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16. Abstract

This study identified and developed bicycle suitability criteria for evaluating state roadways in Texas. The bicycle suitability, or "bicycle friendliness," of a roadway typically is determined by the roadway cross section (shoulder or travel lane width), traffic volumes, and vehicle speeds. Bicycle planners commonly use suitability criteria to evaluate existing bicycle facility conditions and plan for improvements. TxDOT's most immediate need for bicycle suitability criteria is in developing a proposed Texas Bicycle Map that provides roadway information to bicyclists. TxDOT can also use the suitability criteria developed in this study to identify gaps or deficiencies in regional or intercity bicycle route networks.

The recommended bicycle suitability criteria for state roadways in Texas includes shoulder or travel lane width; average daily traffic (ADT) volume per lane; vehicle speed (or posted speed limit); and shoulder or travel lane pavement surface quality. A bicycle suitability score is presented that combines values for these factors into a single numerical score, which is used in quantitative bicycle planning. The research team recommends that TxDOT adopt the bicycle suitability criteria as standard policy for evaluating the "bicycle friendliness" of Texas highways, and that TxDOT integrate the bicycle suitability criteria and score into their planning, design, and maintenance processes. Bicyclists' input should be obtained in providing future refinements and enhancement to the bicycle suitability criteria, and in better understanding bicyclists' roadway information needs for the proposed Texas Bicycle Map.

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BICYCLE SUITABILITY CRITERIA FOR STATE ROADWAYS IN TEXAS

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Sponsored by the
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IMPLEMENTATION STATEMENT

This research study developed bicycle suitability criteria that TxDOT can use for evaluating the physical characteristics of state roadways in Texas. TxDOT can also use the suitability criteria for producing statewide or district bicycle maps and for planning bicycle improvements on state roadways.

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. This report does not constitute a standard, specification, or regulation. It is not intended for construction, bidding, or permit purposes. This report was prepared by Shawn Turner (Texas certification number 82781), Scott Shafer, and William Stewart.

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- Glenn Gadbois, Executive Director, Texas Bicycle Coalition
- Elizabeth Hilton, Field Coordination Engineer, Design Division, TxDOT
- Jacqueline Magill, District Bicycle Coordinator, Austin District, TxDOT

Maria Burke, Field Coordination Engineer in TxDOT's Design Division and Project Director for a related TxDOT bicycle research study (0-1723: Bicycle and Pedestrian Demand Forecasting), attended project meetings and provided useful comments and suggestions.

The authors would like to thank the numerous bicycle professionals and advocates contacted throughout this study. They were most generous with their time and available products, and related a wealth of experience to the research team. Any misstatements of their bicycle experiences or processes are solely the responsibility of the authors.

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LIST OF ACRONYMS

ADT	Average daily traffic volume
ADT/L	Average daily traffic volume per lane
BSIR	Bicycle safety index rating
Caltrans	California Department of Transportation
CDOT	Colorado Department of Transportation
CMAQ	Congestion Mitigation and Air Quality
DelDOT	Delaware Department of Transportation
DOT	Department of Transportation
FDOT	Florida Department of Transportation
FM	Farm-to-market
GIS	Geographic information system
HCM	Highway Capacity Manual
HPMS	Highway Performance Monitoring System
IDOT	Illinois Department of Transportation
IEI	Intersection evaluation index
IHS	Interaction hazard score
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
LOS	Level of service
ODOT	Oregon Department of Transportation
PennDOT	Pennsylvania Department of Transportation
RCI	Roadway condition index
RI	Roadway inventory
RSI	Roadway segment index
SH	State highway
TMA	Transportation management association
TPP	Transportation Planning and Programming
TRM	Texas reference marker
TxDOT	Texas Department of Transportation

SUMMARY

Introduction

The purpose of this study was to identify and develop bicycle suitability criteria for evaluating state roadways in Texas. The study considered both urban and rural highways to the extent possible, as a substantial percentage of TxDOT-maintained roadways are in rural areas. 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. Specifically, 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 or intercity bicycle network; and,
- Evaluate roadway conditions for use by bicycle commuters and recreational cyclists.

Research Approach and Findings

The research team undertook the following steps in development of the criteria:

1. Assess the needs of TxDOT in terms of evaluating bicycle suitability of roadways;
2. Gather and review information related to bicycle suitability;
3. Investigate TxDOT statewide data resources; and,
4. Develop bicycle suitability criteria.

TxDOT's needs for bicycle suitability criteria were identified as the following:

- Developing a Texas Bicycle Map;
- Evaluating and prioritizing roadways in the planning, design, and maintenance processes; and,
- Researching the factors related to bicycle travel demand forecasting.

The research team gathered and reviewed information about bicycle suitability that related to TxDOT's needs. The information was gathered from the literature (research reports, journal articles, newsletters, and maps) and from telephone interviews with bicycle coordinators in 16 different states. Bicycle suitability criteria discussed in the literature primarily have been used at the urban area level. There are many different variations on the suitability criteria, but most use some form of traffic volumes, lane widths, traffic speed, pavement factors, and location factors. Because the criteria are applied at the urban area level, the criteria utilized several data items that have to be collected specifically for development of bicycle suitability scores.

The suitability criteria used by many of the 16 states include traffic volumes (and some adjustment for heavy vehicles), lane or shoulder width, and vehicle speeds. 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 average daily traffic (ADT) volume and the width of outside lanes (or shoulders). Thirty-five percent of the states with suitability criteria also considered heavy vehicles in combination with traffic volume, 25 percent considered pavement conditions, and 15 percent included traffic speed or speed limit criteria.

The bicycle suitability criteria being developed in this study will eventually be applied to all state-maintained roadways in Texas. Thus, there is a need to investigate available data resources at the statewide level. The most important data items found in a statewide roadway inventory are traffic volumes, heavy vehicle traffic, and number and width of travel lanes. Data on roadway speed limits are potentially available in several different data bases maintained at the state and district level. Important data items that were not found in statewide roadway inventories but potentially may be maintained at the district level include shoulder width and travel lane/shoulder pavement conditions.

Recommendations and Implementation

Based on information gathered and analyzed for this study, the following characteristics are recommended to represent bicycle suitability on state roadways (listed in order of significance):

- Shoulder width (or travel lane width where no shoulder is present);
- Average daily traffic (ADT) volume per lane;
- Speed limit (as a surrogate for average vehicle operating speed); and,
- Shoulder (or travel lane) pavement conditions.

Chapter 3 of the report presents these suitability factors with designated ranges that can be applied in developing map displays and suitability scores. A single numerical suitability score (bicycle suitability score) can be obtained by summing the score for the primary suitability factors. Chapter 3 of this report provides examples of using the bicycle suitability criteria and bicycle suitability score for a number of different applications. Other roadway characteristics identified as relevant to include on the Texas Bicycle Map are shoulder "rumble strips," significant grades, and bicycle restrictions or prohibitions.

The research team recommends that TxDOT:

- **Adopt the bicycle suitability criteria** presented in Chapter 3 as standard policy for evaluating the "bicycle-friendliness" of state roadways in Texas;

- **Integrate the bicycle suitability criteria** into TxDOT's programming, planning, design, and maintenance processes; and,

- **Obtain bicyclists' input** in providing future refinements to the suitability criteria and in understanding bicyclists' roadway information needs.

1. INTRODUCTION

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 mandated that bicycle facilities be considered in the statewide and metropolitan planning processes, and provided a number of mechanisms to achieve this requirement. ISTEA required bicycle coordinator positions 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 state how and in what conditions bicyclists should be accommodated on state highways. The technical guidance has centered around planning and design guidelines to accomplish the accommodation policy. Some of this technical guidance has included evaluation criteria to determine the bicycle suitability, or "bicycle friendliness," of state roadways.

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 that bicyclists typically prefer to use streets with low traffic volumes, low vehicle speeds, and wide curb lanes, bicycle lanes, or shoulders. A number of other factors can be used to determine those roadways most suitable for bicycle use.

1.1 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 rating the bicycle suitability of state roadways.

The bicycle suitability criteria will be focused on state roadways 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.

1.2 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. Specifically, 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 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 state roadways in Texas. TxDOT can use the bicycle suitability criteria in evaluating and ranking roadways for potential bicycle improvements at the state or district level, as well as for creating state or district-level bicycle maps. 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.

1.3 Organization of this Report

This report documents research conducted to identify and develop bicycle suitability criteria for state roadways in Texas, and contains four chapters and two appendices:

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

2. **Literature and State-of-the-Practice Review:** contains a summary of the available literature on bicycle suitability or bicycle LOS criteria, and describes the state-of-the-practice for bicycle suitability at several other state DOTs;

3. **Research Approach and Findings:** summarizes the approach used to develop bicycle suitability criteria for Texas state highways and the major findings;

4. **Recommendations and Implementation:** provides recommendations for the implementation of bicycle suitability criteria by TxDOT;

Appendix A: Detailed Information on Bicycle Suitability Criteria; and,

Appendix B: Responses from Informal Electronic Mail Survey.

2. LITERATURE AND STATE-OF-THE-PRACTICE 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. The chapter also summarizes the results of a telephone survey conducted with sixteen state DOT bicycle coordinators regarding statewide bicycle suitability criteria.

2.1 Literature Review

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.

2.1.1 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.

2.1.2 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.

2.1.3 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.

2.1.4 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. Bicycle facility improvements can then be targeted to those streets that indicate high RCI values (i.e., poor bicycle suitability).

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.

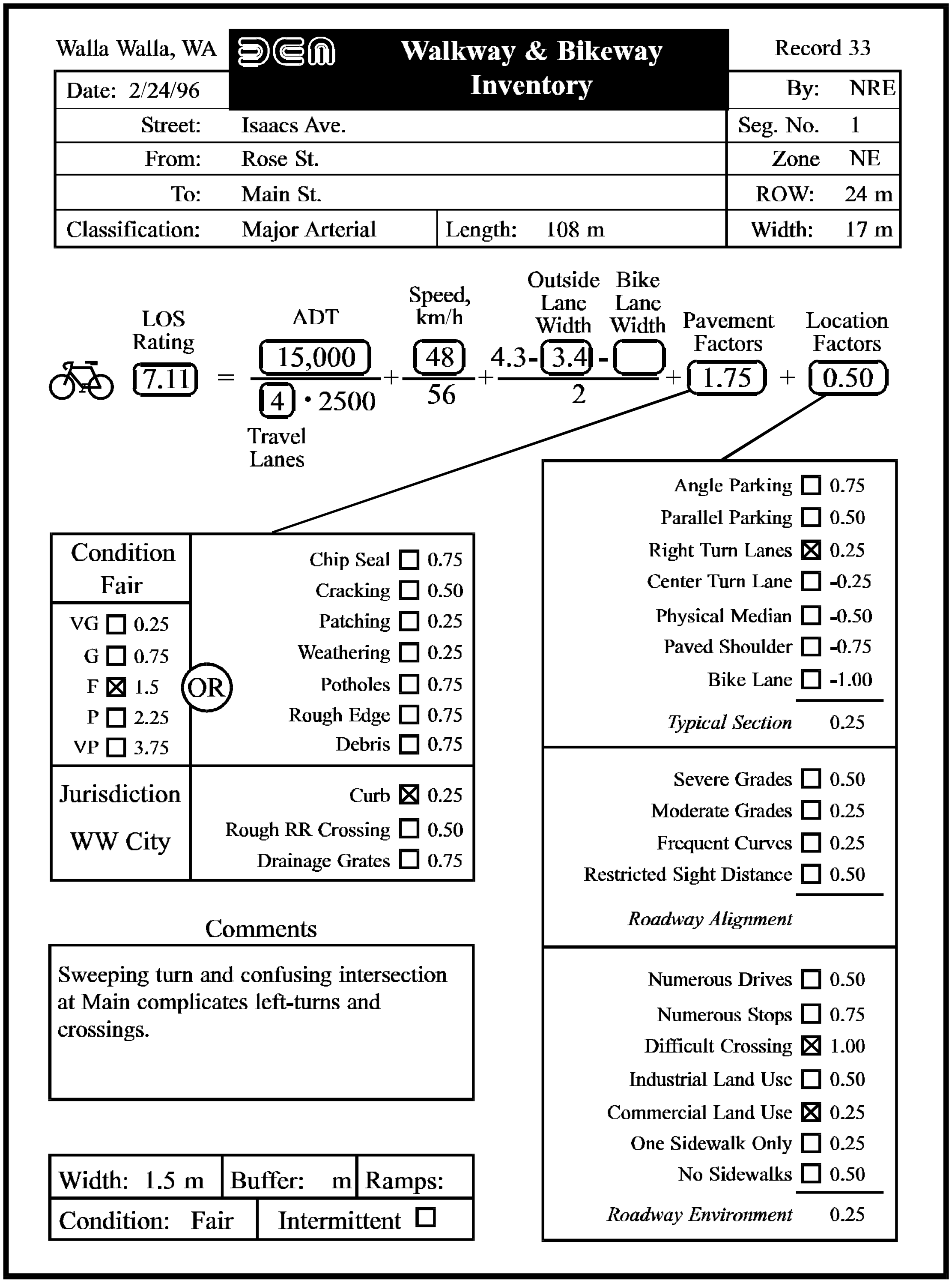
Fair (4.00 to 4.99): Usable by many cyclists but poses hazards. Improvements, such as shoulders or lanes, may be needed.

