BICYCLE SUITABILITY CRITERIA: LITERATURE REVIEW AND STATE-OF-THE-PRACTICE SURVEY

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16. Abstract

This research report reviews and summarizes bicycle suitability criteria being used in the United States, presents preliminary conclusions, and makes preliminary recommendations regarding such criteria. Conclusions and recommendations are presented here as a starting point for discussion on the state-of-the-practice in bicycle suitability and the potential for the institution of such criteria at a statewide level in Texas.

Suitability criteria found in the literature review were varied in nature and mostly used in urban areas. Many criteria require additional data beyond that commonly found in urban transportation data bases. Several bicycle suitability criteria included the presence or width of shoulders, a situation commonly found on Texas state highways. The state-of-the-practice survey revealed that 70 percent (11 of 16 states) had bicycle suitability criteria in place. The two most common criteria (one or both were used in every case) were the traffic volume (ADT) and the width of outside lanes (or shoulders). Thirty-five percent of the states with suitability criteria also indicated that they looked at heavy vehicles when considering traffic volume, 25 percent considered pavement conditions, and 15 percent included traffic speed or speed limit criteria.

The research team concluded that the potential uses and applications are critical in defining the bicycle suitability criteria. The availability of statewide roadway inventory data is also important in establishing and maintaining information about suitability on state roadways in Texas.

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CHAPTER ONE

INTRODUCTION

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 mandated that bicycle facilities be considered in the statewide and metropolitan planning process, and provided a number of mechanisms to achieve this requirement. Bicycle coordinator positions were required at each state department of transportation (DOT) (some had previously existed). These bicycle coordinators are responsible for ensuring that bicycle facilities are considered in the planning, design, and construction of transportation improvements at the state level. Bicycle facilities also became eligible for funding in a number of different categories, most notably the Transportation Enhancements and the Congestion Mitigation/Air Quality (CMAQ) categories. These mechanisms enabled the incorporation of bicycle facilities into the planning, design, and construction of transportation facilities.

Bicycle coordinators in many state DOTs also have assumed the role of setting bicycle accommodation policies and providing technical guidance to achieve these policies. Many of the bicycle accommodation policies have stated how and in what conditions bicyclists should be accommodated on state highways. The technical guidance has been centered around planning and design guidelines to accomplish the accommodation policy. In some cases, this technical guidance has included evaluation criteria to determine the bicycle suitability, or “bicycle friendliness” of state highways.

Bicycle suitability criteria are somewhat analogous to the level of service (LOS) criteria established in the Highway Capacity Manual (1), which engineers and planners commonly use to evaluate the quality of traffic flow on highways and streets. These suitability criteria, like the LOS criteria, can be used to evaluate existing conditions and identify facility improvement needs. Bicycle suitability criteria also can be used to determine those streets or highways that are most amenable to bicycle travel. Many studies have shown, for example, that bicyclists typically prefer to use streets with low traffic volumes, low vehicle speeds, and wide travel lanes. A number of other factors or variables can be used in addition to these to determine those roadways most suitable for bicycle use.

Research Goals and Objectives

The Texas DOT (TxDOT) contracted with the Texas Transportation Institute to perform the following tasks:

1. Identify the state-of-the-practice in the United States in evaluating bicycle suitability, and

2. Develop bicycle suitability criteria for TxDOT to use in evaluating and ranking the bicycle suitability of state roadways.

The bicycle suitability criteria will be focused on state highways in Texas, where an increased emphasis is being placed on bicycle facility improvements. The study will primarily consider rural highways, as a substantial percentage of TxDOT-maintained roadways are in rural areas. The bicycle suitability criteria will be developed with consideration given to TxDOT's statewide roadway data inventory and other data available in statewide data bases.

Research Implementation

Bicycle suitability criteria can be used by engineers, planners, and decision-makers to evaluate the "bicycle-friendliness" of roadways, both from the perspective of the bicyclist and the motorist. The bicycle suitability ratings of roadways can be used in several ways:

- Prioritize bicycle improvement projects for constrained financial resources;
- Identify gaps or deficiencies in a regional (intra city) or intercity bicycle network; and
- Evaluate roadway conditions for use by bicycle commuters and recreational cyclists.

The bicycle suitability criteria developed in this research project can be implemented when making policy decisions about Texas roadways. TxDOT can use the bicycle suitability criteria in evaluating and ranking roadways for potential bicycle improvements at the state or district level. Regional and local governments can use the bicycle suitability criteria for similar ranking schemes at the local level, and to provide roadway conditions and suitability assessments to local bicyclists.

Organization of this Report

This report contains a review of the state-of-the-practice in bicycle suitability evaluation criteria, and is divided into the following chapters:

ONE — *Introduction:* provides an overview of the needs for bicycle suitability criteria, and the context in which bicycle suitability criteria can be applied.

TWO — *Literature Review:* contains a summary of the available literature on bicycle suitability or bicycle LOS criteria.

THREE — *State-of-the-Practice Survey:* summarizes interviews with 16 bicycle coordinators in the leading states in bicycle planning.

FOUR — *Preliminary Conclusions and Recommendations:* synthesizes the information from the literature review and the state-of-the-practice surveys into several conclusive findings, and provides recommendations from this initial task and for subsequent research tasks.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides a summary and review of the literature relating to bicycle suitability evaluation criteria. Several different types of suitability criteria were found in the literature, ranging from simple bicycle stress levels (using three input variables) to complex level of service (LOS) analyses.

Researchers conducted a literature search in the Fall of 1996 for TxDOT Study 0-1723, "Bicycle and Pedestrian Travel Demand Forecasting for Existing and Proposed Transportation Facilities," which served as the primary source of information for this literature review. This earlier literature search included library data base searches, phone conversations, and World Wide Web searches. Several university library data bases were searched, including those at Texas A&M University (NOTIS), the University of California at Berkeley (MELVYL), and Northwestern University. Several key persons and references were identified through searches of the World Wide Web, and they were contacted for additional information.

Table 2-1 provides a summary of bicycle suitability criteria found in the literature review. The table lists the bicycle suitability criteria in the left-most column, and the top-most row includes the pertinent input variables. "Check" marks in the cells of the table indicate the input variables that are considered in each bicycle suitability evaluation methodology.

Three distinct types of bicycle suitability criteria were found in the literature review:

- *Stress Levels*: simple evaluation criteria based upon curb lane vehicle speeds, curb lane vehicle volumes, and curb lane widths. Bicycle stress levels are easy to calculate because of only three input variables, but they do not incorporate other factors hypothesized to affect bicycle suitability.

- *Roadway Condition Index/Suitability-Based Level of Service*: several different variations of this popular suitability rating criteria were found. The variables most common to all criteria were traffic volumes, curb lane width, speed limit, pavement factors, and location factors. Bicycle planners mostly use these types of criteria in urban areas where data can be economically collected for roadways under study.

- *Capacity-Based Level of Service*: volume-based or similar procedures that have been adapted from capacity analyses common in the 1994 Highway Capacity Manual. Capacity-based bicycle suitability procedures appear to be ill suited for most bicycle planning and suitability assessment needs.

Table 2-1. Summary of Bicycle Suitability Methodologies

Methodology \ Input Variables	Traffic Volume Per Lane	Curb Lane Width	Vehicle Speed	Speed Limit	Pavement Type/Condition	Parking/Turn Lanes	Grades	Sight Distance/Visibility	Driveway Frequency	Adjacent Land Use	Signalization/Intersections	Heavy Vehicles	Vehicle LOS	Maintenance	TDM/Multimodal Support	Provision/Type of Facility	Cyclist Input	Passing/Meeting Frequency	Service Volumes	Bicycle Density	Curve Radius	Total Delay	Average Bicycle Speed
Bicycle Stress Level-Based Criteria																							
Bicycle Stress Level (References 2,3,4,5,6)	✔[a]	✔	✔																				
Roadway Condition Index/Suitability-Based Level of Service Criteria																							
Bicycle Safety Index Rating (Ref. 7)	✔[b]	✔		✔	✔[c]	✔[d]	✔[d]	✔[d]	✔[d]	✔[d]	✔					✔[e]							
Bicycle Suitability, Davis (Ref. 8)	✔[b]	✔		✔	✔[c]	✔[d]	✔[d]	✔[d]	✔[d]	✔[d]						✔[e]							
Roadway Condition Index (Ref. 5,9,10)	✔[b]	✔		✔	✔[c]	✔[d]	✔[d]	✔[d]	✔[d]	✔[d]						✔[f]							
Modified Roadway Condition Index (Ref. 9)	✔[b]	✔		✔	✔[c]	✔[d]	✔[d]	✔[d]	✔[d]	✔[d]		✔				✔[f]							
Interaction Hazard Score (Ref. 5,11,12)	✔[b]	✔		✔	✔				✔	✔		✔											
Bicycle Level of Service, Landis et al. (Ref. 13)	✔[g]	✔[h]		✔	✔				✔	✔		✔					✔						
Gainesville Bicycle Map (Ref. 14)																✔[i]							

Notes:
[a] Peak hour curb lane vehicle volume.
[b] Average daily vehicle volume per lane.
[c] Includes drainage grates and railroad crossings.
[d] Variable contributes to a composite "location factor."
[e] Presence of paved shoulder.
[f] Presence of paved shoulder or bicycle lane.
[g] 15-minute directional vehicle volume per lane.
[h] Utilizes an "average effective curb lane width."
[i] Rates suitability by type or presence of bicycle facility (e.g., on-street vs. off-street vs. none).

Table 2-1. Summary of Bicycle Suitability Methodologies (Continued)

Methodology \ Input Variables	Traffic Volume Per Lane	Curb Lane Width	Vehicle Speed	Speed Limit	Pavement Type/Condition	Parking/Turn Lanes	Grades	Sight Distance/Visibility	Driveway Frequency	Adjacent Land Use	Signalization/Intersections	Heavy Vehicles	Vehicle LOS	Maintenance	TDM/Multimodal Support	Provision/Type of Facility	Cyclist Input	Passing/Meeting Frequency	Service Volumes	Bicycle Density	Curve Radius	Total Delay	Average Bicycle Speed
City of Austin Bicycle Map[j] (Ref. 15)	✔	✔	✔		✔		✔	✔			✔					✔[f]	✔						
Middlesex County, New Jersey Bicycle Map (Ref. 16)		✔		✔																			
Gainesville Mobility Plan (Ref. 17)			✔[k]			✔			✔				✔[l]	✔	✔	✔[m]							
Bicycle Suitability, UNC (Ref. 18)	Research in progress.																						
Capacity-Based Level of Service Criteria																							
Bicycle Path LOS, Botma (Ref. 19)																		✔	✔				
Bicycle LOS, Navin (Ref. 20)							✔													✔	✔		
Bicycle LOS, NCSU (Ref. 21) Uninterrupted																		✔					
Interrupted																						✔	
Combined																							✔

Notes: [j] All input variables were qualitative in nature (e.g., high vs. moderate vs. low).
[k] Speed differential between vehicles and bicycles.
[l] Vehicle level of service in adjacent lanes and/or number of lanes.
[m] Presence of wide outside lane or off-street facility.

