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16. Abstract

This report summarizes a literature review that investigated current practices for bicycle and pedestrian travel demand forecasting. The research team examined available literature and contacted several planning agencies that are involved in developing or testing bicycle and/or pedestrian demand forecasting techniques. The literature review revealed that there are several bicycle and pedestrian demand forecasting techniques that could be modified or adapted for use by TxDOT. Although the techniques are untested and could have large errors, they would represent an improvement upon the existing lack of bicycle/pedestrian demand forecasting tools.

The research team identified four basic categories of bicycle/pedestrian demand forecasting models/techniques: (1) aggregate or simplified trip generation models; (2) facility locator or "market travelshed" models; (3) sequential stand-alone bicycle and pedestrian demand models similar to current four-step traffic models; and (4) four-step traffic models modified to account for bicycle and pedestrian environments. The type of model/technique used by a specific agency depended heavily upon their specific needs and application. The research team also discovered several uncoordinated efforts aimed at developing bicycle and/or pedestrian demand forecasting techniques. The Federal Highway Administration is considering funding an effort to identify and examine the best practices of bicycle/pedestrian demand forecasting on a national level.

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BICYCLE AND PEDESTRIAN TRAVEL DEMAND FORECASTING: LITERATURE REVIEW

by

Shawn Turner, P.E.
Assistant Research Engineer
Texas Transportation Institute

Aaron Hottenstein
Graduate Research Assistant
Texas Transportation Institute

and

Gordon Shunk, P.E.
Research Engineer
Texas Transportation Institute

August 1997

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

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ACKNOWLEDGMENTS

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INTRODUCTION

Bicycle and pedestrian facilities are increasingly being considered in transportation planning, design, and operations at the state and local levels. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 prompted much of the emphasis currently being placed upon bicycling and walking as legitimate transportation modes. The ISTEA funding authorization amounted to $24 billion over a six-year period, of which 10 percent, or $2.4 billion, would be allocated to "transportation enhancements." One of the primary objectives of the transportation enhancements program was to encourage greater use of non-motorized transportation by constructing bicycle and pedestrian facilities. Bicycle and pedestrian facilities were also made eligible in several other ISTEA funding categories, most notably the Congestion Management/Air Quality (CMAQ) category.

Many states and regions have taken advantage of this available funding to plan and construct bicycle and pedestrian facilities. At the end of fiscal year 1995, $887 million (55 percent of the $1.6 billion available since the program's inception) had been obligated (1). The Rails-to-Trails Conservancy has estimated that approximately 51 percent of the obligated funds are for bicycle and pedestrian facilities. The ISTEA funding represents a dramatic increase over previous funding available for bicycle and pedestrian facilities.

In the 1990's, environmentalists, community groups, and concerned citizens have voiced their opposition to traditional highway building and expansion, and have instead advocated livable communities that encourage sustainable transportation modes like bicycling and walking. These groups have demanded that transportation engineers and planners recognize bicycling and walking as legitimate transportation modes and that they incorporate these modes into transportation planning and design processes.

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Problem Statement

In a memo to all Texas Department of Transportation (TxDOT) District Engineers, TxDOT Executive Director William Burnett required that "accommodation for both bicycle and pedestrian traffic shall be considered on all projects . . ."(2), thus formally including bicycle and pedestrian facilities in TxDOT's planning, design, and operations processes. TxDOT and other transportation agencies' planning techniques have developed over the past twenty to thirty years and are primarily focused on vehicles. Most of the planning techniques and computer models are ill-equipped to deal with non-motorized transportation.

Increased federal funding, TxDOT emphasis, and local community interest has generated a need for planning techniques that can forecast travel demand for bicycle and pedestrian facilities. Bicycle and pedestrian travel demand forecasts can be used to:

- Assess future non-motorized travel needs and plan for adequate facilities;
- Prioritize transportation improvement projects for scarce financial resources; and
- Gauge the effects of increasing non-motorized travel on other travel modes.

A clear need exists to estimate bicycle and pedestrian travel demand for existing and proposed transportation corridors.

Research Goal and Objectives

The research objective, as identified in the proposal for TxDOT study 0-1723, is to develop a methodology that will provide TxDOT personnel with the information and a decision-making framework to assess existing and proposed travel demand by bicyclists and pedestrians. The research objectives are to:

- Identify existing information for travel demand forecasting for bicycle and pedestrian travel, or non-motorized travel (NMT);
- Identify the factors affecting selection of NMT;
- Assess the influence of factors related to selecting NMT;

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- Assess whether influential factors for NMT are indicated but data is insufficient and recommend additional data collection if necessary;
- Develop quantitative or qualitative relationships between influential factors and NMT;
- Develop several models addressing the affect of influential factors on NMT; and
- Evaluate models for forecasting utility.

The end product for this research study will be a single document containing the findings of validity testing for several bicycle and pedestrian travel demand forecasting models. Should one or more models be validated, detailed documentation will be developed for the future use of these models by TxDOT. A validated demand forecasting model will provide a consistent framework for evaluating and prioritizing existing and proposed corridors for bicycle and pedestrian improvements.

Organization of this Report

This report contains a review of the literature relevant to bicycle and pedestrian travel demand forecasting and is divided into the following sections:

- **Introduction** -- provides an overview of the need for bicycle and pedestrian demand forecasting models and summarizes the objectives for this research study.
- **Findings** -- summarizes the major findings of the literature review and presents various bicycle and pedestrian demand forecasting techniques that have been developed and/or applied in other regions.
- **Conclusions** — provides an analysis of the findings, with a qualitative comparison of the demand forecasting models and their advantages and disadvantages.
- **Recommendations** -- provides recommendations on a preferred demand forecasting model(s) or appropriate explanatory factors to be investigated and the data elements required to investigate and validate a model or set of factors.

CHAPTER 2

FINDINGS

This chapter provides a summary of the findings of the literature review as it relates to travel demand forecasting for bicycle and pedestrian facilities and an overview of the traditional four-step travel demand modeling process. The literature search discovered several bicycle and pedestrian demand forecasting techniques with varying levels of complexity, and this chapter will summarize these techniques.

The literature search conducted for this study included library data base searches, phone conversations, and World Wide Web searches. The authors searched several university library data bases, including those at Texas A&M University (NOTIS), the University of California at Berkeley (MELVYL), and Northwestern University. The authors searched several bibliographic data bases, including Dialog's TRIS, Compendex, WorldCat First Search, and OVID. The literature search and a recent bicycle/pedestrian advocacy conference (ProBike/ProWalk '96 in Portland, Maine) helped to identify key persons involved in bicycle/pedestrian demand forecasting. The key persons were contacted by phone to solicit additional information not available in journal or conference papers. In addition, searches of the World Wide Web identified several key persons and references.

A research team member also attended a Federal Highway Administration (FHWA) project scoping workshop that assembled national bicycle and pedestrian demand forecasting experts. The FHWA scoping workshop was conducted for a planned research study on bicycle/pedestrian demand forecasting techniques. As a result of this workshop, FHWA staff recently awarded a contract to Cambridge Systematics, Inc. to compile a "Best Practices" report on bicycle/pedestrian travel demand forecasting.

Overview of the Four-Step Travel Demand Modeling Process

This section provides a brief overview of the traditional travel demand modeling process and how bicycle and pedestrian travel relates to this process. The literature review found that several research studies focused on improving specific steps or aspects of the four-step modeling process to incorporate bicycle and pedestrian travel. Also, several studies are attempting to build an independent four-step modeling process exclusively for bicycle and pedestrian travel.

The travel demand modeling process is the means by which transportation planners attempt to estimate the future travel demand on a network. The four-step, sequential demand modeling process (Figure 1) has been used widely to estimate vehicle travel demand, and consists of the following steps:

1. **trip generation** -- the decision to travel for a given purpose;

2. **trip distribution** -- the choice of destination;

3. **mode choice** -- the choice of travel mode; and

4. **traffic assignment** -- the choice of route or path.

In these four sequential steps, the output of one step becomes the input for the next step in the process. The following sections briefly discuss the four steps.

