

REFINEMENT OF THE ROADWAY SEGMENT LEVEL OF SERVICE

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

BACKGROUND

This research was comprised of two components that were conducted separately by researchers with Sprinkle Consulting, Inc. and the Department of Urban and Regional Planning at the University of Florida. The research team from the University of Florida also conducted two meetings with three external reviewers, Richard Dowling of Dowling Associates, Inc. in Oakland, California, Mark Virkler of the Department of Civil and Environmental Engineering at the University of Missouri-Columbia and Elena Prassas of the Department of Civil and Environmental Engineering at Polytechnic University in Brooklyn.² The first meeting was conducted in January 2002 during the Annual Meeting of the Transportation Research Board (TRB) in Washington, D.C. and the second meeting was conducted at the Summer Meeting of the TRB Highway Capacity Committee in Milwaukee, Wisconsin in June 2002.

The report is comprised of two loosely connection sections, the report of research findings, which was prepared by Sprinkle Consulting, Inc., and a brief review of literature, which was prepared by researchers at the University of Florida. The text of each of these sections remains as originally prepared with comments from the reviewers incorporated in an *Evaluation* section between them.

Objective of Research

During the development of the Florida Department of Transportation's (FDOT's) original *Pedestrian Level of Service (LOS) Model*³, it was observed that a few unevaluated factors within the roadside environment appeared to have an influence in the participants' responses. Specifically, responses seemed to be affected by the presence of other people within the sidewalk or roadside environment and the presence of structures and buildings proximate to the right-of-way. Thus, the primary objective of this current research was to investigate the expansion of the *Pedestrian LOS Model* to include the effects of these factors. A second objective of this research was to establish the foundation for a preliminary approach to integrating the pedestrian level of service methodology as outlined in the Highway Capacity Manual (Fruin methodology) with FDOT's current roadway segment pedestrian LOS methodology.

Hypotheses

Based on the observations noted above, the research team developed two hypotheses to be evaluated as part of this research. Hypothesis 1: Within some ranges of pedestrian volumes, the presence of other pedestrians would positively influence the respondents' perception of roadside conditions. Hypothesis 2: In situations where pedestrian volumes are low, the presence of buildings immediately adjacent to the street right-of-way, especially tall buildings, would negatively affect pedestrians' perception of roadside conditions.

² All reviewers attended these meeting and sent written comments via e-mail, as necessary. Dr. Prassas did not attend the second review meeting in Milwaukee due to a family emergency.

³ Landis, B.W., Vattikuti, V.R., Ottenberg, R.M., McLeod, D.S., and Guttenplan, M. Modeling The Roadside Walking Environment: Pedestrian Level Of Service. In *Transportation Research Record 1773*, TRB, National Research Council, Washington, D.C., 2001, pp. 82-88.

RESEARCH METHODOLOGY

This research used the pedestrian response database from the original “Walk for Science 2000” course in Pensacola, Florida. However, to evaluate these new hypotheses, additional data were necessary. On Saturday March 23, 2002, approximately two years to the day following the Walk for Science event, pedestrian volume and traffic counts were collected along the original course. The research team collected pedestrian count information in 15-minute intervals for a four-hour period beginning at 8:00 AM. In addition, the team estimated average building height and average building setback along each course segment.

Using the original pedestrian response data and the new pedestrian volume segment information, the team performed Pearson Correlation and step-wise regression analyses to evaluate the two hypotheses. The team also evaluated the ranges of the new variables to evaluate the reliability of the results of the analyses.

