factors such as roadway width, presence of sidewalks and intervening buffers, barriers within those buffers, traffic volume, motor vehicles speed, and on-street parking. The form of the *Pedestrian Level of Service Model*, and the definition of its terms are as follows:

$$\text{Ped LOS} = -1.2276 \ln (W_{ol} + W_l + f_p \times \%OSP + f_b \times W_b + f_{sw} \times W_s)$$

$$+ 0.0091 (Vol_{15}/L) + 0.0004\ SPD^2 + 6.0468$$

Where:

W_{ol} = Width of outside lane (feet)

W_l = Width of shoulder or bike lane (feet)

f_p = On-street parking effect coefficient (=0.20)

%OSP = Percent of segment with on-street parking

f_b = Buffer area barrier coefficient (=5.37 for trees spaced 20 feet on center)

W_b = Buffer width (distance between edge of pavement and sidewalk, feet)

f_{sw} = Sidewalk presence coefficient = $6 – 0.3W_s$ (3)

W_s = Width of sidewalk (feet)

Vol_{15} = average traffic during a fifteen (15) minute period

L = total number of (through) lanes (for road or street)

SPD = Average running speed of motor vehicle traffic (mi/hr)

The Pedestrian LOS score resulting from the final equation is pre-stratified into service categories "A, B, C, D, E, and F", according to the ranges shown in Figure 2-5 and reflect users' perception of the road segments level of service for pedestrian travel. This stratification is in accordance with the linear scale established during the research (i.e., the research project participants' aggregate response to roadway and traffic stimuli).

Figure 2-5: Pedestrian Level-of-Service Categories

LEVEL-OF-SERVICE	Pedestrian LOS 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

The Pedestrian LOS Model is used by planners and engineers throughout the US in a variety of planning and design applications. The Pedestrian LOS Model *can be used to conduct a benefits comparison among proposed sidewalk/roadway cross-sections, identify roadways that are candidates for reconfiguration for sidewalk improvements, and to prioritize and program roadways for sidewalk improvements.*

Additional Data Collection and Inventory Guidelines

Following is the additional list of data used in the computation of the Pedestrian Level of Service scores. Also described are the associated guidelines for their collection and compilation into the database.

Width of Buffer (W_b)

W_S is the width of a grass buffer. The width of the buffer is measured from the edge of pavement (including the width of the curb if present) to the beginning edge of the sidewalk. If a sidewalk has trees planted in it, then the horizontal width of the sidewalk occupied by the trees is collected.

Width of Sidewalk (W_s)

W_S is the width of the sidewalk, measured from either the edge of pavement (including the curb) if a grass buffer is not present. If a grass buffer is present, the width is measured from the edge of the buffer to the backside of the sidewalk.

Sidewalk Percentage

Sidewalk Percentage is the percentage of sidewalk coverage (estimated in increments of 25%) of the segment that is to be collected directionally.

Tree Spacing in Buffer

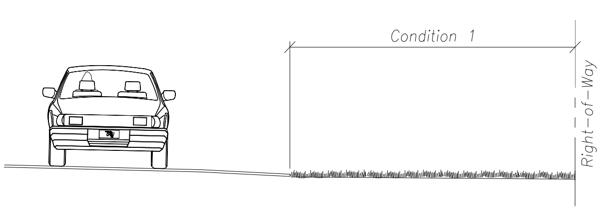
Tree spacing is the spacing of trees within a buffer, measured from the center (width of spacing between trees). Trees can either be in a grass buffer or in a sidewalk.

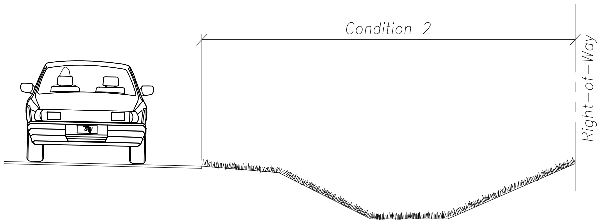
Cross-section

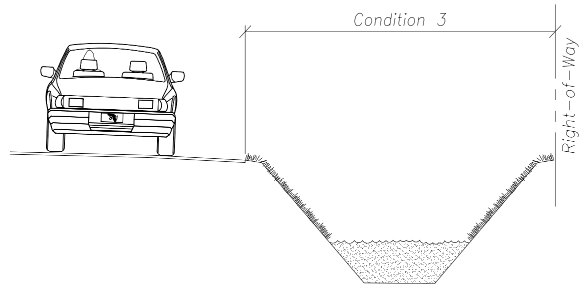
Cross-section indicates whether there is a curb and gutter ("C") or an open shoulder ("S"). Any ditches or swales adjacent to the edge of pavement of the segment are indicated in the comments field.

Roadside Profile Condition

Roadside profile condition is collected to assist in determining the lateral area available for bicycle lane or paved shoulder and sidewalk construction. It is the area between the outside edge of the pavement and the right-of-way line. The profile condition will assist in determining the type of facility, hence its cost [i.e., bicycle lane or paved shoulder or bike path]. Roadside profiles were classified as one of the three types illustrated below. Condition 1, buildable shoulder is defined as an area adjoining the edge of pavement with a minimum width of seven feet and a maximum cross-slope of 6%. Condition 2 is a swale. Condition 3 is a ditch or canal.







Appendix C:

The Latent Demand Method

Methods of Assessing Bicycle Trip Activity

There are three primary methods of assessing bicycle trip activity. The first method is documenting *revealed demand*. This is accomplished by simply counting the existing number of people bicycling on the streets. A second method is to identify, map, and *evaluate key bicycle generators or attractors*. In practice, this method tends to focus on major bicycle 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 activity. It also enables planners and engineers to anticipate and plan for future bicycle 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 on the roadways. Its usefulness is limited to areas that already have an extensive bicycle network that provides an overall high-quality bicycling environment. This method is not usable for the vast majority of U.S. metro area transportation networks, due to their generally poor bicycle accommodation.

Evaluation of Key Bicycle Trip Generators and/or Attractors

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

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

attractors are represented. In fact, virtually every residence, every business, and every social and service establishment in a study area is a *key* bicycle 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 bicycle 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 trip activity (or interchange) between the attractor (park) and generator (population) would be low. Consequently, the method does not account for the bicycle trip interchange reality that exists *among* generators and attractors throughout the Region.

Latent Demand

The method that quantifies both ends of the bicycling 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 Atlanta (GA), Baltimore (MD), Birmingham (AL), Philadelphia (PA), Tallahassee (FL), Tampa (FL), Phoenix (AZ), and Vero Beach & St. Lucie (FL), and Westchester, Rockland & Putnam Cos. (NY).

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 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.