Trip Generation

Trip generation is the process by which transportation planners attempt to predict the number of trip ends for each analysis zone in a target year. Trip ends are trip productions and trip attractions, or origins and destinations, in each zone. The inputs that are required for a trip generation model include area land use and socioeconomic data, such as income, car ownership, residential density and household size. This data is used to develop a model that predicts trips by purpose. Common trip purposes are home-based-work (HBW) , non-home-based (NHB), and home-based-other (HBO). These trip generation equations are usually the result of multiple regression equations, trip rate models, cross-classification models and combinations of all three models. The models are calibrated to the base year before projections are made for future scenarios.
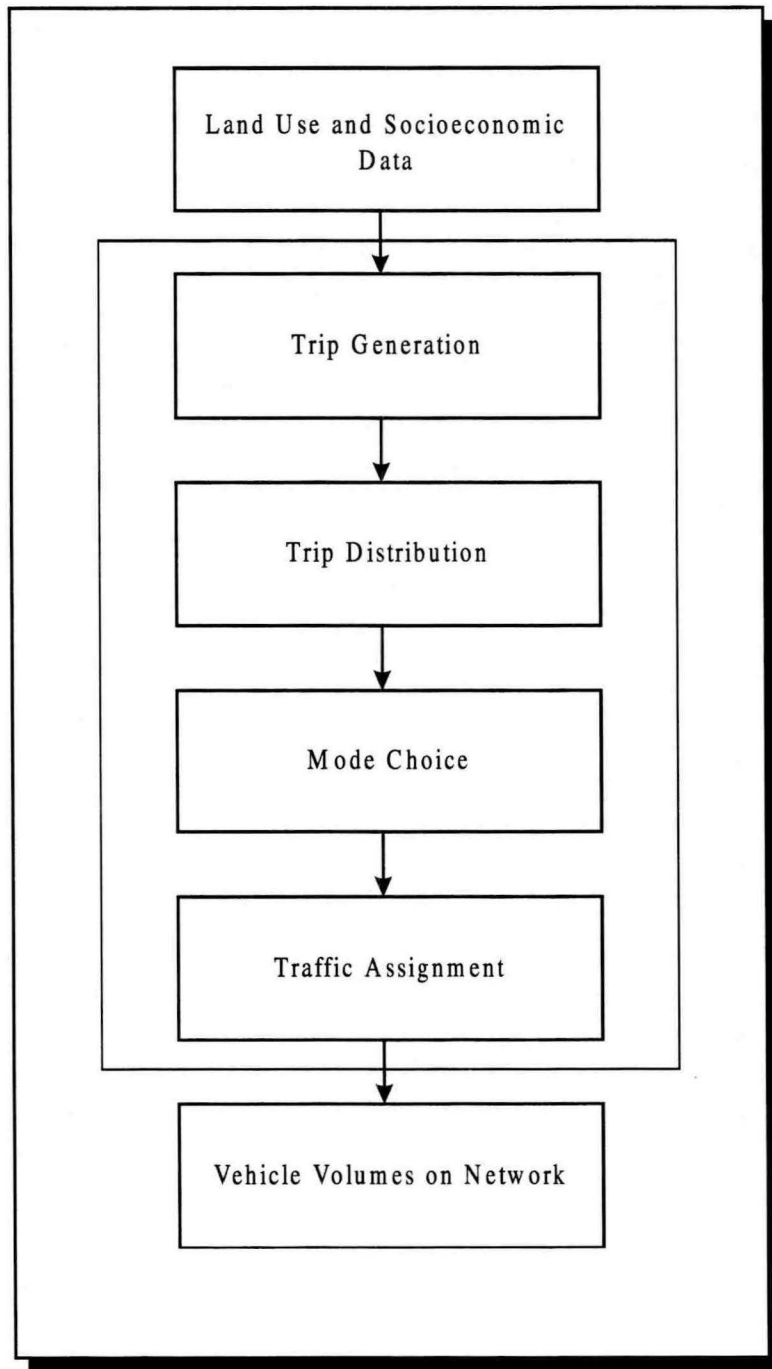
Figure 1. Four-Step Sequential Travel Demand Modeling Process

Trip Distribution

Trip distribution is concerned with the connection of trip productions and attractions, or origins and destinations, to determine the future year trip volumes. The attractiveness of travel between zones is evaluated using travel times, distances between zones, and cost of travel. The inputs for the trip distribution process come from the trip generation step. Common modeling techniques include the use of gravity models and growth factor models. Gravity models distribute trips according to the distances and travel costs between zones. The distance and travel costs are represented as impedance factors in the gravity model (Equation 1).

$$Q_{ij} = P_i \frac{A_j F_{ij}}{\Sigma A_x F_{Ix}} \tag{1}$$

Where: Q_{ij} = Number of Trip Ends,

P_i = Number of Productions in Zone I,

F_{ij} = Travel Time Factor (impedance), and

A_j = Number of Attractions in Zone j.

Mode Choice

The choice of transportation mode is important in determining the volume of vehicle traffic that will be assigned to the roadway network. Mode choice is used to determine the number of trips that will occur by the vehicle mode or public transportation. Bicycle and pedestrian modes are often ignored because they typically constitute less than 5 percent of overall person travel in typical urban areas. Mode choice is affected by the trip maker's behavior regarding the selection of a travel mode. Three factors influence travel mode choice ([3]):

- type of trip (e.g., trip purpose, time of day);
- characteristics of the trip maker (e.g., income, age, auto ownership); and
- characteristics of the transportation system (e.g., relative travel times for the modes available to make the trip).

Traffic Assignment

The traffic assignment step assigns the predicted vehicle traffic volumes to the roadway network according to travel times (impedance) on individual links. Traffic assignment is usually computed using a complex algorithm. Some of the traffic assignment algorithms are FHWA assignment, Frank-Wolfe, Dial's algorithm and incremental assignment techniques. This step estimates the expected vehicle volumes on the highway network. This modeling step can be performed on an all-or-nothing assignment, capacity assignment or stochastic equilibrium assignment methods (3).

Bicycle Demand Forecasting Models

The following sections present the findings from various studies and applications of bicycle travel demand forecasting models.

Rhode Island Pre-ISTEA Study

One of the few attempts to estimate bicycle travel demand before ISTEA was for the Providence-Bristol bicycle facility in Eastern Rhode Island in 1982 (4). The Planning Division of the Rhode Island DOT performed the study for a 23.3 km (14.5 mile) Class I bikeway facility (i.e., bike traffic on right-of-way separate from vehicle traffic) that had previously been a railroad corridor. Bicycle usage was estimated for current conditions (1980) and future conditions (2000) using simplified assumptions for three of the traditional four steps of transportation modeling (mode choice was not applicable).

In the first step, trip generation, it was assumed that bicycle trips would be generated only from those analysis zones within 0.8 km (0.5 mile) of the proposed bicycle facility. This "area of influence" assumption was based on typical walking distances to transit service (0.8 km, or 0.4 mile), then doubled. Because the scope of the Rhode Island study did not permit extensive surveys, the planners utilized trip generation equations that had been developed in Harrisburg, Pennsylvania (5) (see Table 1). Planning staff apparently developed the trip generation equations from Harrisburg in

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response to bicycle planning needs. Northwestern University's "Bicycle Planning and Facilities" workshop course materials included these equations as well (5).

Table 1. Bicycle Trip Generation Equations from Harrisburg, Pennsylvania

(Adapted from Reference 5)

Trip Purposes	Estimated Average Daily Bicycle Trips

Utilitarian/Destination
    To Work
    To School
    To Personal Business
	
	4.9 per 1,000 Employed
	20.3 per 1,000 Enrolled
	11.5 per 1,000 Population

Recreational/Destination To Recreational Facility	 19.1 per 1,000 Population

Recreational/Non-Destinational
    To Visit Friends
    Riding in Neighborhood
    Long Distance
	
	22.4 per 1,000 Population
	57.3 per 1,000 Population
	2.6 per 1,000 Population

The bicycle trip generation equations were aggregated by trip purpose to simplify calculations, and the following bicycle trip generation equations were used:

Total Bicycle Trips = Trips (1) + Trips (2) + Trips (3)

- Trips (1) = 4.9 x 1,000 Employment

- Trips (2) = 20.3 x 1,000 School Enrollment

- Trips (3) = 112.9 x 1,000 Population

The factors necessary to estimate bicycle trip generation were employment, school enrollment, and population. Socioeconomic data and projections for 1980 and 2000 were adjusted based upon the recent 1980 Census and applied to generate total bicycle trips for each analysis zone.

Planning staff simplified the next step of the demand modeling process, trip distribution, by assuming that 25 percent of all bicycle trips generated within the area of influence (analysis zones within 0.8 km of facility) were distributed to the bicycle facility. These assumptions were based

upon knowledge of local conditions and sheer "guesstimates." The number of bicycle trips were also adjusted at several high-use recreational areas based upon knowledge of local conditions.

Planning staff also simplified the last step of the modeling process, trip assignment. An average bicycle trip length of 4.8 km (3 miles) was used based upon the following bicycle trip lengths found in other studies:

- **Census Travel-to-Work** -- 2.25 km (1.4 mi);
- **Tennessee and Pennsylvania** -- work trip, 4.10 km (2.55 mi); school trip, 2.80 km (1.74 mi); and
- **League of American Wheelman** — work and school combined, 6.44 km (4 mi).

In assigning the trips from each zone, an even directional split was assumed (e.g., 50 percent north, 50 percent south). The trip length on the bicycle facility itself was considered to be 3.2 km (2 miles), since many bicyclists would have to ride more than the 0.8 km (0.5 mile) that was considered to be the area of influence. The bicycle trips were then assigned to the proposed facility by zone, and totaled for the various sections of the bicycle facility. The results of this analysis produced bicycle volumes between 200 and 400 bicycles per day. The planning staff made adjustments at several locations of the trail to account for inconvenient access to the facility.

The Providence-Bristol trail was built in the mid-1980's, and a study by the University of North Carolina's Highway Safety Research Center compared actual ground counts to the projected bicycle volumes (6). The original study had estimated 250 and 370 daily bicycles at the southern end and northern end, respectively. In 1991, the authors found daily bicycle volumes of 225 and 325, representing differences of approximately 10 to 15 percent. At three other points along the trail, the authors found that 1991 daily bicycle volumes already exceeded the year 2000 volume projections.