RESEARCH RESULTS

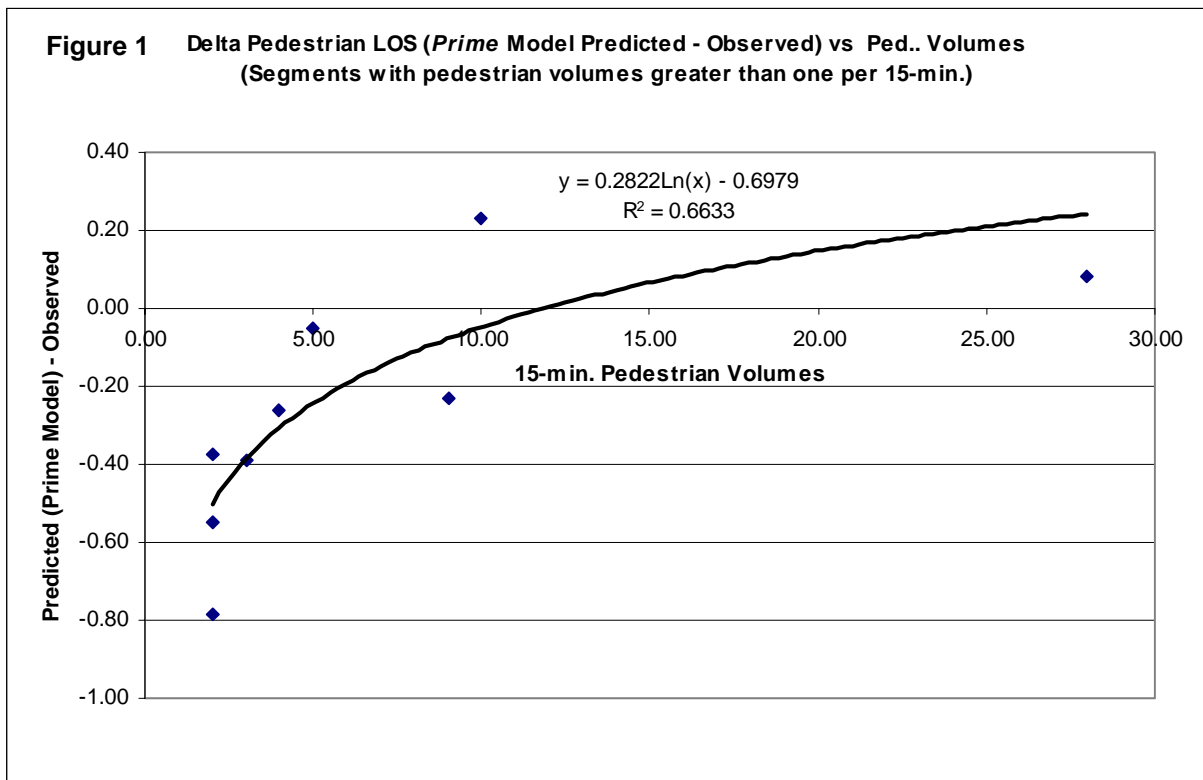
Hypothesis 1

To test the first hypothesis i.e., that respondents’ perceptions of roadside conditions would be positively affected by the presence of other pedestrians, the research team conducted step-wise regression of these perceptions (dependent variable) with respect to the 15-minute pedestrian volume (independent variable) for the approximate times when the respondents walked through each segment. This analysis resulted in a t-statistic of -0.421, which means that a statistically reliable conclusion cannot be drawn with this data set. However, because this is a negative number, there is a potential that under conditions of low volumes of pedestrians, increased pedestrian volumes may result in a *lower* pedestrian level of service score, which equates to a *better* pedestrian level of service. This is supported by the following subsequent analysis:

1. The research team excluded the segments of the course that had an average of two pedestrians or more in a 15-minute period, and then re-regressed the original *Pedestrian Level of Service Model* terms on the remaining observations. This resulted in a model (called the *prime model*) with R^2 value of 0.83. This is very close to the R^2 value (0.86) of the *original* model based on the full data set. It is important to note that the speed term in the *prime* model is only significant at 90% (t-statistic of 1.70), whereas in the *original* model it had 95% significance (2.06).
2. Using this *prime* model, pedestrian LOS values were then predicted for each of the segments with two or more pedestrians. The difference between the predicted value and the average observation by the course participants was plotted against pedestrian volumes (see Figure 1) The resulting plot shows a trend that has an R^2 value of 0.66⁴.