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 2-1). 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 2-2).



Walla Walla, WA | DEA Walkway & Bikeway Inventory | Record 33

Date: 2/24/96		By:	NRE
Street:	Isaacs Ave.	Seg. No.	1
From:	Rose St.	Zone	NE
To:	Main St.	ROW:	24 m
Classification:	Major Arterial — Length: 108 m	Width:	17 m

LOS Rating [7.11] = ADT [15,000] / (Travel Lanes [4] • 2500) + Speed, km/h [48] / 56 + (4.3 − Outside Lane Width [3.4] − Bike Lane Width [ ]) / 2 + Pavement Factors [1.75] + Location Factors [0.50]

Pavement Factors

Condition: Fair

- VG ☐ 0.25
- G ☐ 0.75
- F ☒ 1.5
- P ☐ 2.25
- VP ☐ 3.75

OR

- Chip Seal ☐ 0.75
- Cracking ☐ 0.50
- Patching ☐ 0.25
- Weathering ☐ 0.25
- Potholes ☐ 0.75
- Rough Edge ☐ 0.75
- Debris ☐ 0.75

Jurisdiction: WW City

- Curb ☒ 0.25
- Rough RR Crossing ☐ 0.50
- Drainage Grates ☐ 0.75

Comments

Sweeping turn and confusing intersection at Main complicates left-turns and crossings.

Width: 1.5 m	Buffer: m	Ramps:
Condition: Fair	Intermittent ☐	

Location Factors

- Angle Parking ☐ 0.75
- Parallel Parking ☐ 0.50
- Right Turn Lanes ☒ 0.25
- Center Turn Lane ☐ -0.25
- Physical Median ☐ -0.50
- Paved Shoulder ☐ -0.75
- Bike Lane ☐ -1.00

Typical Section 0.25

- Severe Grades ☐ 0.50
- Moderate Grades ☐ 0.25
- Frequent Curves ☐ 0.25
- Restricted Sight Distance ☐ 0.50

Roadway Alignment

- Numerous Drives ☐ 0.50
- Numerous Stops ☐ 0.75
- Difficult Crossing ☒ 1.00
- Industrial Land Use ☐ 0.50
- Commercial Land Use ☒ 0.25
- One Sidewalk Only ☐ 0.25
- No Sidewalks ☐ 0.50

Roadway Environment 0.25

Figure 2-1. Walkway and Bikeway Inventory Form (Adapted from Reference 10)

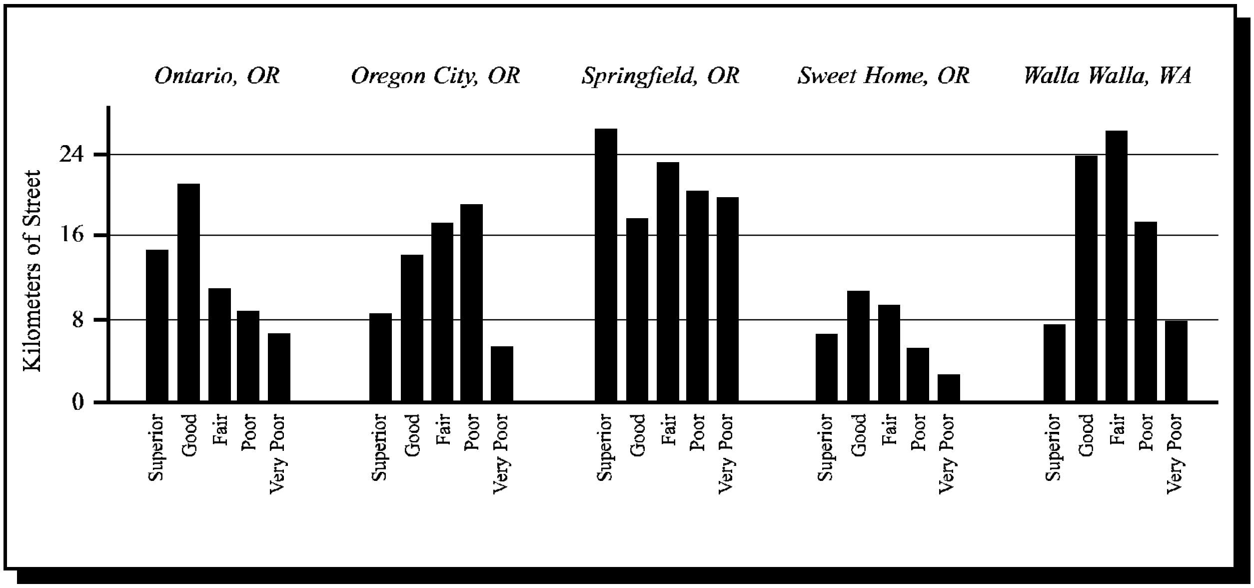


Figure 2-2. Distribution of Bicycle LOS Scores from Different Urban Areas (Adapted from Reference 10)

2.1.5 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.

2.1.6 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.

2.1.7 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.

2.1.8 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 2-3) 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 2-4) 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.

2.1.9 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 (18,22). 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.

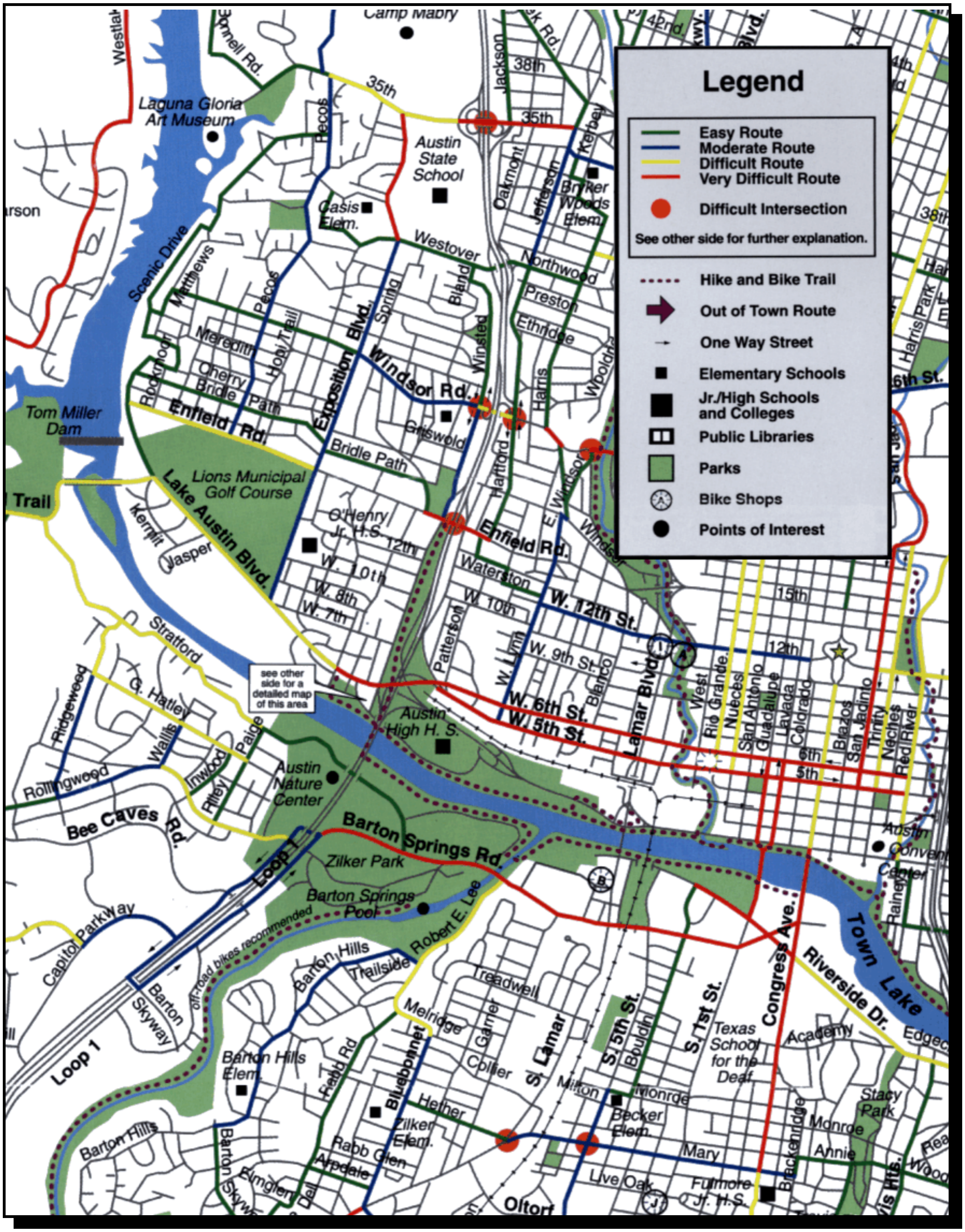


Figure 2-3. Austin Bicycle Suitability Map

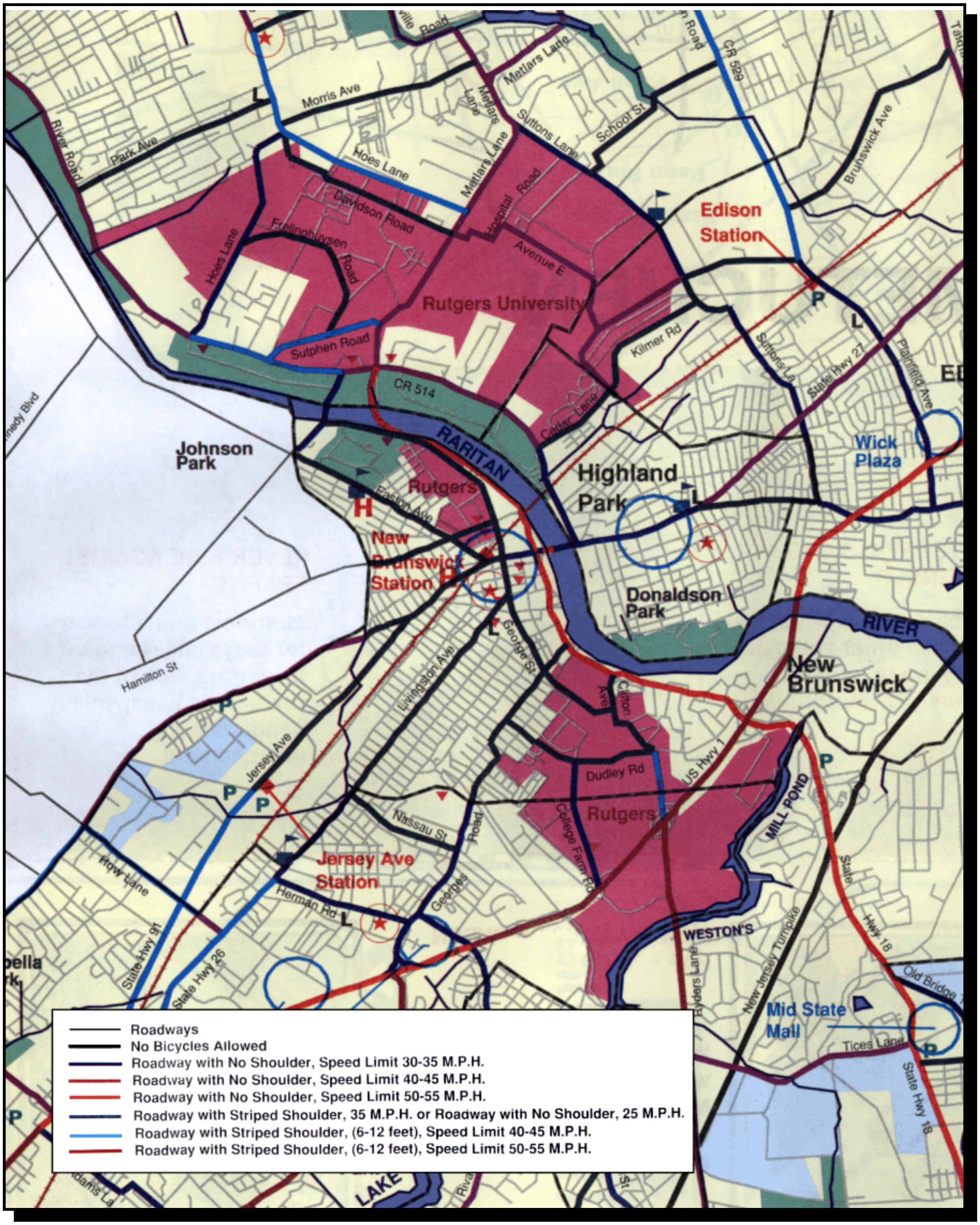


Figure 2-4. Middlesex County, New Jersey Bicycle Suitability Map

2.1.10 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.