Metro-Dade Transit Agency Bikes-on-Bus Program

Researchers studied bicycle demand for a bikes-on-bus program for the Metro-Dade Transit Agency (MDTA) (7). The study was performed to estimate bicycle usage in Dade County and assumed that three factors could serve as bicycle demand predictors for transit access:

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- location of transportation disadvantaged persons;
- location of bicycle commuters; and
- demographic characteristics.

These factors were all examined at the census tract level.

Researchers identified the location of transportation disadvantaged persons as a factor affecting bicycle use with the assumption that a large number of bicycle trips would be made by **low-income groups** that are **neither elderly nor disabled**. Transportation disadvantaged persons are defined as " . . . those persons who because of physical disability, income status, or age are unable to transport themselves or to purchase transportation and are, therefore, dependent upon others to obtain access to health care, employment, education, shopping, social activities, or other life-sustaining activities. . . ." This technique used data from regional transportation surveys. The number of transportation disadvantaged persons in each census tract ranged from 93 to 899 per 1,000 residents, with a mean of 416 and a standard deviation of 138 (8).

Researchers determined the location of bicycle commuters using data reported for the 1990 Census. The total number of bicycle commuters was based upon those **persons 16 years or older** who reported the bicycle as their primary method of traveling to work in the first week of April 1990. The number of bicycle commuters per census tract ranged from none to 31 per 1,000 residents, with an average of 2 and a standard deviation of 3 (8). The authors noted that work trips typically account for less than 10 percent of all bicycle trips (according to the 1990 Nationwide Personal Transportation Study).

The third technique combined the use of demographic characteristics from the 1990 Nationwide Personal Transportation Study (NPTS) and the 1990 Census. Using the 1990 NPTS, the authors computed average annual bicycle trips for various gender, race, and age classifications (see Table 2). This bicycle trip-making frequency was then applied to each individual census tract using detailed demographic information from the 1990 Census (Census Summary Tape File 3A) and normalized to a daily basis. Bicycle trips for each census tract estimated with this technique ranged

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between 8 and 35 daily trips per 1,000 residents (8). The authors considered this technique to be most reliable, as it incorporated significant survey data and included major factors that the authors considered to influence bicycling: **age, race, and gender**. This technique has several weaknesses:

- Income level was not able to be included in the model because of discrepancies between the 1990 NPTS and the 1990 Census.

- Bicycle trips were not adjusted by specific facility characteristics, like the presence of a bike lane.

- Bicycle trip-making frequency from the 1990 NPTS was not adjusted for regional climate or geography.

Table 2. Average Annual Bicycle Trips by Demographic Category from the 1990 NPTS (Adapted from Reference 7)

Sex	Age	Race	
		White	**Other**
Male	12 to 18	39.9	17.6
	19 to 24	13.9	20.9
	25 to 29	16.2	15.6
	30 to 39	8.7	5.6
	40 to 59	1.9	0.7
	Over 60	5.6	4.9
Female	12 to 18	10.7	2.7
	19 to 24	8.2	3.1
	25 to 29	5.1	0.0
	30 to 39	4.0	1.0
	40 to 59	1.9	0.0
	Over 60	0.5	0.0

These three demand estimation models were then used in a qualitative fashion to identify high-demand locations (as delineated by census tracts) that coincided with current bus routes. The authors used this information to select three bus routes on which to demonstrate the bicycles-on-bus program in Dade County.

Comparison of Dade County Demand Models

In a 1995 study, Epperson compared the demand estimates from four bicycle demand models to each other and to actual bicycle counts (8). The four demand models included the three developed for the MDTA's Bikes-on-Bus program and an additional model, developed by Epperson, based upon accident rates (9). Epperson based the accident rate model on the assumption that high bicycle accident rates were correlated to high bicycle use. The study by Epperson concluded that accident victimization rates ". . . were best explained by the level of bicycle use within neighborhoods, with the level of bicycle use most affected by increased poverty, low automobile availability, and poor transit service" (8).

In a comparison of the four demand models, Epperson found no clear correlation between any of the four predictors of bicycle demand. Table 3 shows the correlation between the bicycle use predictors, with greater numbers close to 1.0 indicating a very good correlation. The statistics in Table 3 indicate that several models had an inverse (i.e., negative) correlation, which Epperson theorized was related to several models not incorporating recreational bicycle trips. Epperson indicated that, according to the 1990 NPTS, 55 percent of all bicycle trips are taken solely for recreational purposes. Epperson also attributed the discrepancies in Table 3 to the presence of two distinct types of cyclists: (1) voluntary cyclists who bike primarily for recreation, but do make some utilitarian trips; and (2) involuntary cyclists, including those who are too young to have a driver's license or those with no access to an automobile or public transit.

Table 3. Pearson Product-Moment Correlations of Bicycle Use Predictors

(Adapted from Reference 8)

	Transportation Disadvantaged Persons	Accident Victims	Bicycle Commuters	Demographic Characteristics
Transportation Disadvantaged Persons	1.000			
Accident Victims	0.310	1.000		
Bicycle Commuters	-0.046	0.028	1.000	
Demographic Characteristics	-0.468	-0.121	0.158	1.000

In comparison to several areas in Dade County, Epperson found that the demographic characteristics technique did not predict bicycle demand accurately for one area that contained an affluent, non-white community. He also found that all four demand estimation techniques did predict bicycle trips reasonably for one high-use recreation area.

From his study, Epperson concluded the following:

- It is vital to differentiate between recreational and utilitarian bicycle trips. Recreational trips outnumber all other trips combined, so focusing on those trips would reasonably predict other trips;

- Simplified models can be used to predict areas of high bicycle use, and knowledge of local conditions and large bicycle attractors (e.g., schools, colleges/universities, and recreational amenities) can be used within this process;

- A high level of bicycle commuters combined with a high level of transportation disadvantaged persons is a good indicator of utilitarian bicycle trips; and

- A high level of bicycle commuters combined with a high level of demographically predicted bicycle trips is a good indicator of recreational or voluntary utilitarian trips.

North Central Texas Council of Governments' Bicycle Needs Index

The North Central Texas Council of Governments (NCTCOG), the metropolitan planning organization (MPO) for the Dallas/Fort Worth metropolitan area, has developed a bicycle needs index as a means to identify traffic survey zones with high bicycle use, and therefore, a need for bicycle facilities (10). A bicycle level of service analysis is then used to identify individual facilities within a traffic survey zone that could benefit from bicycle improvements. The bicycle needs index was based upon 1990 Census data, regional land use data, literature reviews, and regression analyses. The following sections describe the development and calculation of NCTCOG's bicycle needs index.

In constructing the bicycle needs index, NCTCOG performed a single and multiple regression analysis of 1990 Census and land use data compiled for the Dallas-Ft. Worth region. The single

regression analysis yielded the following factors that were closely related to bicycle mode share (listed in order of correlation):

- percentage of residents under sixteen years of age (AGE);
- number of hours worked per week (HR);
- percentage of land devoted to employment uses (LE);
- population density (PD);
- employment density (ED);
- population density of residential land uses (PRD); and
- ratio of workers to population (WPR).

The regression equation was as follows:

$$\frac{Bicycle}{Mode\ Share} = \begin{array}{l} 0.02999(AGE)\ +\ 0.05459(LE)\ -\ 0.00053(ED)\ - \\ 0.00335(WPR)\ -\ 0.00026(PRD)\ +\ 0.05(HR)\ +\ 0.00398 \end{array} \qquad (2)$$

The R-squared statistic for this multiple regression is 0.42, which means that the various factors explain about 42 percent of the variation in bicycle mode share. The authors noted several concerns with the multiple regression model:

- The bicycle mode share data from the 1990 Census does not include children under the age of 16 who use their bicycles as transportation to and from school;
- Several of the model variables or factors are correlated to each other; and
- The model only considers demographic and land use factors in determining bicycle mode share and does not include facility-specific factors like bicycle parking or route suitability.

From a literature review, the NCTCOG authors identified the following factors as affecting bicycling: **climate, topography, average commute trip length, gender, age, presence of bicycle facilities, annual income level, and individual perceptions** (i.e., personal values about recreation and safety). A limited number of factors were selected from the literature review and the regression analysis to form the basic factors in the bicycle needs index.

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The actual bicycle needs index is calculated from five different factors, each having a ranking weight applied to it as shown in Table 4. The following steps apply for calculating the bicycle needs index:

1. The factor value for each traffic survey zone is normalized by the region average (Equation 3), resulting in values greater than 1.0 if the survey zone factor value is greater than the regionwide average. Conversely, if the zone factor value is less than the regionwide average, the index value will be less than 1.0.

$$index\ score\ =\ \frac{traffic\ survey\ zone\ factor\ value}{regionwide\ factor\ value} \qquad (3)$$

2. Multiply the index scores for each factor by the weight shown in Table 4 (Equation 4). This results in a weighted index value for each factor and each traffic survey zone. The NCTCOG authors apparently developed the weights in Table 4 in relation to the factor importance.

$$weighted\ index\ value\ =\ factor\ index\ score\ \times\ factor\ weight\ (Table\ 4) \qquad (4)$$

3. For each traffic survey zone, sum the weighted index values for each of the factors. This summation results in a single index value for each traffic survey zone. A mean and standard deviation are computed from index values for all zones within the region, and a qualitative needs assessment (using the bicycle needs index) for each survey zone is determined by rating each zone in relation to the regionwide bicycle needs index mean and standard deviation (see Table 5). The results of this needs assessment are then shown in graphical formats on region maps.

