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16. Abstract


This report summarizes research activities conducted to develop a bicycle and pedestrian travel demand forecasting methodology. Previous research reports documented the literature review (Report 1723-1) and data collection activities (Report 1723-2). The appendix of this report contains guidelines for estimating bicycle and pedestrian travel demand based upon the type and intensity of land uses adjacent to a study corridor.

Since little information or data on bicycle and pedestrian travel demand forecasting were available in Texas, the research team developed a sketch planning methodology by collecting and analyzing bicycle and pedestrian trip survey data at eight urban locations in four different cities in Texas. The bicycle/pedestrian survey data that were collected included specific information about individual trip origins and destinations, trip lengths, trip purpose, and trip frequency. These data, in conjunction with supporting information from other locations, were used to develop bicycle and pedestrian trip generation rates. Bicycle and pedestrian volumes obtained during the survey data collection were used to test and validate the sketch planning method described in this report.



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# DEVELOPMENT OF A METHODOLOGY TO ESTIMATE BICYCLE AND PEDESTRIAN TRAVEL DEMAND

by

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

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

and

Aaron Hottenstein
Graduate Research Assistant
Texas Transportation Institute

Report 1723-S
Research Project Number 0-1723
Research Project Title: Bicycle and Pedestrian Travel Demand Forecasting
for Existing and Proposed Transportation Facilities

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

# IMPLEMENTATION RECOMMENDATIONS

This study developed a methodology to estimate bicycle and pedestrian travel demand for existing and proposed transportation facilities. The bicycle and pedestrian demand estimation procedures can be used by TxDOT in roadway planning, project development, or design.

The recommendations of the study are as follows:

1. **Interpretation of Demand Estimates -** TxDOT should consider developing guidance or policy for roadway planners or designers to use in interpreting the demand estimates produced with the recommended demand forecasting procedures. This guidance or policy will help to provide consistent and systematic accommodation of bicyclists and pedestrians on state roadways.

2. **Integrate Demand and Supply Analyses -** TxDOT should consider integrating the demand forecasting procedures developed in this study (0-1723) with the bicycle suitability (supply) procedures developed in another study (7-3988). The roadway suitability procedures should also be expanded to incorporate analysis of pedestrian facility supply, or a pedestrian environment factor. These procedures should be integrated to provide a more complete analysis of demand/supply issues for bicycle and pedestrian facilities.

3. **Encourage and Monitor Use of the Procedures and Provide Enhancements -** TxDOT should encourage and monitor the use of the recommended demand forecasting procedures to identify potential areas for improvement. Demand estimates should be compared to actual volume counts where bicycle and/or pedestrian facilities are constructed along state roadways. The recommended demand forecasting procedures should be enhanced to improve their accuracy and usability.

## DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation. This report was prepared by Shawn Turner (Texas certification number 82781), Gordon Shunk (California certification number 0936), and Aaron Hottenstein.

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# CHAPTER 1

# INTRODUCTION

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

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

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

## RESEARCH OBJECTIVES

The overall research goal for TxDOT study 0-1723 was to develop a sketch planning methodology that can be used to assess potential travel demand by bicyclists and pedestrians. The sketch planning method would most likely be used by TxDOT in the planning and project development process. The potential demand estimates can be used in that process to make more informed decisions about where and how best to accommodate travel by bicyclists and pedestrians.

Since little information or data on bicycle/pedestrian travel demand forecasting were available in Texas, the research team developed a sketch planning methodology by collecting and analyzing bicycle and pedestrian trip survey data at eight urban locations in four different cities. The bicycle/pedestrian survey data that were collected included specific information about individual trip origins and destinations, trip lengths, trip purpose, and trip frequency. These data, in conjunction with supporting information from other locations, were used to develop bicycle and pedestrian trip generation rates. Bicycle and pedestrian volumes obtained during the survey data collection were used to test and validate the sketch planning method described in this report.

## ORGANIZATION OF THIS REPORT

This report summarizes research activities conducted in the development of a bicycle and pedestrian demand forecasting methodology. An appendix to this report contains guidelines for the bicycle and pedestrian travel demand forecasting methodology. The report is divided into the following chapters:

- **Chapter 1: Introduction -** presents the objectives for this research study;
- **Chapter 2: Background -** summarizes background information and activities relevant to the study;
- **Chapter 3: Study Design -** discusses the research approach for developing the bicycle and pedestrian demand forecasting methodology;
- **Chapter 4: Findings -** summarizes the study findings; and
- **Chapter 5: Conclusions and Recommendations -** provides conclusions and recommendations of this two-year study.

# CHAPTER 2

# BACKGROUND

This chapter summarizes background information that is relevant to this research area. The first part of the chapter provides a summary of the literature review, which was discussed in detail in Report 1723-1 (1). The second part of the chapter summarizes a national study that developed a guidebook and supporting documentation on methods to estimate non-motorized travel (2,3).

## SUMMARY OF LITERATURE REVIEW

A literature review was performed at the beginning of this study to identify and analyze information related to bicycle and pedestrian travel demand forecasting. The literature review is briefly summarized here to provide background information. Interested readers should refer to Report 1723-1 for more details and discussion of the available literature (1).

### 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., including 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 types of bicycle/pedestrian demand forecasting techniques:

- aggregate or simplified trip generation models (e.g., Metro-Dade County's Bikes-On-Bus (4), Epperson's Dade County accident model (5,6), NCTCOG's Bicycle and Pedestrian Needs Index (7));
- facility locator or "market travelshed" models (e.g., Goldsmith's Seattle Pine Street methodology (8), Landis's Latent Demand Score (9,10));
- stand-alone, sequential bicycle/pedestrian demand models similar to current four-step vehicular travel forecasting models (e.g., Rhode Island study, Ridgway (11)); and
- four-step traffic models modified to account for bicycle and pedestrian environments (12) (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 are not sensitive to different bicycle or pedestrian facility designs.

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, is very similar to traditional four-step travel forecasting 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 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 travel forecasting models modified to account for bicycle and pedestrian environments. This technique improves the ability of existing four-step travel forecasting 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 has 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 the TRANSIMS computer model, but the model will not be available in the immediate future.

**Uncoordinated Efforts Aimed at Various Improvements**

Several agencies consider bicycle and pedestrian demand forecasting to be a high research priority, especially considering the amount of funding available through the Intermodal Surface Transportation Efficiency Act (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. Some 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.

FHWA has begun to take a lead role in coordinating nationwide efforts and sponsored a two-day Bicycle and Pedestrian Travel Demand Forecasting Workshop held in Washington, D.C., November 25-26, 1996 (13). 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 that workshop, FHWA staff awarded a contract to Cambridge Systematics, Inc. to compile a "Best Practices" report on bicycle/pedestrian travel demand forecasting (an update on that effort is described in the next section).