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

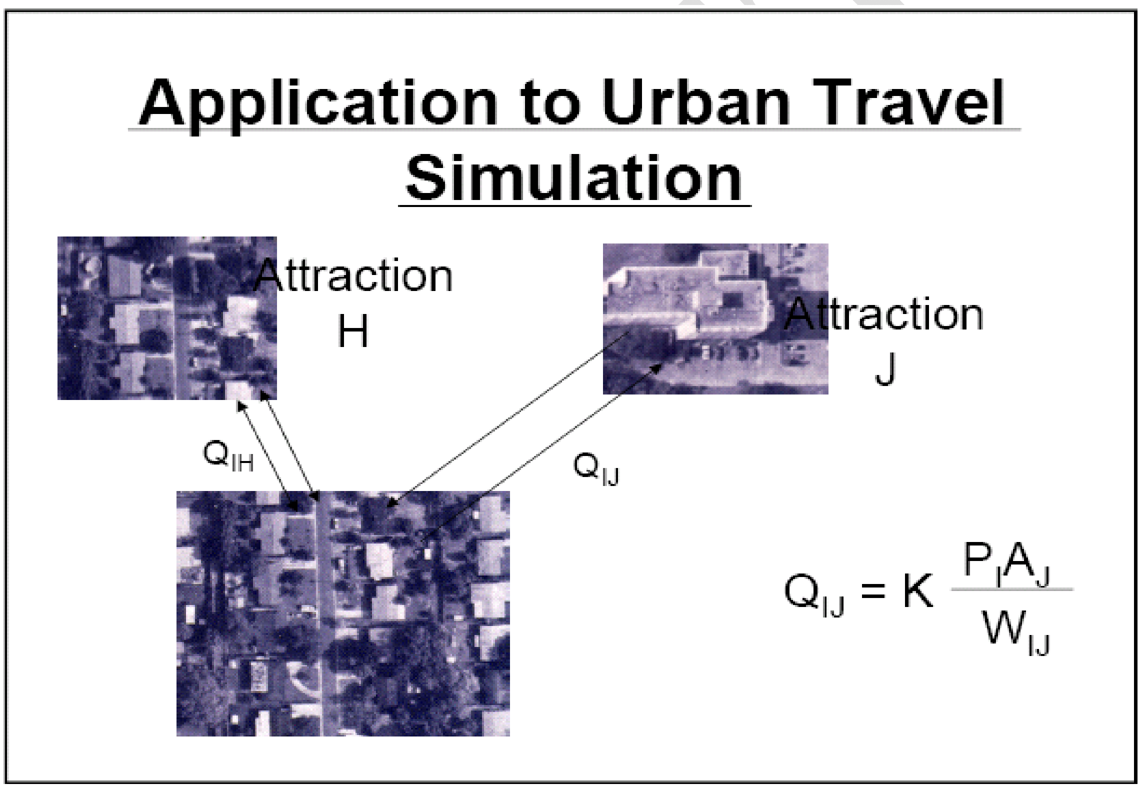


Figure 1 Newton's gravity model as applied to trip interchange.

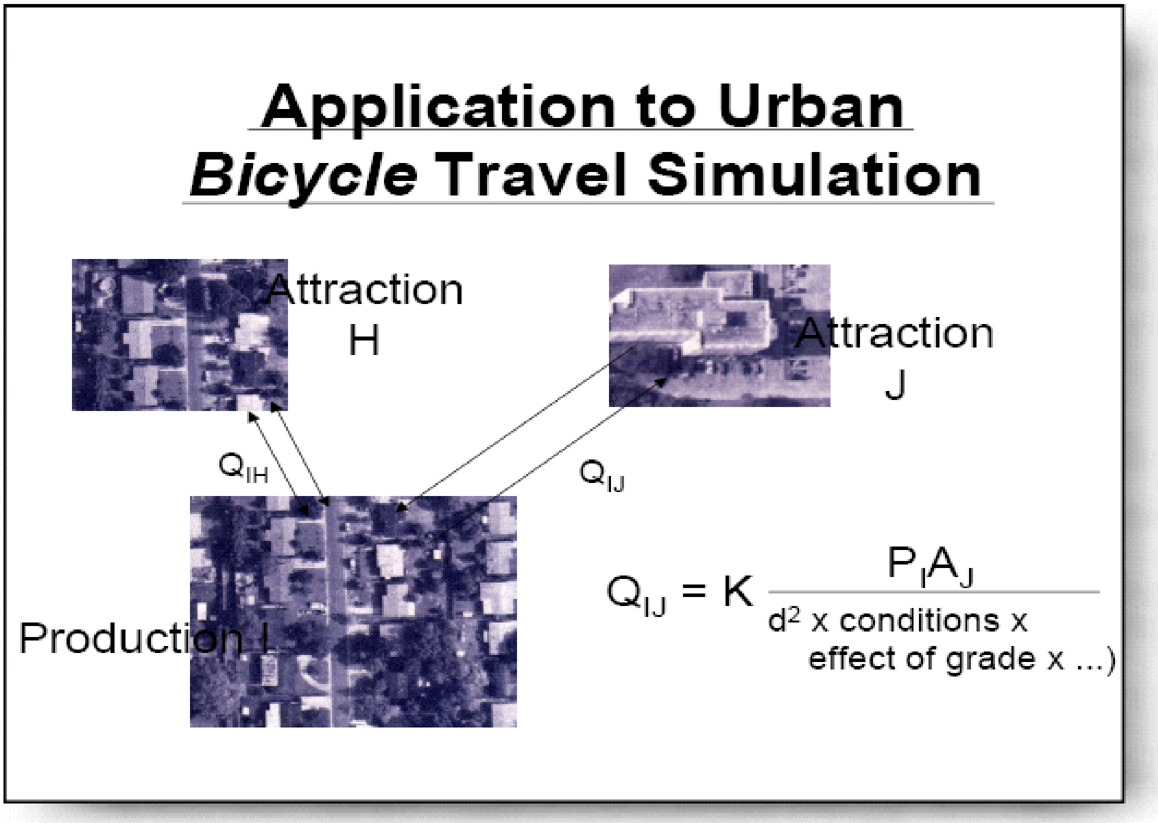


Figure 2 Bicycling trip interchange relationship.

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 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 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 trip occurring. One of the

Figure 3 Roadway conditions have a large effect on bicycling.