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Table 4. Factors in NCTCOG's Bicycle Needs Index

(Adapted from Reference 10)

Factor	Factor Characteristic	Ranking Weight
Trip Distance	High percentage of total trips which are five miles or less	3.0
Land Use	High percentage of land use devoted to employment	2.0
Median Household Income	Low median household income	2.0
Population Density	High Population Density	1.0
Employment Density	High Employment Density	1.0

Table 5. NCTCOG's Bicycle Needs Index Qualitative Ranges

(Adapted from Reference 10)

Qualitative Assessment Range	Bicycle Needs Index Value
Very High	BNI Value > (Mean + 1.5 Standard Deviations, SD)
High	(Mean +1.5 SD) > BNI Value > (Mean + 0.5 SD)
Average	(Mean +0.5 SD) > BNI Value > (Mean - 0.5 SD)
Low	(Mean - 0.5 SD) > BNI Value > (Mean - 1.5 SD)
Very Low	BNI Value < (Mean - 1.5 Standard Deviations, SD)

Goldsmith's Study of Seattle's Pine Street Bicycle Lanes

Goldsmith performed a bicycle demand study in the Seattle area to predict the effects of a proposed bicycle facility on regional vehicle-miles of travel and the creation of mobile source emissions (11). The study was based on a "facility locator" model, which assumes that a bicycle facility is a destination itself (traditional demand models assume that various land uses are the destinations). According to Epperson (12), facility locator models have the following characteristics:

- A given bicycle route or facility is treated as the destination;
- The location of facilities and analysis zones are often simplified to a single point;
- Trip origins and destinations are treated the same, and the direction of travel is ignored in favor of the absolute level of interaction; and
- Trip producers and attractors affect the bicycle facility in proportion to their size and in inverse proportion to their distance of separation.

Goldsmith developed a methodology to estimate the number of new bicycle commute trips. The methodology (Figure 2) used census data, stated preference surveys, and other several assumptions about bicycle users and travel. Calculations for the methodology can be automated using a geographic information system (GIS) and a computer spreadsheet. Figure 3 shows an example of the methodology as applied to Seattle. One of the methodology's assumptions was that only bike lanes and paths can be expected to generate a noticeable increase in bicycle use. This assumption is perhaps reasonable for immediate effects, but ignores any long-range shifts in demand due to changes in land use or transportation facilities. Goldsmith also defined and delineated "travelsheds," or areas parallel to the bicycle facility that are suspected of using the facility. This study used the census tract on either side of the bicycle facility to delineate the travelshed.

Two types of trips were defined in the model: journey-to-work and non-work trips. Estimation of journey-to-work trips utilized data from the 1990 Census, whereas estimation of non-work bicycle trips relied on a recent telephone survey conducted in the area. Goldsmith estimated that the construction of new bicycle lanes would generate 288 new, one-way bicycle commuter (work) trips, and 762 utilitarian bicycle trips. In addition, he estimated that the bicycle lane would eliminate 398 one-way single occupant auto trips per day and reduce 742 daily vehicle-km (461 daily vehicle-mi) of travel.

Define travel shed area

For generic travel shed of unspecified location

If location known & boundaries determined

Estimate population of travel shed using city's average population density

Determine population of census tracts within travel shed

(If lacking survey data) Determine proportion of population under 45 yrs relative to city average - can use to estimate potential riding population

Assume % of general commuting population equals city average

Use census to determine % of population within travel shed that has daily commute

Assume bicycle commuting rate at citywide average

Use census (or survey data) to determine bicycle mode split for each census tract within the travel shed

Assume % of *potential* bicycle commuters same as city survey indicates. Subtract estimated number of current bicycle commuters for travel shed.

Base estimate of % potential bicycle commuters on rate of current bicycle commuting in travel shed in comparison. If census indicates bicycle mode split twice as high as city average, assume % of potential bicyclists also twice as high. Multiply this rate times all commuters in travel shed. Subtract number of current bicycle commuters.

To calculate expected number of new bicycle trips, assume 26% of potential bicycle commuting population (based on survey result) will actually become bicycle commuters

Determine the proportion of these trips that would have been SOV trips (1 in 2, according to Seattle survey)

Assume length of bicycle commute trips at city wide average; calculate by converting census data from minutes to miles

Use city wide average or calculate trip distance from central location within census tracts to main trip generator (if applicable)

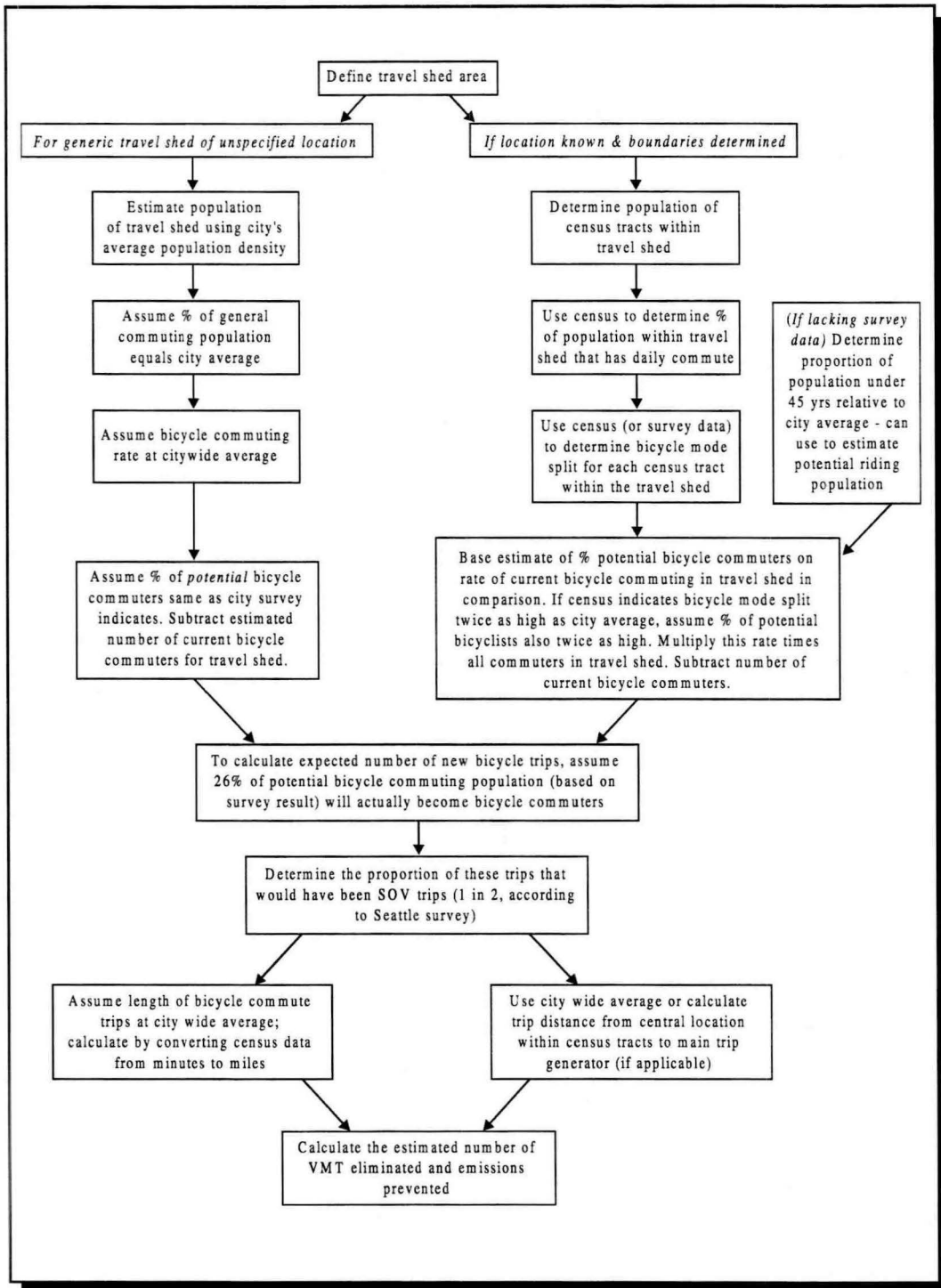Calculate the estimated number of VMT eliminated and emissions prevented

Figure 2. Goldsmith Methodology for Estimating New Bicycle Commuters (Adapted from Reference 11)

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ESTIMATING SOV TRIPS ELIMINATED PER MILE OF BIKE LANE:
SAMPLE CALCULATIONS (Based on Seattle data)