## FHWA GUIDEBOOK ON ESTIMATING NON-MOTORIZED TRAVEL

Cambridge Systematics, Inc., in cooperation with the Bicycle Federation of America, Michael Replogle, and the University of North Carolina, recently completed a *Guidebook on Methods to Estimate Non-Motorized Travel* (2). The guidebook, which was sponsored by FHWA, describes and qualitatively compares the various methods that have been developed to estimate future levels of bicycle and pedestrian travel. The guidebook also discusses other quantitative planning procedures that support demand forecasting. Table 1 illustrates the 11 types of quantitative demand forecasting methods discussed in the bicycle/pedestrian guidebook.

The FHWA guidebook contains an overview of each of the 11 basic methods, including a qualitative assessment of the method's ease of use, data requirements, accuracy, sensitivity to design factors, and range of use. Examples or case studies were provided to illustrate where and which agencies have experience with each method. An additional volume contains detailed technical documentation for each of the methods as well (3).

**Table 1. Categorization of Available Bicycle and Pedestrian Demand Forecasting Methods**

| Purpose | Method | Description |
|---|---|---|
| *Demand Estimation*<br><br>Methods which can be used to derive quantitative estimates of demand. | Comparative Studies | Aggregate-level methods which predict non-motorized travel on a facility by comparing it to usage and surrounding population and land use characteristics of other similar facilities. |
| | Aggregate Behavior Studies | Aggregate-level methods which relate non-motorized travel in an area to its local population, land use, and other characteristics, usually through regression analysis. |
| | Sketch Plan Methods | Aggregate-level methods which predict non-motorized travel on a facility or in an area based on "back-of-the-envelope" calculations and rules of thumb about travel behavior. |
| | Discrete Choice Models | Disaggregate-level models which predict an individual's travel decisions based on characteristics of the alternatives available to them. |
| | Regional Travel Models | Integrated models of various aspects of travel behavior, set within an overall spatial framework which includes land use characteristics and transportation networks. |
| *Relative Demand Potential*<br><br>Methods which do not predict actual demand levels, but which can be used to assess potential demand for or relative levels of non-motorized travel. | Market Analysis | Methods which identify a likely or maximum number of bicycle or pedestrian trips which may be expected given an ideal network of facilities. |
| | Facility Demand Potential | Methods which use local population and land use characteristics to prioritize projects based on the relative potential for use. |
| *Supply Quality Analysis*<br><br>Methods which describe the quality of non-motorized facilities ("supply") rather than the demand for such facilities. These may be useful for estimating demand if demand can be related to the quality of available facilities. | Bicycle and Pedestrian Compatibility Measures | Measures which relate characteristics of a specific facility to its overall attractiveness for bicycling or walking. |
| | Environment Factors | Measures of facility and environment characteristics at the area level which describe how attractive the area is to bicycling and walking. |
| *Supporting Tools and Techniques*<br><br>Analytical methods to support demand forecasting. | Geographic Information Systems | Emerging information management tools which can be used in many ways to evaluate both potential demand and supply quality. |
| | Preference Surveys | Survey techniques which can be used on their own to determine qualitative factors which influence demand, and which also serve as the foundation for quantitative forecasting methods such as discrete choice modeling. |

Source: adapted from (2)

# CHAPTER 3
# STUDY DESIGN

This chapter describes the study design used to collect and analyze bicycle and pedestrian trip survey data at eight sites in Texas. The survey data were used to develop the demand forecasting methods. Bicycle and pedestrian counts were used to test the validity of the methods.

## DATA COLLECTION AND REDUCTION

This section summarizes the data collection and reduction activities conducted for this study. Report 1723-2 (14) provides specific documentation on data collection and reduction, and interested readers are referred to that report for additional information.

For this study, eight sites were selected in four Texas cities: College Station, Austin, Houston, and Dallas (Table 2). Several criteria determined site selection:

- Adequate provision of bicycle and pedestrian facilities;
- Relatively high levels of use;
- Geometric and traffic characteristics typical of state roadways;
- Trip purposes predominantly transportation-related; and
- Ability to position video data collection equipment.

Initially, the researchers experienced difficulty in identifying state roadways with adequate bicycle/pedestrian provisions and high levels of use. Consequently, several of the data collection sites were chosen where high-use facilities intersected with state roadways. Also, several shared-use trails were selected because of their high levels of use for transportation purposes. The number of sites was spread geographically among the urban areas of Texas, and the bicycle and pedestrian facilities at these sites incorporate a number of different design characteristics and adjacent land uses. Table 2 describes the characteristics of the roadways at each site.

## Table 2. Description of Data Collection Sites

| Site | Primary Corridor | | | | | Intersecting Corridor | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Street** | **State Highway? (Yes/No)** | **Street Type and Cross Section** | **Bike/Ped Facilities** | **Anticipated Bike/Ped. Usage** | **Street** | **State Highway? (Yes/No)** | **Street Type and Cross Section** | **Bike/Ped Facilities** | **Anticipated Bike/Ped. Usage** |
| 1 | FM 2347 (Geo. Bush Dr.), College Station | yes | 4-lane divided arterial | 2-way bike lanes, sidewalk, jogging path | moderate commuter, recreational | Bizzell/ Timber Street | no | 2-lane collector | sidewalk | high commuter |
| 2 | FM 2818, College Station | yes | 4-lane undivided arterial | 1.2 m shoulders | low recreational | Welsh Street | no | 2-lane collector | bike lanes/ sidewalks on both sides | moderate commuter, recreational |
| 3 | RM 2222, Austin | yes | urban major arterial | sidewalks on both sides | low recreational | Shoal Creek Boulevard | no | 2-lane collector | bike lanes/ sidewalks on both sides | moderate commuter, recreational |
| 4 | Loop 360, Austin | yes | suburban state highway | 1.8-2.4 m shoulders | high recreational | Courtyard Drive | no | 2-lane local | sidewalk | low |
| 5 | North Braeswood, Houston | no | urban minor arterial | parallel bicycle and jogging trail | high recreational, moderate commuter | Main Street | no | 4-lane undivided arterial | sidewalks | low |
| 6 | Allen Parkway, Houston | no | 6-lane divided arterial | parallel bicycle and jogging trail | high recreational, moderate commuter | Shepherd | no | 3-lane one way pair | sidewalks, dirt paths | moderate recreational, low commuter |
| 7 | Royal Lane, Dallas | no | 4-lane undivided arterial | parallel bicycle path | moderate recreational, low commuter | Greenville Avenue | no | 4-lane undivided arterial | sidewalks on both sides | low commuter |
| 8 | Mockingbird Lane, Dallas | no | suburban minor arterial | parallel bicycle path | high recreational, low commuter | Vicinity of White Rock Lake | n/a | | | |

Intercept survey cards (Figure 1) were distributed to bicyclists and pedestrians at these eight sites during peak and off-peak periods of travel over a three-day period. The survey cards were in the form of a postage prepaid postcard that recipients could take with them to complete and mail to TTI at a later date. The survey cards consisted of five questions that asked about basic trip characteristics, such as trip origin and destination, purpose, frequency, and trip time.