Bicycle Stress Levels

Bicycle stress levels have been defined by Sorton to quantify the apparent stress experienced by bicyclists when riding on streets or highways (2,3,4,5,6). Sorton developed these stress level ratings to evaluate the "bicycle compatability" of streets in urban and suburban areas. The bicycle stress level is applied by dividing streets into smaller segments with similar roadway cross sections, then applying the bicycle stress criteria for each of the three stress level components. The overall bicycle stress level is then computed and compared against other street segments.

The stress level values range from 1 (lowest stress level, best bicycling conditions) to 5 (highest stress level, worst bicycling conditions) and are calculated by summing individual stress values for curb lane traffic volume, curb lane width, and curb lane vehicle speed. Table A-1 in Appendix A contains interpretations of the bicycle stress level values and the stress level values for individual components.

Street segments can be ranked or prioritized for future bicycle facility improvements (e.g., widening a curb lane or adding a bicycle lane), and the street segments can be further evaluated given these improvements. Bicycle suitability maps also are produced with these stress level ratings as an aid to bicyclists planning the safest or lowest stress route in an urban area (6).

Sorton and Walsh attempted to validate the bicycle stress level values against actual bicyclist perceptions in a study of 23 street segments in Madison, Wisconsin (2,3). A total of 61 cyclists reviewed video tape of the three stress level factors (traffic volume, lane width, and vehicle speed) for the 23 segments and rated the perceived stress on a scale of 1 to 5. The results of the analysis were statistically inconclusive, but the general patterns from the study indicated that bicyclists can recognize the variations in traffic volume, lane width, and vehicle speed that affect perceived stress. The study authors also concluded that relationships exist between a bicyclist's experience or skill level and the amount of stress perceived.

The bicycle stress level is a simple concept that incorporates the three most intuitive factors that affect bicyclist stress: traffic volume, lane width, and vehicle speeds. The data required for calculation of the criteria can be collected with minimal effort in most cases. The stress level can be easily communicated to non-technical audiences because of its simple input variables and relatable stress level interpretations.

Bicycle Safety Index Rating

Davis developed the bicycle safety index rating (BSIR) to provide a "mathematical model for indexing bicycle safety to physical roadway features" (7). The BSIR is comprised of a roadway segment index (RSI) which evaluated individual street segments, and an intersection evaluation index (IEI) which evaluated intersections connecting the street segments. Table A-2 in Appendix A contains the procedures for calculating the BSIR. This table shows that the index is comprised of several input variables:

- Average daily traffic volume per lane (ADT/L);
- Speed limit;
- Width of outside traffic lane;
- Pavement factor (pavement condition, presence of hazardous railroad tracks or drainage grates);
- Location factor (parking and turning lanes, grades, sight distance/visibility, driveway frequency, and adjacent land use); and
- Signalization/Intersection factors.

Davis tested the BSIR on seven Chattanooga roads but never compared it to actual bicyclist safety perceptions or accident records. Criticisms of this early (1987) model of bicycle safety/suitability are (9):

- The rating system does not include information about the frequency of signalized intersections, only the severity of each;

- The pavement and location factors can dominate the rating values by overwhelming the contributions of vehicle volume, speed, or lane width; and

- The rating system was never validated against cyclist perceptions or actual accident statistics.

Bicycle Suitability Rating--Davis

In a subsequent revision of the BSIR, Davis dropped the intersection evaluation index from the rating criteria, leaving the roadway segment index as the only component of a bicycle suitability rating. The terms and factor values of Davis' bicycle suitability rating are the same as those shown in Table A-2.

In an analysis of this revised suitability rating, Davis collected 29 bicyclists' perceptions of eight routes in the Atlanta, Georgia metropolitan area and compared those perceptions to calculated suitability ratings (8). His analysis yielded the following conclusions:

- Bicyclists' perceptions can differ from a numerical prediction of bicycle suitability;

- The ability of bicyclists to assess roadway space and lane width were not evident due to large ranges within a route and lack of variation between routes;

- The most important and understandable factors toward determining bicyclist suitability were traffic volume and speed; and

- The initial bicycle suitability rating formula should be modified to better predict bicyclists' perceptions through derived analytical procedures.

Roadway Condition Index

Bicycle planners in Broward County, Florida adapted Davis' roadway segment index portion of the BSIR (with no major changes) and renamed it the roadway condition index (RCI). Broward County planners currently use the RCI to assess bicycle suitability on major streets and highways within their jurisdiction. These planners have developed maps that employ color codes to illustrate the existing or proposed bicycle suitability of major streets (Figure 2-1). Bicycle facility improvements can then be targeted to those streets that indicate high RCI values (i.e., poor bicycle suitability), shown as red in the figure.

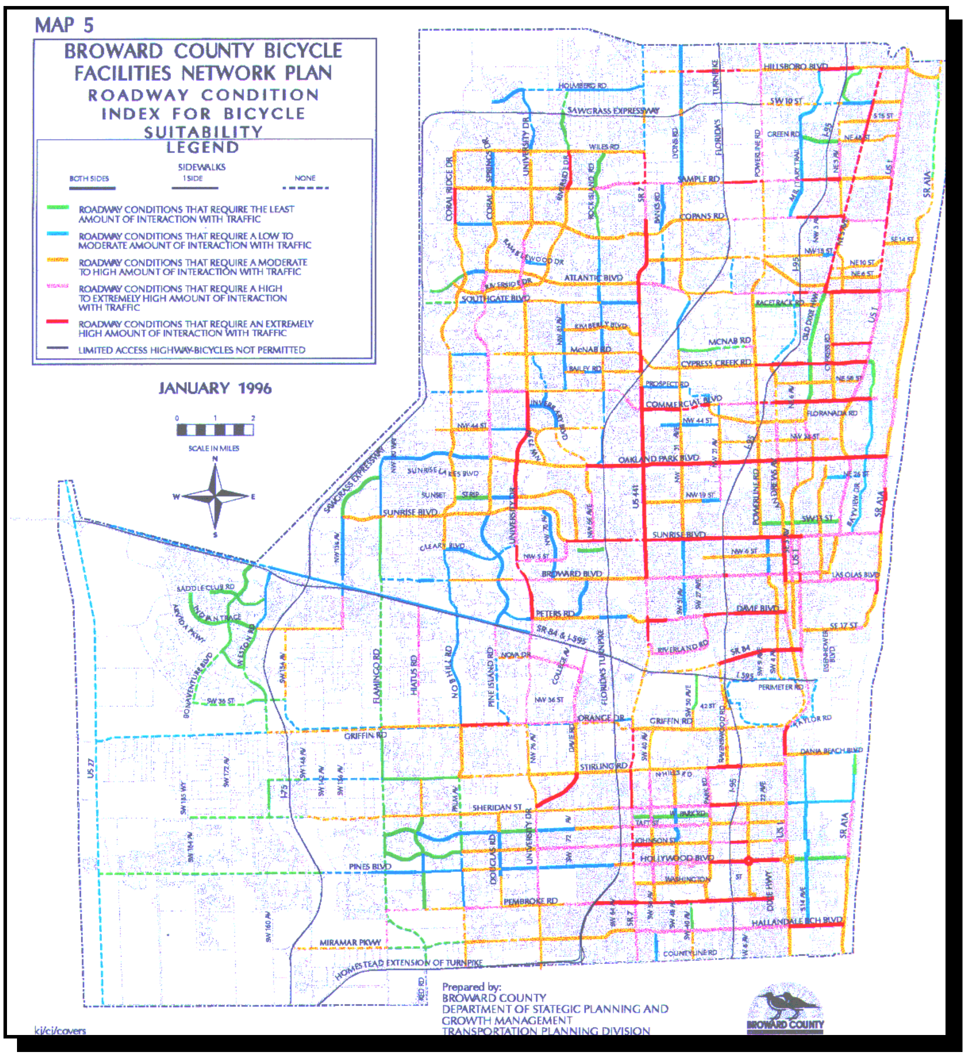

Figure 2-1. Bicycle Suitability Schematic of Broward County, Florida

Eddy adapted Broward County, Florida's RCI (with minor modifications) to evaluate the bicycle LOS in several small urban areas in Oregon and Washington State (10). Eddy defined five bicycle LOS categories as follows:

Superior (less than 3.00):	Conducive to bicycle use. Minor improvements, if any, needed.
Good (3.00 to 3.99):	Accommodates most cyclists. Minor improvements may improve to superior rating.
Fair (4.00 to 4.99):	Usable by many cyclists but poses hazards. Improvements, such as shoulders or lanes, may be needed.
Poor (5.00 to 6.99):	Usable by some cyclists but poses significant hazards. Improvements, such as shoulders or lanes, probably needed.
Very Poor (> 6.99):	Substandard conditions combined with heavy traffic create significant hazards. Should be improved.

Walkway and bikeway inventory data collection forms were developed for each segment to be evaluated (Figure 2-2). Once the data were collected and entered into a data base and geographic information system, Eddy illustrated several uses of bicycle LOS scores:

- Estimating the effects of improvements;
- Evaluating bicycle facility network continuity;
- Comparing bicycle level of service to other geographic features or attributes like off-street walkways, land use and density, and crash locations;
- Providing maps for cyclists; and
- Comparing bicycle facilities in different urban areas by graphing the distribution of bicycle level of service scores (Figure 2-3).