⁴ A stepwise regression analysis of the prime model using all roadway segments (regardless of pedestrian volume) revealed no correlation or trend.

This plot indicates that the presence of other pedestrians does have an *affect* on people’s perception of safety at relatively low pedestrian volumes, i.e. when the volume of pedestrians is less than ten (10) for every 15-minute period, however, without having segments with a greater range of pedestrian volumes (particularly at the higher end), reliable conclusions cannot be drawn from the existing data. Of the 42 segments included in this analysis, 33 had less than two pedestrians per 15-minute interval, and all but one of the other segments had 10 or fewer pedestrians per 15-minute interval. This limited range is due to the fact that the street segments were chosen as part of the walking course in the original research for their range of traffic and geometric conditions, and not with respect to pedestrian volume. It is clear that further research in environments with high pedestrian volumes would be necessary to fully quantify the affect.



Hypothesis 2

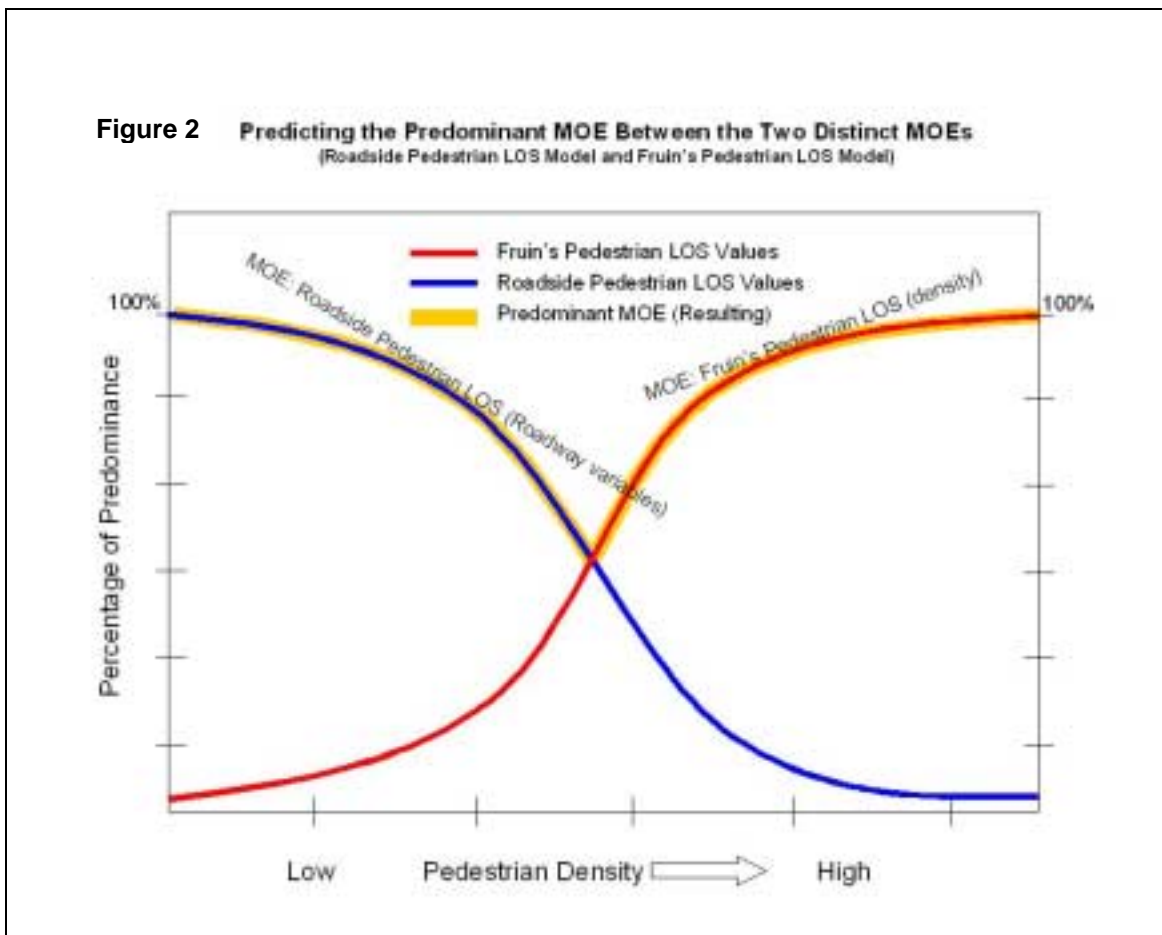
To test the second hypothesis, i.e., that respondents’ perceptions of road-side/street-side conditions would be negatively affected by the presence of buildings immediately adjacent to the street right-of-way in situations where pedestrian volumes are low, the team conducted step-wise regression of the participants’ perceptions (dependent variable) with respect to building height and building setback (independent variables). The regression of the perceptions with respect to building height resulted in a very low t-statistic of 0.127, not a statistically significant factor.