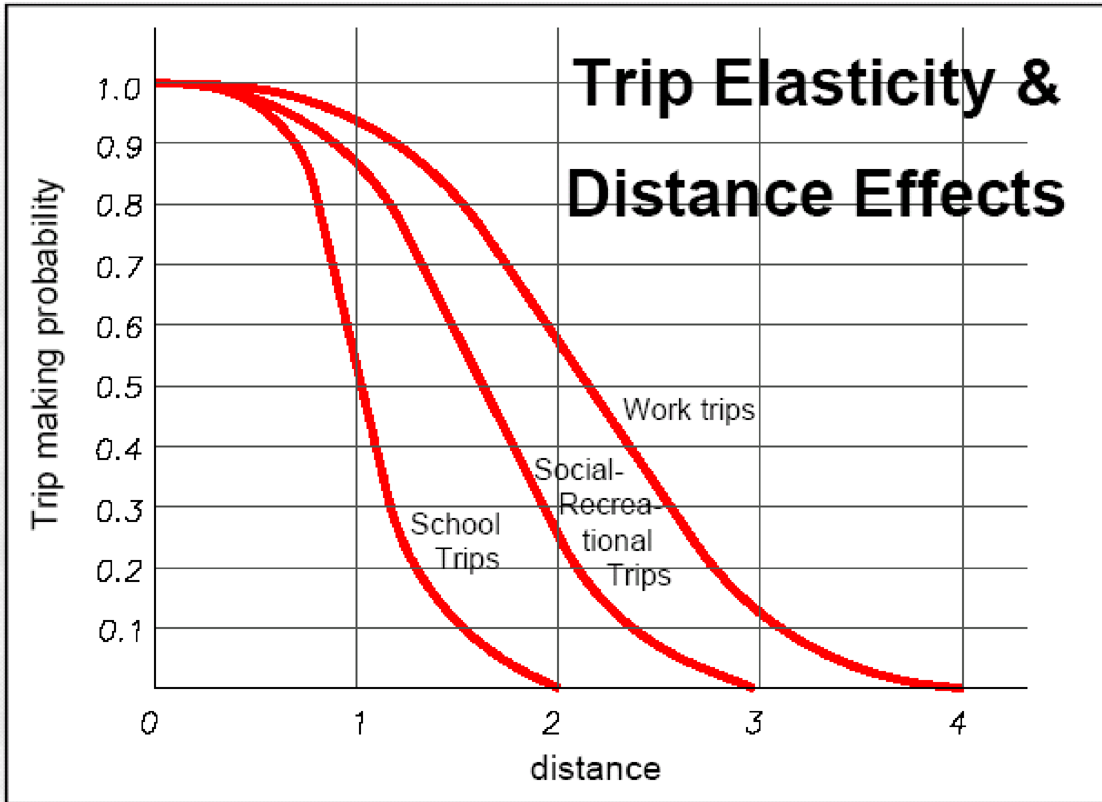


Figure 4 Typical trip making probability (impedance effects) due to distance.

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 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 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.

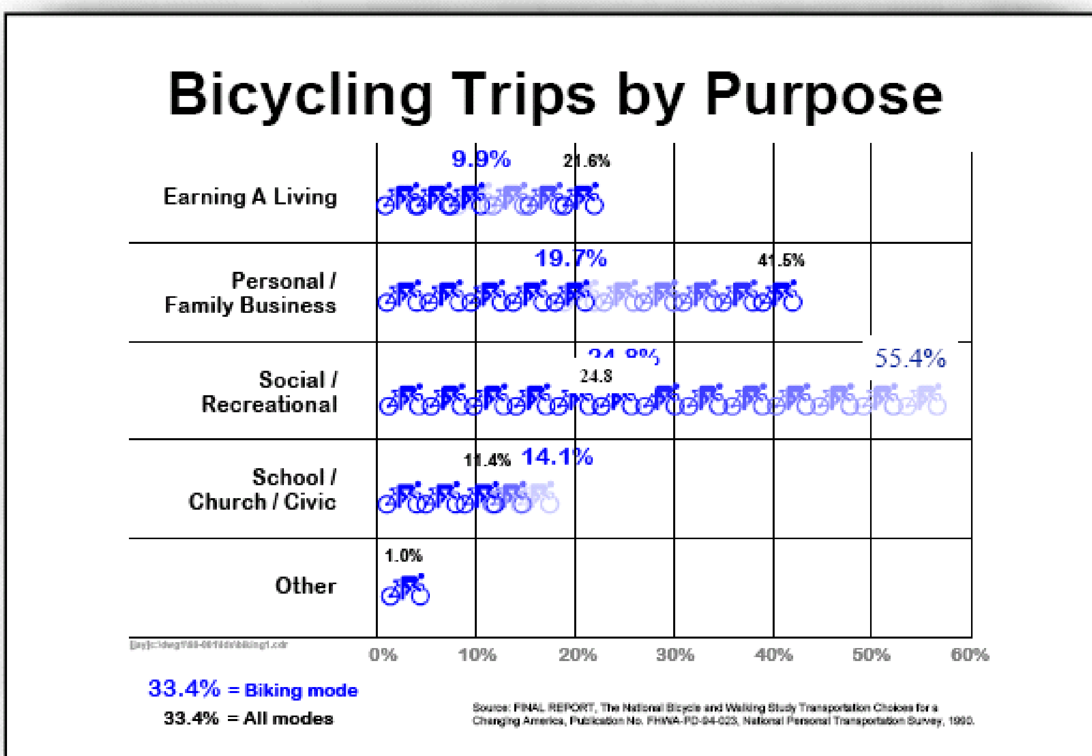


Figure 5 Bicycling Trips by Purpose.

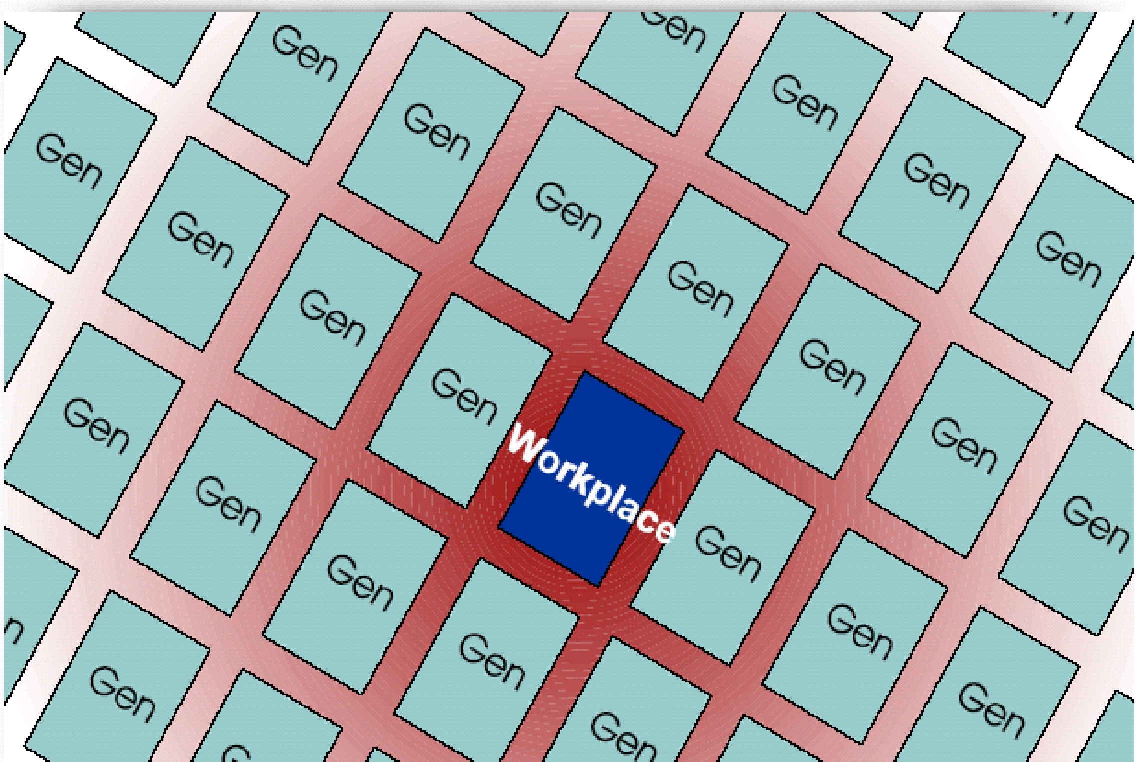


Figure 6 Potential trip activity around a work trip attractor.