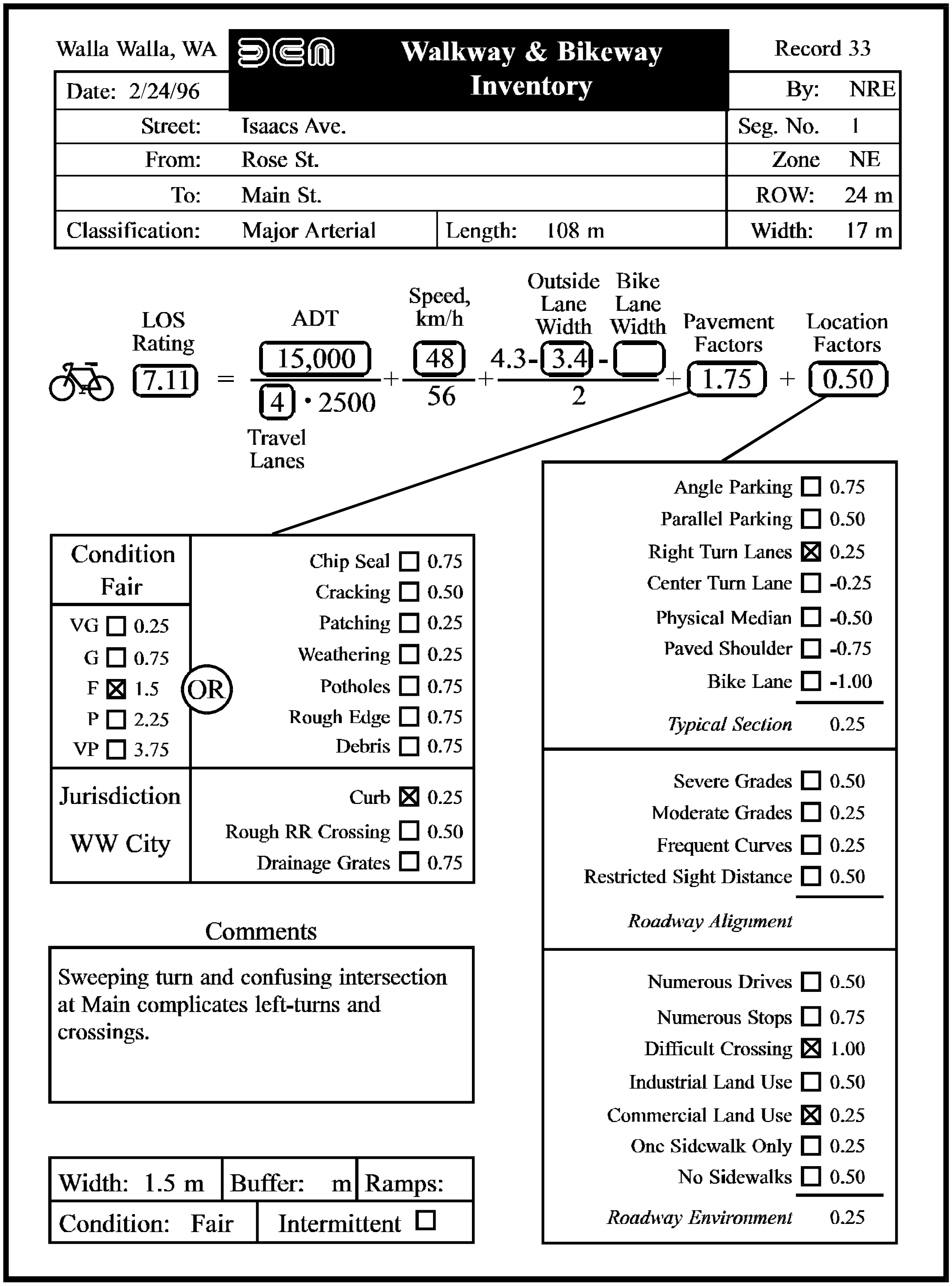

Figure 2-2. Walkway and Bikeway Inventory Form (Adapted from Reference 10)

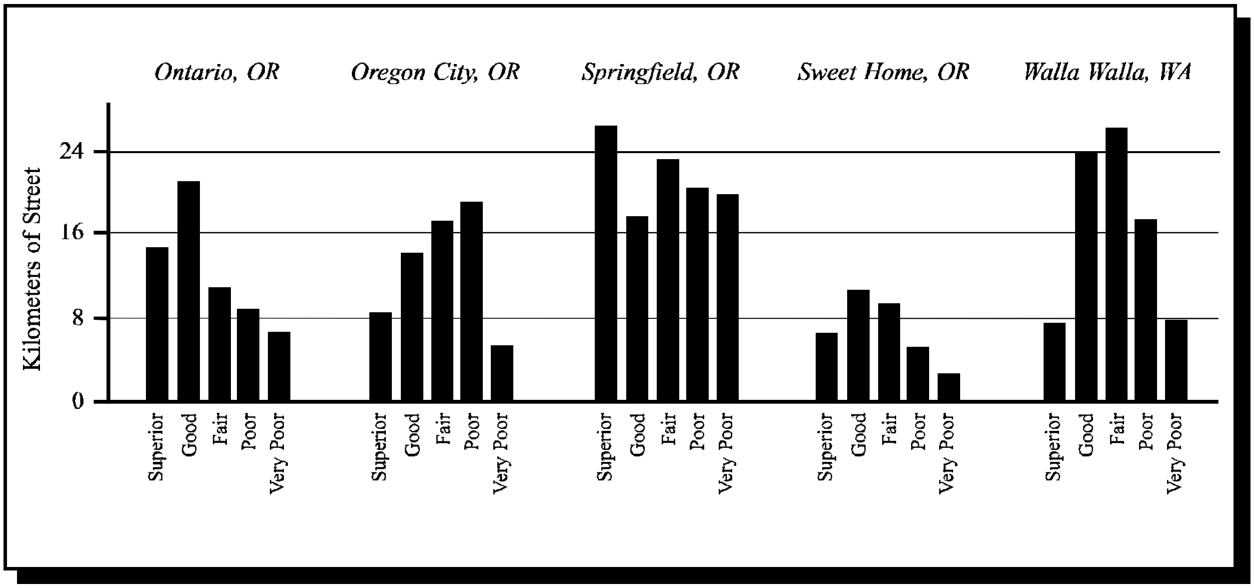

Figure 2-3. Distribution of Bicycle LOS Scores from Different Urban Areas (Adapted from Reference 10)

Modified Roadway Condition Index (Epperson-Davis)

Bicycle planners in the city of Hollywood, Florida made more substantial revisions to Davis' index to create a modified RCI (Table A-3, also called Epperson-Davis modification) which had the following significant changes from Davis' original BSIR (9):

- The intersection evaluation index portion of the rating was dropped;
- The location and pavement factors were modified so that they contributed less in determining the RCI value; and
- The lane width term was multiplied by the speed limit to place greater weight on narrow road segments with high vehicle speeds.

Epperson compared the modified Epperson-Davis RCI to bicycle accident rates in the city of Hollywood and found that the modified RCI rating could only explain 18 percent of the variation in bicycle accident rates, thus implying a weak link between the modified RCI rating and actual bicycle safety of streets (9). Epperson concluded that the amount of bicycle use and patterns of use were contributing factors to bicycle accidents, and he considered neither in his analysis. He recommended increased use of subjective input from bicyclists in combination with objective data about route choices to develop more meaningful LOS criteria for bicycle facilities.

Interaction Hazard Score

Landis developed an interaction hazard score (IHS) that he used to evaluate bicycle suitability in numerous urban areas, including Birmingham, Alabama; Charlotte-Mecklenburg, North Carolina; Philadelphia, Pennsylvania; Tampa, Florida; and several other urban areas within Florida (11,12). The IHS uses several factors associated with other suitability criteria but combines them in a unique manner (Table A-4). Because the IHS has been applied in several areas, Landis has obtained bicyclists' comments regarding overall IHS values. He also developed calibration coefficients for the purpose of adjusting IHS values to bicyclists' comments and perceptions.

Bicycle Level of Service, Landis

In later work, Landis et al. validated the IHS model to produce a bicycle LOS model, which is shown in Table A-5 (13). Approximately 150 bicyclists of varying skill levels and ages rode a course in Tampa, Florida, which consisted of 30 distinctly different roadway segments that formed a loop around the city. Bicyclists rated the roadway segments at "grading stations" located at the end of each distinct roadway segment. Landis et al. included the following variables in their regression analysis:

- Traffic volume (15-minute) in outside lane;
- Traffic speed and mix of vehicle types;
- Transverse turbulence caused by driveways, intersecting streets, etc;
- Pavement surface condition; and
- Proximity of bicyclist to vehicle traffic stream (including presence of pavement striping).

Landis et al. combined these variables in an equation that provided the best fit with the subjective rank order ratings provided by cyclists riding the test course. In developing the final model (Table A-5), Landis et al. discovered that the actual striping of a bike lane was significant in predicting level of service. The "width of striped bicycling cross section" was incorporated into the average effective lane width variable. Landis et al. also discovered that pavement condition played a larger role in bicyclists' perceptions of roadway suitability than was previously thought.

Bicycle Maps

The researchers also found several bicycle maps or articles about the production of bicycle maps in the literature search (14). Kanely describes the development of a bicycle suitability map in Gainesville, Florida. The map doesn't contain suitability ratings per se, but provides an indication of the type of bicycle facility. For example, the maps shows different legends for the different bicycle facility types (Table A-6). Simple suitability ratings like these may be adequate for a bicycle map, but they do not differentiate between varying degrees of suitability for a given bicycle facility type. Kanely's suitability rating by bicycle facility type does not lend itself to quantitative analyses like those performed in bicycle planning.

The Texas Bicycle Coalition developed qualitative suitability criteria to use in developing an Austin Bicycle Map (15). The suitability criteria (Table A-7) assigned weighted point values to rate different roadway and traffic characteristics that were collected by bicyclists from local cycling clubs. After collecting and developing these qualitative ratings, cycling groups reviewed and adjusted them based upon local perceptions and experience. The Texas Bicycle Coalition published the Austin Bicycle Map (Figure 2-4) in 1993, and currently sells it at local bicycle stores in Austin.

The transportation management association (TMA) of Middlesex County, New Jersey, has taken a different approach to creating a bicycle suitability map. Their method does not make judgments of adequate roadway conditions for bicycling. Instead, the Middlesex County map (Figure 2-5) conveys six separate categories of roadways based on the presence of roadway shoulders and vehicle speed limit, allowing bicyclists to make their own choices given such conditions. The map also includes major bicycle trip generators like colleges, public libraries, train stations, and retail centers. Note that the choice of color coding makes it difficult to interpret the suitability of individual roadways.