The step-wise regression of the participants’ perceptions with respect to building setback resulted in a t-statistic of -0.463. Therefore, a statistically reliable conclusion cannot be drawn from this data.

INTEGRATION OF THE FDOT PEDESTRIAN LOS MODEL & THE FRUIN METHOD

The two methods of calculating pedestrian level of service produce results in a similar A through F letter grade format. However, these models reflect completely different measures of effectiveness (MOEs) that consider very different aspects of the pedestrian environment. The MOE for the current FDOT *Pedestrian LOS Model* is based on a statistical evaluation of pedestrians' perceptions of the effects of motor vehicle traffic on their safety and comfort. The MOE for the Fruin methodology is the amount of space available for pedestrian flow, which affects the ability for walkers to maintain their desired speed and/or mobility. Therefore, for any given segment of roadway, two distinct pedestrian LOS results can be obtained.

If both models are calibrated with comparable data sets, it should be possible to combine the two models for pedestrian level of service by identifying the predominate measure of effectiveness for a given pedestrian density. The hypothesis is that as pedestrian volumes increase, individual pedestrians will become less concerned about their safety and comfort as affected by motor vehicle traffic, and be more aware of the fact that they must change their walking pace or alter their route due to the presence of other pedestrians. Figure 2 presents this theoretical relationship.



This current research confirms that the existing data set from the development of FDOT's Pedestrian LOS model did not have a large enough range of pedestrian densities to test this

hypothesis. For example, the segment with the most pedestrians had 28 pedestrians in a 15-minute period, equivalent to a pedestrian flow rate of 0.3 pedestrians/min/ft based on an effective sidewalk width of 6 feet. In the Fruin methodology, the pedestrian flow rate equivalent to Level of Service “A” is 0 to 5 pedestrians/min/ft. Clearly, the current data set covers only a tiny portion of the full range of pedestrian flow rates considered in the Fruin methodology. Thus, to adequately integrate the Fruin methodology and the FDOT model, both models must be tested on segments that include the full range of pedestrian flow rates identified in the Highway Capacity Manual for calculating pedestrian level of service.

Because a combined LOS model cannot be developed without additional research, a simple interim method of selecting which model to use is necessary. The proposed method is to calculate the level of service using both methods and then use the worse level of service for each sidewalk segment. Away from dense urban retail and business districts, very few sidewalks have pedestrian volumes high enough to result in anything besides level of service “A” when using the Fruin methodology. Therefore, the vast majority of sidewalks in US metropolitan areas should be evaluated using the FDOT roadside conditions *Pedestrian LOS Model*. Furthermore, the FDOT’s *Pedestrian LOS Model* can be used whether or not a sidewalk is present whereas the Fruin method is only applicable when a sidewalk is present.

Research Plan for Integrating the Two Pedestrian LOS Models

Below is a plan to conduct further research to combine the FDOT *Pedestrian LOS Model* with the Highway Capacity Manual (Fruin) methodology.