If there are 6,000 people with access to 1.6 km (1 mile) of bike lane
⇓
and 60% of general population has daily commute = 3,600 potential commuters
⇓
and 5.6% of this population are active or potential bike commuters = 202 bicycle commuters
⇓
and Census bicycle mode split (off-season rate) = 1.6% = 22 commuters per square km
(58 commuters per square mile)
⇓
then total - current = 202 - 58 = 144 potential new bicycle commute trips
⇓
and if 26% of potential bicycle commuting public would bicycle commute with better
facilities
⇓
then 26% x 144 = 37 new bicycle commuters per 0.6 km (1 mile) of bike lane
⇓
and assuming that one in two bicycle trips replace an automobile trip, then
⇓
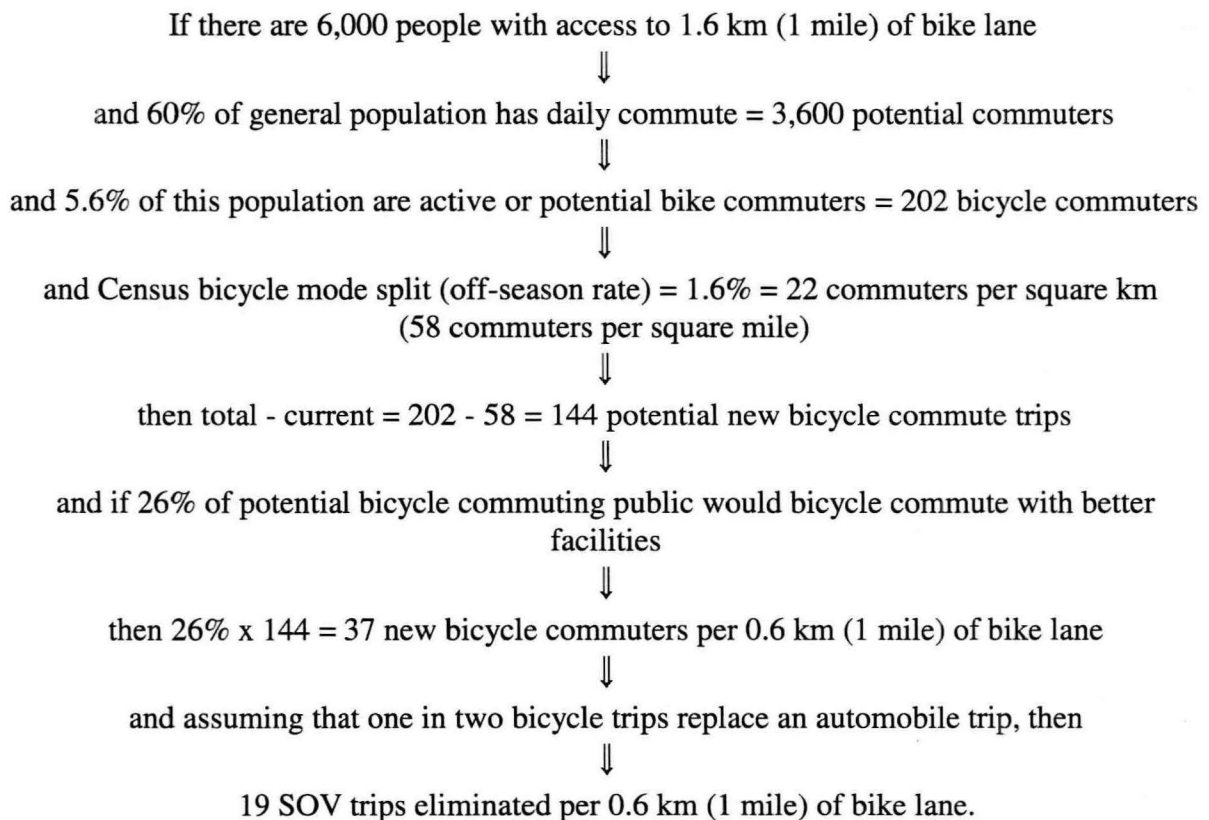19 SOV trips eliminated per 0.6 km (1 mile) of bike lane.

Figure 3. Example of Goldsmith Methodology (Adapted from Reference 11)

Landis's Latent Demand Score

Landis has developed and applied a demand forecasting technique that uses a probabilistic gravity model to estimate the relative travel demand for individual bicycle facilities (13), (14). Landis's model, like the one used by Goldsmith, can be characterized as a facility locator model, in which it is assumed that the bicycle facility is the trip destination. The Latent Demand Score (LDS) model consists of two of the typical demand modeling steps, trip generation and trip distribution. Landis's LDS model does not include the trip assignment step because it assumes that a specific bike facility or roadway segment is the destination for a trip. At this time, the LDS model only estimates the relative latent demand for an existing or proposed bicycle facility, which can be used as an indicator of the actual bicycle demand. The LDS for a particular facility is calculated using Equation 5, which is a modified version of the basic gravity model used in the traditional four-step travel demand modeling process.

$$LDS = \sum_{n=1}^{4} \left[TTS_n \times \frac{\sum_{n=1}^{4}(GA_n \times \overline{TG}_n)}{(GA_n \times \overline{TG}_n)} \times \left[\overline{TG}_n \sum_{d=1}^{l} P_{nd} \times ga_n \right] \right] \qquad (5)$$

Where:
n	=	bicycle trip purpose (e.g., work, personal/business, recreation, school);
TTS	=	trip purpose share of all bicycle trips (obtained from Census data);
GA	=	number of generators or attractors per trip purpose;
TG	=	average trip generation of attractor or generator;
P	=	effect of travel distance on bike 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; and
l	=	maximum travel distance from generator or attractor.

The following paragraphs describe the components of the LDS model and the steps necessary to calculate the LDS.

The following six steps summarize calculation of the LDS (13):

1. **Establish bicycle trip attractors and generators for four basic trip purposes**. The attractors and generators include home-based work markets (census tracts with households that have a high level of home-based work trips with durations of less then ten minutes by motor vehicle, as reported in the 1990 Census) per census block group, commercial employment per traffic analysis zone, public parks (stratified into minor, staffed, and major), and elementary and middle schools' student population. The four trip purposes are home-based work, home-based shopping, home-based recreational/social, and home-based school trips.

2. **Geocode or map the attractors and generators**, and for each identifiable roadway segment, record the number of attractors/generators within the affected distance, as determined in Step 1.

3. **Determine the trip generation of attractors/generators** by using ITE's Trip Generation handbook, then multiply the trip generation by the trip purpose share for that trip purpose. This calculation yields the relative number of bicycle trips generated, which must be adjusted by a distance probability factor.

4. **Compute the trip-making probability summation**. The following steps apply:

    a. Calibrate for the region the bicycle trip elasticity curve (see Figure 4) for each trip purpose;

    b. Multiply, for each predefined distance range, the number of attractors and generators by their distance impedance (in Equation 5, $[TG_n \sum P_{nd} \times ga_n]$; and

    c. For each of the four trip purposes, sum the value by segment. This summed value is a demand indicator value.

5. **Multiply the trip-making probability by the relative number of generated bicycle trips**. The resulting value is the number of bicycle trips for a particular purpose.