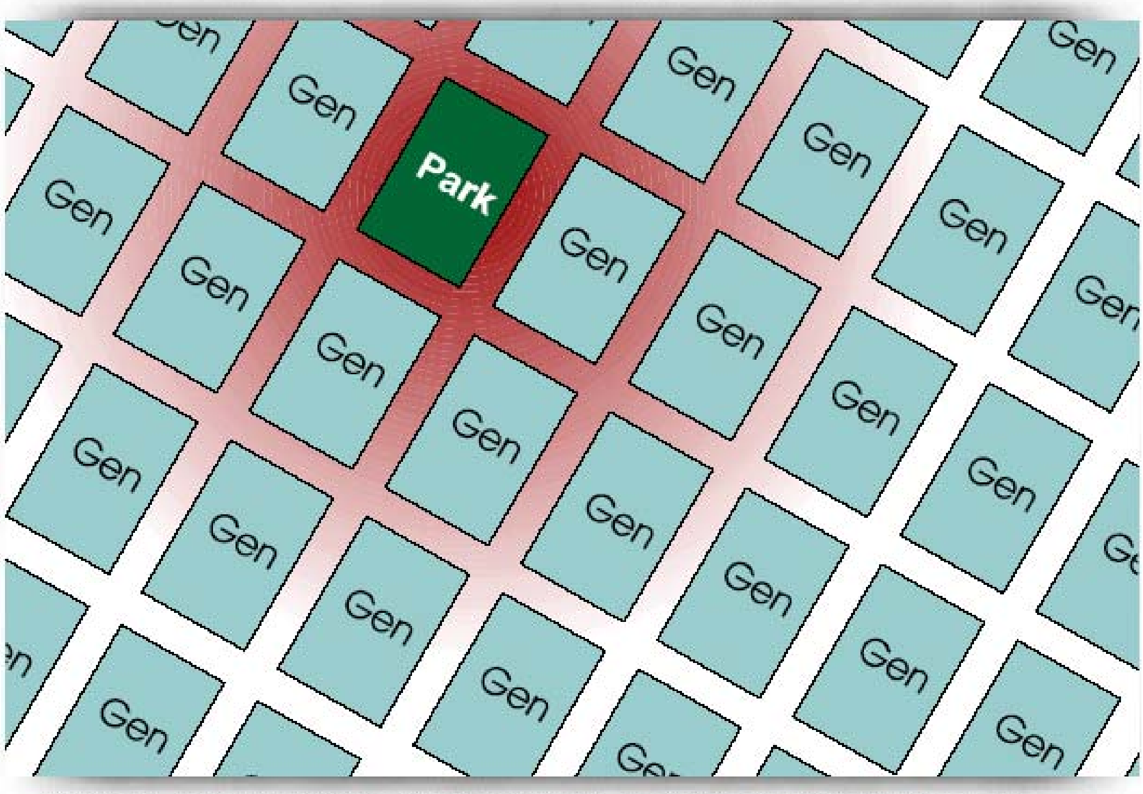


Figure 7 Potential trip activity around a social/recreational attractor.

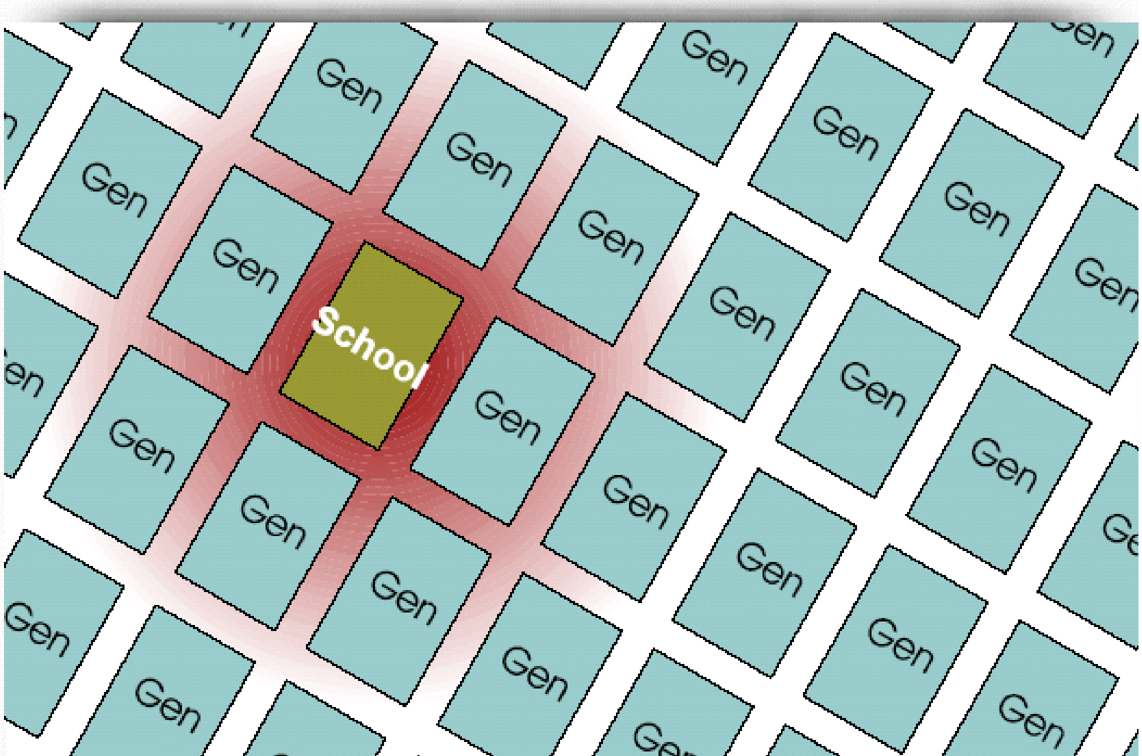


Figure 8 Potential trip activity around a school.