Howdy! The Texas Transportation Institute is conducting a survey of bicyclists and pedestrians for the Texas Department of Transportation. The results of the survey will be used to **improve conditions for bicycling and walking** in the state of Texas. Please take 5 minutes to answer the following questions, then stick the postcard in any U.S. mailbox. If you have any questions about this survey, please contact Shawn Turner at (409) 845-8829. Thanks for your cooperation.

**Where did your trip begin? (closest intersection/building)**

**What is your final destination? (closest intersection/building)**

**What is the purpose of this trip? (circle one)**
Work Recreation Shopping Personal
Other:___________________________

**Typically, how much time do you spend making this trip?**

**How many times per week do you make this trip by biking or walking? (count your return trip)**

**Any other comments?**

**Figure 1. Intercept Survey Card**

The researchers also videotaped each site using portable video cameras mounted on a towable trailer assembly. The research team recorded 12 hours of video per day at each site, resulting in 36 hours of video per site. The videotapes were later reduced to hourly bicycle and pedestrian volumes. This data collection began on March 19, 1997, and ended on June 5, 1997. The results of the survey and video data collection are comprehensively documented in Report 1723-2 (14).

## DATA ANALYSIS

The data analysis for this study was focused on two distinct areas:

- **trip length distribution -** determining the range and distribution of bicyclist and pedestrian trip lengths for different locations or different trip purposes; and
- **trip generation rates -** using origin and destination patterns to determine bicyclist and pedestrian trip generation rates for different types of land uses (e.g., single-family residential, commercial, etc.).

The research team analyzed trip length distribution by first entering each reported trip origin and destination into geographic information system (GIS) software. The GIS software was then used to calculate an approximate trip length for each trip using the shortest street network distance. Trip lengths that were calculated automatically by the GIS software were verified by assuming an average speed for bicyclists and pedestrians and comparing the calculated trip time to the self-reported trip time. Once the trip lengths had been verified, they were organized by site and by trip purpose. Statistical analyses were performed to determine whether site or trip purposes were significant in categorizing the trip distributions. The results of this analysis are reported in the next chapter.

The locations of bicyclist and pedestrian origins and destinations were analyzed according to the adjacent land use, with the ultimate goal of developing bicyclist and pedestrian trip generation rates for several different types of land uses. The following steps were taken separately for bicyclists and pedestrians to analyze trip origins/destinations and develop trip generation rates:

1. **Identify market area for each site -** A trip generation boundary (also referred to as market area) was drawn around each site that encompassed about 98 to 99 percent of all trip origins and destinations. The market area inside the trip generation boundary was considered as providing the potential to generate bicycle

or pedestrian trips. About one to two percent of trip origins and destinations were excluded because they were a great distance from the site, thus representing a long recreational trip from outside the market area.

2. **Identify land use zones within the market area -** Land within the market area for each site was subdivided into zones of homogenous land use using land use maps obtained from the local planning agencies. The market area for each site was subdivided into approximately 40 to 80 zones, each zone being roughly neighborhood-sized. The types of land use considered in the zones were single-family residential, multi-family residential, commercial, and university/college.

3. **Inventory the unit and quantity of land use -** Within each zone, the quantity or intensity of land use was inventoried using aerial photographs or site reconnaissance. For residential land uses, the basic unit of measurement was a dwelling unit (e.g., house, duplex unit, or apartment). For commercial land uses, the basic unit was square footage of occupied space. For university/college land uses, the basic unit was the number of full-time equivalent students.

4. **Calculate the trip generation rate for each land use zone -** The number of trip origins and destinations were inventoried for each land use zone, and was then normalized by the basic unit for each land use. The trip generation rates were also expanded based on the ratio of surveyed trips passing through the site to the number of total trips passing through the site. For example, a single-family residential zone with five trips, 1,000 dwelling units, and an expansion factor of eight, the trip generation rate for that zone would be $(5 \times 8) / 1{,}000$, or four trips per 100 dwelling units. Zonal trip generation rates for each land use were averaged to develop a single trip generation rate for each of the prevalent land uses at each site.

5. **Compare and analyze trip generation rates for different sites -** The trip generation rates were analyzed at each site for comparability and reasonableness. It was determined that the trip generation rates for several sites differed significantly, and the differences were hypothesized to be due to the type of development (e.g., typical suburban vs. dense development). So each site (and the respective trip generation rates) was categorized by the type of development occurring in the area. The results are presented in the next chapter.

# CHAPTER 4
# FINDINGS

This chapter summarizes the findings of the data collection and analysis efforts. The trip length distributions for different trip purposes are presented, as well as the trip generation rates for the different sites.

## TRIP LENGTH DISTRIBUTION

The trip length distributions for each site and trip purpose were analyzed for significance. The researchers determined that the trip purpose was most important in determining the trip length, so three trip length distribution curves were developed for bicycle trips and two curves for pedestrian trips. Figures 2 through 4 show the bicycle trip length distribution curves for work, recreation, and school-based trips, respectively. Figures 5 and 6 show the pedestrian trip length distribution curves for home-based work and home-based non-work trips, respectively. Because the pedestrian survey sample sizes were quite small, the pedestrian curves were developed using household surveys conducted in several Texas urban areas by TxDOT and analyzed by TTI. The pedestrian trips recorded in TxDOT's household survey were only recorded to the nearest mile; however, they still provide useful information about pedestrian trip lengths.

The researchers found that each of the bicycle trip length distribution curves were different in scale and distribution-wise. Most work trips range between 1.6 and 9.7 km (1 and 6 mi), whereas recreational trips range up to 16 km (10 mi) or more and school-based trips were mostly less than 4.8 km (3 mi). Another significant finding was that each of the underlying trip length distributions for these three trip purposes was distinctly different and non-normal. Several other bicycle demand forecasting models assume that bicycle trip lengths are distributed normally about a mean value.