2.1.11 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 (20). 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 (21). 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 (20));
- *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).

2.1.12 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 children bicyclists. Only Landis' bicycle LOS criteria examined a reasonable cross section of skill levels and ages for validation of criteria.

2.2 State-of-the-Practice Review

This section 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 assessing the status of statewide planning for bicycle use on state roads, including suitability criteria, level of public input, and implementation issues.

The conclusions from this survey (Table 2-2) 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.

Table 2-2. 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

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.

2.2.1 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 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.

2.2.2 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.

2.2.3 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 (Figure 2-5). 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 (Figure 2-6). 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.

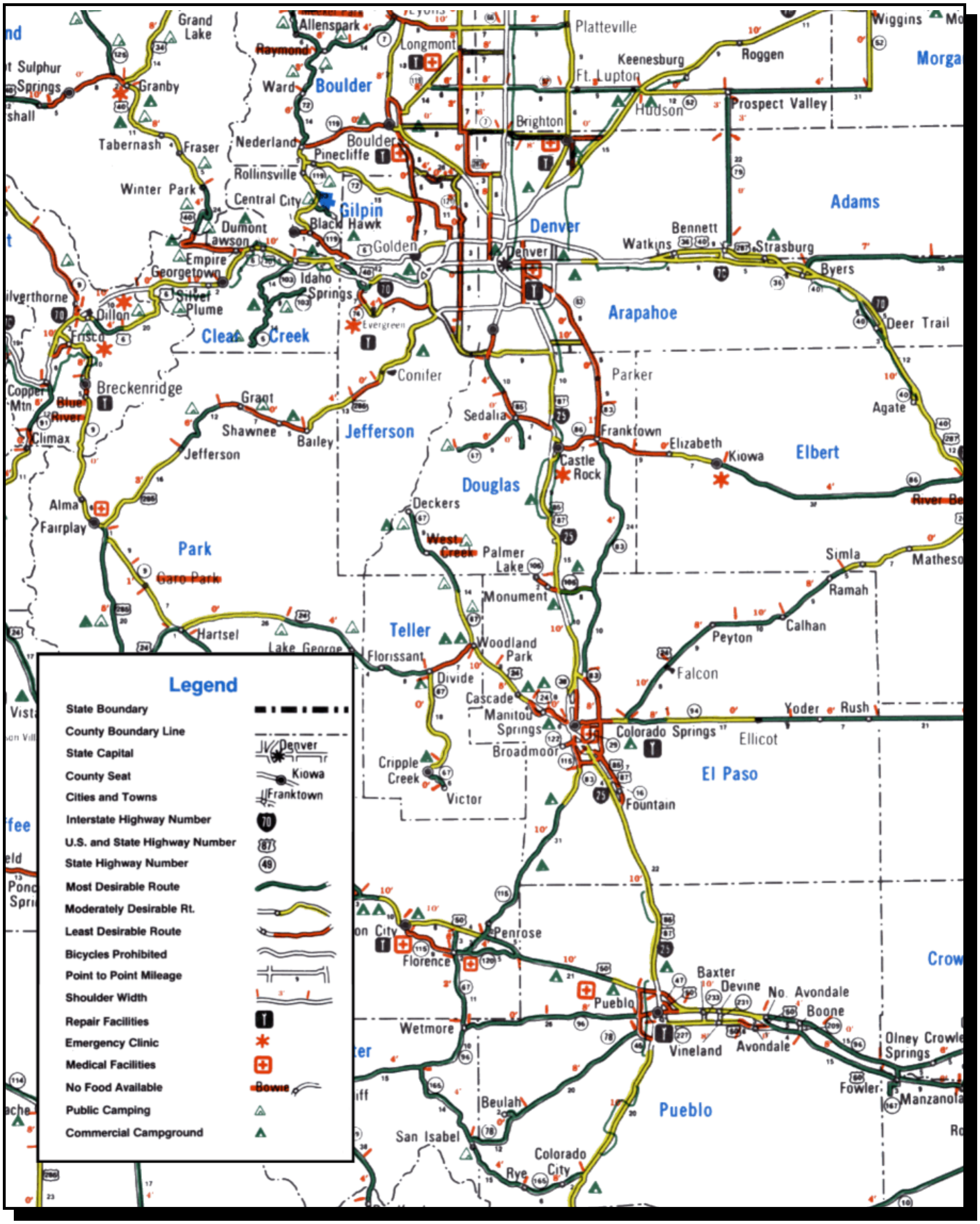


Figure 2-5. Sample of Colorado DOT State Bicycle Map

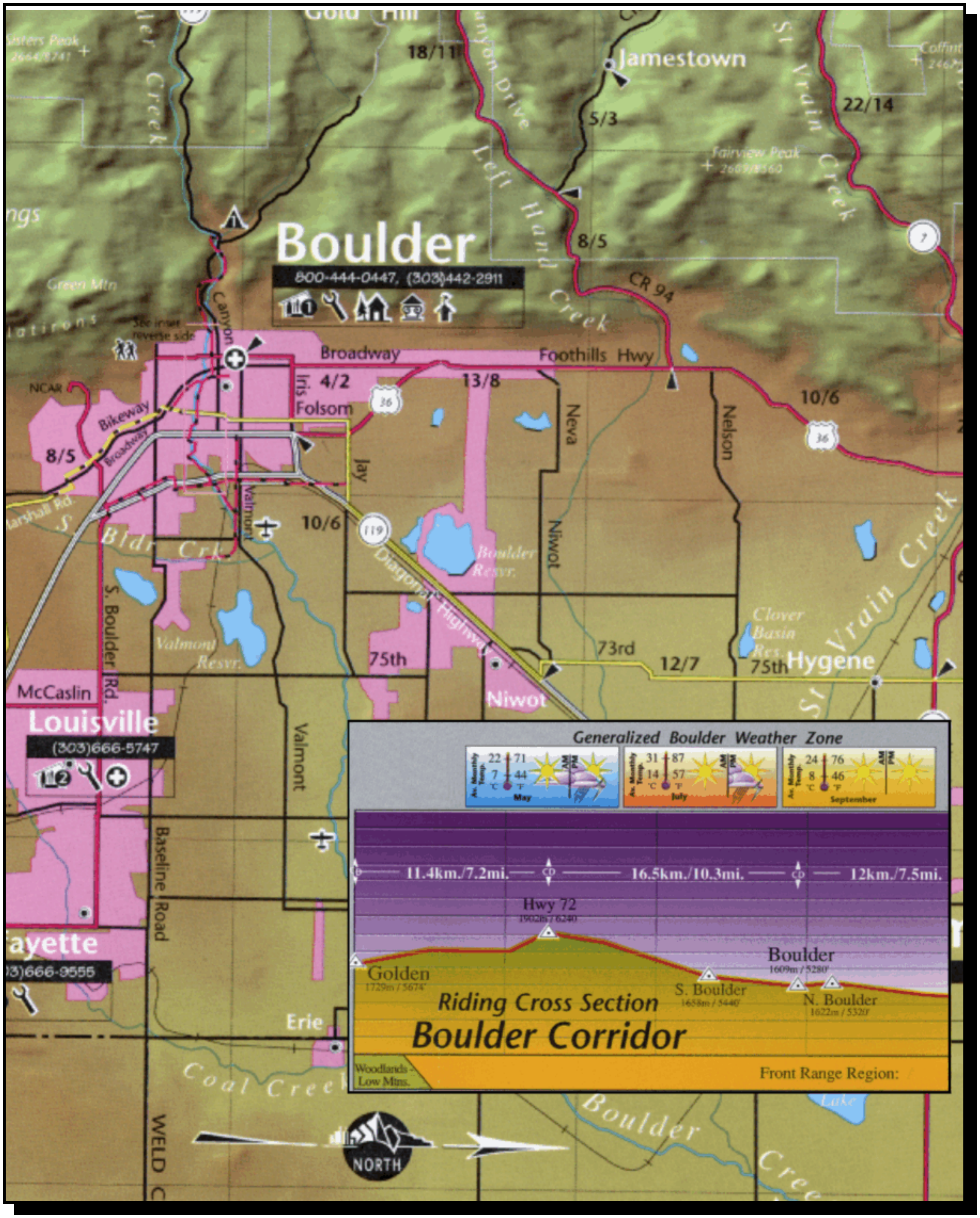


Figure 2-6. Sample of Colorado DOT State Bicycle Touring Map Series

2.2.4 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.

2.2.5 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.

2.2.6 State of Illinois

The state of Illinois has produced a series of bicycle suitability maps (Figure 2-7) 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.

Figure 2-7. Sample of Illinois DOT State Bicycle Map

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.

2.2.7 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.

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.

2.2.8 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 (Figure 2-8). Maps based on their new criteria are due out in Fall 1997.

2.2.9 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 data base has not been updated on elevation change for state roadways, New Mexico DOT has been struggling with the development of a map.

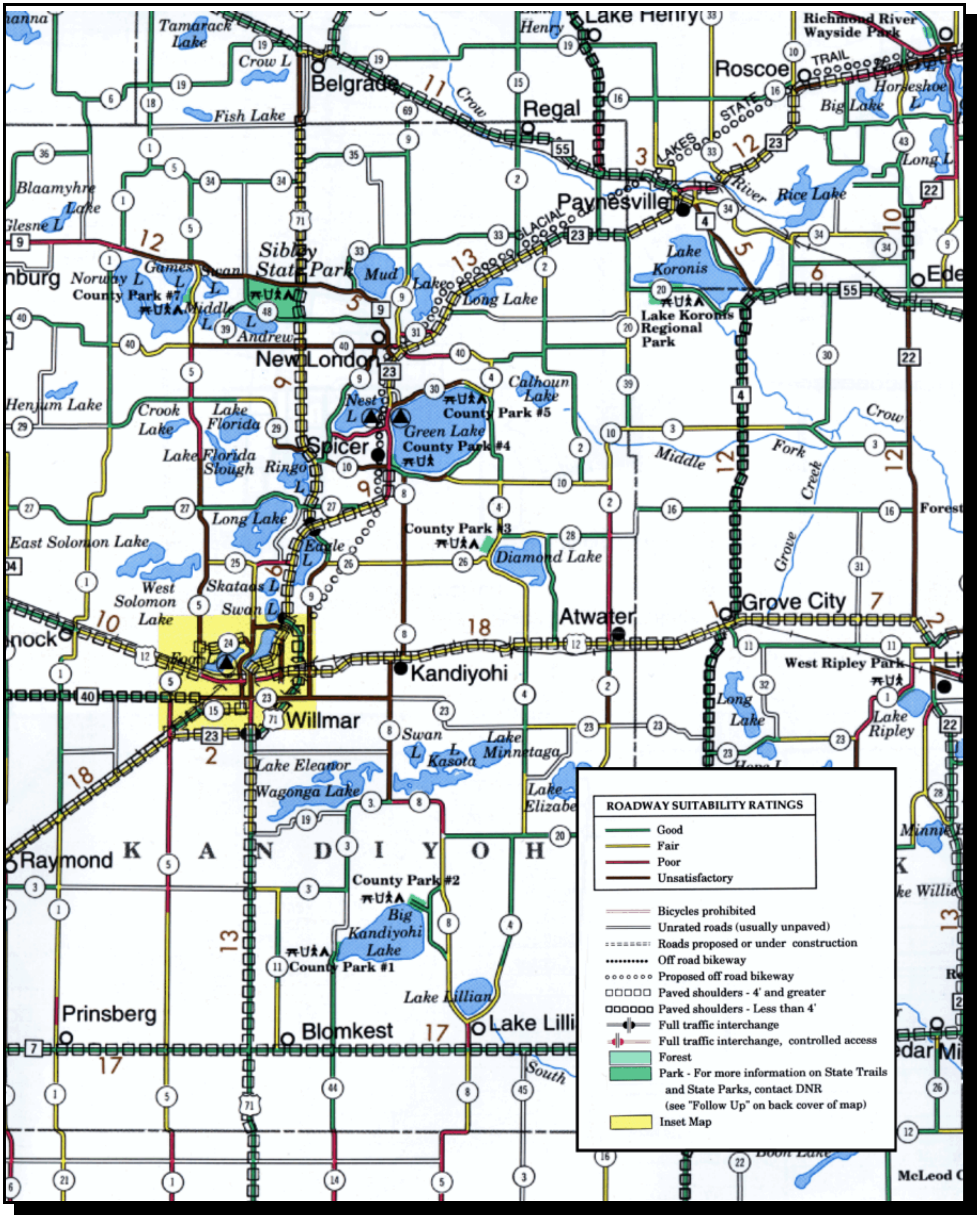


Figure 2-8. Sample of Minnesota DOT State Bicycle Map

2.2.10 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 quality 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. An example of the Raleigh bicycle map is shown in Figure 2-9.