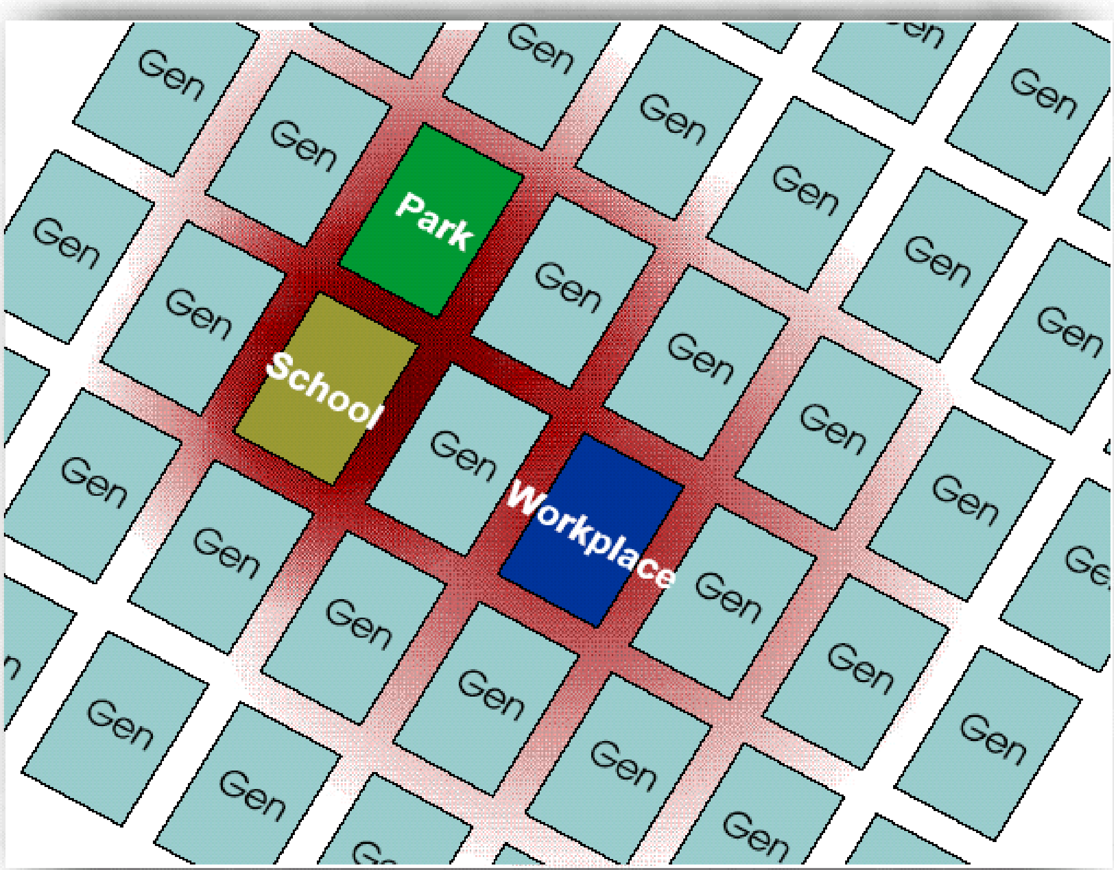


Figure 9 Composite of potential trip activity for three types of trip attractors.

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

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 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

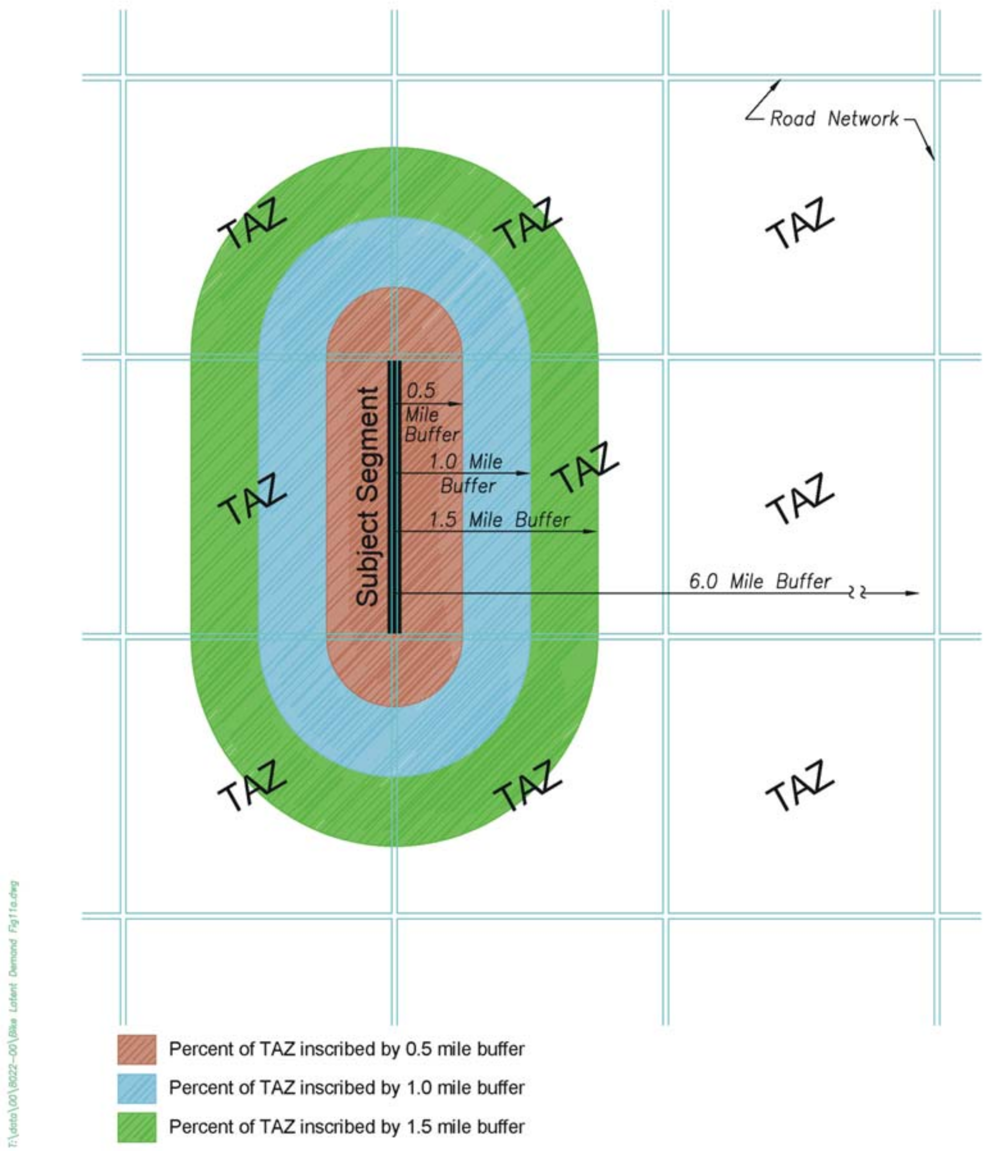
Restriction:

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

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

Figure 11a

Work Trip Spatial Queries (Segment-Based)



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.

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

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.