6. **Sum the bicycle trips for the four trip types**. This summation yields the Latent Demand Score, a relative indicator of the total demand for a bicycle facility with little or no impedance.
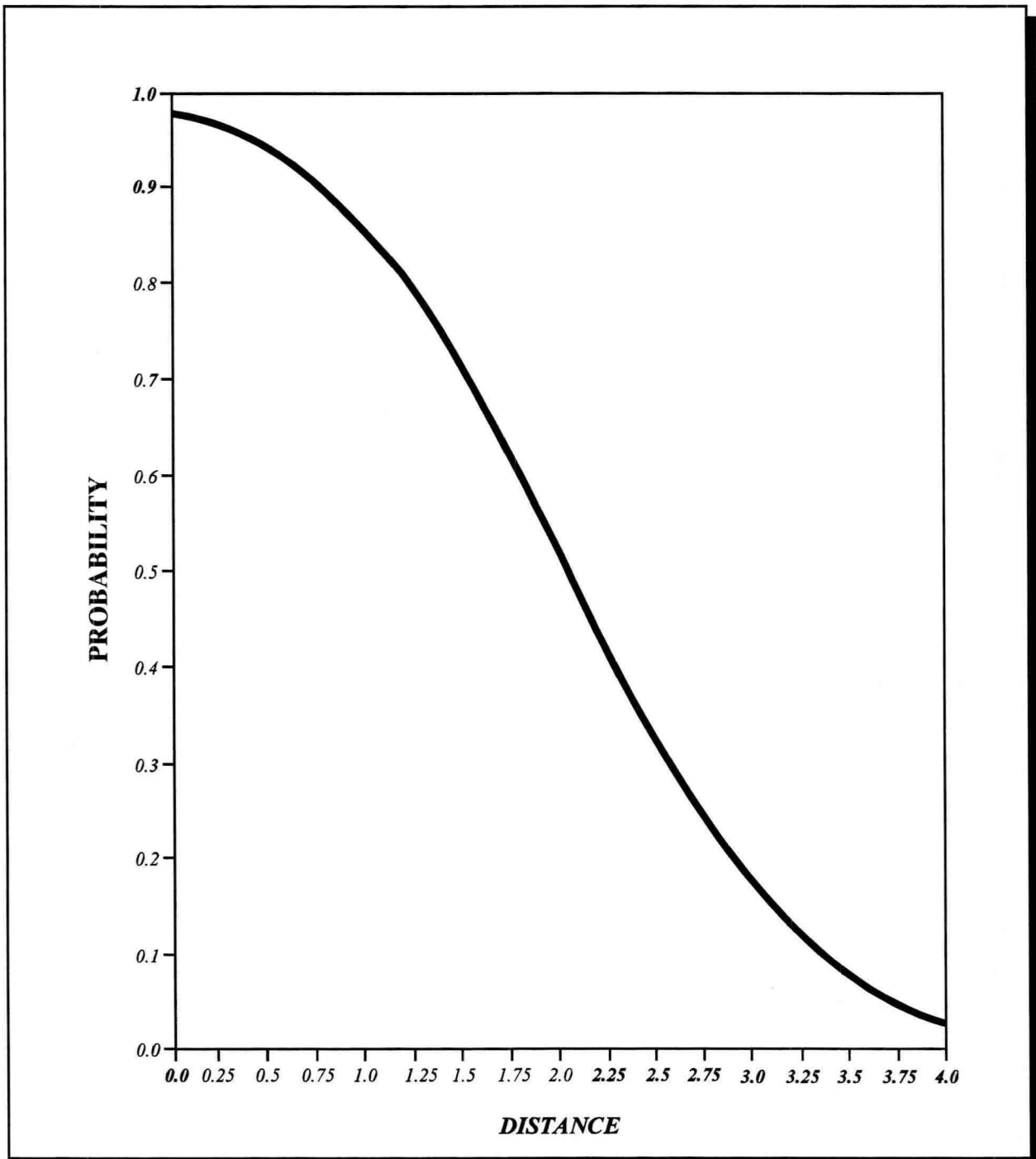
Figure 4. Example of a Bicycle Trip Elasticity Curve (Adapted from Reference 13)

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Landis's LDS model can be accomplished easily in a geographic information system (GIS), which is the method Landis has used in quantifying LDS for bicycle planning in several urban areas, including Tampa, Vera Beach, and St. Lucie, Florida; Birmingham, Alabama; and, Philadelphia, Pennsylvania. The LDS can also be calculated using aerial maps or detailed roadway network/land use plots.

According to Landis, the LDS does not quantify non-destination trips, or those recreational bicyclist trips which are not focused on a specific destination. Landis has used public input in most cases to supplement the use of the LDS. In these cases, recreational cyclists may quickly note particular high-use recreation routes. As indicated by its name, the LDS value only represents the relative latent demand for a bicycle facility. If the examined bicycle facility is suitable for bicyclists (i.e., low vehicle speeds, adequate pavement widths, etc.), then it is theorized that the LDS would closely approximate actual use. If the examined bicycle facility is unsuitable for bicyclists (i.e., high vehicle speeds, narrow pavement widths, etc.), the LDS would overestimate the actual bicycle trips because the latent bicycle demand would be shifted to another mode or perhaps the trip would not be taken.

Ridgway's Demand Modeling Techniques for Bicycles

Ridgway has adapted the four-step traffic modeling process to bicycle demand forecasting in several planning applications in California (15). Ridgway's bicycle travel demand model (Figure 3) contains the four traditional modeling steps. The following paragraphs contain a discussion of the Ridgway model's application in Berkeley, California.

Bicycle trips are generated using socioeconomic and land use data. The trip generation can be accomplished through simple equations or complex multi-nomial logit models (which use various factors to influence trip rates). The bicycle trips are classified into three separate purposes: home-based work, home-based other, and non-home-based. Bicycle trips by each trip purpose are then generated for each traffic analysis, survey, or census zone. The results look similar to those shown in Table 6.
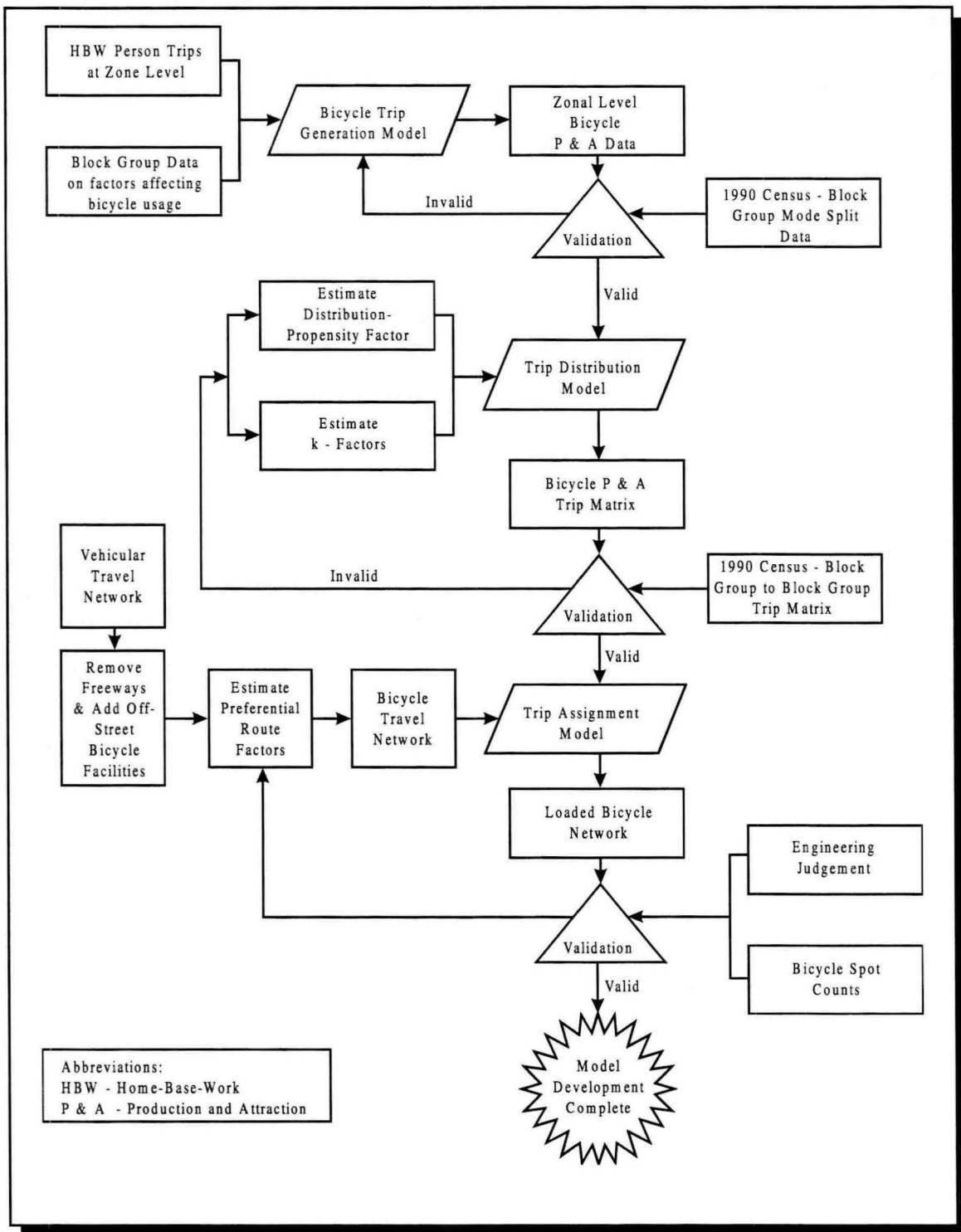
25

Figure 5. Ridgway's Bicycle Travel Demand Model (Adapted from Reference 15)

Table 6. Example of a Bicycle Trip Production and Attraction Table

(Adapted from Reference 15)

Zone #	Person Trip Productions	Person Trip Attractions	% Bicycle Mode Split	Bicycle Trip Productions	Bicycle Trip Attractions
1	24,900	13,200	2.0	498	264
2	5,200	640	2.5	130	16
3	31,000	13,800	1.0	310	138
4	13,000	7,867	3.0	390	236
5	29,105	14,227	8.3	2,414	1,180
6	83,400	69,800	4.0	3,336	2,792
7	58,240	15,600	2.5	1,456	390
8	69,529	176,353	3.4	2,364	5,996
9	9,739	14,377	6.9	672	992
10	9,269	4,519	10.4	964	470
External	40,300	43,300	2.0	806	866
Totals	373,683	373,683	n.a.	13,340	13,340

Once the bicycle trips have been generated for each analysis zone, the trips are distributed between analysis zones using a traditional gravity model. The gravity model uses a distribution-propensity factor, which is a function of travel distance. The distribution-propensity factor would have to be calibrated to local trip-making conditions. The output of this step is a zone-to-zone trip matrix like that shown in Table 7.