2.2.11 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.

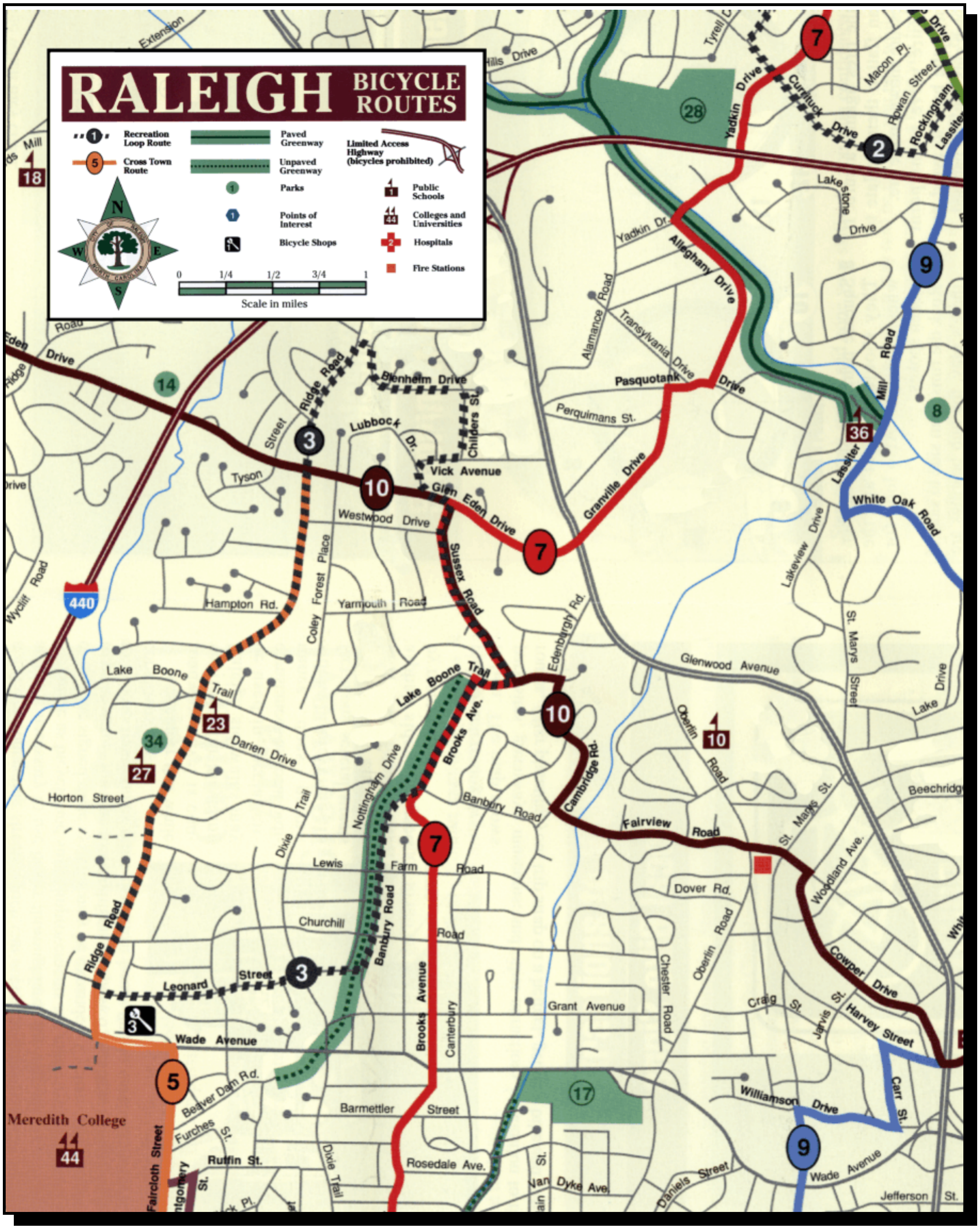


Figure 2-9. Sample of North Carolina DOT City of Raleigh Bicycle Map

2.2.12 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.

2.2.13 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.

2.2.14 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.

2.2.15 State of Washington

The state of Washington also has produced a state bicycle map (Figure 2-10) 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).

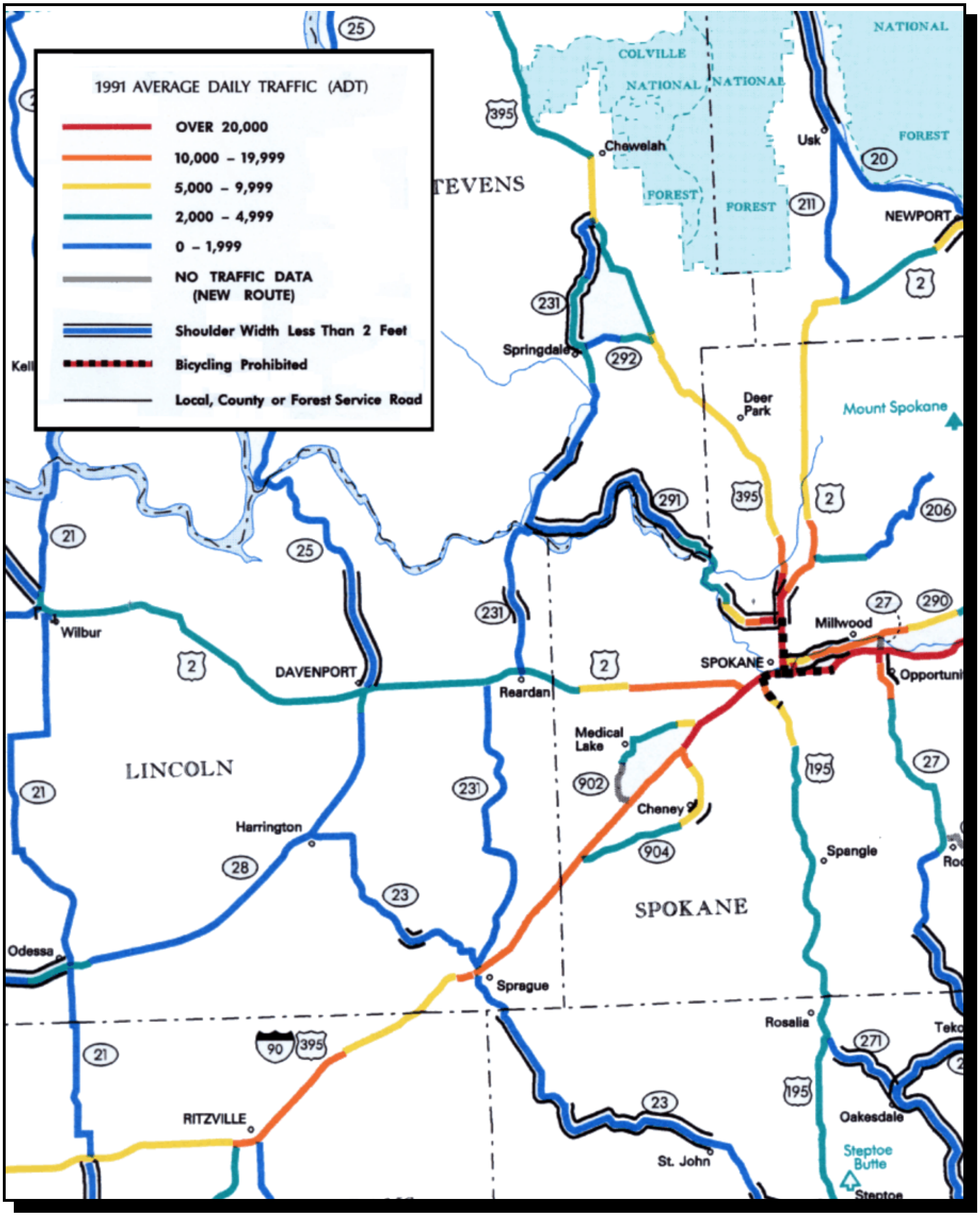


Figure 2-10. Sample of Washington DOT State Bicycle Map

2.2.16 State of Wyoming

The Wyoming DOT, like Colorado, also developed bicycle suitability criteria and maps (Figure 2-11) 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.

2.2.17 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 data bases.

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.

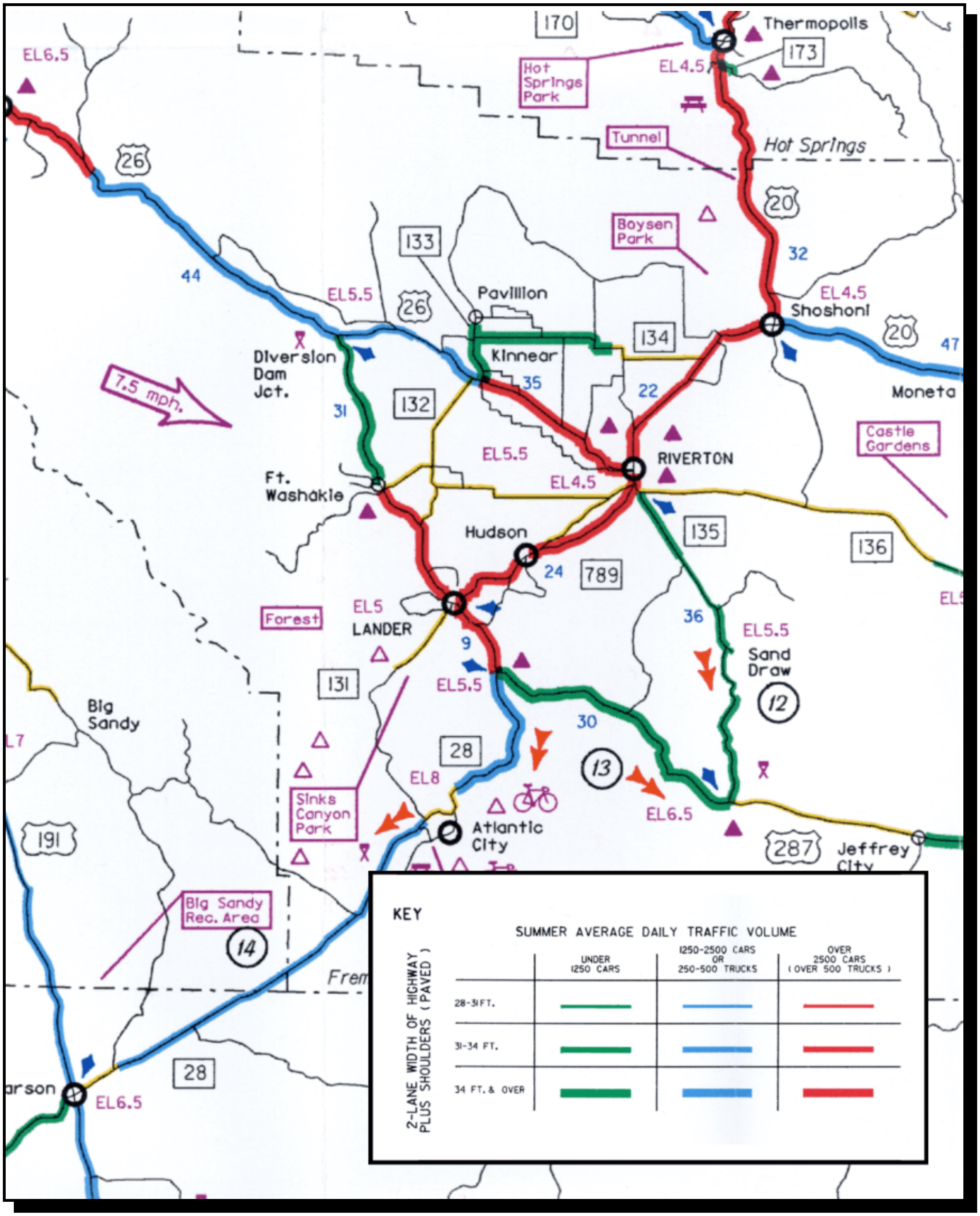


Figure 2-11. Sample of Wyoming DOT State Bicycle Map

3. RESEARCH APPROACH AND FINDINGS

This chapter presents the approach or methodology used to develop bicycle suitability criteria for state roadways in Texas. The research team undertook the following steps in developing the criteria:

- Assess the needs of TxDOT in terms of evaluating bicycle facilities or roadways for bicycle use;
- Gather and review information from literature and current practices at other state DOTs;
- Investigate TxDOT statewide data resources; and,
- Develop logical, practical criteria based upon TxDOT needs, existing and proposed practices, and available data resources.