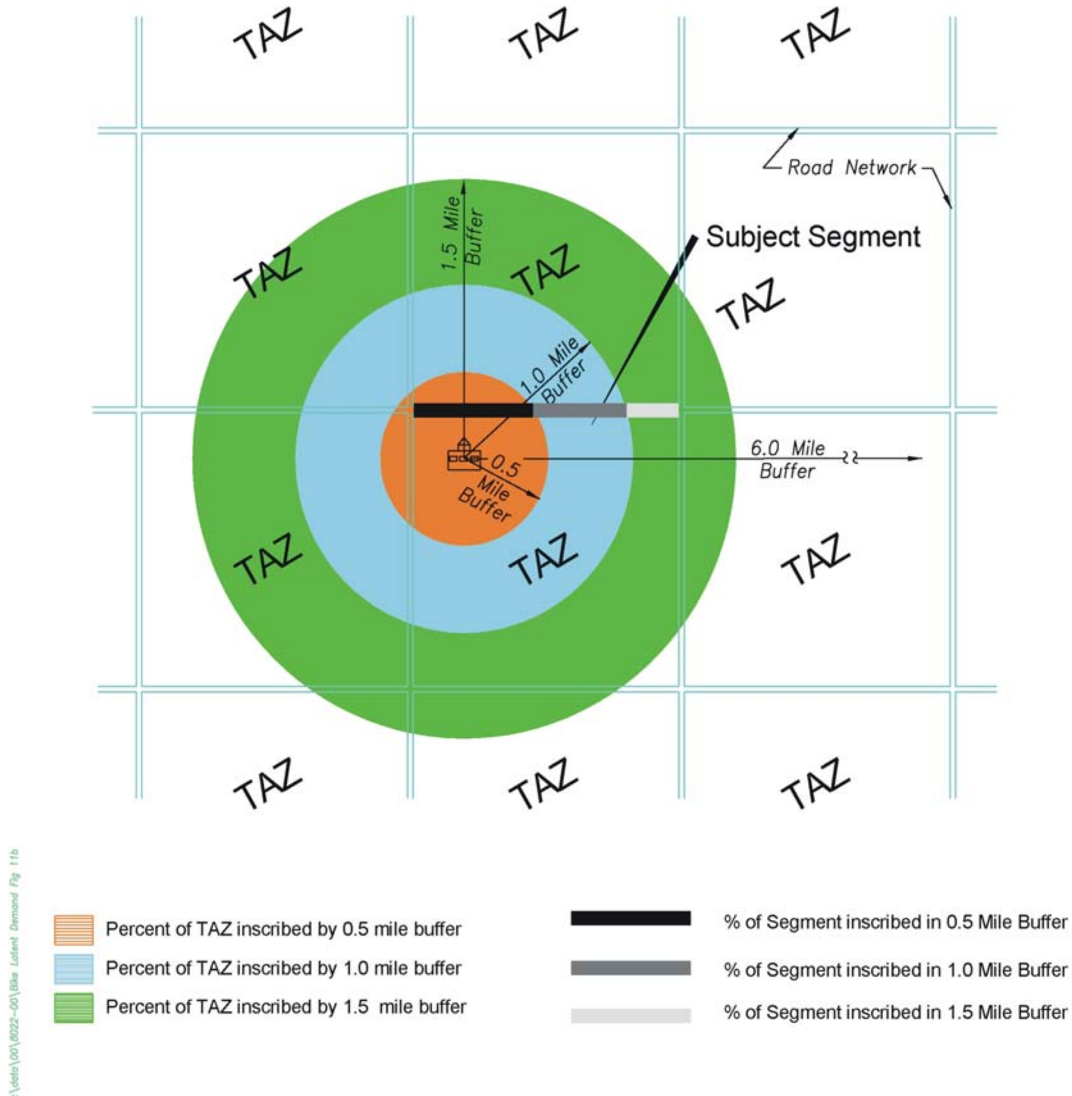
Equation 3 is the mathematical expression that quantifies these two categories of shopping and errand trips.

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

Where:

Figure 11b

Spatial Queries for Colleges and Universities (Attractor-Based)



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.

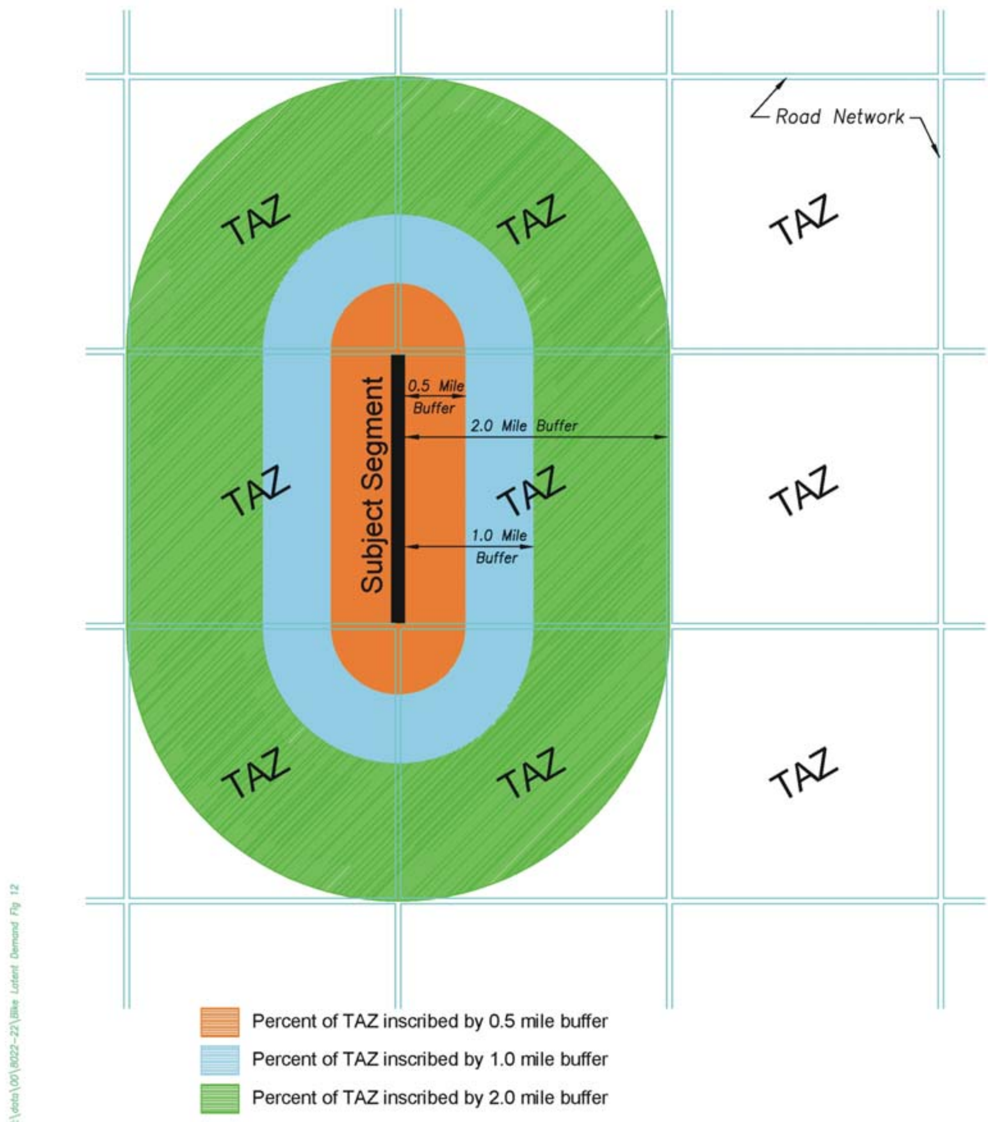
School (Sc) Trips The locations of elementary, middle and high schools are the attractors for this trip type. Since students living within a two-mile radius of a school are generally not eligible to use the school transportation system, they are considered potential bicyclists. This two-mile radius constitutes 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.