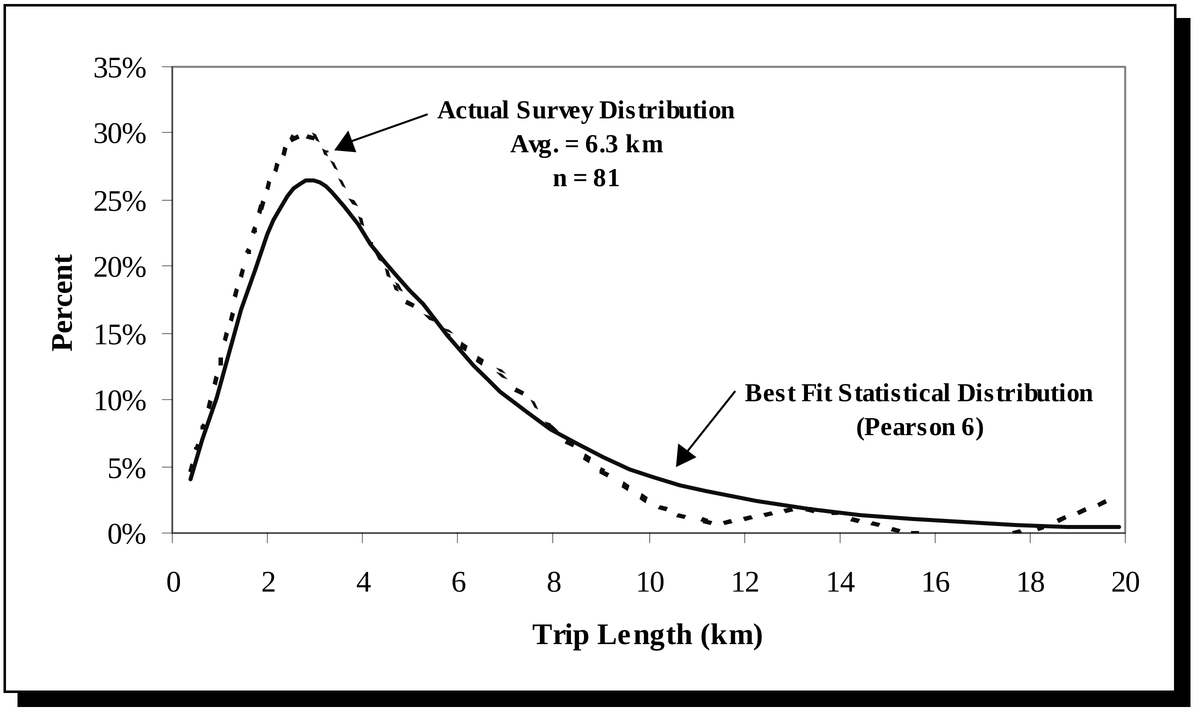


**Figure 2. Bicycle Trip Length Distribution for Work-Based Bicycle Trips**

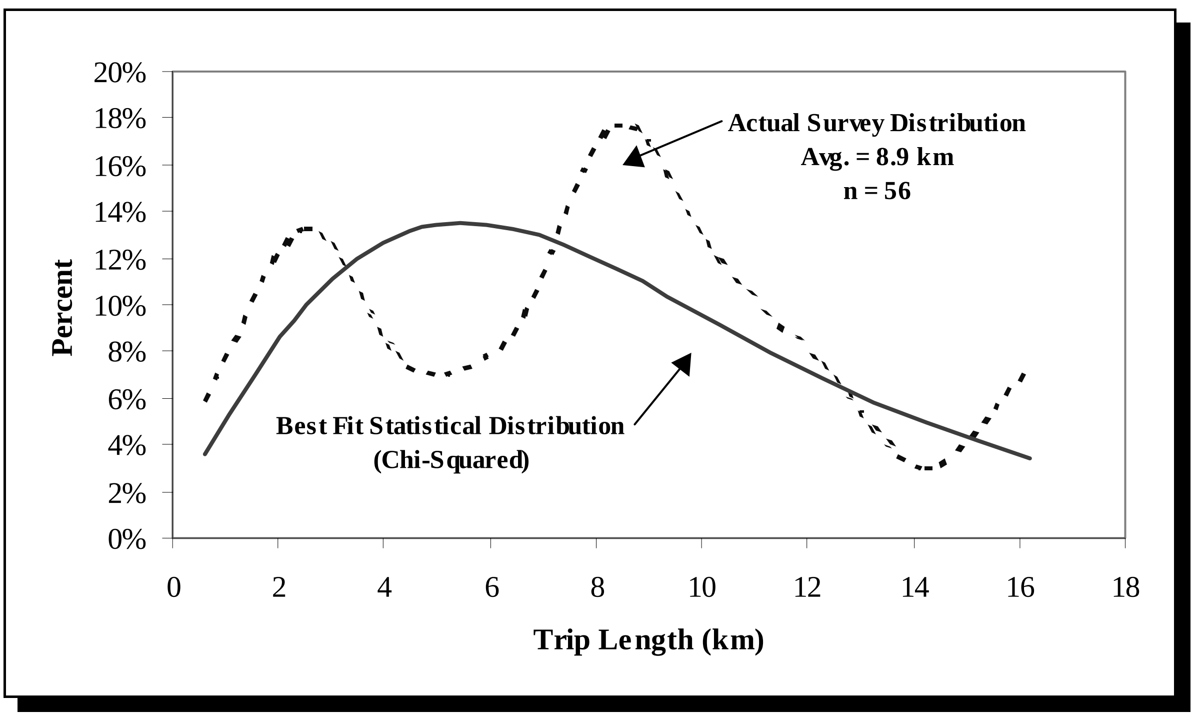


**Figure 3. Bicycle Trip Length Distribution for Recreation-Based Bicycle Trips**

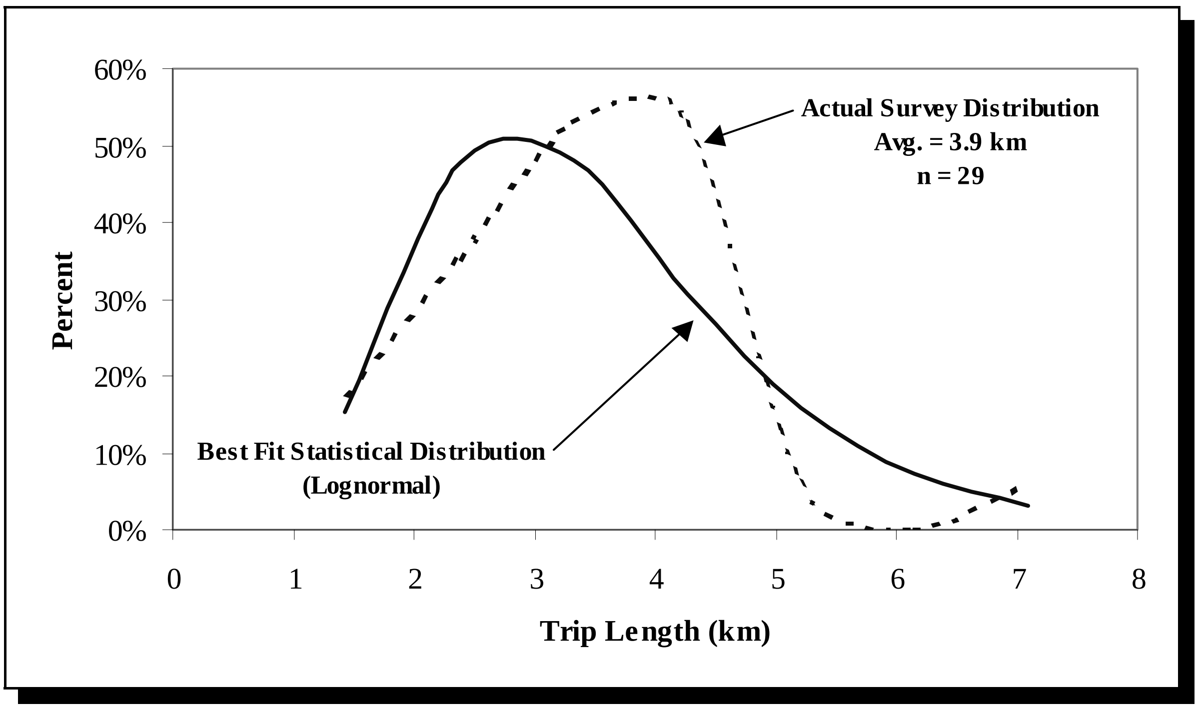


**Figure 4. Bicycle Trip Length Distribution for School-Based Bicycle Trips**

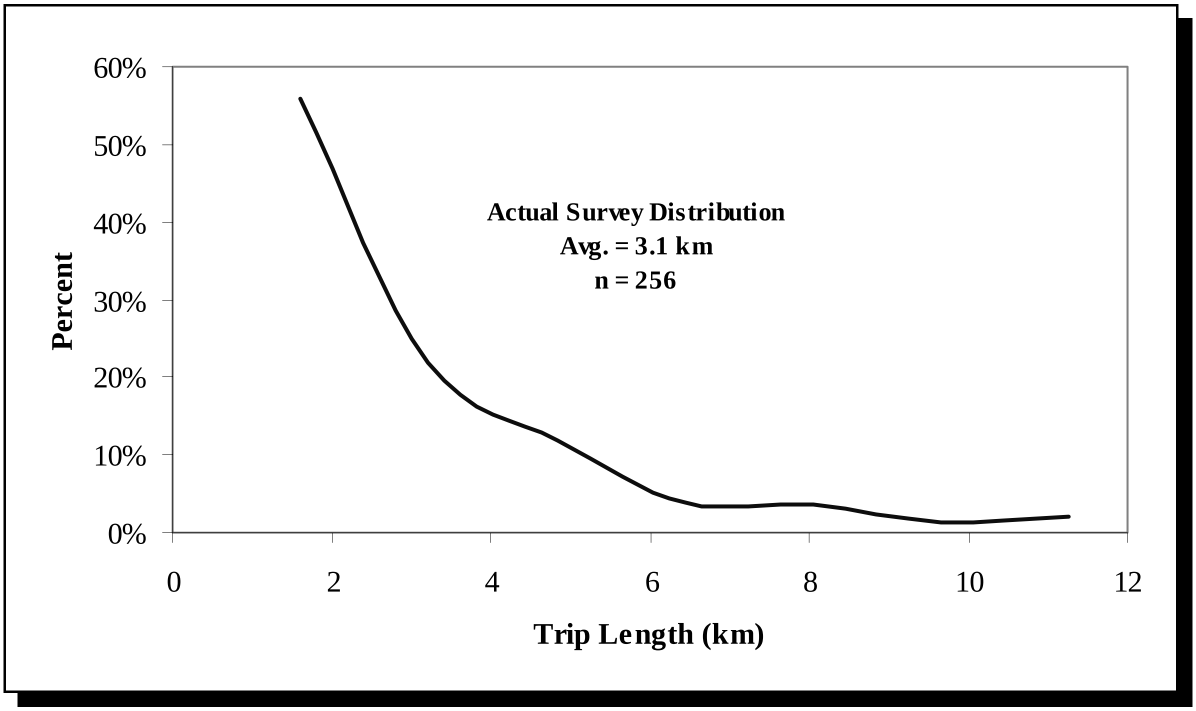


**Figure 5. Trip Length Distribution for Home-Based Work Pedestrian Trips**

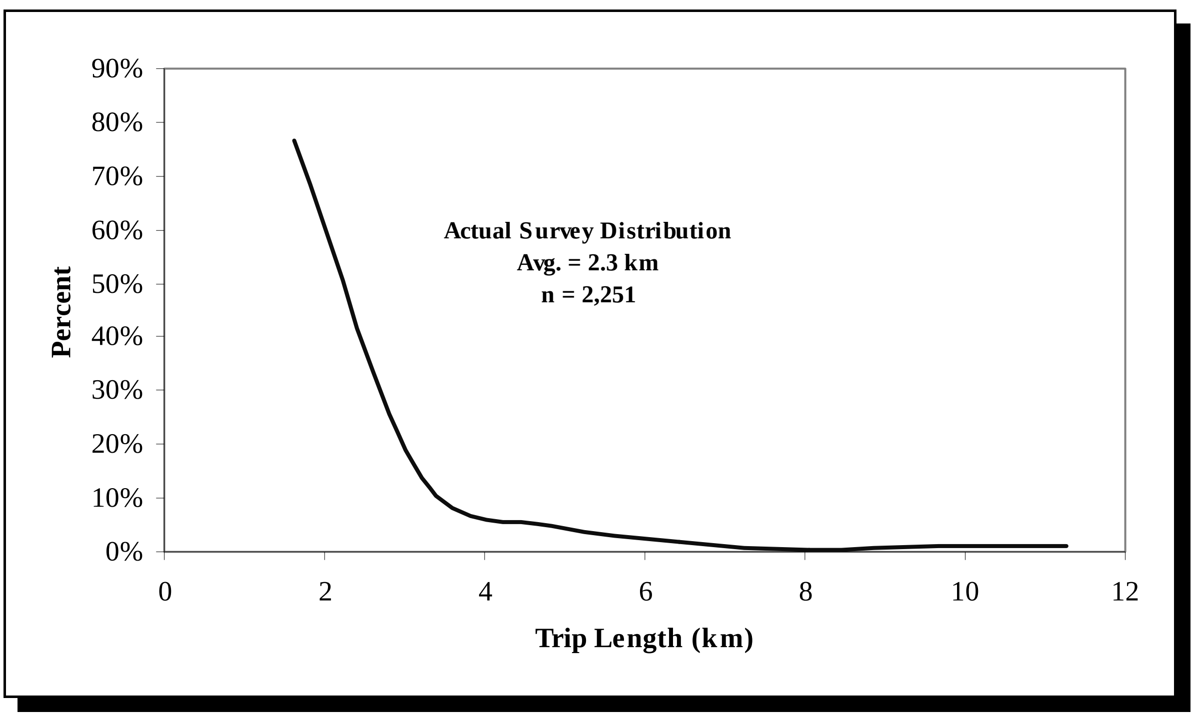


**Figure 6. Trip Length Distribution for Home-Based Non-Work and Non-Home Based Pedestrian Trips**

## TRIP GENERATION RATES

Bicycle and pedestrian trip generation rates were calculated for prevalent land use types for as many of the sites as possible. There were several sites, however, that were not considered because a very small number of trip surveys were returned (i.e., less than 10). Tables 3 and 4 present a summary of the various trip generation rates at the various sites. The researchers found that the trip generation rates varied significantly between sites and attempted to identify the reason for this variability. It was hypothesized that a contributing factor was the type of development at or near each site. Because of trip generation rate differences, the analysis categorized the trip generation rates by area type. Tables 5 and 6 were created from Tables 3 and 4 by transferring available data and extrapolating where no trip generation data were available from this study or from other available sources. These trip generation tables are used directly in the proposed bicycle and pedestrian demand forecasting methodology.

## Table 3. Surveyed Bicycle Trip Generation Rates

| Site | Area Type or Development Pattern | Survey Expansion Factor | Trip Generation Rate (trips per specified unit) | | | |
|---|---|---|---|---|---|---|
| | | | single-family residential (per 100 dwelling units) | multi-family residential (per 100 dwelling units) | university / college (per 1,000 full-time students) | commercial (per million sq. ft. gross leased area, GLA) |
| FM 2347 and Bizzell, College Station | Dense or Special Use | 4.27 | 4.67 | 3.84 | 6.13 | n.a. |
| FM 2818 and Welsh, College Station | Suburban | 3.64 | 1.20 | 0.34 | 0.93 | n.a. |
| Royal and Greenville, Dallas | Suburban | 3.32 | 0.40 | 0.19 | n.a. | 0.1 |
| RM 2222 and Shoal Creek, Austin | Mixed-Use Urban | 2.35 | 0.19 | 0.13 | 0.10 | 3.9 |