Conduct Another Walk for Science

To integrate the pedestrian level of service models, a new “Walk for Science” would need to be conducted. Selecting an appropriate course will be challenging because the course needs to capture the full range of pedestrian volumes or densities identified in the Highway Capacity Manual. The event will likely need to be conducted in an urban area with a vibrant central business district. All of the data necessary to calculate pedestrian LOS using both models must be collected for the segments that are rated by the participants.

After all the data have been collected and reduced, the actual observations should be compared with the predicted values from both LOS models. Next, the difference between the actual observation and the prediction of each model should be calculated for each segment of the course. For each model, a plot (similar to Figure 1 of this report) should be developed that depicts this value against the pedestrian flow rate for each segment. For each plot, a fitted curve should be developed through the data points. Comparison of these curves will indicate which model is more accurate in predicting pedestrian level of service at any given pedestrian volume. Depending on the result of this analysis, additional statistical analyses can then be conducted to clearly develop a combined roadside conditions/pedestrian flow model for calculating pedestrian level of service.

EVALUATION

The primary objective of this research was to investigate the expansion of the *Pedestrian Level of Service Model* to include two factors that appeared to influence the responses of participants in the original “Walk for Science,” the presence of other people within the sidewalk or roadside environment, and the presence of structures and building proximate to the right-of-way. The two hypotheses could not be confirmed because of the narrow range of data available in the original survey. When the route for the “Walk for Science” was designated in 2000, the researchers did not explicitly consider the variables of this study. If they had considered those factors at that time, they may have conducted the study in a different location or along a different route with a broader range of pedestrian volumes. As the case may be, the original research was conducted in Pensacola in March of 2000.

The goal of this study was to incorporate the additional variables into the original model using data collected along the same route under similar field conditions. Thus, the data was collecting for the variables of interest at the same time of the year and under similar field conditions.

This study raises an issue of how to best design field measures of LOS. The researcher can only measure LOS over the range of conditions experienced by the individual within a reasonable walking distance within a single community. This will always limit the range of conditions over which the survey results are valid, and this will limit the applicability of any model developed in one community to any other community with a different range of field conditions (Dowling 2002). This suggests that a reevaluation of the general theory of perceived LOS need to be developed based on the field work already conducted and some less expensive, but more in-depth research methods, such as focus groups or other survey techniques. This theory could then be applied to a full range of communities, rather than using an intensive data collection effort in one community and applying it without modification to other communities. The model could then be calibrated to individual communities through some less expensive survey work (Dowling 2002).

This research failed to support the inclusion of additional variables in the original *Pedestrian Level of Service Model* because of the need for a wider range of pedestrian volumes. While the results were either inconclusive or unreliable using the existing data set, this research suggests the importance of additional research using other strategies, like focus groups or surveys, and research conducted in communities with a broader range of pedestrian volumes and other field conditions. This research is another step in the effort to better understand pedestrian perceptions of the level of service under various walking conditions.

LITERATURE PERTAINING TO THE REFINEMENT OF THE ROADWAY SEGMENT PEDESTRIAN LEVEL OF SERVICE FACTORS

For the most part, variables related to the modeling of pedestrian LOS can be divided into two categories:

1. Variables used to predict pedestrian demand
2. Variables used to qualify supply of pedestrian facilities

As in the case of automobile level of service, the quality, and quantity, of facilities supplied influences the demand for those facilities, but for the purpose of variable inventory, the above categorization is a useful one. Indeed, while some demand models do consider Pedestrian Environment Factors (PEFs) as well, many address only latent demand as expressed in land use organization, density, and intensity; network connectivity measures; and demographic data. Following is an annotated list of studies addressing pedestrian supply and demand.