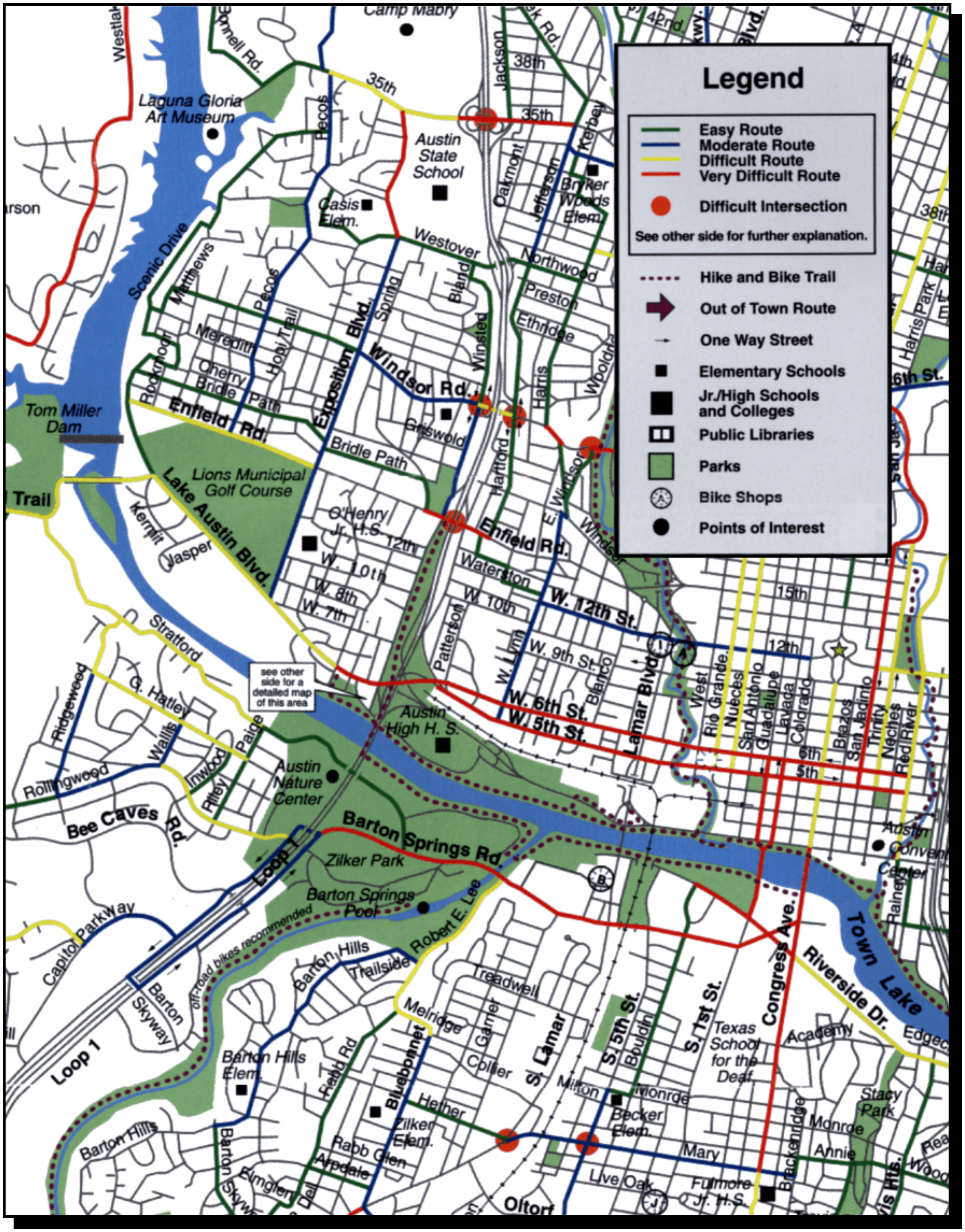

Figure 2-4. Austin Bicycle Suitability Map

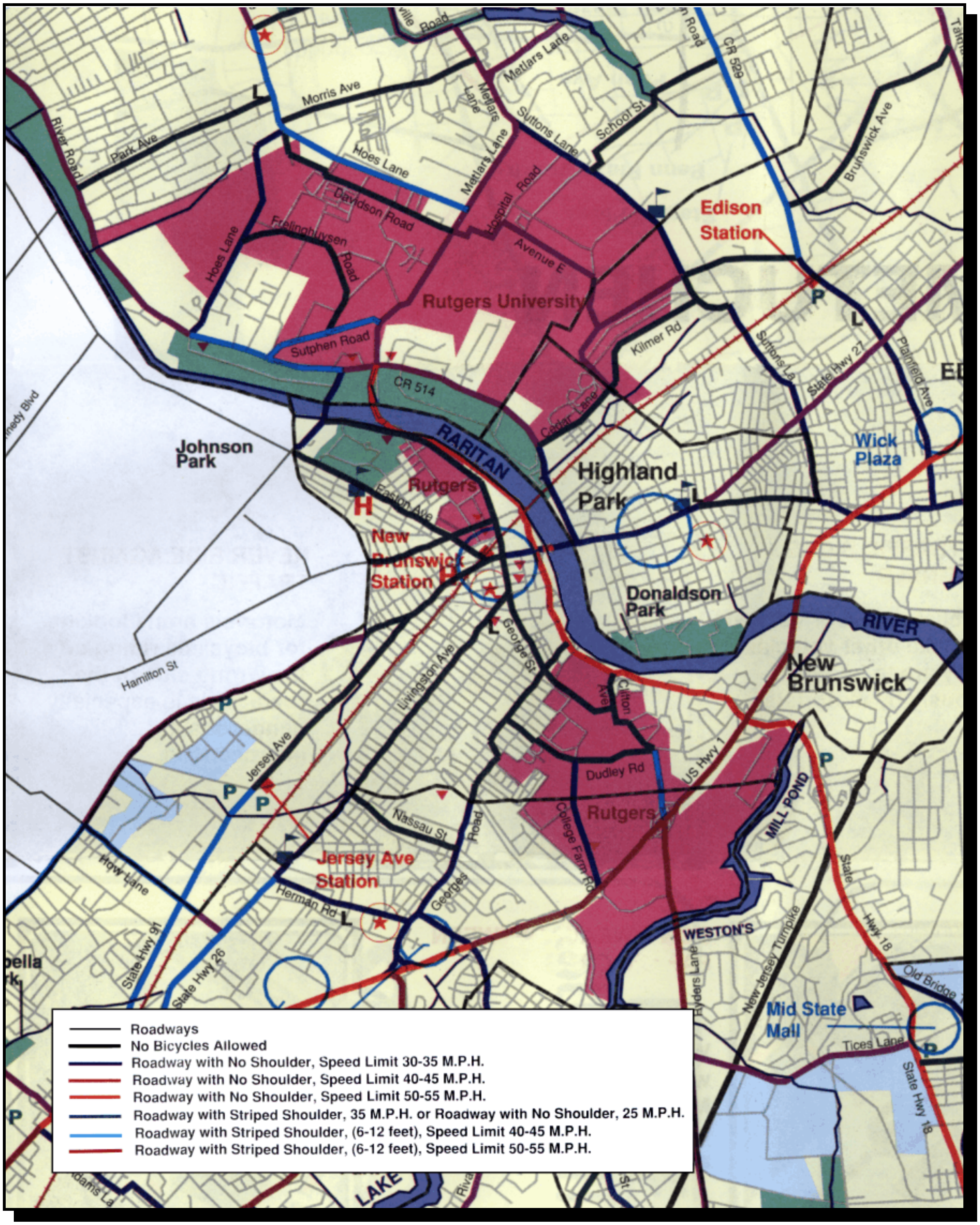

Figure 2-5. Middlesex County, New Jersey Bicycle Suitability Map

Virtual Reality Bicycle Suitability Experiments

The Highway Safety Research Center at the University of North Carolina is conducting experiments with bicycle suitability using virtual reality technology (18). The experiments, which are being conducted for the Federal Highway Administration, expose bicyclists to a wide range of roadway geometry and traffic volume conditions in the safety of a laboratory. Researchers can then vary conditions instantaneously, getting feedback from bicyclists at any instant. The researchers also plan to perform limited experiments in the field to validate and/or calibrate the laboratory findings.

Laboratory experiments have several advantages and disadvantages. A wide range of conditions can be simulated without additional or circuitous travel by bicyclists. The safety aspects of a controlled laboratory experiment, especially for high speed, high traffic volume conditions, offer obvious advantages. The chief criticism of this approach has been that bicyclists react and perceive stimuli very differently in a clean laboratory setting than in actual roadway conditions.

Gainesville, Florida Mobility Plan

The city of Gainesville, Florida developed a congestion management system/mobility plan that includes bicycle LOS performance measures (17). The bicycle performance measures were developed to evaluate and monitor existing streets and bicycle facilities. The performance measures also will be used in the Gainesville Mobility Plan to identify bicycle improvements, gauge the effects of these improvements, and prioritize and rank these bicycle improvements. The LOS performance measures are based upon a points system, and the points for individual segments can be summed to provide a rating for an entire corridor (Table A-8). The primary input variables used in the criteria include:

- Provision of a bicycle facility;
- Potential driveway and side street conflicts;
- Vehicle and bicycle speed differential;
- Vehicle level of service value;
- Maintenance of street and bicycle facilities; and
- Transportation demand management/multimodal support.

The bicycle performance measures were calculated and monitored as part of Gainesville's congestion management system. The measures were used largely in a relative sense to evaluate street corridors and were not used in providing information to area bicyclists. Attempts were not made to correlate these bicycle performance measures with bicyclists' perceptions.

Capacity/Level of Service Analyses

Several articles in the literature discuss the application of highway capacity-based procedures to evaluate bicycle facilities. Highway capacity-based procedures compare traffic volumes to a theoretical capacity (i.e., maximum possible volume under prevailing conditions) to evaluate quality of traffic flow. The Highway Capacity Manual (HCM) (1) is a standard traffic engineering reference that engineers and planners use to evaluate the operation of highways, streets, and street intersections. The bicycle chapter of the 1994 HCM does not recommend any specific technique for evaluating bicycle facilities and only provides maximum reported bicycle volumes on one-way bicycle lanes/paths and two-way bicycle paths.

Botma defined LOS criteria for separated bicycle paths that were based upon the frequency of bicyclist meetings and/or passings along the path (19). Because it is difficult to collect the frequency of bicyclist meetings and/or passings, Botma suggested the use of service bicycle volumes to determine bicycle LOS on one- or two-way bicycle paths.

Navin used bicycle density (square meters per bicycle) to define LOS for bicycle paths (20). Like Botma's LOS criteria, bicycle density must typically be calculated by relating it to other more easily collected data like bicycle volumes or a bicycle volume-to-capacity ratio. Navin also suggested that grade and curve radius be incorporated into bicycle LOS evaluations for bicycle paths.

Researchers at the North Carolina State University are conducting bicycle and pedestrian capacity analysis research for the year 2000 HCM. This research is taking an approach very similar to current HCM evaluation methodologies, looking at bicycle facilities in terms of interrupted sections, uninterrupted sections, and sections with a combination of both. The LOS criteria for each are as follows:

Uninterrupted Facilities: frequency of meetings and/or passings (computed using procedures defined by Botma (19));

Interrupted Facilities: total bicycle delay (computed using procedures similar to those for signalized and unsignalized intersections in Chapters 9 and 10 of the HCM); and;

Combined Facilities: average travel speed (computed using procedures similar to those for arterial streets in Chapter 11 of the HCM).