## Table 4. Surveyed Pedestrian Trip Generation Rates

| Site | Area Type or Development Pattern | Survey Expansion Factor | Trip Generation Rate (trips per specified unit) | | | |
|---|---|---|---|---|---|---|
| | | | single-family residential (per 100 dwelling units) | multi-family residential (per 100 dwelling units) | university / college (per 1,000 full-time students) | commercial (per million sq. ft. GLA) |
| FM 2347 and Bizzell, College Station | Dense or Special Use | 7.91 | 1.99 | 3.55 | 2.03 | n.a. |
| FM 2818 and Welsh, College Station | Suburban | 8.99 | 0.45 | 0.77 | n.a. | n.a. |
| Royal and Greenville, Dallas | Suburban | 6.54 | 0.32 | 0.98 | n.a. | 0.9 |
| RM 2222 and Shoal Creek, Austin | Mixed-Use Urban | 7.33 | 0.89 | 0.39 | n.a. | 6.7 |

**Table 5. Proposed Bicycle Trip Generation Rates**

| Land Use Type | Daily Bicycle Trip Generation Rate | | |
|---|---|---|---|
| | Suburban | Mixed-Use Urban | Dense or Special Use |
| single-family residential | 0.6 trips per 100 dwelling units | 3 trips per 100 dwelling units | 5 trips per 100 dwelling units |
| multi-family residential | 0.2 trips per 100 dwelling units | 2 trips per 100 dwelling units | 4 trips per 100 dwelling units |
| university/college | 0.5 trip per 1,000 full-time students | 2 trips per 1,000 full-time students | 6 trips per 1,000 full-time students |
| commercial | 4 trips per million sq. ft. GLA | 8 trips per million sq. ft. GLA | 12 trips per million sq. ft. GLA |

**Table 6. Proposed Pedestrian Trip Generation Rates**

| Land Use Type | Daily Pedestrian Trip Generation Rate | | |
|---|---|---|---|
| | Suburban | Mixed-Use Urban | Dense or Special Use |
| single-family residential | 0.5 trip per 100 dwelling units | 1 trip per 100 dwelling units | 2 trips per 100 dwelling units |
| multi-family residential | 1 trip per 100 dwelling units | 2 trips per 100 dwelling units | 4 trips per 100 dwelling units |
| university/college | 0.3 trip per 1,000 full-time students | 1 trip per 1,000 full-time students | 2 trips per 1,000 full-time students |
| commercial | 5 trips per million sq. ft. GLA | 10 trips per million sq. ft. GLA | 20 trips per million sq. ft. GLA |