The focus of this literature review is on variables that can be measured in the roadway right-of-way; as such, this literature review should not be seen as a comprehensive review of the literature. Readers are encouraged to review the following two documents for more extensive discussion of the measurement of pedestrian environments:

1. Federal Highway Administration. 1998. *Guidebook on Methods to Estimate Non-Motorized Travel: Supporting Documentation* Washington, DC: U.S. Department of Transportation Publication No. FHWA-RD-98-166) (<http://www.tfhrc.gov/safety/pedbike/vol2/contents.htm>)

2. Cambridge Systematics, Inc. with Barton Aschman Associates. 1994. *Short-Term Travel Model Improvements Final Report*, Prepared for U.S. Department of Transportation and U.S. Environmental Protection Agency; Washington, DC: U.S. Department of Transportation Publication No. DOT-T-95-05 <http://ntl.bts.gov/DOCS/445.html> (see, Section 2: Modeling Non-Motorized Travel, in particular.)

Pedestrian Demand Studies:

1. Pushkarev, Boris and Jeffery M. Zupan. *Pedestrian Travel Demand*. Highway Research Record 355, 1971.

In this midtown Manhattan study, adjacent land use (square feet of office, retail, and restaurant), distance to transit entrances, and sidewalk and plaza space per block were used as independent variables in a regression model. Pedestrian volume was measured by analysis of aerial photos. Additionally, flow characteristics by time of day; traffic characteristics, and trip generation characteristics of specific building types were analyzed.

2. Behnam, Jahanbakhsh and Bharat G. Patel, A Method for Estimating Pedestrian Volume in a Central Business District. Pedestrian Controls, Bicycle Facilities, Driver Research, and System Safety, Transportation Research Record 629, Washington, DC 1977.

Using mid-block pedestrian counts in the Milwaukee CBD, a regression model was developed to predict pedestrian volume based on eight land use types: Commercial, Office Space, Cultural and Entertainment, Manufacturing, Residential, Parking, Vacant, Storage and Maintenance.

3. Ercolano, James M., Jeffrey S. Olson, Douglas M. Spring, *Sketch-Plan Method for Estimating Pedestrian Traffic for Central Business Districts and Suburban Growth Corridors*, Transportation Research Record 1578, Washington, DC, 1997.

Ercolano, et al. uses existing data routinely collected by most transportation providers (at a minimum, vehicles per hour from traffic counts and local mode shares from the census) to estimate peak pedestrian travel demand in suburban and developing rural activity centers.

Variables:

- a. Peak vehicle-per-hour (VPH) turning movements
- b. Transit ridership
- c. Walk/bike only mode shares (based on the U.S. Census)
- d. Zoning or land use map
- e. Square meters or feet of new development space
- f. Aerial photographs and/or specific site, corridor, or subarea block configurations.

4. Matlick, Julie Mercer. *If We Build it, Will They Come? #69 Forecasting Pedestrian Use and Flows, Forecasting the Future*, Bicycle Federation of America -- Pedestrian Federation of America, Pro Bike/Pro Walk '96, 1996, pp. 315-319.

Using household population, national transportation survey percentages, and activity center data potential walking trips in specific corridors were calculated

Variables:

- a. Land uses
- b. Maps
- c. Transportation mode split information
- d. Generator information: Housing types, density, persons per household unit, and hotels
- e. Attractor information: retail, recreation, social facilities, schools, employment, and churches;
- f. Daily transit ridership information;

- g. Local school information: number of enrolled children, percentage of bussed and non-bussed students;
 - h. Park and ride lot information: lots, size, and occupancy rates.
5. Rossi, Thomas. T. Keith Lawton and Kyung Hwa Kim. *Revision of Travel Demand Models to Enable Analysis of Atypical Land Use Patterns*. Cambridge Systematics, Inc. and Metropolitan Service District, May 1993.

1,000 Friends of Oregon. Making the Land Use Transportation Air Quality Connection; 1991-1997. Includes multiple volumes describing modeling efforts in Portland to incorporate pedestrians and bicyclists. Available on the web at http://www.friends.org/resources/lut_reports.html

Metro, the MPO for Portland, OR, included the non-motorized mode (walking/bicycling) as an option in the mode choice models for each trip purpose. Mode choice is predicted in two steps: first, motorized vs. non-motorized, and second, auto vs. transit for motorized trips. The motorized vs. non-motorized mode choice is a function of: 1) travel distance, 2) ratio of cars to workers in the household, 3) total employment within one mile of zone (a density measure), and 4) a pedestrian environment factor (PEF)

Portland's PEF includes four elements:

- a. sidewalk availability
- b. ease of street crossing
- c. connectivity of street/sidewalk system
- d. terrain. Montgomery County's

6. Hunt, J.D., A.T. Brownlee, and L.P. Doblanko. Design and Calibration of the Edmonton Transport Analysis Model. Presented at the 1998 Transportation Research Board Annual Meeting, Paper #981076, January 1998.