Findings from the Literature Review

The researchers found three types of bicycle suitability criteria in the literature review:

- *Stress Levels*: simple evaluation criteria based upon curb lane vehicle speeds, curb lane vehicle volumes, and curb lane widths. Bicycle stress levels are easy to calculate because of only three input variables, but they do not incorporate other factors hypothesized to affect bicycle suitability.

- *Roadway Condition Index/Suitability-Based Level of Service*: several different variations of this popular suitability rating criteria were found. The variables most common to all criteria were traffic volumes, curb lane width, speed limit, pavement factors, and location factors. Bicycle planners mostly use these types of criteria in urban areas where data can be economically collected for roadways under study.

- *Capacity-Based Level of Service*: volume-based or similar procedures that have been adapted from capacity analyses common in the 1994 HCM. Capacity-based bicycle suitability procedures appear to be ill suited for most bicycle planning and suitability assessment needs.

The majority of suitability criteria in the literature review were for evaluating roadways in urban areas. In addition, many criteria contained input variables that require additional data beyond that commonly found in urban or statewide transportation data bases. Several bicycle suitability criteria included the presence or width of shoulders, a situation commonly found on state roadways in Texas.

Several efforts to validate bicycle suitability ratings against actual bicyclists' perceptions have been attempted. Davis used a sample of 29 persons to test his bicycle suitability rating but was unable to obtain any statistically conclusive results. Sorton and Walsh used a sample of 61 bicyclists but obtained no statistically conclusive results or empirically derived formula. Epperson compared the modified RCI to bicycle accident rates but found little correlation. Landis et al. used 150 bicyclists in developing a bicycle LOS model, in what could be considered the most successful validation attempt. Researchers at the University of North Carolina are using virtual reality techniques in perhaps the largest bicycle suitability validation test to date.

Several of the suitability criteria considered bicyclist skill level and age. The most common place for inclusion of skill level and age were in the suitability rating value interpretations. As an example, for poor bicycle suitability ratings, the roadways might be deemed unsafe for beginner or child bicyclists. Only Landis' bicycle LOS criteria examined a reasonable cross section of skill levels and ages for validation of criteria.

The next chapter summarizes the findings from the state-of-the-practice surveys and interviews with bicycle coordinators from 16 different state DOTs.

CHAPTER THREE

STATE-OF-THE-PRACTICE SURVEY

This chapter summarizes interviews conducted on a selected sample of sixteen state DOT bicycle coordinators. Researchers conducted these interviews to assess the current implementation status of bicycle suitability procedures and to determine the different types of suitability criteria and application of these criteria to the planning and implementation of bicycle facilities on state roadways. State DOTs were selected that were either similar to Texas in geographic characteristics (i.e., western sun-belt) or that were known to have initiated a statewide bicycle plan. During the telephone interviews, researchers directed conversations at statewide planning for bicycle use on state roads, including suitability criteria, level of public input, and implementation issues.

The conclusions from this survey (Table 3-1) indicate that, with some exceptions, state implementation of various bicycle suitability criteria is still in its inception. Lane width or shoulder width and traffic volume surfaced in most of the interviews as being the two primary criteria for determining bicycle suitability. In addition, other criteria included shoulder pavement condition, percent truck use, and vehicle speed or speed limits. Of those states that were sampled, several had developed public input procedures to validate or adjust their suitability criteria.

There was wide variability across the sixteen states regarding the ease of implementing suitability criteria. Part of the variability was due to differing goals of implementation. Some states' (e.g., Pennsylvania) directed suitability criteria implementation at agency planning efforts, and did not provide bicycle suitability criteria for public purview. Such an implementation goal requires bicycle coordinators to develop links with other DOT agencies and districts in order to integrate multi-modalism within agency operations. Agency-oriented maps, workshops, and technical memorandums often are associated with this implementation goal. Other states' (e.g., Oregon, Maine) implementation goal was externally oriented and directed at encouraging the public to use bicycles. States with this latter goal were likely to have a history of legislation related to development of bicycle-friendly transportation infrastructure. Although the two goals are associated with distinct end-users, implementation of one goal affects implementation of the other. In North Carolina's case, the bicycle coordinator had developed a user-friendly state bicycle map which, after several years of public feedback, became part of agency culture and institutionalized as a DOT planning tool.

Regardless of the implementation goal, other important factors affecting implementation are related to agency culture, institutional history regarding multi-modalism, and the ability for the DOT to play a leadership role in statewide planning. The political climate of some DOTs was aligned with ISTEA and multi-modalism; whereas other DOTs were still struggling with (or wondering about) ramifications of ISTEA on their own operations. In general, DOTs with the former agency culture were in more advanced stages of implementation than DOTs with the latter. The following sections discuss specific results of telephone interviews that illustrate current state-of-the-practice.

Table 3-1. Summary of Selected State Bicycle Suitability Criteria

State DOT	Statewide Suitability Criteria? (Yes/No)	If Yes, Suitability Criteria Variables If No, Mitigating Reasons
Arizona	Yes	Traffic volume (and percent trucks), lane width, shoulder pavement condition
California	No	Political and liability issues
Colorado	Yes	Traffic volume and outside lane width (On scenic corridors, cyclist input on elevation changes, "scenery," and "available amenities" criteria)
Delaware	Yes	Currently developing statewide bicycle suitability criteria
Florida	No	Mandated provision of shoulders on all state roadways
Illinois	Yes	Traffic volumes (including truck traffic), lane widths (outside lanes on multi-lane roads), width of paved shoulders, and road surface type and condition
Maine	Yes	Traffic volumes (and percent trucks), speed, lane width, parking and location factors (Landis LOS)
Minnesota	Yes	Traffic volume, speed, and lane width
New Mexico	Yes	Shoulder width and traffic volume
North Carolina	Yes	Traffic volume (and % trucks), pavement condition, availability of services, and cyclist input
Oregon	Yes	Lane/shoulder width and traffic volume
Pennsylvania	No	Essential roadway inventory data were not available or were not updated frequently
South Carolina	No	
Utah	No	
Washington	Yes	Traffic volume
Wyoming	Yes	Traffic volume, lane/shoulder width, and percent grade

State of Arizona

Like several other states contacted for this survey, Arizona does not retrofit state roadways for bicycle use; however, all new and reconstructed state roads are being built to accommodate bicycles. The previous criteria for bicycle suitability, which was developed by a governor's task force comprised of special interests and transportation planners, identified volume, percent truck use, and width of lane from center stripe to shoulder; the latter criterion was twice the weight of the other two. Arizona DOT recently included shoulder pavement condition as an additional criteria for suitability.

One of the challenges confronting the implementation of the bicycle suitability criteria in Arizona is associated with the limitations of their state roadway data base. Since data exists in sixteen-kilometer (ten-mile) segments, its level of detail overlooks disjoints and periodic breaks in shoulder, pavement width, and other factors relevant to the criteria. Since most of the state roads in metropolitan areas are limited-access interstate highways on which bicycles are prohibited, Arizona DOT is not directing attention to bicycle improvements in urban areas. Local metropolitan planning organizations (MPOs) in Arizona provide most of the leadership to bicycle access in urban locations. The publication of a statewide bicycle map for Arizona is forthcoming.

State of California

The California DOT (Caltrans) appears to play a minor role in statewide comprehensive planning for bicycles. In contrast to the powerful position of Caltrans a few decades ago, local communities and MPOs currently provide most of the initiatives in California regarding transportation planning. California does not have a statewide bicycle plan (mandated by ISTEA), nor is there significant interaction between Caltrans and local jurisdictions. The Caltrans interviewee indicated bicycle lane development decisions are purely political; if there were any criterion, then perhaps lane width would be the sole parameter of concern. Caltrans' liability and legal risks are reported to be obstacles in the opening of state roads to bicycles.

State of Colorado

Colorado has moved toward simplifying variables used to determine bicycle suitability. Average daily traffic (ADT) volume criteria and outside lane width are the two criteria used to define bicycle route suitability for the state bicycle map. As with Arizona, the primary reason for this has been available roadway data. Under their updated system, they have moved from three shoulder width categories (i.e., 0-0.3 meter (0-1 ft.), 0.6-0.9 meter (2-3 ft.), and 1.2 meters (4 ft.) or greater) to two categories (i.e., less than 1.2 meters (4 ft.), 1.2 meters (4 ft.) or greater). Colorado DOT uses four traffic volume categories for different levels of suitability:

- Less than 1,000 vehicles per day (most suitable for bicyclists);
- Between 1,000 and 2,500 vehicles per day;
- Between 2,500 and 5,000 vehicles per day; and
- More than 5,000 vehicles per day (least suitable for bicyclists).

For touring bicyclists, Colorado DOT (CDOT) has developed several loop rides that have been mapped to provide bicyclists with information about services and elevation changes along each route. More recently, CDOT has begun development of two cross state corridors. These corridors have been developed using ADT and width but have also included an "effort" criterion based on elevation changes, a "scenery" criterion, and an "available amenities" criterion. These last three criteria have been developed based on the judgment of bicyclists from around the state. In many of the western counties of the state, CDOT has consulted with communities along potential routes to help promote tourism to the satisfaction of local residents.

State of Delaware

Bicycle planners at the Delaware DOT (DelDOT) are currently developing suitability criteria for a statewide assessment of roadways. The state roadway suitability criteria are based upon earlier criteria that were developed for the city of Dover, Delaware. Because the state roadway mileage in Delaware is relatively low, DelDOT will be collecting additional roadway inventory data for the express purpose of this bicycle suitability evaluation. Roadway inventory data are typically available in several of the urban areas, but DelDOT will be sampling approximately 25 percent of the rural roadway mileage. From this sample of rural roadway mileage, they will then assume various conditions are the same for other roadways not sampled.

They are currently applying this suitability methodology to a single county but plan to eventually expand it to the other two counties in Delaware. DelDOT planners intend to use the bicycle suitability criteria for evaluation and planning of bicycle facilities, and like most other agencies, create a bicycle suitability map for state bicyclists.

State of Florida

The Florida DOT (FDOT) bicycle coordinator indicated that Florida does not have a statewide bicycle suitability evaluation process, per se, because of pro-bicycle policies and strong urban area bicycle planning. FDOT has established certain policies, like the mandated provision of 1.5-meter (5-ft.) shoulders on all new or reconstructed rural roads, that preclude certain statewide bicycle planning tasks. The strong pro-bicycle policies can be attributed to agency culture and strong support at the highest levels of FDOT. Also, the state of Florida utilizes a geographic information system (GIS) at the state level, and the GIS contains information about the presence and condition of shoulders.

In urban areas, the de facto policy is the provision of bicycle lanes and sidewalks on all new or reconstructed roadways (where average daily traffic is greater than 1,600 vehicles). Like other states, most of Florida's bicycle facility planning and evaluation is performed at the urban area level. Many of Florida's urban areas have been using bicycle suitability criteria for several years, and in some respects, led the development and adoption of suitability criteria. These urban areas include Tampa, Gainesville, Tallahassee, Hollywood-Ft. Lauderdale, Miami, and St. Lucie.