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

Where:

Figure 12

Spatial Queries for Shopping and Errands (Segment-Based)



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.

Recreational and Social (RS) Trips Public parks 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

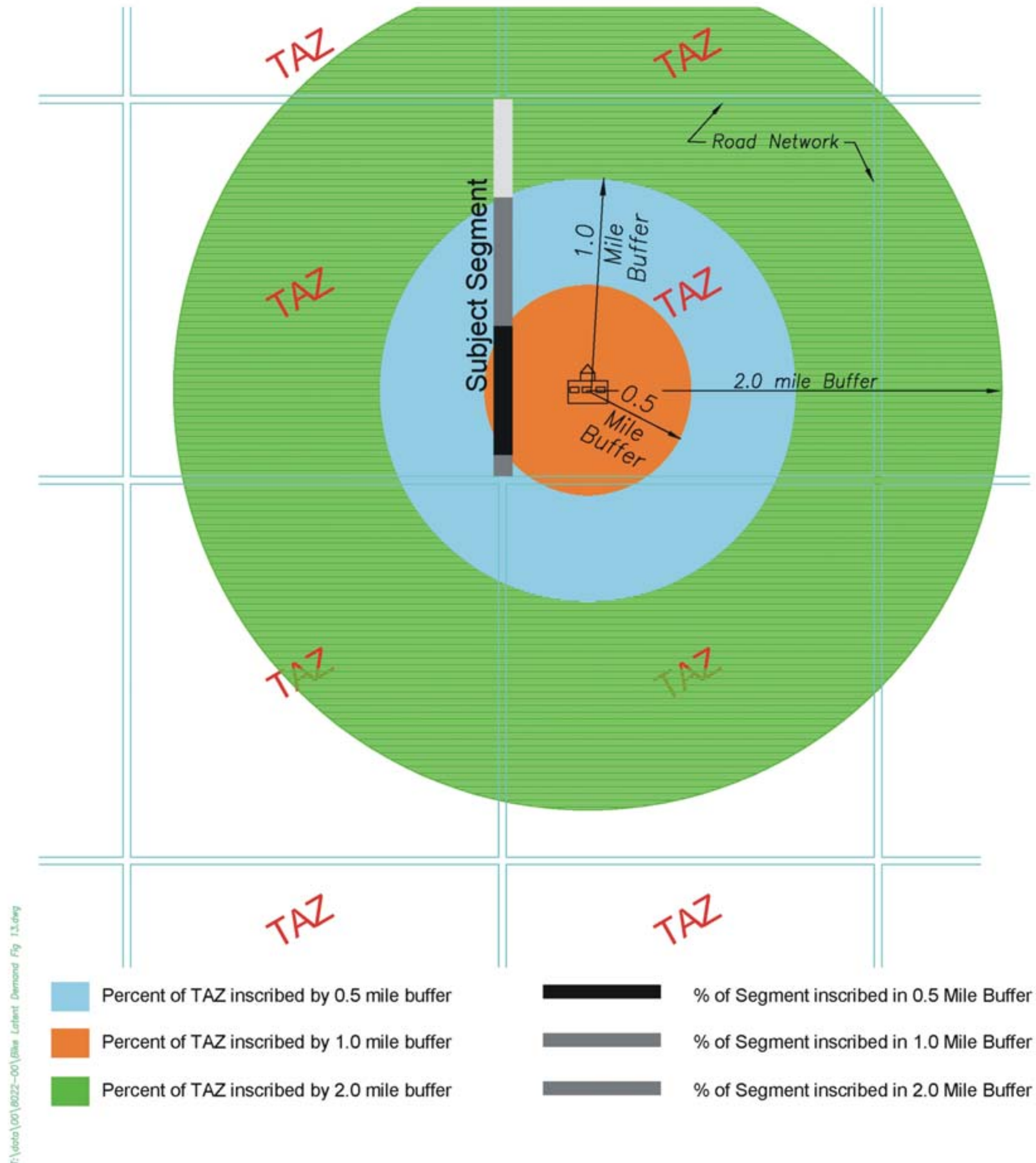
P = Effect of travel distance on trip interchange, expressed as a probability (see Figure 5)

T_t = Total number of park trips (or Q_{parks}) + total number of urban trail trips (or Q_{trails})

r= Population within buffer

Figure 13

Spatial Queries for School Trips (Attractor-Based)



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 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.

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 2.99 trips per acre by the average major park size.]
- Staffed Parks – these typically have intermittently programmed events and staffed events. Trip generation is calculated by multiplying the trip generation rate of 19.17 trips per acre by the average major park 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 2.26 trips per acre by the average major park 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.

As previously described, quantification of the travel demand associated with trails is 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 the same figure as for a staffed park.