The following sections discuss these steps in more detail and present the findings from this study as they pertain to each step.

3.1 Assess TxDOT Needs

The first step in the research approach was to assess the needs of TxDOT in terms of bicycle suitability criteria. These needs, coupled with the potential applications of the suitability criteria, would govern the features and characteristics of the criteria.

The most pressing and obvious need is for a **Texas Bicycle Map** in which roadway physical characteristics are used to evaluate over 123,970 km. (77,000 mi.) of Texas state roadways. Bicyclists will use the Texas Bicycle Map for planning trips or tours on state highways. The Texas Bicycle Map is analogous to the "Texas Official Travel Map" currently published by TxDOT on an annual basis. TxDOT's Transportation Plan (23) includes development of suitability criteria and a state map as objectives in the non-motorized transportation plan:

> *"Potential Action 2.3.7: Evaluate and document levels of bicycle usage and bicycling promotion programs and include criteria essential for identification of suitable bicycle routes in the state road inventory and other transportation information data bases."*

> *"Potential Action 2.3.8: Fund, develop, and disseminate a Texas bicycle suitability map based on American Association of State Highway and Transportation Officials guidelines."*

The primary audience for the Texas Bicycle Map will be touring or other bicyclists who ride in the rural areas of the state. These bicyclists are typically intermediate to experienced bicyclists and have knowledge of safe and effective bicycling skills. The bicyclists could be touring across all or part of the state, or could simply be taking a longer day ride into rural areas. A Texas Bicycle Map can give bicyclists advance information about the roadway's physical characteristics and traffic conditions, which could then be used for route selection and planning.

Another need for bicycle suitability criteria that surfaced in discussions with TxDOT district personnel is **evaluating and prioritizing roadways in the planning process**. Several persons mentioned the need for quantitative tools that could be used to determine which roadway sections were in most critical need of bicycle improvements. Suitability criteria could be used to illustrate the roadways with poor or very poor bicycle suitability, thus in need of bicycle improvements. The suitability criteria also could be used to identify gaps or deficiencies in a regional or statewide system of "bicycle-friendly" roadways. This need for evaluating and prioritizing roadways for bicycle improvements requires consistent, quantitative criteria that can be applied objectively on a frequent basis, if necessary.

Another potential need for the suitability criteria is in **bicycle travel demand forecasting**. An ongoing TxDOT research study, 0-1723, is attempting to quantify the demand for bicycle and pedestrian facilities along state roadways. Preliminary findings from this study's data collection efforts and other national research indicate that the physical conditions, or suitability, of the roadway affects bicycle travel demand. Thus, it is necessary to develop bicycle suitability criteria that can be incorporated into the bicycle travel demand forecasting process.

The potential bicycle demand can then be combined into a bicycle needs index (24), which is essentially the bicycle demand normalized by the bicycle suitability score (Equation 1). The bicycle needs index is a high number when demand is high but suitability is low--a high bicycle needs index indicates a critical need for bicycle improvements. Low bicycle demand and high suitability yields a low bicycle needs index, which could indicate that no bicycle improvements are necessary at this time. The bicycle needs index is analogous to the volume-to-capacity ratio, which has been used in the past to plan and program highway improvements.

$$Bicycle\ Needs\ Index = \frac{Bicycle\ Demand}{Bicycle\ Suitability\ Score} \quad \textbf{(3-1)}$$

3.2 Gather and Review Information

The research team gathered and reviewed information about bicycle suitability that related to TxDOT's needs. The two primary sources of information are:

- **Literature:** existing research reports, journal articles, newsletters; and,
- **State DOT Bicycle Coordinators:** telephone interviews were conducted with bicycle coordinators in sixteen different states.

Chapter 2 reviewed and summarized the bicycle suitability information. The major findings are as follows:

- Bicycle suitability criteria discussed in the literature primarily have been used at the urban area level. There are many different variations on the suitability criteria, but most use some form of traffic volumes, lane widths, traffic speed, pavement factors, and location factors. Because the criteria are applied at the urban area level, the criteria utilized several data items that have to be collected specifically for development of bicycle suitability scores.
- Bicycle suitability criteria used by state DOTs are fairly simple and rely on data items that are available through statewide data bases. The criteria used by state DOTs commonly include traffic volumes (and some adjustment for heavy vehicles), lane or shoulder width, and vehicle speeds. Some states collected supplemental information for bicycle tourists like grade, available amenities, and scenery.

3.3 Investigate Statewide Data Resources

The bicycle suitability criteria being developed in this study will eventually be applied to over 123,970 km. (77,000 mi.) of state-maintained roadways in Texas. Thus, there is a need to investigate available data resources at the statewide level. The researchers hoped that the physical roadway characteristics used to calculate bicycle suitability would be available and updated regularly at the TxDOT state or district level in a computerized data base. The collection of additional data for 123,970 km. (77,000 mi.) of roadway could potentially delay implementation of bicycle suitability criteria and be met with institutional resistance at the district level.

Researchers sent a list of data items that potentially could be incorporated into the bicycle suitability criteria to TxDOT's Transportation Planning and Programming (TPP) Division. The TPP division maintains several statewide data bases and responded to the request with the availability of data. Table 3-1 presents TxDOT's available data resources related to bicycle suitability criteria. The last cell of this table briefly explains the various data sources.

The most important **data items found to be in a statewide roadway inventory** were:

- traffic volumes;
- heavy vehicle traffic; and,
- number and width of travel lanes.

Data on roadway speed limits is potentially available in several different data bases maintained at the state and district level. Important **data items not found in statewide roadway inventories** but potentially may be maintained at the district level, include

- shoulder width; and,
- travel lane and shoulder pavement conditions.

The research team also discovered that TxDOT's statewide Roadway Inventory data base is being converted to the Texas Reference Marker (TRM) system, and that the roadway inventory likely has not been updated in the past several years. Therefore, it is likely that each TxDOT District will have to verify relevant information in the roadway inventory if TxDOT needs bicycle suitability scores within the next one or two years (before complete conversion of Roadway Inventory to TRM data base).

Table 3-1. Availability and Source of Potential Data for Bicycle Suitability Criteria (from Reference 25)

Roadway Data Item	Availability and Source of Data
Traffic volumes	Roadway Inventory
Heavy vehicle traffic	Roadway Inventory
Number of travel lanes	Roadway Inventory
Width of travel lanes	Roadway Inventory
Width of shoulders	Districts
Speed limit	Districts, TRM, Traffic Operations Division
Design speed	Wade Odell
Travel lane pavement type	Roadway Inventory
Travel lane pavement condition	HPMS, Districts
Shoulder pavement type	Roadway Inventory
Shoulder pavement condition	HPMS, Districts
Grade (%)	Straight lines, construction plans
Driveway or intersection frequency	TRM
Bicycle restrictions	TRM, Traffic Operations Division

Explanation of Data Sources:

Roadway Inventory = statewide data base of roadway conditions maintained by TPP
TRM = Texas Reference Marker = statewide data base maintained by TPP
HPMS = Highway Performance Monitoring System, statewide data base maintained by TPP
Traffic Operations Division = data maintained at state level
Districts = data not maintained at state level, but could be maintained at District level in computerized or paper formats
Straight lines, construction plans = data maintained at state and/or district level but is stored in paper plan format

3.4 Develop Logical, Practical Criteria

The development of statewide bicycle suitability criteria relied on information gathered from the literature and other state DOTs, and from available statewide data resources. The research team considered several factors in developing the bicycle suitability criteria:

- **Meet TxDOT needs:** The criteria must meet TxDOT's primary need for developing a Texas Bicycle Map. However, the suitability criteria also can be used in planning and programming bicycle facility improvements.

- **Keep it simple:** The criteria should be simple to use and understand for technical and non-technical audiences, yet address basic elements that affect bicycle suitability. Simple criteria will aid in implementation and use of the bicycle suitability criteria. Additional complexities and/or refinements based on agency user or bicyclist input can be added at a later date.

- **Incorporate basic elements of bicycle suitability:** The criteria should incorporate the roadway physical characteristics that have been associated with bicycle suitability, as found in the literature review and state DOT survey.

- **Utilize data available in state roadway inventories:** As much as practical, the suitability criteria should use data that is available on a statewide basis. Implementation could be significantly delayed if the suitability criteria require additional data collection for over 123,970 km. (77,000 mi.) of state roadways.

Based on these considerations, the researchers selected the following characteristics to represent bicycle suitability on state roadways (listed in order of significance):

- Shoulder width (or travel lane width where no shoulder is present);
- Annual daily traffic (ADT) volume per lane;
- Speed limit (as a surrogate for average vehicle operating speed); and,
- Shoulder pavement conditions (or travel lane pavement conditions where no shoulder is present).

These characteristics are considered primary factors for assessing bicycle suitability of state roadways that are predominantly rural in nature. Table 3-2 presents these suitability factors with designated ranges that can be applied in developing map displays and suitability scores.

In an informal electronic mail survey of bicyclists in Texas and other states, most bicyclists' responses included one or more of these characteristics as being most important in determining bicycle suitability of roadways (see Appendix B for informal survey responses). Most bicyclists also indicated that they like specific information about roadway conditions, like the shoulder width or traffic volume, and not a composite suitability score that they could not relate to or understand.

Table 3-2. Recommended Bicycle Suitability Criteria for State Roadways in Texas

Suitability Factor	Value Range	Factor Score	Map Display
Shoulder Width [If no shoulder, Curb/Travel Lane Width in brackets]	1.8 m (6 ft.) or greater [4.5 m (15 ft) or greater]	2	(thick line width)
	0.6 to 1.2 m (2 to 4 ft) [3.6 to 4.2 m (12 to 14 ft)]	0	(regular line width)
	No Shoulder [Less than 3.6 m (12 ft)]	-2	(narrow line width)
Traffic Volumes, ADT per Lane	Less than 1,000	2	(green line color)
	1,000 to 1,999	1	(blue line color)
	2,000 to 4,999	0	(magenta line color)
	5,000 to 9,999	-1	(orange line color)
	10,000 or greater	-2	(red line color)
Posted Speed Limit (or Average Vehicle Speed)	Less than 65 km/h (40 mph)	2	no display on map
	65 to 79 km/h (40 to 49 mph)	1	
	80 to 94 km/h (50 to 59 mph)	0	
	95 to 110 km/h (60 to 69 mph)	-1	
	115 kph (70 mph) or greater	-2	
Shoulder/Travel Lane Pavement Surface Quality (HPMS "pavecon" rating)	New or very good condition (pavecon rating of 4 to 5)	2	no display on map
	Good condition (pavecon rating of 3)	0	
	Poor to very poor (pavecon rating of 1 to 2)	-2	

Note: The suitability criteria in this table are oriented toward intermediate or experienced bicyclists who are familiar with the rules of the road and effective cycling.

. Other roadway characteristics identified as relevant to include on the Texas Bicycle Map are:

- Shoulder rumble strips: indicate with a graphical or text notation.
- Significant grades: indicate with carats (">" represents 5% to 7%; ">>" represents 8% to 10%; and ">>>" represents 11% or greater).
- Bicycle restrictions or prohibitions: indicate with a sign symbol showing no bikes.

Procedures should be developed for regular updates of the data required for bicycle suitability. Eventually, the proposed Texas bicycle map may only need to be updated every three to five years. However, TxDOT should consider updating the suitability data every year for internal transportation planning purposes.

The value ranges in Table 3-2 were selected such that each suitability factor has three (or five) possible ranges. The middle range for each suitability factor was set such that it corresponded to minimum desirable bicycling conditions, as indicated by information contained in Chapter 2 and current federal guidance in designating bicycle routes (26,27). The low suitability score range was set such that it corresponds to desirable bicycling conditions, whereas the high suitability score range was set to correspond to less than desirable bicycling conditions. The suitability factor ranges were selected based upon available information from several other studies and reports. The selection of these ranges should ideally be based upon bicyclists' input and their perception of roadway characteristics; however, this was beyond the scope of this study. Calibration of these value ranges according to bicyclists' input and perception could be considered as a refinement at a later date.