State of Illinois

The state of Illinois has produced a series of bicycle suitability maps (Figure 3-1) that are used for a variety of purposes. There are nine bicycle maps in the Illinois state series, each covering a specific region of Illinois in detail. The Illinois DOT (IDOT) distributes the maps free of charge to bicyclists but also uses them in districts for bicycle facility planning. IDOT developed a bicycle accommodation policy, and uses the bicycle suitability ratings to ensure that any transportation improvement project does not lower the bicycle suitability rating.

The suitability criteria used in Illinois are similar to the bicycle stress levels described earlier, with a few modifications. The basic variables (ranked in order of relevance and importance) included in IDOT's bicycle suitability criteria include:

- Traffic volumes, including truck traffic;
- Lane widths (outside lanes on multi-lane roads);
- Width of paved shoulders; and
- Road surface type and condition.

IDOT staff used bicyclists' input to refine the weighting of each variable in the suitability criteria equation, and also used decision-making software in this evaluation process. Bicycle suitability ratings were then calculated using a state roadway inventory data base. For the bicycle maps, IDOT marked the following simple categories for roads with and without shoulders:

- Most suitable for bicycling;
- Caution advised; and
- Not recommended for bicycling.

State of Maine

The state of Maine has integrated multi-modalism into all aspects of their DOT. Maine's DOT no longer focuses on a single class of users (i.e., private vehicles) but embraces a pluralism of users regarding transportation modes. Maine has legislation from 1976 that allows for DOT funds to be spent on bicycle and pedestrian projects. The 1992 Maine Sensible Transportation Policy Act embraced multi-modalism by requiring alternative transportation modes to be considered prior to any new road construction. The state legislature is currently considering a bill that would classify bicyclists as "slow moving vehicles" which, among other things, would empower bicyclists within the state's political system.

Figure 3-1. Sample of Illinois DOT State Bicycle Map

Characteristics of the intermediate (or "design cyclist" type B) bicyclist are the target for Maine's bicycle suitability standards. They are applying Landis' LOS model and integrating it with input from a panel of cyclists who field check the formula's output. Their state data bases provide the requisite information to apply the LOS model. In short, the implementation of Maine's bicycle program appears successful due to authority from state legislation and from a DOT organizational culture and structure that embraces multi-modalism.

State of Minnesota

The state of Minnesota originally looked to Montana for assistance in the development of bicycle suitability criteria in the late 1970s. Like Colorado, they are in the process of simplifying their roadway rating system. They have been using lane width, ADT, speed, parking (by type), and presence of existing facilities (e.g., lane striping). New criteria in Minnesota have been simplified to ADT, speed, and lane width, where suitable width will be judged variably dependent on ADT and speed for a given roadway. The Minnesota DOT selected these criteria to match the Federal Highway Administration's "base plate" and because data for these criteria are available through the Minnesota Transportation Information System. Minnesota uses a State Bicycle Advisory Committee as a sounding board for the development of new state routes. Their policy calls for urban situations to be considered individually by working with local officials and bicyclists. They have been publishing maps for 20 years based on the four criteria listed above. Maps based on their new criteria are due out in Fall 1997.

State of New Mexico

The state of New Mexico relied heavily on advice from Colorado DOT in the development of their bicycle plan. During 1996, both a bicycle plan and an equestrian plan were developed by the state DOT. The plan indicates that bicycle lanes will be added to new and reconstructed roads; they do not retrofit bicycle lanes. Shoulder width is the primary criterion, with ADT playing a secondary role. If a state roadway has a shoulder width of 1.2 meters (4 ft.) or wider, then it is recommended as a bicycle route. At a width of 0.6 to 0.9 meter (2 to 3 ft.), if ADT is less than 1,500 then it would be recommended for bike use; and if shoulders are 0 to 0.3 meter (0 to 1 ft.), ADT needs to be less than 500 to be suitable. New Mexico passed legislation that allows bicyclists on interstate highway shoulders; however, they are prohibited on interstate highways within urban areas.

The New Mexico DOT and the regional transportation planning agencies, including the state's three MPOs (for Albuquerque, Santa Fe, and Las Cruces), have variable relationships regarding their ability to cooperate on policy. In general, the state DOT has held meetings throughout the state to garner public input on bicycle and equestrian transportation issues. One of the main problems with the development of a statewide map has been the lack of a data base that includes current elevation change. Bicycle maps usually provide chevron markers that indicate the grade of slope. Since their database has not been updated on elevation change for state roadways, New Mexico DOT has been struggling with the development of a map.

State of North Carolina

The state of North Carolina has been actively establishing bicycle routes on state roads for over 20 years. They began in the mid 1970s with mapped routes based on ADT data. They still use ADT as the primary criterion for the selection of bicycle routes and have recently incorporated an "availability of services" criterion as well. They also have used percent truck traffic, alignment, pavement and edge quality as criteria to a lesser extent. At a statewide level, rural roads with 800 to 1,200 vehicles per day (ADT) have proven to be the best bicycle routes. After an initial route is selected based on ADT, DOT personnel and local cyclists help establish and rate route suitability through field testing. While field testing, they assess roadways on traffic speed, pavement quality, and width of lanes. North Carolina's current system of bicycle suitability includes mapped routes at the state, county/region, and urban levels. State and regional routes use the same basic criteria while urban routes typically have been determined by supplementing ADT with criteria related to speed and roadside parking. Bicycle suitability maps originally developed for bicycle tourists have become popular with the public to the point of being instituted by the DOT and commonly referenced by DOT personnel in the early stages of project development.

State of Oregon

The Oregon DOT (ODOT) may be in the best position regarding statewide leadership in the implementation of bicycle suitability criteria. State legislation was passed in 1971 that required all new or reconstructed state roadways to accommodate both bicycles and pedestrians. This legislation also created a state bicycle program and directed ODOT to be responsible for technical advice to local jurisdictional levels. ODOT's primary criterion for bicycle suitability is lane or shoulder width. In addition, if ADT is greater than 1,000 vehicles per day, then shoulders need to be at least 1.2 meters (4 ft.) to be suitable for bicycle lanes. However, since Oregon has a long history of paving shoulders to minimize erosion from rainfall, most state roadways are suitable for bike lanes. All new state roadway construction in Oregon typically includes 1.8-meter (6-ft.) shoulders. In urban areas, classification of roadways has become important for bicycle suitability; ODOT stripes bicycle lanes on arterial and major collector streets, but not on local or minor collector streets. ODOT holds about three meetings per year with local jurisdictions to work on bicycle and pedestrian issues. The purpose of the meetings is to share information among local transportation planners and for ODOT to share information and provide advice to constituents.

State of Pennsylvania

The Pennsylvania DOT (PennDOT) considered developing bicycle suitability criteria for statewide planning efforts but was unable to do so because of an inadequate state roadway inventory data base. Several data items in their roadway inventory, like pavement type and condition, were either not contained in the state data base or were not collected on a frequent or reliable basis. Also, local paving practices in rural Pennsylvania sometimes create shoulders with pavements less smooth than the roadway surface, complicating the data recording process. Many of Pennsylvania's local or rural roads are under township (not state) jurisdiction, so information collected on these roadways is not complete.

Several of the urban areas in Pennsylvania are in the process of developing bicycle suitability criteria. These urban areas include Harrisburg and Philadelphia, where Tri-County Planning and the Delaware Valley Regional Planning Commission, the urban areas' respective metropolitan planning organizations, are developing suitability criteria for bicycle facility planning and potential bicycle map development. PennDOT is assisting these agencies where necessary for the urban area bicycle planning.

State of South Carolina

The South Carolina DOT has not defined bicycle suitability criteria and, at this time, is not planning to develop any statewide suitability criteria. South Carolina was one of the few states contacted that had no state level policy for the provision of bicycle facilities. They expressed an interest in what Texas DOT might do as they are starting to consider the implementation of bicycle suitability criteria.

State of Utah

Utah DOT did not have any tradition in bicycle suitability criteria and did not have any in place. Utah has no state mandate for the development of bicycle suitability criteria. State administrators are now becoming much more interested in promoting and accommodating bicycle travel on state roadways due to increased interest from the national bicycling public. Some parts of the state have experienced large increases in bicycling-related tourism, and Utah DOT is now attempting to serve these new customers. Utah DOT may rely on lessons learned in Wyoming and Colorado as they develop state routes for the purpose of enhancing bicycle tourism.

State of Washington

The state of Washington also has produced a state bicycle map (Figure 3-2) that they are distributing to bicyclists interested in intercity bicycle touring. The bicycle map does not contain suitability ratings but does present the average daily traffic (ADT) volumes (which some bicycle planners consider to be the strongest indicator of bicycle suitability).