## DEVELOPMENT OF RECOMMENDED METHODOLOGY

Based upon the findings discussed in this chapter and in previous research reports (1,14), the researchers developed a methodology that can be used to estimate bicycle and pedestrian travel demand. The methodology does require that analysts have basic information about the type and location of land uses adjacent to the study corridors. The methodology is presented in full in this report's appendix, and the following steps are listed as follows:

Step 1. Define Study Corridor and Analysis Sub-Sections
Step 2. Define the Influence Area Along the Study Corridor
Step 3. Identify and Quantify Land Uses in the Influence Area
Step 4. Apply Trip Generation Rates to the Analysis Sub-Sections
Step 5. Sum Trip Estimates for Each Sub-Section
Step 6. Sum the Trips for the Entire Study Corridor
Step 7. Apply Reasonableness Checks and Adjust Trip Estimates if Necessary

# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATIONS

The research team provides the following conclusions and recommendations based upon this two-year study.

## CONCLUSIONS

- **Simplicity of Demand Forecasting Methodology -** Since the demand forecasting procedures will be used by numerous TxDOT district personnel, the TxDOT review panel encouraged the research team to provide simple, easy to use demand estimation procedures. The recommended procedures in this report's appendix are essentially that—a simplified version of a rather complex demand forecasting process. The recommended procedures could certainly be enhanced to incorporate more sophisticated trip generation and distribution steps. However, based upon the survey data collected for this study, it is questionable whether greater sophistication will lead to more accurate estimates of bicycle and pedestrian demand at this time. Users of the recommended demand forecasting methodology should also understand the simplistic nature of the procedures and not associate extraordinary precision or accuracy to the demand estimates.

- **Interpreting Bicycle and Pedestrian Demand -** The recommended demand forecasting procedures produce an order of magnitude estimate of bicycle and pedestrian travel demand. At the direction of the TxDOT review panel, no guidance is provided or implied in this document for determining what level of demand prepared with the procedures described in this report should be used to justify or "warrant" bicycle/pedestrian facility design decisions. This demand interpretation guidance should be provided so that roadway planners and designers can be more consistent and systematic in accommodating bicyclists and pedestrians on state roadways.