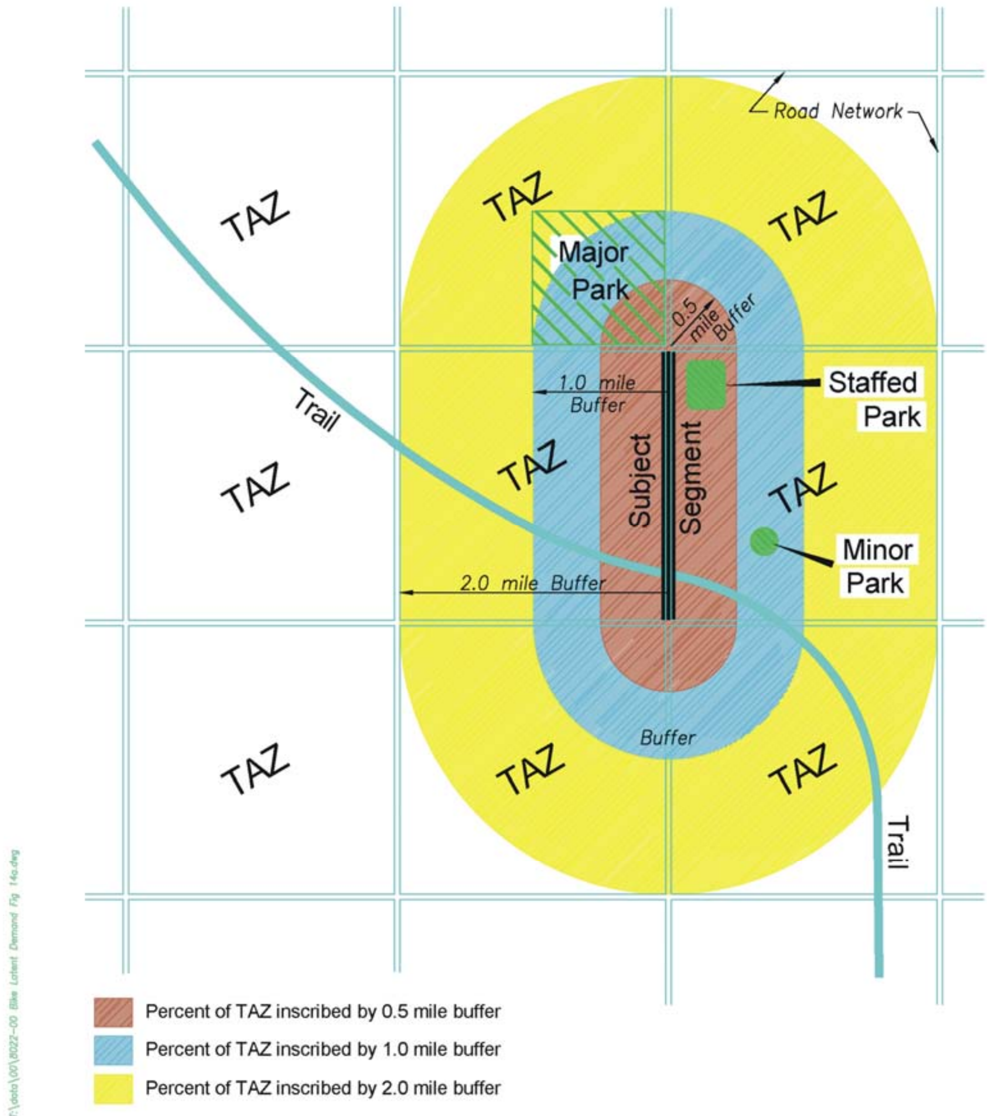
Equation (5b) represents the calculation of potential trip activity for trails:

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

Where:

Figure 14a

Spatial Queries for Parks (Segment-Based)



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.

In addition to being recreational facilities, urban trails are also transportation facilities. The generator for this trail *transportation* trip is similar to the road network which includes population, employment, school locations, and transit routes. The attractor for trail *transportation* trips is the trail itself. Spatial queries are performed similar to those for trails (as depicted in Figure 14b), *except that the subject segment is the trail*.

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:

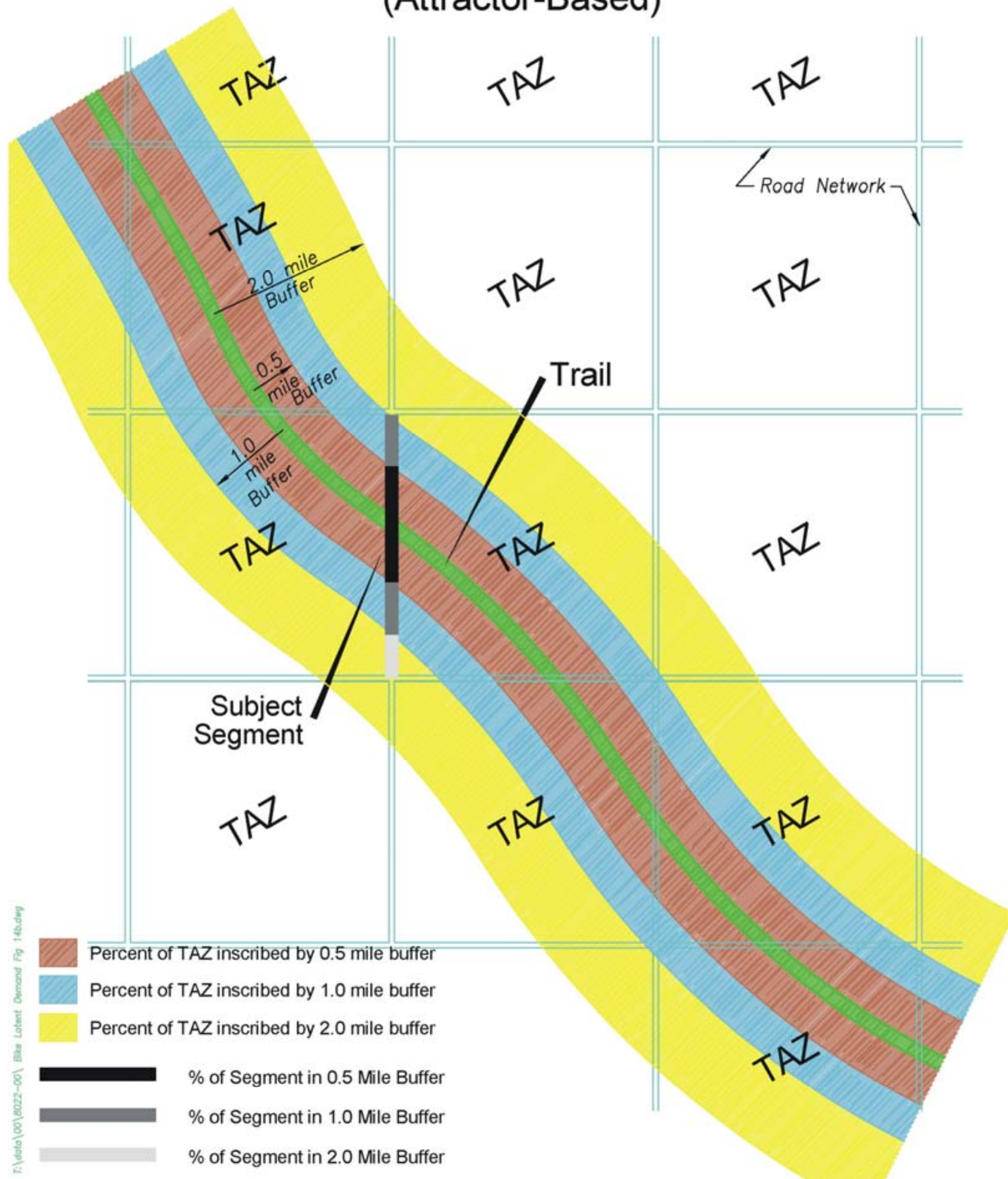
R = Transit route

n = Total number of transit routes

T = number of bus/transit trips

Figure 14b

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



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 computations calculating the final 100% *Latent Demand* score for each network study segment:

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

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