The final step in Ridgway's bicycle model is trip assignment. A coded network of streets and off-street bicycle facilities is required, and traditional vehicle model networks may be used with some modifications. The trip assignment for zone-to-zone trips is typically made based on the travel distance. However, the authors noted that several other link attributes could be related to the trip

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assignments, like type of bicycle facility, vehicle traffic volumes, or vehicle speeds. These link attributes would rate the suitability of possible links, and assign bicycle traffic to these links based upon the suitability. The output from this step is a "loaded" bicycle network with two-way bicycle volumes on each link of the network.

Table 7. Example of a Bicycle Trip Production and Attraction Matrix

(Adapted from Reference 15)

	Attractions											
Zone	1	2	3	4	5	6	7	8	9	10	External	Total
P 1	244	0	0	0	20	0	0	0	0	0	0	264
r 2	0	16	0	0	0	0	0	0	0	0	0	16
o 3	0	14	94	14	16	0	0	0	0	0	0	138
d 4	0	0	18	128	24	44	0	22	0	0	0	236
u 5	0	0	0	30	846	48	14	0	14	8	220	1180
c 6	50	34	42	34	410	1424	266	178	118	98	138	2792
t 7	0	0	0	0	0	0	390	0	0	0	0	390
i 8	66	0	52	58	936	1342	748	1974	172	226	422	5996
o 9	66	0	12	44	66	218	10	88	332	142	14	992
n 10	28	0	0	0	26	0	0	36	12	356	12	470
s External	44	66	92	82	70	260	28	66	24	134		866
Total	498	130	310	390	2414	3336	1456	2364	672	964	806	

There are many factors and assumptions used within each of these three steps. One that the author describes as problematic is the future mode split. This variable may change significantly over time. Ridgway used 1990 Census data to perform a regression analysis between many factors and percentage mode split for 18 California cities (15). Ridgway found the following three variables to be correlated (with respective correlation coefficient, R) at the aggregate, citywide level:

- Age, or percent of population less than 25 years old, R=0.31;
- Travel time, mean travel time for all person trips, R=0.42; and
- Number of students, percentage of students 12 years and older, R=0.43.

The resulting model composed of these three variables was used to predict mode split for the same 18 California cities, with a correlation coefficient (R) of 0.81 between the estimated and actual mode split percentages. The author considered this accuracy to be adequate. In application of the model to individual census tracts in Berkeley, the correlation coefficient between estimated and actual mode split percentages dropped to 0.53, indicating a loss of accuracy at the census tract level. Ridgway suggested that refinement or improvements to the model may be necessary at the census tract level to adequately predict mode split percentage.

From his studies, Ridgway recommends the following steps in bicycle demand modeling:
- Refine factors and processes within each demand modeling step to improve prediction accuracy;
- Expand trip purposes to include linked trips to transit;
- Include pedestrian trips as part of the model; and
- Integrate vehicle and bicycle demand models, or consider bicycle and pedestrian trips in the mode choice step of traditional vehicle models.

Pedestrian Demand Forecasting Models

North Central Texas Council of Governments' Pedestrian Needs Index

NCTCOG has developed a pedestrian needs index as a means to identify traffic survey zones with high pedestrian use, and therefore, a need for pedestrian facilities (16). A pedestrian environmental factor analysis is then used to identify how to meet specific pedestrian needs within a traffic survey zone. The pedestrian needs index was based upon 1990 Census data, regional land use data, literature reviews, and regression analyses. The following sections describe the development and calculation of NCTCOG's pedestrian needs index.

In constructing the pedestrian needs index, NCTCOG performed a single and multiple regression analysis of 1990 Census and land use data compiled for the Dallas-Ft. Worth region. The single regression analysis yielded the following factors that were closely related to pedestrian mode share (listed in order of correlation):

- high number of hours worked per week (HHR, inverse correlation);
- low number of hours worked per week (LHR, direct correlation);
- percentage of land devoted to employment uses (LE);
- ratio of workers to population (WPR);
- employment density (ED);
- percentage of land devoted to residential uses (LR, inverse correlation);
- percentage of residents under 16 (AGE);
- population density of residential land uses (PRD);
- low income (P); and
- population density (PD).

The regression equation was as follows:

$$\text{Pedestrian Mode Share} = \begin{array}{l} 0.219 - 0.239(HHR) + 0.075(LE) + 0.008(WPR) - \\ 0.031(LR) + 0.0013(PD) + 0.085(LHR) + 0.0036(AGE) \end{array} \qquad (6)$$

The R-squared statistic for this multiple regression is 0.43, which means that the various factors explain about 43 percent of the variation in bicycle mode share. The authors noted several concerns with the multiple regression model:

- Several of the model variables or factors are correlated to each other; and
- The model only considers demographic and land use factors in determining pedestrian mode share and does not include environment-specific factors like street layout, ease of intersection crossing, or availability of sidewalks.

From a literature review, the NCTCOG authors identified the following factors as affecting pedestrians: climate, topography, average commute trip length, population density, and individual

perceptions. A limited number of factors were selected from the literature review and the regression analysis to form the basic factors in the pedestrian needs index.

The pedestrian needs index is calculated from six different factors (selected from the regression analysis and literature review), each having a ranking weight applied to it as shown in Table 8. The following steps apply for calculating the pedestrian needs index:

1. The factor value for each traffic survey zone is normalized by the region average (Equation 3), resulting in values greater than 1.0 if the survey zone factor value is greater than the regionwide average. Conversely, if the zone factor value is less than the regionwide average, the index value will be less than 1.0.

2. Multiply the index scores for each factor by the weight shown in Table 9 (Equation 4). This results in a weighted index value for each factor and each traffic survey zone.

3. For each traffic survey zone, sum the weighted index values for each of the factors. This summation results in a single index value for each traffic survey zone. A mean and standard deviation are computed from index values for all zones within the region, and a qualitative needs assessment (using the pedestrian needs index) for each survey zone is determined by rating each zone in relation to the regionwide mean and standard deviation (see Table 9). The results of this needs assessment are then shown in graphical formats on region maps.

Table 8. Factors in NCTCOG's Pedestrian Needs Index (Adapted from Reference 16)

Factor	Factor Characteristic	Ranking Weight
Bus Service	TSZ has bus service from a local transit agency	1.5
Rail Service	TSZ is within a half-mile of future commuter rail station	1.5
Population Density	High population density	2.0
Employment Density	High employment density	2.0
Land Use	High percentage of land uses devoted to employment	1.0
Median Household Income	Low median household income	1.0

Table 9. NCTCOG's Pedestrian Needs Index Qualitative Ranges

(Adapted from Reference 16)

Qualitative Assessment Range	Pedestrian Needs Index Value
Very High	PNI Value > (Mean + 1.5 Standard Deviations, SD)
High	(Mean +1.5 SD) > PNI Value > (Mean + 0.5 SD)
Average	(Mean +0.5 SD) > PNI Value > (Mean - 0.5 SD)
Low	(Mean - 0.5 SD) > PNI Value > (Mean - 1.5 SD)
Very Low	PNI Value < (Mean - 1.5 Standard Deviations, SD)

Montgomery County, Maryland/Washington D.C. Area

In 1987, the Maryland-National Capital Park and Planning Commission (M-NCPPC), the MPO for Montgomery County, Maryland, devised a pedestrian and bicycle friendliness index as part of their existing work trip mode choice model (17). The index was a score assigned to traffic analysis zones and was based upon the availability of sidewalks (6 categories), bicycle paths, bus stop shelters (3 categories), the extent of building setbacks from the street (3 categories), and the heterogeneity of land use at a local level (4 categories). The index was considered to be statistically significant for explaining variation in auto-transit mode choice. The index was incorporated into a vehicle modeling software program (EMME/2).

More recently, Metropolitan Washington Council of Governments (MWCOG), the MPO for the metropolitan Washington, D.C. area, has developed a similar mode choice model that serves as input to the region's transportation model (18). MWCOG's proximity mode choice model, or PROMO, was developed by Tom Rossi of Cambridge Systematics and Michael Replogle of the Environmental Defense Fund. PROMO is a pivot point spreadsheet program used to determine the sensitivity of auto, transit, and walk travel to changes in several key factors:

- transit in-vehicle travel time;
- transit out-of-vehicle travel time;
- auto versus transit travel cost;
- quality of pedestrian and bicycle environment factor; and
- employment density.

The quality of pedestrian and bicycle environment factor is similar to that used by M-NCPPC, Portland and Sacramento. The factor is based on ease of crossing streets, sidewalk continuity, street connectivity, building setbacks, land use mix, topography, and traffic calming and bike network connectivity/facilities. These factors affect the mode choice of travelers. The results of the PROMO spreadsheet model are then used as input into the Washington, D.C.'s regional travel demand model program (MINUTP) to determine the effects of mode choice changes.

Portland METRO's Pedestrian Environment Factor

Portland METRO (regional MPO for Portland, Oregon) is at the forefront of non-motorized travel modeling. METRO has developed a pedestrian environment factor (PEF), the concept of which has been used by MPOs in Sacramento, Washington, D.C., and Dallas-Ft. Worth (19). The PEF is an ordinal value between 4 and 12, with a range of 1 to 3 points assigned for each of the following ranges:

- sidewalk availability;
- ease of street crossing;
- connectivity of the street and sidewalk system; and
- terrain.