A single numerical suitability score (bicycle suitability score) can be obtained by summing the score for each factor (Equation 3-2). With this equation, it is assumed that each suitability factor is weighted equally (i.e., no factor is more important than the other in determining overall roadway suitability). Equal weighting of each factor was selected for simplicity. Agency user or bicyclist input could lead to later refinements, such as differential weighting by factor. Interpretations of bicycle suitability score values are contained in Table 3-3.

$$\textit{Bicycle Suitability Score},\ S_{Bicycle} = S_{Width} + S_{Traffic} + S_{Speed} + S_{Pavement} \qquad \textbf{(3-2)}$$

Where $S_{Bicycle}$ = bicycle suitability score;
S_{Width} = factor score for shoulder or travel lane width (Table 3-2);
$S_{Traffic}$ = factor score for traffic volume (Table 3-2);
S_{Speed} = factor score for speed limit (Table 3-2); and,
$S_{Pavement}$ = factor score for shoulder or travel lane pavement conditions (Table 3-2).

Table 3-3. Interpretation of Bicycle Suitability Scores

Bicycle Suitability Score Range	Interpretation
6 to 8	All four suitability factors have greater than minimum desirable values. The physical characteristics of the roadway are most likely desirable by intermediate to experienced bicyclists.
-1 to 5	At least three of the four suitability factors have minimum desirable or greater than minimum desirable values. One suitability factor may have less than desirable values. The physical characteristics of the roadway could be desirable by intermediate to experienced bicyclists.
-2 to -5	At least two of the four suitability factors have less than minimum desirable values. One or two of the suitability factors may have minium desirable values. The physical characteristics of the roadway may not be desirable by intermediate to experienced bicyclists.
-6 to -8	All four of the suitability factors have less than the minimum desirable values. The physical characteristics of the roadway are most likely undesirable by intermediate to experienced bicyclists.

3.5 Example Applications of the Bicycle Suitability Criteria and Score

As described earlier, bicycle suitability criteria have several applications in planning, designing, and maintaining bicycle facilities. This section provides several illustrative examples of how the bicycle suitability criteria can be applied. These examples include:

- **Bicycle map:** illustrates the designation of roadway physical characteristics for use in providing roadway information to bicyclists;

- **Evaluating suitability changes due to roadway improvements:** shows how bicycle suitability scores can be used to ensure that roadway improvements do not degrade bicycling conditions; and,

- **Ranking bicycle improvements:** describes how to rank or prioritize bicycle improvements.

3.5.1 Bicycle Map

The first example of a bicycle map is most applicable to current TxDOT needs. Assume there are two roadways: SH 7, a north-south route, and FM 3988, an east-west route. Table 3-4 contains information on the roadways' physical characteristics and shows displays of the four suitability factors.

From the table, one can see that SH 7 is a state roadway with moderate traffic (2,500 ADT per lane) with wide shoulders (2.4 m, or 8 ft.). The speed limit is 90 km/h (55 mph) and pavement conditions are excellent. The map displays these characteristics by showing a thick magenta line (wide shoulders, moderate traffic). FM 3988, however, is a well-traveled state roadway (7,200 ADT per lane) with no shoulders and 3.6-m (11-ft.) travel lanes. The speed limit is 90 km/h (55 mph) and pavement conditions are poor. The map displays FM 3988 using a narrow orange line (narrow lane/shoulder width and moderately high traffic).

3.5.2 Evaluating Suitability Changes Due to Roadway Improvements

The second example illustrates how bicycle suitability can be affected by roadway improvements. For example, assume that FM 3988 is being improved by redesigning the horizontal and vertical curvature and adding an additional lane in each direction. In the redesign of the roadway, engineers determine that the speed limit can be safely raised to 115 km/h (70 mph). The reconstruction includes new asphalt pavement, including 1.2-m (4-ft.) shoulders. Planners expect the ADT of FM 3988 to increase 10 percent within one year of the reconstruction.

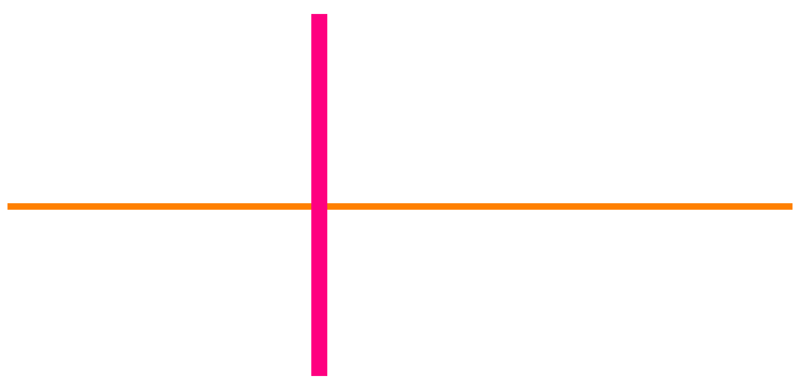
The table indicates that the roadway improvements increase the bicycle suitability score from a value of -5 to a value of 0. This roadway improvement can be expected to produce a more desirable roadway environment than was the case with existing conditions. The increase in suitability is primarily due to the provision of space for bicyclists (1.2-m (4-ft.) wide shoulder) and new pavement.

Some state DOTs have adopted policies that discourage roadway construction or reconstruction that lowers existing bicycle suitability scores. Examples include widening roadways without providing adequate space for bicyclists or other improvements that increase vehicle speeds without mitigating the effects on bicyclists. Such policies are an attempt to maintain or improve the quality of state roadway conditions for bicyclists.

Table 3-4. Example 1: Using Suitability Criteria for Creating Bicycle Maps

Physical Characteristic	Value	Map Legend
SH 7: North-South		
Shoulder Width	2.4 m (8 ft.)	(thick line width)
Traffic Volume per Lane (ADT per lane)	2,500	(magenta line color)
Speed Limit	90 km/h (55 mph)	n.a. for map
Pavement Conditions	Very good (pavecon=4)	n.a. for map
Map Representation		(thick magenta line)
FM 3988: East-West		
Lane Width (no shoulder)	3.6 m (11 ft.)	(narrow line width)
Traffic Volume (ADT)	7,200	(orange line color)
Speed Limit	90 km/h (55 mph)	n.a. for map
Pavement Conditions	Poor (pavecon=2)	n.a. for map
Map Representation		(narrow orange line)

Map Display **SH 7**



FM 3988

Table 3-5. Example 2: Evaluating Suitability Changes Due to Roadway Improvements

Suitability Factor	Before Reconstruction		After Reconstruction	
	Factor Value	Factor Score	Factor Value	Factor Score
Shoulder/Lane Width	no shoulder, 3.6-m (11-ft.) lanes	-2	1.2-m (4-ft.) shoulders	0
Traffic Volume per Lane	7,200	-1	3,960	0
Speed Limit	90 km/h (55 mph)	0	115 km/h (70 mph)	-2
Pavement Conditions	Poor (pavecon=2)	-2	New (pavecon=5)	2
Bicycle Suitability Score		**-5**		**0**

3.5.3 Ranking Bicycle Improvements

The last example provided here is of ranking bicycle improvements for programming or funding purposes. In this ranking example, the bicycle suitability scores are normalized by the project costs. Two ranking methods are shown here:

Method 1. Ranking by change in bicycle suitability score; and,
Method 2. Ranking by existing bicycle suitability score.

Table 3-6 shows the bicycle suitability scores before and after planned improvements. The bottom cells of the table show how the two different ranking methods would arrange the proposed improvements. The first method, ranking by change in bicycle suitability score, ranks the improvements by the increase in suitability per dollar spent. This method may be preferred when most roadways meet minimum desirable characteristics and few roadways have extremely low suitability scores. The second method, ranking by existing bicycle suitability score, concentrates improvements on facilities that are most in need. The second method may be preferred when several roadways have low suitability scores, and it is desirable to provide a minimum suitability score on all roadways.

Table 3-6. Example 3: Ranking Bicycle Improvements

Bicycle Improvement Roadway	Project Cost ($)	Suitability Score			Suitability Change per Million $
		Existing	After Improvement	Change	
FM 1131	300,000	-2	2	4	13.3
FM 1723	500,000	0	3	3	6.0
FM 2500	250,000	-1	2	3	12.0
FM 2901	600,000	-4	0	4	6.7
FM 3988	700,000	-5	0	5	7.1

Prioritization of Projects Using Method 1 (Suitability Change per Million $)

1. FM 1131 (13.3 per million $ spent)
2. FM 2500 (12.0 per million $ spent)
3. FM 3988 (7.1 per million $ spent)
4. FM 2901 (6.7 per million $ spent)
5. FM 1723 (6.0 per million $ spent)

Prioritization of Improvements Using Method 2 (Lowest Existing Suitability Score)

1. FM 3988 (-5 suitability score)
2. FM 2901 (-4 suitability score)
3. FM 1131 (-2 suitability score)
4. FM 2500 (-1 suitability score)
5. FM 1723 (0 suitability score)

4. RECOMMENDATIONS AND IMPLEMENTATION

This chapter contains the recommendations for this study and are based upon the literature and state-of-the-practice review and an assessment of TxDOT's bicycle planning and evaluation needs. The research team recommends that TxDOT:

- **Adopt the bicycle suitability criteria** presented in Table 3-2 as standard policy for evaluating the "bicycle-friendliness" of state roadways in Texas;

- **Integrate the bicycle suitability criteria** into TxDOT's programming, planning, design, and maintenance processes; and,

- **Obtain bicyclist input** in providing future refinements to the suitability criteria and in understanding bicyclists' roadway information needs.

4.1 Adopt Bicycle Suitability Criteria

The research team recommends the formal adoption of the bicycle suitability criteria in Table 3-2 as the standard policy for evaluating the "bicycle-friendliness" of state roadways in Texas. The recommended bicycle suitability criteria is based upon four roadway characteristics:

- Shoulder or travel lane width;
- Traffic volume per lane (ADT per lane);
- Vehicle speed; and,
- Pavement condition or surface quality.

These roadway characteristics are included in nearly all bicycle suitability criteria used by other state DOTs, cities, or counties. These characteristics also are available in TxDOT statewide or district data bases.

The suitability criteria in Chapter 3 also provided specific details for displaying suitability information on a map. An informal survey of bicyclists in Texas and several other states found that most bicyclists want suitability information in the form of actual characteristics, which would entail displaying legends for shoulder width, traffic volume, etc. Because of information overload, it may be necessary to display only two or three of the suitability characteristics on the Texas Bicycle Map. In this case, shoulder widths and traffic volumes are deemed the most important characteristics to include. Bicyclists' input should be obtained in developing the Texas Bicycle Map, and ease of use and graphical considerations should help guide decisions about map features.

4.2 Integrate Bicycle Suitability Criteria into TxDOT Processes

The research team recommends that TxDOT integrate the bicycle suitability criteria into programming, planning, design, and maintenance processes. TxDOT district personnel (i.e., district bicycle coordinators) should be provided with training and technical assistance in using the bicycle suitability criteria to address bicycle issues. Although the primary purpose for developing the bicycle suitability criteria in this study was for a Texas Bicycle Map, the criteria and bicycle suitability score can be used for number of different applications.

Chapter 3 provides three examples that illustrate the application of bicycle suitability for different processes: a Texas Bicycle Map, evaluating bicycle suitability changes due to roadway improvements, and ranking or prioritizing bicycle improvements. The bicycle suitability score presented in Chapter 3 is best suited to quantitative analyses in planning, design, and evaluation of roadways (last two examples in Chapter 3). A bicycle suitability map and scores can be used to identify gaps or deficiencies in a regional (intra city) or intercity bicycle network.

TxDOT should also consider incorporating any missing data items used to determine bicycle suitability into the statewide roadway inventory or TRM data bases. There are several data items critical to evaluating bicycle suitability that TxDOT currently does not maintain in statewide data bases (e.g., shoulder or curb lane width, shoulder pavement conditions). The regular maintenance of these data items in a statewide data base facilitates regular updates of bicycle maps and scores.

4.3 Obtain Cyclist Input

The research team recommends that TxDOT obtain bicyclists' input in providing future refinements to the suitability criteria and in understanding bicyclists' roadway information needs. Bicyclists' input could be gathered on several different areas:

- Determine if the **suitability criteria matches with the perception of most bicyclists**, both in the characteristics used to determine suitability and the different levels or ranges within each suitability criterion. For example, five different levels of traffic volume were chosen for the recommended criteria, but cyclists may only perceive two to three levels (e.g., low, moderate, high). Also, researchers assumed that wide curb lanes to be equivalent to comparable shoulder widths, but bicyclists may perceive the need for more space in wide curb lanes.