- **Integration of Demand and Supply Analyses -** This research study (0-1723) developed procedures to analyze bicycle and pedestrian demand whereas another recently completed study (7-3988) developed procedures to analyze roadways for bicycle suitability (i.e., supply). The roadway suitability procedures should also be expanded to incorporate analysis of pedestrian facility supply, or a pedestrian environment factor. These procedures should be integrated to provide a more complete analysis of demand/supply issues for bicycle and pedestrian facilities.

- **Levels of Bicycling and Walking in Texas -** The researchers collected detailed bicycle and pedestrian data at eight locations in four different cities in Texas, as well as made observations at numerous other locations while performing site reconnaissance. The researchers noted significant usage levels at several locations that were particularly conducive to bicycle and pedestrian travel (e.g., locations with separated multi-use paths, bicycle lanes along "scenic" roadway corridors, greenways, or recreational corridors). Anecdotal observations revealed very few bicyclists or pedestrians along state roadways that made no provision for their safe travel (i.e., sidewalk, shoulder, wide curb lane, etc.).

## RECOMMENDATIONS

- **Interpretation of Demand Estimates -** TxDOT should consider developing guidance or policy for roadway planners or designers to use in interpreting the demand estimates produced with the recommended demand forecasting procedures. This guidance or policy will help to provide consistent and systematic accommodation of bicyclists and pedestrians on state roadways.

- **Integrate Demand and Supply Analyses -** TxDOT should consider integrating the demand forecasting procedures developed in this study (0-1723) with the bicycle suitability (supply) procedures developed in another study (7-3988). The roadway suitability procedures should also be expanded to incorporate analysis of pedestrian facility supply, or a pedestrian environment factor. These procedures should be integrated to provide a more complete analysis of demand/supply issues for bicycle and pedestrian facilities.

- **Encourage and Monitor Use of the Procedures and Provide Enhancements -** TxDOT should encourage and monitor the use of the recommended demand forecasting procedures to identify potential areas for improvement. Demand estimates should be compared to actual volume counts where bicycle and/or pedestrian facilities are constructed along state roadways. The recommended demand forecasting procedures should be enhanced to improve their accuracy and usability.

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# APPENDIX

# BICYCLE AND PEDESTRIAN TRAVEL DEMAND FORECASTING GUIDELINES

## BICYCLE AND PEDESTRIAN TRAVEL DEMAND FORECASTING GUIDELINES

These guidelines describe procedures that can be used to estimate bicycle and pedestrian travel demand on existing and proposed bicycle and pedestrian facilities. The guidelines are intended to provide TxDOT with estimates of potential travel demand for use in deciding the feasibility and design of such facilities. The guidelines were developed in TxDOT research study 0-1723 by the Texas Transportation Institute (TTI) from 1996 to 1998 (for more information, see research reports 1723-1, 1723-2, and 1723-S).

The procedures described here are based on the premise that bicycle and pedestrian travel demand is largely influenced by location, type, and intensity of land use along and for a specific distance away from bicycle or pedestrian facilities. The procedures assume that adequate bicycle and/or pedestrian facilities (designed to current AASHTO and/or TxDOT guidelines) do or will exist in the study corridor. The procedures also make no distinction in terms of demand levels between different facility designs (e.g., wide curb lane, bike lane, multi-use trail). There are several other factors that may influence bicycle and/or pedestrian travel demand that are not are explicitly addressed in these procedures, such as the following:

- demographic characteristics of residents or others in the roadway corridor;
- average bicycle and pedestrian trip lengths;
- local and regional lifestyles;
- weather; and
- topography.

The bicycle and pedestrian demand forecasting guidelines consist of the following steps:

Step 1. Define Study Corridor and Analysis Sub-Sections
Step 2. Define the Influence Area along the Study Corridor
Step 3. Identify and Quantify Land Uses in the Influence Area
Step 4. Apply Trip Generation Rates to the Analysis Sub-Sections
Step 5. Sum Trip Estimates for each Sub-Section
Step 6. Sum the Trips for the Entire Study Corridor
Step 7. Apply Reasonableness Checks and Adjust Trip Estimates if Necessary

To use these procedures, the analyst should obtain the following information:

- type and location of land uses in the study corridor; and
- a map or GIS files of study corridor.

The map should show all streets that cross the study corridor. If the map is printed from a geographic information system (GIS) database, the land uses within the influence area should be coded in a GIS file.

**Step 1. Define Study Corridor and Analysis Sub-Sections**

Clearly define the corridor where the suitable bicycle or pedestrian facility will be located and its end limits. Divide the corridor into sub-sections or segments along its length for analysis, and on the map mark the boundaries of the sub-sections. Sub-section limits could be where major roadways cross the corridor and/or where land use character changes. The result will be a continuous series of sub-sections for the full length of the study corridor. As a general guideline, the analysis sub-sections should be between 3.2 to 4.8 km (2 to 3 mi) long for bicycle travel analyses and 0.8 to 1.6 km (0.5 to 1 mi) long for pedestrian travel analyses. The exact length of the analysis sub-sections will vary depending upon the street network and adjacent land uses but should generally fall within the recommended ranges. Number the individual sub-sections for reference and tabulation of data in the remainder of the analysis.

**Table A-1. Recommended Analysis Sub-Section Lengths**

| Demand Analysis | Analysis Sub-Section Length |
|---|---|
| Bicyclists | 3.2 to 4.8 km (2 to 3 mi) |
| Pedestrians | 0.8 to 1.6 km (0.5 to 1 mi) |

**Step 2. Define the Influence Area Along the Corridor**

Define the influence area from which bicycle and pedestrian travel demand will originate or to which it will be destined. Bicycle trips may be expected to begin or end 3.2 to 4.8 km (2 to 3 mi) from the bicycle facility being considered, and pedestrian trips will begin or end within 0.8 to 1.6 km (0.5 to 1 mi) of their potential facility. The area of influence for bicycle travel, for example, will therefore be 3.2 to 4.8 km (2 to 3 mi) either side of the bicycle facility of interest and therefore 6.4 to 9.7 km (4 to 6 mi) wide. The exact size and shape of the market area will vary depending upon land uses adjacent to the study corridor but should generally be within the recommended range of distances. The approximate shape of the market area will be rectangular with irregular edges along its length that correspond to major changes in land use or a major roadway. Mark the boundaries of the influence area on the map at those distances from the facility of interest for use in the remainder of the analysis.

Local knowledge of bicycling and/or walking patterns may be useful to adjust the size of the influence area. For example, along some recreational bicycling corridors, bicycle trips may originate from as far away as 16 to 24 km (10 to 15 mi) or more.

**Table A-2. Recommended Market or Influence Areas**

| Demand Analysis | Market or Influence Area |
|---|---|
| Bicyclists | 3.2 to 4.8 km (2 to 3 mi) either side of corridor |
| Pedestrians | 0.8 to 1.6 km (0.5 to 1 mi) either side of corridor |

**Step 3. Identify and Quantify Land Uses in the Influence Area**

Identify the types of land uses within **each individual sub-section** of the influence area and measure or estimate the independent variables shown in Table A-3 for each type of land use.