The Edmonton Transport Analysis Model includes both walk and bicycle as separate modes and also includes bicycle network characteristics in determining mode choice. Links in the network model can be coded in three ways: bicycle path, bicycle lane, or mixed traffic. A coefficient in the mode choice model is estimated for bicycle equivalent travel time, which is actual travel time adjusted by a factor representing the *relative onerousness* of bicycling on each facility type. Time-equivalent penalties by facility type are derived from a stated-preference survey of bicyclists (Hunt and Abraham, 1997), showing that for the average cyclist, one minute of bicycling in mixed traffic is as onerous as 2.8 minutes on bike paths or 4.1 minutes on bike lanes. A similar method might be applicable to pedestrian travel time models.

7. Metropolitan Transportation Commission. San Francisco Bay Area 1990 Travel Model Development Project: Compilation of Technical Memoranda (Volumes II-VI). Oakland, CA, 1995-1997.

The MPO for the San Francisco Bay Area, includes both walk and bicycle modes in their latest set of mode choice models. Bicycle and walk utilities are based on: 1) travel time, 2) employment density (for work trip models), and 3) dummy variables for the Stanford, Palo Alto, and Berkeley zones. Travel times are calculated using highway network distances and an assumed speed of 19.3 km/h for bicycles and 4.8 km/h for pedestrians. The MTC models are noteworthy for the variety of trip purposes modeled. Separate trip generation, distribution, and mode choice models are developed for home-based work, home-based shop, home-based school (grade school, high school, and college), home-based social/recreation, and non-home-based trips. Some models have separate time coefficients for bicycle and walk. The MTC also attempted to include population density and area type (CBD, urban, suburban, etc.) in the mode choice models but these variables were not significant in predicting non-motorized mode choice.

Supply Quality Analysis:

1. Mozer, David. *Calculating Multi-Mode Levels-of-Service*, International Bicycle Fund, <http://www.halcyon.com/fkroger/bike/los.htm>, 1994.

To determine the level-of-access of street segments for pedestrian use, this method uses four primary factors: walk area width-volume, walk area-outside-lane buffer, outside-lane traffic volume, and outside-lane motor vehicle speed; and three secondary factors: walk area penetrations, heavy vehicle volumes, and intersection wait-time.

Walk area Width-Volume:

- Peak-hour pedestrian volume;
- Non-pedestrian mode split such as bicyclists, skaters, etc.;
- Walk area width (meters);
- Travel pattern (equals "1" if one-way and "2" if bi-directional); and
- Whether the facility meets the Americans with Disabilities Act requirements.
- Walk area-Outside Lane Buffer Factor:
- Walk area-outside lane buffer width; and
- Aesthetic quality (living or non-living material).

Outside-Lane Volume:

- Peak-hour volume per lane;
- K-factor: assumed as 10 percent for urban areas; and
- Number of lanes.

In addition, secondary variables are as follows:

- Walk area penetrations (based on number of driveways, average peak-hour penetrations per driveway, and average distance between driveways);
 - Heavy vehicle volumes (percentage is added to the primary LOS subtotal); and
 - Intersection wait-time (a percent of a minute is added to the primary LOS subtotal).
2. Dixon, Linda. *Adopting Corridor-Specific Performance Measures for Bicycle and Pedestrian Level of Service*, Transportation Planning, Vol. XXII, No. 2, summer 1995.
- The method uses the following criteria to determine the pedestrian LOS for specific roadway segments (a bicycle LOS can also be computed from similar data):
- Basic facility provided (based on continuity, width, etc.);
 - Conflicts;
 - Amenities;
 - Motor vehicle LOS;
 - Maintenance; and
 - Multimodal provisions (presence of Travel Demand Management measures).