- Determine the **information needs of bicyclists for a Texas Bicycle Map**. An informal survey of bicyclists (Appendix B) indicated that most bicyclists would like specific information about shoulder widths, traffic volumes, etc. Several bicyclists noted that a composite bicycle suitability number, like the bicycle suitability score presented in Chapter 3, may be difficult to relate to or understand. Bicyclists sent many good suggestions for a Texas Bicycle Map, and many more good ideas could be obtained through a pro-active public involvement process.

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APPENDIX A

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 (km/h)**	**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 (km/h);
- 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

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

where: RCI = Roadway Condition Index;
ADT = average daily traffic (vehicles);
L = number of traffic lanes;
S = speed limit (km/h);
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 km/h (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 12.3 m or 40 ft.)	1 2 3
Roadway width	1 (2 lanes of less than 3.6 m or 12 ft.) 2 (2 lanes greater than 3.6 m or 12 ft.) 3 (4 lanes of less than 3.6 m or 12 ft.) 4 (4 lanes greater than 3.6 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 3.6 m (12 ft.) Outside Lane 3.6 to 4.2 m (12 to 14 ft.) Outside Lane greater than 4.2 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 km/h (30 mph) 40 to 48 km/h (25 to 30 mph) 24 to 32 km/h (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

APPENDIX B

RESPONSES FROM INFORMAL ELECTRONIC MAIL SURVEY

Bicyclist Input on Texas Bicycle Map

Researchers sent an electronic mail (Figure B-1) to a "Texas cycling" list that contains about 100 bicyclists in Texas. Bicyclists on this list forwarded the electronic mail to several other lists that encompassed bicyclists from several other states. A number of good suggestions and constructive input were received from the bicyclists' responses. The responses are included in this appendix and can be used in developing the Texas Bicycle Map.

To: <tx-cycling@snaefell.tamu.edu>
Cc: <bvc@snaefell.tamu.edu>, <bvc-chat@snaefell.tamu.edu>
From: "Shawn Turner" <shawn@ttiadmin.tamu.edu>
Subject: TX-CYCLING: Texas Bicycle Map
Date: Thursday, May 8, 1997 at 3:16:43 pm CDT

Texas A&M is working with the Texas Department of Transportation in developing criteria for a Texas Bicycle Map that will be of use to cyclists touring in the rural parts of the state (outside of urban areas). The map is being designed for cyclists with some base level of riding experience, therefore not geared toward inexperienced riders or children. The map (and underlying roadway rating criteria) may also be used as the basis for making road improvements, such as adding shoulders or repaving.

I would like to get input from cyclists from around the State on the kind of rating information that would be provided on a statewide map. There are basically two lines of thought:

1. Information on shoulder widths, traffic volumes and vehicle speeds (and potentially pavement conditions) are provided on the map, and cyclists choose "suitable" routes based upon their previous experience and willingness to ride in certain conditions.

2. A single rating or score that is calculated from shoulder widths, traffic, speeds, and pavement conditions. This would be a single numerical rating that has maybe 3-5 levels on the map, with roadways being different colors for higher or lower ratings or scores.

Any thoughts or comments would be greatly appreciated. Please feel free to forward this e-mail to other cyclists not on this list.

Thanks
Shawn Turner
Texas Transportation Institute
Texas A&M University
shawn-turner@tamu.edu

This message sent to the TX-CYCLING mailing list. See
http://team-internet.tamu.edu/cycling/tx-cycling.html
to get on or off the list.

Figure B-1. Electronic Mail Requesting Bicyclist Input

To: "Shawn Turner" <shawn@ttiadmin.tamu.edu>
From: mikee@spindle.net (mikee@spindle.net)
Subject: Re: TX-CYCLING: Texas Bicycle Map
Date: Thursday, May 8, 1997 at 4:18:09 pm CDT

What about a combination of both ideas? On a map the second method would be best for 'at-a-glance' traveling and the first method would be best for planning an overall route. How difficult would it be to put both methods where they are easily accessible?

Mike Eggleston

To: "Shawn Turner" <shawn@ttiadmin.tamu.edu>
From: timmhc@mail.utexas.edu (Hans Christoph Timm)
Subject: Re: TX-CYCLING: Texas Bicycle Map
Date: Thursday, May 8, 1997 at 10:43:24 am CDT

Great idea, Shawn. Since I have spent the major part of my life in Germany, a country for which a plethora of cycling-specific maps is available, I have some thought I'd like to pass on:

Since you will probably have to go with some sort of color coding-system, you'll have to develop your own subjective rating system. IMHO shoulder width/existence is unimportant on small roads; thus traffic volume is the primary factor. However, on roads with a good shoulder, even lots of traffic can be not as bad as it may seem. I would suggest:
- roads with very low traffic volume
- roads with bearable traffic volume
- roads with rideable shoulder
- unrideable roads (lots of fast traffic and no or unrideable shoulder)

Poor road condition should be a different category, maybe indicated by a dotted line. Choosing roads according to their condition has more to do with the type of riding and your type of bike.

Chris

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----------------------------------------------------------------------
HANS CHRISTOPH TIMM        e-mail:          timmhc@mail.utexas.edu
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  _~@      _~@ _~@         Snail Mail:      Pearl Street Co-Op
 _ \<,_   _ \<,_\<,_                        2000 Pearl St., Room 223
(*)x/(\) (*)x===x/(\)                       Austin, TX 78705 - USA
                           Phone:           (+1) 512-472-5020
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To: <shawn@ttiadmin.tamu.edu>
From: pnevill_at_dsc-os8@ccmail.dsccc.com
Subject: Re: TX-CYCLING: Texas Bicycle Map
Date: Thursday, May 8, 1997 at 5:05:22 pm CDT

Comment on your rating systems. I prefer the second method listed because it is easier to understand "at a glance":

I strongly suggest that the criteria be included or weighted based on SAFETY: i.e., shoulder width is more important that pavement conditions...without a decent shoulder, traffic and speeds have more impact, etc....

A color based on rating level is excellent, but I would still want to know the relative level of the road on regular highway basis, too: like on the existing maps with divided highways as thicker lines, FM roads a single line, unpaved roads as faint double lines. The reason for this is that the map may be color coordinated based on bicycling rating, but might not be a "major" road for facilities, which is also important.

Another point: some "major" highways can be safer for bicycling than minor roads. For example, a divided state highway with shoulders is much better than a two-lane blacktop with no shoulders. Bicyclists have more room and can be seen better by cars moving at 70 MPH.

Good luck with your project.

Paul Nevill
Richardson, Texas

To: <shawn@ttiadmin.tamu.edu>
From: jan@twri.tamu.edu (Jan Gerston)
Subject: Re: BVC-CHAT: Texas Bicycle Map
Date: Thursday, May 8, 1997 at 6:01:17 pm CDT

Shawn,

The Texas Cycling map is a _terrific_ idea.

Texas was my favorite "five" states in a cross-country bike tour a few years ago :-) I have a lot of experience bicycle-touring in Arizona, New Mexico, and Florida (as well as TX). So much for credentials.

Are you familiar with the Adventure Cycling (formerly Bikecenntennial) maps? Their narratives on bicycle conditions may give you some ideas. League of American Cyclists also has some bicycle mapping information available. I can hook you up with either organization if you like.

My overwhelming preference is option #1 below, although it seems like more work.

But ideal would be an amalgam of the two--the single rating for the majority of routes, with notations on specific "problem" conditions.

For example, one Adventure Cycling map describes two difficult, quite scary bridges on an otherwise pleasant, wide-shouldered road. (The map even suggested taking a breather between two separate narrow bridges over the Appalachicola River to allow traffic to pass.) Another map warned about the 1920s-era narrow 9-mile (?) WPA bridge over the Atchafalaya River (with bayou on either side and absolutely no shoulder).

This system seems too generic. I much prefer a wide shoulder/heavily traveled road to a narrow/lightly traveled road, but most cyclists don't share this preference. I need more information to make my decision.

Just as a point of information--US Highways (like 290, 90, and even historic Route 66) afforded the best cycling overall across the country.

To: <shawn@ttiadmin.tamu.edu>
From: gdb.mail@juno.com (David S Phillips)
Subject: Re: TX-CYCLING: Texas Bicycle Map
Date: Thursday, May 8, 1997 at 6:13:22 pm CDT

A single rating would be virtually useless. Specific info on volume, shoulder width etc. is clearly better. Also consider info on grades (hilliness) and rest stop opportunities. ABSOLUTE MUST: indicate bike-banned roads, such as in Collin Co., and elsewhere, if any.

David Phillips, Activities Director, Greater Dallas Bicyclists
L.A.B. Effective Cycling Instructor

To: "'Shawn Turner'" <shawn@ttiadmin.tamu.edu>
From: "Wilson, EO Earl (7253)" <WilsonEO@gvl.esys.com>
Subject: RE: TX-CYCLING: Texas Bicycle Map
Date: Friday, May 9, 1997 at 9:01:32 am CDT

Shawn,

I applaud your efforts to create a Texas Bicycle Map! I hope things go well because I will definitely obtain one or two of the maps when they become available.

I would vote for option 1 in your message. An overall rating (option 2) would not, in my opinion, be very useful. It would hide the information the cyclist really wants to see. Option 1 does not hide any information.

Additionally, I definitely believe that pavement conditions and/or pavement type (road surface) should be included on the map. Why? Because many of the roads I ride on where I live are great roads to ride on except for one thing. The road surface is what I call tar and rock. Whenever the road is resurfaced, the Highway Department lays down a layer of sticky stuff (tar?) and then places a layer of rock over it. This makes for a very rough ride.

If you would like any more opinions, I would be happy to give them. For your information, I live in Greenville, in Hunt County, which is 45 miles northeast of Dallas. I ride mostly from March thru October with occasional rides during November thru February (I dislike the cold). I ride 3000+ miles a year.

Earl Wilson
wilsoneo@gvl.esys.com

To: <shawn-turner@tamu.edu>, <mwooldridge@TTIADMIN.tamu.edu>
From: kob@aloft.micro.lucent.com (Ken_J_Obrien)
Subject: re:Developing Texas Bicycle Map
Date: Friday, May 9, 1997 at 10:29:42 am CDT

Except for roadways with VERY, VERY, few, very similarly designed intersections, the most proper place for bicyclists is in the roadway lane, sharing the lane with other roadway traffic. Width of rightmost roadway lane as a function of prevailing speed and traffic volume would be the most proper way for scaling roadways.

Officials should generally not be encouraging shoulder riding for all the same reasons that bike lanes should not be placed... mainly it will confuse situations approaching intersections, and encourage poor behavior on the part of bicyclists and motor vehicle drivers approaching intersections.

Ken O'Brien

To: <mwooldridge@TTIADMIN.TAMU.EDU>
Cc: <shawn@TTIADMIN.TAMU.EDU>
From: Jack Goertz <tandems@bham.mindspring.com>
Subject: Re: [T@H] re:Development of a Texas Bicycle Map
Date: Friday, May 9, 1997 at 7:45:00 am CDT

Shawn, good luck on your project! As a life member of the League of American Bicyclists (formerly League of American Wheelmen), I hope that you are as successful as the League was originally with their "Good Roads" program back in the 1890's. Ever wonder why a road map is folded to the size it is? That's what fit into a bicycle map pocket in the 1890's.

Michigan and Wisconsin have similar bicycle suitability maps as to what you propose. I suggest you contact their DOT's and get their thoughts on how well it has worked, and what problems they've had. Wisconsin drove every paved road in the state with a video camera out the front window, then sat in a screening room and reviewed the tapes for terrain, road condition, and road width (They may have had other criteria, too). I'm not sure how MI created their maps -- I do know they had much input from cyclists. Both states' maps have been in existence for more than 15 years now. I don't know if they have been updated.

I consider myself a fairly experienced touring cyclist and have toured with each of these maps in both states, when the maps were fairly new. These were the "gotcha's" I found: 1) terrain is very difficult to rate consistently. 2) road surface in the north can vary tremendously one year to the next on the same stretch of road, depending on the freeze/thaw cycle and how much money is available that year for road reconstruction. 3) traffic count can change the suitability of the road quickly. Is a new factory being built?