**Table A-3. Land Use Types Used in Trip Generation**

| Land Use Type | Independent Variable |
|---|---|
| single-family residential | dwelling units |
| multi-family residential | dwelling units |
| college/university | full-time equivalent students |
| commercial | square feet of occupied space |

The types and quantities of land use along the study corridor can be identified from several sources:

- the regional metropolitan planning organization (MPO);
- other governmental agencies within the region (e.g., city, chamber of commerce);
- aerial photographs; or
- on-site reconnaissance.

Definitions of the land use types and independent variables are as follows:

- Single-family residential - the number of single-family dwelling units;
- Multi-family residential - the number of multi-family dwelling units (e.g. duplex, apartment, condo);
- College/university - the number of registered full-time equivalent students (part-

time students count as 0.5 full-time equivalent students); and

- Commercial - the square footage of occupied business space.

Also in this step, analysts should consider other bicycle and pedestrian trip generators that are not captured in these specified land uses. Examples of other common bicycle and/or pedestrian trip generators include:

- bus or transit stops (contact transit agency for bicyclist/pedestrian boardings at specific transit stops);
- elementary, middle, and high schools (contact school district for estimated percentage of students who bike or walk to school); and
- recreational areas (contact recreation/parks department).

**Step 4. Apply Trip Generation Rates to the Analysis Sub-Sections**

Multiply the land use independent variables for each segment by the trip generation rates in Tables A-4 and A-5. Tables A-4 and A-5 show different trip generation rates for three different area types: suburban, mixed-use urban, and dense or special use. These area types are defined as follows:

> **Suburban -** This is the most common development pattern occurring at the edge of most cities in Texas. The residential density typically varies from four to eight dwelling units per acre, and most residential land use is separated from commercial use by a significant distance. Commercial land use is predominantly strip center development with extensive parking between the street and commercial storefronts. Wide, multi-lane freeways and arterial streets predominate in this type of development. Examples of this area type can be found in most Houston suburbs outside of Beltway 8, many of the Dallas suburbs north of I-635, and north of Austin along US 183.
>
> **Mixed-Use Urban -** This pattern of development often incorporates commercial land use in close proximity or immediately adjacent to residential use. The residential density can range from six to 12 or more dwelling units per acre, and residential use is sometimes mixed with commercial use (e.g., apartments above retail shops). These mixed-use urban areas are typically not bisected by large freeways or arterial streets, and minor arterial or collector streets predominate this development. Examples of this area type include Rice Village and the Post Oak area in Houston, old east Dallas/Lakewood and north Oak Cliff/Kessler park in Dallas, or inner city Austin.
>
> **Dense or Special Use -** This pattern of development is found most often near downtown areas, college and university campuses, high-use recreational areas and corridors, or pedestrian zones and malls. This type of land use often places a large number of people

in a relatively small area. Because of the high concentration of people, vehicle parking is limited and often at a premium. Examples of this area type include many areas of downtown Houston and Austin, most university campuses throughout Texas, and the Barton Springs area in Austin or Memorial Park area in Houston.

**Table A-4. Bicycle Trip Generation Rates for Different Area and Land Use Types**

| Land Use Type | Daily Bicycle Trip Generation Rate | | |
|---|---|---|---|
| | Suburban | Mixed-Use Urban | Dense or Special Use |
| single-family residential | 0.6 trips per 100 dwelling units | 3 trips per 100 dwelling units | 5 trips per 100 dwelling units |
| multi-family residential | 0.2 trips per 100 dwelling units | 2 trips per 100 dwelling units | 4 trips per 100 dwelling units |
| university/college | 0.5 trip per 1,000 full-time students | 2 trips per 1,000 full-time students | 6 trips per 1,000 full-time students |
| commercial | 4 trips per million sq. ft. GLA | 8 trips per million sq. ft. GLA | 12 trips per million sq. ft. GLA |

**Table A-5. Pedestrian Trip Generation Rates for Different Area and Land Use Types**

| Land Use Type | Daily Pedestrian Trip Generation Rate | | |
|---|---|---|---|
| | Suburban | Mixed-Use Urban | Dense or Special Use |
| single-family residential | 0.5 trip per 100 dwelling units | 1 trip per 100 dwelling units | 2 trips per 100 dwelling units |
| multi-family residential | 1 trip per 100 dwelling units | 2 trips per 100 dwelling units | 4 trips per 100 dwelling units |
| university/college | 0.3 trip per 1,000 full-time students | 1 trip per 1,000 full-time students | 2 trips per 1,000 full-time students |
| commercial | 5 trips per million sq. ft. GLA | 10 trips per million sq. ft. GLA | 20 trips per million sq. ft. GLA |

**Step 5. Sum Trip Estimates for Each Sub-Section**

Sum the number of estimated bicycle or pedestrian trips to or from all land uses in each sub-section in the influence area.

**Step 6. Sum the Trips for the Entire Study Corridor**

**Step 7. Apply Reasonableness Checks and Adjust Trip Estimates if Necessary**

Compare the bicycle and pedestrian travel demand estimated in the preceding steps to pedestrian and bicycle travel observed in roadway corridors in several Texas cities and listed in Table A-6. These observed data were collected as part of the project (TxDOT 0-1723) which developed this estimation procedure.

Local agencies may have knowledge of specific conditions or plans that may predispose the study corridor to higher (or lower) bicycle and pedestrian travel. Examples of such conditions are a planned recreational trail or corridor, pedestrian malls or zones, or a signed or mapped bicycle touring route.

**Table A-6. Existing Bicycle and Pedestrian Trips in Texas, 1997**

| Location and Streets | Estimated Average Daily Volume | |
|---|---|---|
| | Bicyclists | Pedestrians |
| College Station: George Bush Drive (FM 2347) at Timber (near Texas A&M Univ.) | 500 | 175 |
| College Station: FM 2818 at Welsh Avenue (typical suburban) | 84 | 42 |
| Austin: RM 2222 at Shoal Creek (suburban recreational route) | 128 | 44 |
| Austin: Loop 360 (recreational route) | 65 | 6 |
| Houston: Allen Parkway/Buffalo Bayou Trail at Taft Street (urban commuting and recreational route) | 178 | 659 |
| Houston: Brays Bayou Trail at S. Main Street (urban commuting route) | 205 | 291 |
| Dallas: Royal Lane and Greenville (suburban and recreational) | 119 | 98 |
| Dallas: White Rock Lake Trail at Mockingbird (heavy recreational route) | 364 | 85 |

Source: TxDOT Study 0-1723, Report 1723-2