Environmental Factors:

1. 1,000 Friends of Oregon. *Making the Land Use Transportation Air Quality Connection: Volume 4A, The Pedestrian Environment*. Portland, OR, 1993. Available at http://www.friends.org/resources/lut_vol4.html

Rossi, Thomas. T. Keith Lawton and Kyung Hwa Kim. *Revision of Travel Demand Models to Enable Analysis of Atypical Land Use Patterns*. Cambridge Systematics, Inc. and Metropolitan Service District, May 1993.

Cambridge Systematics, Inc. *Short-Term Travel Model Improvements*, Travel Model Improvement Program. U.S. Department of Transportation; DOT-T-95-05, pp. 2-1 to 2-7, October 1994. (1994a).

Environment factors are quantitative and may be a composite of a number of quantitative descriptors and/or subjective factors that have been quantified through an ordinal rating. Examples of factors considered include lane or sidewalk width, street continuity, topography, and the aesthetic quality of the environment. The specific factors included, and the means of aggregating them into an overall index, vary according to the application.

Portland's Pedestrian Environment Factor (PEF), developed for use in its regional travel model, includes four elements:

- Sidewalk availability;
- Ease of street crossing;
- Connectivity of street/sidewalk system; and

- Terrain.

Each zone is ranked for each element on a scale of zero to three, with higher numbers representing higher quality pedestrian environments, so the overall PEF can range from 0 to 12. A Pedestrian and Bicycle Environment Factor (PBEF) includes an additional three-point rating for bicycle facilities, so the PBEF can range from 0 to 15.

Montgomery County's PBEF <http://ntl.bts.gov/DOCS/445.html> includes five elements:

- Amount of sidewalks;
- Land use mix;
- Building setbacks;
- Transit-stop conditions; and
- Bicycle infrastructure.

Each factor can be rated at various levels for which specific fractional points are assigned (e.g., 0.00 for "little or no bicycle infrastructure," 0.05 for "some bicycle paths or routes," 0.10 for "many bicycle paths, lanes, or routes forming network"), yielding an overall PBEF of between zero and one for each zone.

Amount of Sidewalks

- .00 No sidewalks
- .05 Discontinuous, narrow
- .15 Narrow sidewalks along all major streets
- .25 Adequate sidewalks along all major streets
- .35 Adequate sidewalks along most streets with some off-street paths
- .45 Pedestrian district with sidewalks everywhere, pedestrian streets, and auto restraints

Land Use Mix

- .00 Homogeneous land use within easy walking distance
- .10 Some walk accessible lunch time service retail in employment centers
- .20 Mixed land use at moderate density
- .25 Mixed land use at high density

Building Setbacks

- .00 Mostly set-back sprawled campus style
- .05 Mixed campus style but clustered with bus stops within walking distance
- .10 Few or no building setbacks from transit-accessed street

Transit Stop Conditions

- .00 No shelters
- .05 Some bus stop shelters
- .10 Widely available bus stop shelters

Real Accessibility Index:

Thomas Jefferson Planning District Commission. 2002. *Measuring and Improving Multi-modal Transportation Accessibility in the Thomas Jefferson Planning District using the Real Accessibility Index*. Charlottesville, VA.

(http://tjpd.org/trans/epi/epi_neighborhood_accessibility_index.html)

In addition to the studies described above, in the *Guidebook on Methods to Estimate Non-Motorized Travel*, the Real Accessibility Index scores the pedestrian quality of an area based on the following characteristics:

1. Access to land uses characterized as frequent, regular, and occasional usage
2. Sidewalk coverage
3. Presence of crosswalks
4. Obstacle free walking environment
5. Handicapped Access
6. Lighting
7. Calm Traffic
8. Cleanliness
9. Availability of weather protection