Things to consider for your project:
1) Funding for maintenance and updating over the year.
2) Procedures/Organizations to continue the maintenance and updating (Projects tend to finish with no provisions for the continual updates -- Bicycles don't rate without a champion on the committees).
3) TX laws pertaining to bicycling/driving on the shoulder. Shoulders are attractive, but in many states they are not considered part of the roadway and are illegal to drive on. Accidents or injuries to a driver while driving on the shoulder can negate the drivers rights that they would have had if they had been on the other side of the shoulder. For this reason, a wider outside lane is my preference to a shoulder. Since bicyclists have all the rights/responsibilities of a driver, these limitations apply to bicyclists except where specifically listed in the statutes that a bicyclists riding on the shoulder has all rights of a driver.

As a further note, John Forrester's book on traffic engineering gives some great comments on the necessary lane widths for perceived safety for different average speeds of traffic. I don't remember the title of the book, but it is on my reference shelf. Again, good luck with your project!

Jack Goertz
LAW National President, 1980-81

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To: <shawn-turner@tamu.edu>
From: robert_seaquist@mail.uwlax.edu (Bob Seaquist)
Subject: Bike Map
Date: Friday, May 9, 1997 at 2:42:46 pm CDT

Shawn,

Take a look at the Wisconsin Bicycle Map, if you haven't already, then ratchet back some. It is so exhaustive in its information that it is very difficult to read for those of us needing reading specs.

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608 785-8497
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To: <shawn-turner@tamu.edu>, <mwooldridge@TTIADMIN.tamu.edu>
From: Alan Bloom <alanb@manta.sr.hp.com>
Subject: Bicycle maps
Date: Friday, May 9, 1997 at 7:43:20 am CDT

My vote would be for option 1. In my travels, I have found a single rating system to be unhelpful. That is especially true when there is no information given on just how the ratings are derived. Even when that information is provided, I find that often my criteria for a good bicycle route are different from the map maker's. It seems like many of these maps are made by folks with little cycling experience. Traffic engineers in particular often seem to have little understanding of cycling.

My experience: I'm 47 years old and have been cycling off and on for 25 years, almost 100% on roads. I've used bicycles for commuting (for awhile as my only transportation) as well as recreation. I have done a number of long-distance bicycle tours, including a 4000-mile coast-to-coast tour last summer, using a route I planned in advance using maps from a number of sources. In my researches, I did get some cycling maps from various state governments. You might consider canvassing the other 49 states to get ideas.

Good luck!
Alan Bloom
alanb@sr.hp.com

To: <shawn@ttiadmin.tamu.edu>
From: bob.love@juno.com
Subject: Re: Development of a Texas Bicycle Map
Date: Friday, May 9, 1997 at 11:59:49 am CDT

IMHO, if you have multiple information about the roads, don't develop a single rating system, but use a hybrid rating system such as 1-A where 1 represents the physical conditions of the road, and A represents the traffic conditions. Both are important, but different.

Bob Lovellette
Santa Monica, California
lovebike@geocities.com

To: <shawn-turner@tamu.edu>
From: Dennis Bell <dbell@wrq.com>
Subject: Texas Bicycle Map
Date: Friday, May 9, 1997 at 4:52:54 pm CDT

Shawn-

Such a map should have indicators for hills. This is usually done with the carat approach:
\> = 5-9%
\>> = 10-13%
\>>> = 14% and up

This is the standard that Michelin uses for their "Yellow" road atlas of France, but you should probably adjust it based on the range of hill gradients you have in Texas. The carats should point up the hill. These indicators should only be marked for sustained grades, not for a short "blip" of a hill.

Another use of the carat is to indicate the top of a pass, or col, which is shown by a >.< with the elevation of the summit marked nearby. A dot without carats is used to mark any known elevation, often used to indicate the low point in a stretch of road.

I'm eager to hear how your map project progresses, and to see the final project. I think every state should produce a map for cyclists, but I have not seen many. Wyoming has one which displays traffic flows like what you describe, and it also shows profiles of all the major roads, but there are not very many roads in that state. Wisconsin has a wonderful set (of two) maps which cover the entire state, highlighting the optimal roads for cycling. The trouble there is that there are so many good biking roads that you almost don't need to be told which one to take. We should all have such problems.

Regards,
Dennis Bell

To: <bvc-chat@snaefell.tamu.edu>
From: Jeannine Kantz <jkantz@txcyber.com>
Subject: Re: BVC-CHAT: Texas Bicycle Map
Date: Friday, May 9, 1997 at 10:20:21 pm CDT

I vote for Number 2.

Jeannine Kantz
jkantz@txcyber.com

To: <shawn@ttiadmin.tamu.edu>
From: "Phillip A. Tarman" <ptarman@sosinc.net>
Subject: Re: Texas Bicycling Map
Date: Sunday, May 11, 1997 at 0:47:37 am CDT

Shawn,

After having driven through Texas on my way to San Antonio for a wedding a couple of weeks ago, I am convinced that I want to go back and spend time cycling in large parts of the state. So far, I have ridden several really nice loops out of Mt. Pleasant while visiting my in-laws there, but the stretches between Sweetwater and Junction looked as if they held a great deal of promise.

You might want to write to the Wyoming Tourist Bureau (I don't have the address, but it's in Cheyenne and that means it's pretty easy to get). They have done a bicycle map of Wyoming that has information like shoulder width and estimated traffic counts, plus a good bit of other information which helps to plan tours in Wyoming.

Utah has divided the state into five regions and each region has a map -- contact Bicycle Utah (sorry, but, again, I don't have the address -- I think it's in Park City). Their maps are not as rich in cycling-specific information as the Wyoming map, but are more attractive and very useful in tour planning.

Good luck -- if you get a map (or maps) put together for Texas, I'd be interesting in seeing (maybe even *purchasing*, if necessary) them.

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 ( * ) /   ' ( * )      ( * ) / --'----/  ' ( * )

  91 RB-T              94 Burley Duet
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Phil Tarman, Ft. Morgan, CO
"Riding in The Great American Desert"

To: <mwooldridge@TTIADMIN.TAMU.EDU>, <shawn-turner@tamu.edu>
From: Brian and Tera DeSousa <desousa@deltanet.com>
Subject: Re: Development of a Texas Bicycle Map
Date: Saturday, May 10, 1997 at 5:16:00 pm CDT

Have you ever seen the bicycle maps made by BikeMaps Massachusetts? I have one of the ones for Eastern Massachusetts (Cape Ann & North Shore/Cape Cod & the Islands). These maps follow Approach #2 outlined below - recommended roads in green, secondary recommended roads in red.

The address is:
BikeMaps Massachusetts
P.O. Box 1035
Cambridge, MA 02140

Brian DeSousa
desousa@deltanet.com

To: "'shawn-turner@tamu.edu'" <shawn-turner@tamu.edu>
From: Steve Peaslee <speaslee@pclink.com>
Subject: Bike maps
Date: Sunday, May 11, 1997 at 10:48:09 am CDT

check with MNDOT (Minnesota Dept. of Transportation) They put together a series of bike maps similar to what you described in "2. A single rating or score that is calculated from shoulder widths, traffic, speeds, and pavement conditions. This would be a single numerical rating that has maybe 3-5 levels on the map, with roadways being different colors for higher or lower ratings or scores. "

Initially the maps were large scale, then they scaled the map production down with fewer maps which cover larger areas. Roads were rated good, fair, poor, based on design and ADT. The last edition I have seen is from 1986. I think they may have discontinued the program.

To: <shawn-turner@tamu.edu>
From: "Don Willson" <dwillson@airmail.net>
Subject: Texas Bicycle map
Date: Sunday, May 11, 1997 at 5:47:46 pm CDT

As I was reading the e-mail I thought "I hope they include shoulder =
width". I would definitely go for the first choice, so I can decide if =
it fits my needs.

To: "shawn-turner" <shawn-turner@tamu.edu>
From: Chuck Tharp <tharpgc@raleigh.ibm.com>
Subject: Texas bicycle map
Date: Monday, May 12, 1997 at 2:57:41 am CDT

Shawn, I commend your efforts at developing a bicycle touring suitability map. My personal opinions (based on 18 years of touring experience):Don't make the map too complicated. A combined rating, based on your criteria, would probably be most useful, plus some sort of warning of particularly dangerous places (narrow bridges, etc).Given a combined rating, I think the criteria should be prioritized with traffic count highest, followed by speed, and lastly shoulders. Most truly experienced bicyclists will tell you that shoulders are not the best places to ride (gravel, glass, pavement surfaces, etc).Just my personal opinions... Good luck! Chuck Tharp

To: Shawn Turner@ECO@TTI
From: "Hansen, Charles" <chansen@jhancock.com>
Subject: Maps
Date: Fri, 9 May 1997 19:26:00 -0400

There's been some discussion of maps and I thought I'd share my favorite map 'trick' for touring. I usually get good quality, detailed maps (say Michelin 1:200,000) before I go because I like to do my actual route planning in advance. I then photocopy them, generally enlarging at the same time for more clarity, with one day's ride on each sheet. I highlight my route, sometimes using different colors for alternate routes that I want to evaluate in the field.

These are then used in my handlebar bag for basic navigation, although I take the original along - safely wrapped - to look over the next day's ride each night. This protects the expensive original from all the folds necessary to get the appropriate section to display in the handlebar bag. I also look at the original during the day if I can't get enough information from the copy - the colors do help in deciphering small details. If only I had access to a color photocopier! Bringing the originals adds a good few pounds to my kit, but I consider map browsing terrific entertainment as well as a tour necessity.

This can also be used for tour planning - highlight several alternate routes on the photocopies for evaluation without marking up your original. When I toured the Dordogne I marked the suggested itineraries from three different books and combined what I liked best from each into my final route - with my own modifications.

To: <bvc-chat@snaefell.tamu.edu>
From: Jonathan Coopersmith <j-coopersmith@tamu.edu>
Subject: Re: BVC-CHAT: Texas Bicycle Map
Date: Monday, May 12, 1997 at 2:43:05 pm CDT

Possibly combine the two with the numerical ratings for each of the indicators?>

To: "Shawn Turner" <shawn@ttiadmin.tamu.edu>
From: Edward Tasch <txinfo@eden.com>
Subject: State Bicycle Map info
Date: Wednesday, May 14, 1997 at 6:46:11 pm CDT

I received your email from the Texas Cycling listserver. I am writing to let you know that I have put together a website (URL listed below) that details some cycling routes within the Hill Country and West Texas regions. I thought I would bring this online resource to your attention on account that you are assisting in the development of rural state roadway information for cyclists. Let me know if I can answer any questions and please keep me informed as work progresses on the Texas Bicycle Map project. I look forward to seeing what your group puts together.

Best Regards,
Edward
==
Texas Hill Country Information Service voice 1.800.365.9370
Edward Tasch fax 1.512.477.3148
1710 Northwood Road edward@txinfo.com
Austin, Texas 78703 http://www.eden.com/~txinfo

From: Paul Smee <P.Smee@bristol.ac.uk>
Date: Tue, 27 May 1997 11:16:59 +0100 (BST)
Subject: Re: Developing Texas Bicycle Map

Someone locally has put out a 'cyclist's map' of the greater Bristol area. Basic idea is that the more suitable a road is for cycling, the wider it appears on the map. Motorways (sort of like Interstates) that cyclists aren't allowed on at all are thin black lines.

I suppose it *might* be useful for beginners, but I personally have real problems with it, since it generally means that the smaller the road is in real life, the larger it will be on the map. It's completely backwards. Tiny country lanes, great for cycling, look huge. Maybe I'm just too used to real maps, but...

- --
http://www.cse.bris.ac.uk/~ccpes/

From: Don Piven <djp@suba.com>
Date: Tue, 27 May 1997 07:02:09 -0500
Subject: Re: Developing Texas Bicycle Map

Quoth Paul Smee:
>Someone locally has put out a 'cyclist's map' of the greater Bristol
>area. Basic idea is that the more suitable a road is for cycling, the
>wider it appears on the map. Motorways (sort of like Interstates) that
>cyclists aren't allowed on at all are thin black lines.
>
>I suppose it *might* be useful for beginners, but I personally have
>real problems with it, since it generally means that the smaller the
>road is in real life, the larger it will be on the map. It's
>completely backwards. Tiny country lanes, great for cycling, look
>huge. Maybe I'm just too used to real maps, but...

That would also bother me to no end: it strikes me that the two purposes of a map are to 1) tell you how to get there, and 2) let you find out where you are. Interstates and the like might not be legal to ride on, but they still have lots of landmark value, which that map seems to be deliberately trying to reduce. For instance, I might not be *riding on* I-94 between Chicago and Milwaukee, but I sure do want to know whether I'm west or east of it.

Don Piven | If your car gets broken into, your hard drive crashes, you've
Chicago IL | lost your wallet, and what REALLY bugs you is that clicking
djp@suba.com | noise in your bottom bracket . . .
'94 RB-T | [humphrie@umiacs.umd.edu] . . . you might be a
cyclist.