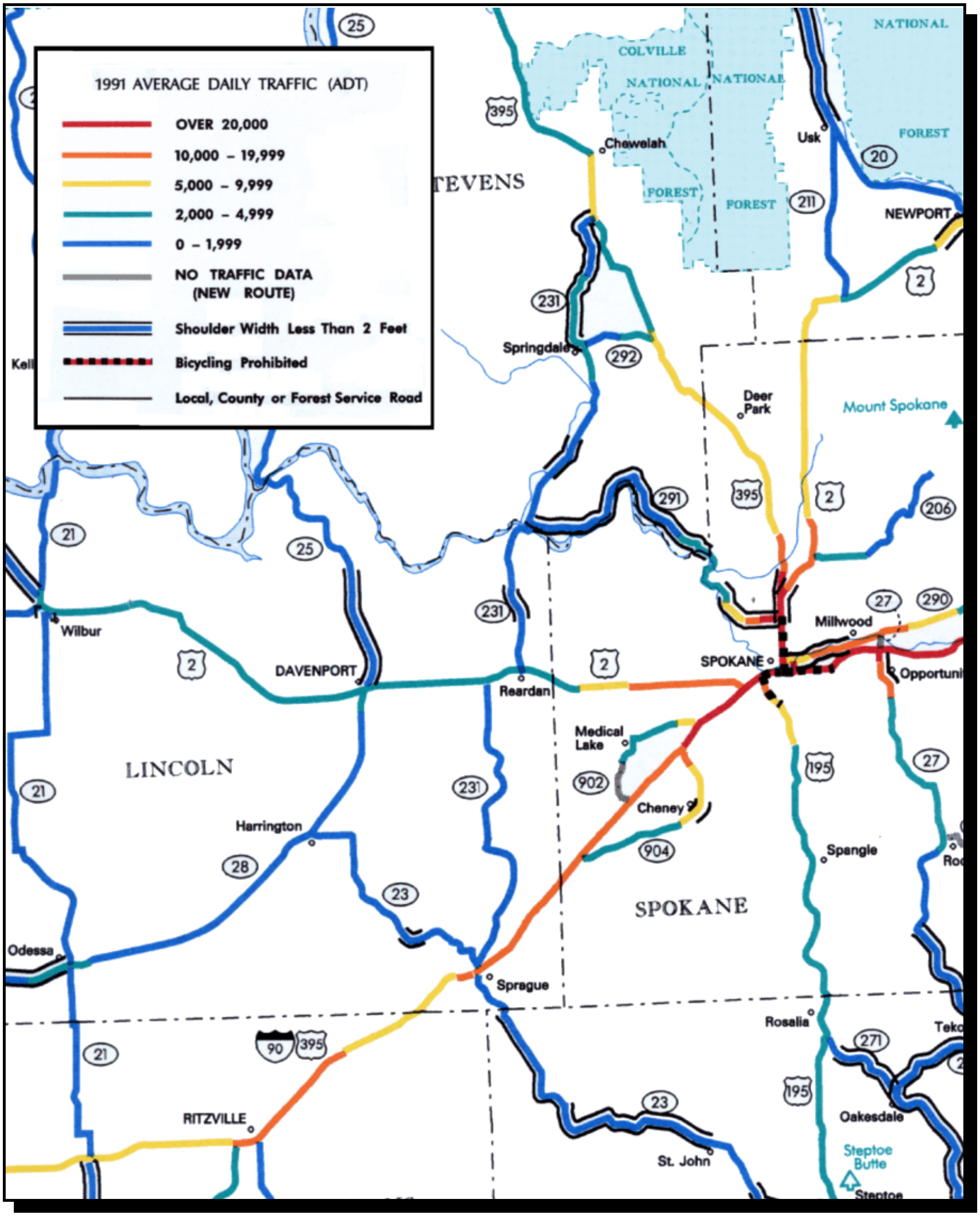

Figure 3-2. Sample of Washington DOT State Bicycle Map

State of Wyoming

The Wyoming DOT, like Colorado, also developed bicycle suitability criteria and maps oriented toward the bicycle tourist. They developed a statewide system of routes based on ADT, road width, and percent grade. Maps have been produced to aid cyclists in selecting routes based on time available and skill level. They attempt to solicit user feedback from people to whom they have sent maps. Such user feedback helps to validate the accuracy of their roadway suitability ratings. In addition to suitable routes based on the three criteria mentioned, the state also provides updated information on scheduled road construction to anyone who requests the state map.

Findings from the State-of-the-Practice Survey

Of the 16 states contacted, 70 percent (11 states) had bicycle suitability criteria in place. Among that 70 percent, the two most common criteria (one or both were used in every case) were the traffic volume (ADT) and the width of outside lanes (or shoulders). Thirty-five percent of the states with suitability criteria also indicated that they looked at heavy vehicles when considering traffic volume, 25 percent considered pavement conditions, and 15 percent included traffic speed or speed limit criteria. Two of the western states, who encourage and accommodate bicycling as a form of tourism, have also used criteria related to percent grade of the roadway, quality of scenery, and the availability of services along a route.

The majority of those states that had bicycle suitability criteria in place had done so to meet state legislation that mandated their formation and use as a part of a multimodal transportation plan. It appeared that the use of traffic volume and lane width as primary suitability criteria was closely related to the fact that this information was available in state DOT databases.

The five states that did not have statewide bicycle suitability criteria were at different points in the process of developing them. One state, Florida, had never implemented them because such strong implementation of criteria at the local level has alleviated the need for anything at the state level. Other states without criteria seem to be hampered by a lack of political backing. For example, states such as South Carolina and Utah have had no legislative mandate to provide for bicyclists and seem to have lacked advocacy at the state level.

CHAPTER FOUR

PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

This chapter contains the preliminary conclusions and recommendations from Task One of this research study. These conclusions and recommendations were formulated after reviewing the literature and conducting a state-of-the-practice survey with 16 state DOTs.

Definition of Bicycle Suitability

The bicycle suitability criteria found in the literature were defined as representing a wide range of attributes beyond bicycle suitability, including bicycle compatibility, friendliness, safety, comfort, convenience, user stress, level of service, or facility performance. Several of these bicycle facility attributes are complementary, like bicycle friendliness, comfort, and user stress. However, attempts to include all of these attributes into a single set of suitability criteria may fail because of conflicting goals among them. The majority of suitability criteria developed at state DOT's were simple and represented the bicycle friendliness or compatibility of roadways (as measured by physical attributes of the roadway).

Conclusion: Bicycle suitability has been used to represent many different (and sometimes conflicting) attributes of roadway facilities. It is important to define exactly what bicycle suitability represents.

Recommendation: An explicit definition of bicycle suitability should be developed when implementing bicycle suitability criteria in Texas. This definition will be developed by the research team in a later task, with input from TxDOT and other partner agencies as needed.

Uses and Applications of Suitability Criteria

The uses or applications of bicycle suitability criteria discussed in this report primarily were focused on the evaluation of roadways. The context of this application varied widely, though, and used slightly different aspects of the suitability criteria. For example, suitability criteria used within urban areas were more complex and data intensive than the criteria applied at statewide levels. Suitability criteria were used in some areas to identify and program improvements within the MPO or DOT; in other places, they were used to create bicycle maps for regional or intercity bicyclists. The exact details of the suitability criteria varied by the uses and applications for the suitability ratings.

Conclusion: The uses and applications of suitability criteria affect the formulation of bicycle suitability criteria. To some extent, the applications of the bicycle suitability criteria will also affect the definition of bicycle suitability (as discussed above).

Recommendation: All potential uses and application contexts (e.g., rural and/or urban areas, internal DOT vs. public use) should be determined before formulating the bicycle suitability criteria. These uses and application contexts will help the research team to precisely define what the bicycle suitability criteria represents and how it can be used.

Importance of Data Resources

Many of the state DOTs in the state-of-the-practice survey indicated that the available statewide data resources were a critical factor in developing statewide bicycle suitability criteria. Several states developed suitability criteria based on available data, whereas other states were not able to develop criteria because of missing data considered essential to bicycle suitability. Very few states planned to collect additional data (beyond what they already collect for roadway inventory purposes) at the statewide level for bicycle suitability criteria.

Conclusion: Available and potential statewide data resources are critical for the implementation of statewide bicycle suitability criteria in Texas.

Recommendation: The research team is investigating available and potential data resources in the next task of this study.

Importance of Agency Support and Culture in Implementation

A large percentage of the state DOTs that were surveyed and had implemented bicycle suitability criteria indicated that the success of the implementation relied heavily on support from upper-level DOT management and agency culture. Several DOT bicycle efforts were mandated by state legislation aimed at creating multi-modalism.

Conclusion: Agency culture and support from upper-level management are important in successful implementation of statewide bicycle suitability criteria.

Recommendation: The project director and research team should plan for the successful implementation of the suitability criteria by examining current support at the management level and potentially the district (implementation) level.

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APPENDIX

DETAILED INFORMATION ON BICYCLE SUITABILITY CRITERIA

Table A-1. Bicycle Stress Level Values and Components (Adapted from References 2,3,4)

$$\text{Bicycle Stress Level} = \text{stress level (traffic volume)} + \text{stress level (lane width)} + \text{stress level (vehicle speed)} \quad (1)$$

Stress Level	**Interpretation**
1 (Very Low)	Street is reasonably safe for all types of bicyclists (except for children under 10).
2 (Low)	Street can accommodate experienced and casual bicyclists, and/or may need altering[a] or have compensating conditions[b] to fit youth bicyclists.
3 (Moderate)	Street can accommodate experienced bicyclists, and/or contains compensating conditions[b] to accommodate casual bicyclists. Not recommended for youth bicyclist.
4 (High)	Street may need altering[a] and/or have compensating conditions[b] to accommodate experienced bicyclists. Not recommended for casual or youth bicyclists.
5 (Very High)	Street may not be suitable for bicycle use.

Curb Lane Traffic Volume (vehicles per hour per lane)	**Curb Lane Width (meters)**	**Curb Lane Vehicle Speed (kph)**	**Stress Level Component**
≤ 50	≥ 4.6	≤ 40	1
150	4.3	50	2
250	4.0	60	3
350	3.7	65	4
≥ 450	≤ 3.3	≥ 75	5

Notes: [a] "Altering" means that street may be widened to include wide curb lane, paved shoulder additions, etc.
[b] "Compensating conditions" can include street with wide curb lanes, paved shoulders, bike lanes, low volume, etc.

Table A-2. Bicycle Safety Index Rating and Components (Adapted from References 7,9)

Bicycle Safety Index Rating (BSIR) = **Weighted Average of Roadway Segment Index and Intersection Evaluation Index**

Safety Index Range	**Classification**	**Description**
0 to 4	Excellent	Denotes a roadway extremely favorable for safe bicycle operation.
4 to 5	Good	Refers to roadway conditions still conducive to safe bicycle operation but not quite as unrestricted as in the excellent case.
5 to 6	Fair	Pertains to roadway conditions of marginal desirability for safe bicycle operations.
6 or above	Poor	Indicates roadway conditions of questionable desirability for bicycle operation.

Roadway Segment Index (RSI)

$$RSI = \left[\frac{ADT}{L \times 2{,}500}\right] + \left[\frac{S}{56}\right] + \left[(4.25 - W) \times 1.635\right] + \sum [PF] + \sum [LF] \qquad \textbf{(2)}$$

where: RSI = Roadway Segment Index;
ADT = average daily traffic (vehicles);
L = number of traffic lanes;
S = speed limit (kph);
W = width of outside traffic lane (m);
PF = pavement factors (see below); and
LF = location factors (see below).

Table A-2. Bicycle Safety Index Rating and Components (Continued)

Pavement Factor Values		Location Factor Values	
Factor	**Value**	**Factor**	**Value**
Cracking	0.50	Angled parking	0.75
Patching	0.25	Parallel parking	0.50
Weathering	0.25	Right-turn lanes	0.25
Potholes	0.75	Raised median	-0.25
Rough road edge	0.75	Center turn lane	-0.25
Curb and gutter	0.25	Paved shoulder	-0.75
Rough railroad crossing	0.50	Grades, severe	0.50
Drainage grates	0.75	Grades, moderate	0.25
		Curves, frequent	0.25
		Restricted sight distance	0.50
		Numerous drives	0.50
		Industrial land use	0.50
		Commercial land use	0.25

Intersection Evaluation Index (IEI)

$$IEI = \left[\frac{VC + VR}{10{,}000}\right] + \left[\frac{VR \times 2}{VC + VR}\right] + \sum [GF] + \sum [SF] \qquad \textbf{(3)}$$

where:
IEI = Intersection Evaluation Index;
VC = cross street volume (ADT);
VR = traffic volume on route being indexed (ADT);
GF = geometric factors (see below); and
SF = signalization factors (see below).