The PEF value is a qualitative assessment performed according to individual(s) judgments of the pedestrian environment. METRO considers the PEF value to be statistically significant in predicting vehicle-miles of travel for several trip purposes (home-based work, home-based other, non-home-based work, and non-home-based non-work), but no statistics were provided as a basis for this claim. The PEF value is then used along with density as an input to METRO's mode choice, automobile ownership, and trip distribution models.

METRO's mode choice model currently considers employment, household density, the PEF, and a measure of the proportion of automobiles to workers. They are in the process of updating their model to include grade, a measure of the bicycle network, and bicycle access to employment. Currently, their bicycle model must be calculated in their computer model for all analysis zonal pairs, whereas the PEF only considers walk trips within a single analysis zone.

Sacramento Council of Governments

The Sacramento Council of Governments (SACOG) uses a pedestrian factor similar to Portland METRO's PEF in their computerized mode choice modeling process (19). SACOG has two separate mode choice modules: one for auto travel, and one for transit, bicycle and pedestrian travel. A pedestrian factor is used in the second mode choice module that deals with transit, bicycle,

and pedestrian shares. SACOG's pedestrian factor is an ordinal, qualitative value related to the circuity of streets and the presence of sidewalks. SACOG uses aerial photographs to assign each traffic analysis zone a rank for each factor between 1 and 3. The bicycle trip purposes included in the model are home-based work, home-based shopping, other, and non-home based.

SACOG recently completed the update of their regional travel demand model, of which the pedestrian factor was an improvement. They have no extensive plans in the future to extend their non-motorized travel demand forecasting processes.

CHAPTER 3

CONCLUSIONS

This chapter summarizes the findings of the literature review and provides several conclusions related to pedestrian and bicycle travel demand forecasting. The following major points summarize the literature review findings elaborated on in the following paragraphs:

- **Existence of Several Demand Forecasting Models/Techniques** -- The literature review identified several bicycle and pedestrian models/techniques that could be modified and adapted for use by TxDOT. Although these techniques are relatively untested and could have large margins of error, they would represent an improvement upon the existing lack of bicycle and pedestrian demand forecasting tools.

- **Four Basic Categories of Demand Forecasting Models** -- The literature review identified four basic categories of bicycle/pedestrian demand forecasting models/techniques: (1) aggregate or simplified trip generation models; (2) facility locator or "market travelshed" models; (3) sequential stand-alone bicycle and pedestrian demand models similar to current four-step traffic models; and (4) four-step traffic models modified to account for bicycle and pedestrian environments.

- **Uncoordinated Efforts Aimed at Various Improvements** -- There is a genuine nationwide interest in forecasting the demand for bicycle and pedestrian facilities. The topic is a highly ranked research problem of the Transportation Research Board's Committee on Bicycling. To date, however, there is no strong consensus on how bicycle and pedestrian trips can be modeled, either separately or as part of a regional transportation modeling process.

The following sections discuss these findings in more detail.

Existence of Several Demand Forecasting Models/Techniques

The literature review identified bicycle and pedestrian demand forecasting techniques that have been used in several locations in the U.S.:

- Rhode Island;
- various regions in Florida;
- Portland, Oregon;
- Seattle, Washington;
- Sacramento, Davis, and Berkeley, California;
- Montgomery County, Maryland and Washington, D.C. region; and
- Dallas-Ft. Worth, Texas.

Many of the regions have developed models that fit their specific transportation planning and forecasting needs. These techniques could be adapted to the specific needs of TxDOT.

Four Basic Categories of Demand Forecasting Techniques

The researchers found four basic types of bicycle/pedestrian demand forecasting techniques:

- aggregate or simplified trip generation models (e.g., Metro-Dade County's Bikes-On-Bus, Epperson's Dade County accident model, NCTCOG's Bicycle and Pedestrian Needs Index);
- facility locator or "market travelshed" models (e.g., Goldsmith's Seattle Pine Street methodology, Landis's Latent Demand Score);
- stand-alone, sequential bicycle/pedestrian demand models similar to current four-step models (e.g., Rhode Island study, Ridgway); and
- four-step traffic models modified to account for bicycle and pedestrian environments (e.g., Portland METRO, Sacramento COG, Montgomery County).

The first category of techniques, aggregate or simplified trip generation models, relies on aggregated data, typically at the census tract or traffic analysis zone level, to predict the relative

magnitude or propensity of bicycle/pedestrian use at a census tract or zonal level. The trip generation for this technique typically relies on 1990 Census data, Journey-to-Work data, or NPTS data. These techniques have proven suitable for identifying high-use bicycle and pedestrian areas, but have not been used to estimate demand for specific bicycle or pedestrian facilities. These aggregated techniques have been commonly used to identify high-use areas for additional study. Also, the demand estimates produced by these techniques would not be sensitive to different types or changes in bicycle or pedestrian facilities.

The second category of techniques, facility locator models, assumes that the bicycle or pedestrian facility is the trip destination. This technique also assumes that trips within a specified travelshed are attracted to the facility in proportion to a trip attractor/generator's size and in inverse proportion to the distance of separation. The facility locator models identified in the literature review were sensitive to the presence or absence of bicycle and pedestrian facilities, but not to the quality or suitability of these facilities for safe, convenient travel.

The third category of techniques, sequential demand models, are very similar to traditional four-step travel models, with the exception that they deal specifically with bicycle and/or pedestrian travel. The areas that utilized these types of techniques had varying degrees of detail in the modeling process. The Rhode Island study, for example, contained many assumptions and simplifications within each of the three sequential steps (mode choice was not included). Ridgway, on the other hand, described a demand forecasting model that was more akin to typical traffic models, with surveys and other tools being used within each step to avoid assumptions and simplifications.

Several large MPOs have used the fourth category of techniques, four-step traffic models modified to account for bicycle and pedestrian environments. This technique improves the ability of existing four-step traffic models to account for bicycle and pedestrian-friendly environments. Most of the modeling efforts in this category focus on pedestrians, but could presumably be modified to evaluate the bicycle environment. These models also focus primarily on the trip generation, trip distribution, and mode choice aspects of the modeling process. To date, none of these models have

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actually addressed the issue of bicycle and pedestrian trip assignment to a bicycle or pedestrian facility network. The Federal Highway Administration's Travel Model Improvement Program (TMIP) is examining the incorporation of non-motorized travel into the next generation of travel models. The next generation of travel models will presumably be more microscopic than current models and will be activity-based. Los Alamos National Laboratories is developing a TRANSIMS computer model, but the model will not be available in the immediate future.

Uncoordinated Efforts Aimed at Various Improvements

Many groups consider the issue of bicycle and pedestrian demand forecasting to be a high research priority, especially considering the amount of funding available through ISTEA for bicycle/pedestrian projects. However, there is not a clear consensus among the many transportation and advocacy groups on a vision for the ideal bicycle and pedestrian demand forecasting methodology. Many MPOs and regional transportation agencies are attempting to incorporate bicycles and pedestrians into existing vehicle-based traffic models. Smaller MPOs and cities have used aggregate models or simplified four-step models to determine high-use zones within a city or region. Researchers are examining various issues and sub-methodologies of the traditional four-step modeling process for adaption and modification to bicycle and pedestrian demand forecasting. These research efforts are, for the most part, independent and uncoordinated.

The FHWA is beginning to take a lead role in coordinating nationwide efforts with the organization of a two-day Bicycle and Pedestrian Travel Demand Forecasting Workshop held in Washington, D.C., on November 25-26, 1996. The workshop brought together bicycle and pedestrian demand forecasting experts from around the country to help FHWA scope a planned study on bicycle and pedestrian demand forecasting. As a result of this workshop, FHWA staff recently awarded a contract to Cambridge Systematics, Inc. to compile a "Best Practices" report on bicycle/pedestrian travel demand forecasting.

CHAPTER 4

RECOMMENDATIONS

The authors offer the following recommendations for consideration by TxDOT:

- **Proceed with the data collection and methodology development phases of this research study.** The literature review found several bicycle and pedestrian methodologies or techniques that could be adapted or modified for use in the state of Texas. The research team feels that there are a sufficient number of methodologies or techniques that could be validated or calibrated with local data collection.

- **Further investigate facility locator or simplified three-step methodologies in future efforts.** Facility locator or simplified three-step models (mode choice not included) can be used to determine the effects of the presence or absence of specific bicycle facilities. These models are also stand-alone (demand can be forecast independent of four-step traffic models) and should not require significant survey, calibration, or network coding efforts. The research team feels these methodologies may best fit TxDOT's immediate needs, and that these techniques should be more closely investigated in the model development phase.

- **Maintain expectations consistent with the level of effort.** The current four-step traffic models used by almost all urban areas have been developed with significant research and effort, yet still exhibit a high degree of error (typically ± 25 percent or more) in predicting vehicle volumes. Bicycle and pedestrian travel demand forecasting is in its infancy, and significant research remains before this process can become comparable to the vehicle modeling process. The research team recommends that TxDOT maintain realistic expectations while realizing that any models or methodologies developed will be an improvement upon existing conditions and a step in the right direction.

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