Geometric Factor Values		Signalization Factor Values	
Factor	**Value**	**Factor**	**Value**
No left-turn lane	0.50	Traffic-actuated signal	0.50
Dual left-turn lane	0.50	Substandard clearance interval	0.75
Right-turn lane	0.75	Permissive left-turn arrow	0.25
Two through lanes	0.25	Right-turn arrow	0.50
Three or more through lanes	0.50		
Substandard curb radii	0.25		
Restricted sight distance	0.50		

Table A-3. Epperson-Davis RCI and Components (Adapted from Reference 9)

Epperson-Davis RCI

$$\text{Modified RCI} = \left[\frac{ADT}{L \times 3{,}100}\right] + \left[\frac{S}{48}\right] + \left[\left(\frac{S}{48}\right) \times (4.25 - W) \times 1.635\right] + \sum [PF] + \sum [LF] \quad \textbf{(4)}$$

where: RCI = Roadway Condition Index;
ADT = average daily traffic (vehicles);
L = number of traffic lanes;
S = speed limit (kph);
W = width of outside traffic lane (m);
PF = pavement factors (see below); and
LF = location factors (see below).

Safety Index Range	**Classification**
0 to 3	Excellent
3 to 4	Good
4 to 5	Fair
5 or above	Poor

Pavement Factor Values		**Location Factor Values**	
Factor	**Value**	**Factor**	**Value**
Cracking	0.50	Angle parking	0.75
Patching	0.25	Parallel parking	0.25
Weathering	0.25	Right-turn lane (full length)	0.25
Potholes	0.25 to 0.50*	Raised median (solid)	-0.50
Rough road edge	0.25 to 0.50*	Raised median (left turn bays)	-0.35
Curb and gutter	0.25	Center turn lane (scramble lane)	-0.20
Rough railroad crossing	0.50	Paved shoulder or bike shoulder	0.75
Drainage grates	0.50	Severe grades	0.50
		Moderate grades	0.20
	* Depends upon severity	Horizontal curves, frequent	0.35
		Restricted sight distance	0.50
		Numerous drives	0.25
		If industrial land use, add OR	0.25
		If commercial land use, add	0.25

Table A-4. Interaction Hazard Score Equation and Components (Adapted from References 11,12)

Interaction Hazard Score

$$IHS = \left[\left(\frac{ADT}{L}\right) \times \left(\frac{14}{W}\right)^2 \times \left[a_1 \frac{S}{30} \times (1 + \%HV)^2 + a_2 PF\right] + a_3 LU \times CCF\right] \times \frac{1}{10} \quad \textbf{(5)}$$

Where:

IHS	=	Interaction Hazard Score;
ADT	=	average daily traffic (vehicles);
L	=	total number of through lanes;
W	=	usable width of outside through lane (includes width of any bike lanes; measured from pavement edge, or gutter pan, to center of road, yellow stripe, or lane line, whichever is less);
S	=	speed limit;
%HV	=	presence of heavy vehicles (e.g., trucks) expressed as a decimal;
PF	=	pavement factor (the reciprocal of FHWA Highway Performance Monitoring System (HPMS) PAVECON factor, see below);
LU	=	land use intensity adjoining the road segment (commercial value=15, noncommercial value=1);
CCF	=	curb cut (or on-street parking) frequency, a measure of uncontrolled access (i.e., turbulence per unit of distance); and
a_1,a_2,a_3	=	calibration coefficients initially equal to unity.

PAVECON (Pavement Condition Rating)

5.0 **Very good -** only new or nearly new pavements are likely to be smooth enough and free of cracks and patches to qualify for this category.

4.0 **Good -** Pavement, although not as smooth as those described above, gives a first class ride and exhibits signs of surface deterioration.

3.0 **Fair -** Riding qualities are noticeably inferior to those above, may be barely tolerable for high speed traffic. Defects may include rutting, map cracking, and extensive patching.

2.0 **Poor -** Pavements have deteriorated to such an extent that they affect the speed of free-flow traffic. Flexible pavement has distress over 50 percent or more of the surface. Rigid pavement distress includes joint spalling, patching, etc.

1.0 **Very Poor -** Pavements that are in an extremely deteriorated condition. Distress occurs over 75 percent or more of the surface.

Table A-5. Landis' Bicycle Level of Service Model and Components (Adapted from Reference 13)

Landis' Bicycle Level of Service (BLOS)

$$BLOS = a_1 \ln\left(\frac{Vol_{15}}{L}\right) + a_2 \ln(SPD_p(1 + \%HV)) + a_3 \ln(COM15 \times NCA) + a_4 (PC_5)^{-2} + a_5 (W_e)^2 + C \quad \textbf{(6)}$$

Where:
- BLOS = bicycle level of service, or perceived hazard of the shared roadway environment;
- VOL_{15} = volume of directional traffic in 15-minute time period;
- L = total number of through lanes;
- SPD_p = posted speed limit (a surrogate for average running speed);
- %HV = percentage of heavy vehicles (as defined in the 1994 Highway Capacity Manual;
- COM15 = trip generation intensity of the land use adjoining the road segment (stratified to a commercial trip generation of "15," multiplied by the percentage of the segment with adjoining commercial land development;
- NCA = effective frequency per mile of non-controlled vehicular access (e.g., driveways and/or on-street parking spaces);
- PC_5 = FHWA's five point pavement surface condition rating;
- W_e = average effective width of outside through lane:
  = $W_t + W_l - \sum W_r$
  - where W_t = total width of outside lane (and shoulder) pavement;
  - W_l = width of paving between the outside lane stripe and the edge of pavement;
  - W_r = width (and frequency) of encroachments in the outside lane;
    = $W_p \times$ % of segment with on-street parking + W_g
    - where W_p = width of pavement occupied by on-street parking activity;
    - W_g = combined width and frequency factor of other encroachments; and,
- a_1 = 0.589 (calibration coefficient)
- a_2 = 0.826 (calibration coefficient)
- a_3 = 0.019 (calibration coefficient)
- a_4 = 6.406 (calibration coefficient)
- a_5 = 0.005 (calibration coefficient)
- C = 1.579 (calibration coefficient)

Bicycle Level of Service	Level of Service
≤ 1.5	A
> 1.5 and ≤ 2.5	B
> 2.5 and ≤ 3.5	C
> 3.5 and ≤ 4.5	D
> 4.5 and ≤ 5.5	E
> 5.5	F

Table A-6. Bicycle Suitability Criteria for Gainesville Bicycle Map (Adapted from Reference 14)

Bicycle Facility Type	Description
Street Oriented Route	These roads have an in-street bicycle facility (bike lane, wide curb lane, or parking lane with minimal use) or a paved shoulder. These roads are best suited for bicycle transportation.
Alternative Street Oriented Route	These roads do not have an in-street bicycle facility. However, due to low traffic volumes, they provide an alternative and convenient route for bicyclists.
No In-Street Facility (Sidewalk Present)	These roads do not have an in-street bicycle facility. However, a 1.5-m (5-ft.) sidewalk with ramps at intersecting streets exists on one or both sides of the roads.
No In-Street Facility (No Sidewalk)	These roads do not have an in-street bicycle facility. Also, they do not have a sidewalk (or a usable sidewalk) for bicycle transportation. Avoid these roads or use an adjacent off-street facility if one is available. These roads are least suited for bicycle transportation.
Off-Street Facility	An off-street facility is present. It will normally be 1.5 to 2.4 meters (5 to 8 ft.) in width and either concrete or asphalt. Off-street facilities in Gainesville are shared with pedestrians.
Residential Roads	Residential streets are not shown on the map. Although suited for bicycle transportation, they normally are short in length. These roads are usually at least 6.1 meters (20 ft.) in width with on-street parking.

Table A-7. Suitability Criteria Used in Austin Bicycle Map (Adapted from Reference 15)

Suitability Criteria	Possible Rating Categories	Points
Speed 56 kph (35 mph) or more?	Yes Uncertain No	9 6 3
Volume of Traffic	1 (low) 2 3 (high)	3 6 9
Grade	1 (flat) 2 (gentle rolling to occasional hills) 3 (more than 1 hill per 0.6 km or 1 mi.)	1 2 3
Curves/visibility	1 (good) 2 3 (frequently less than 12.2 m or 40 ft.)	1 2 3
Roadway width	1 (2 lanes of less than 3.7 m or 12 ft.) 2 (2 lanes greater than 3.7 m or 12 ft.) 3 (4 lanes of less than 3.7 m or 12 ft.) 4 (4 lanes greater than 3.7 m or 12 ft.)	9 4 8 3
Road surface	1 (good) 2 3 (rough, frequent potholes, etc.)	1 2 3
Shoulder (not used for classification)	Yes No	no points no points

Total Points	**Color Classification**
12 to 16.5	Green
17 to 19.5	Blue
20 to 24.5	Yellow
25 to 36	Red

Table A-8. Gainesville's Bicycle Performance Measure Point System (Adapted from Reference 17)

Performance Measure Category	Criterion	Points
Bicycle Facility Provided (maximum value = 10)	Outside Lane greater than 3.66 m (12 ft.) Outside Lane 3.66 to 4.27 m (12 to 14 ft.) Outside Lane greater than 4.27 m (14 ft.) Off-Street Facility/Parallel Alternative	0 5 6 4
Conflicts (maximum value = 4)	Driveways and Side Streets Barrier Free No On-Street Parking Medians Present Unrestricted Sight Distance Intersection Implementation	1 0.5 1 0.5 0.5 0.5
Speed Differential (maximum value = 2)	Greater than 48 kph (30 mph) 40 to 48 kph (25 to 30 mph) 24 to 32 kph (15 to 20 mph)	0 1 2
Motor Vehicle LOS (maximum value = 2)	LOS = E, F, OR 6 or more lanes LOS = D and less than 6 lanes LOS = A, B, C and less than 6 lanes	0 1 2
Maintenance (maximum value = 2)	Major or Frequent Problems Minor or Infrequent Problems No Problems	-1 0 2
Transportation Demand Management/Multimodal Support (maximum value = 1)	No Support Support Exists	0 1
Calculations	**Segment Score** (sum of points in the six categories)	21
	Segment Weight (segment length / corridor length)	1
	Adjusted Segment Score (segment score × segment weight)	21
	Corridor Score (sum of adjusted segment scores in the corridor)	21

Segment/Corridor Score	**Bicycle Level of Service**
17 to 21	A
14 to 17	B
11 to 14	C
07 to 11	D
03 to 07	E
00 to 03	F