

Guide for the Development of Bicycle Facilities

2012 • Fourth Edition



AMERICAN ASSOCIATION OF
STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
AASHTO
THE VOICE OF TRANSPORTATION



Documents
Document Sharing Hub

Guide for the Development of Bicycle Facilities

2012 • Fourth Edition



AMERICAN ASSOCIATION OF
STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
AASHTO
THE VOICE OF TRANSPORTATION

American Association of State Highway and Transportation Officials

444 North Capitol Street, NW, Suite 249

Washington, DC 20001

202-624-5800 phone 202-624-5806 fax

www.transportation.org

© 2012 by the American Association of State Highway and Transportation Officials. All rights reserved.
Duplication is a violation of applicable law.

Front cover photographs courtesy of Alaska DOT, Carole Reichardt (Iowa DOT), and the Alliance for Biking and Walking. Back cover photograph courtesy of Patricia Little.

Publication Code: GBF-4 • ISBN: 978-1-56051-527-2

Executive Committee 2011–2012

Officers

President: Kirk Steudle, P.E., MICHIGAN
Vice President: Michael P. Lewis, RHODE ISLAND
Secretary/Treasurer: Carlos Braceras, UTAH

Regional Representatives

REGION I
Beverley K. Swaim-Staley, MARYLAND
James P. Redeker, CONNECTICUT

REGION II
Robert St. Onge, SOUTH CAROLINA
Eugene Conti, NORTH CAROLINA

REGION III
Kevin Keith, MISSOURI
Mark Gottlieb, WISCONSIN

REGION IV
Francis G. Ziegler P.E., NORTH DAKOTA
John Cox, WYOMING

Non-Voting Members

Executive Director: John Horsley, AASHTO
Immediate Past President: Susan Martinovich, P.E., NEVADA

Technical Committee on Geometric Design

Officers

Jeff Jones, Tennessee, Chair
James Rosenow, Minnesota, Vice Chair
Brooke Struve, FHWA, Secretary

Members

Kent Belleque	OREGON
James O. Brewer	KANSAS
Rick Bruce	OHIO
Marshall Elizer	AMERICAN PUBLIC WORKS ASSOCIATION
Mark A. Leiferman	SOUTH DAKOTA
Donald A. Lyford	NEW HAMPSHIRE
Deanna Maifield	IOWA
Eric Marabello	MARYLAND
Reza Maleki	PORT AUTHORITY OF NEW YORK AND NEW JERSEY
Joe Ruffer	NATIONAL ASSOCIATION OF COUNTY ENGINEERS
Brent Story	GEORGIA
Bart Thrasher	VIRGINIA
Max Valerio	NEW MEXICO
Ted Watson	NEBRASKA
Stanley Wood	MASSACHUSETTS
Reza Amini	OKLAHOMA
Ray Derr	TRANSPORTATION RESEARCH BOARD
Robert Wunderlich	NATIONAL LEAGUE OF CITIES

Highway Subcommittee On Design

Barry Schoch, Pennsylvania, Chair
Richard Land, California, Vice Chair
David A. Nichol, FHWA, Secretary
Keith M. Platte, AASHTO, Staff Liaison

ALABAMA	William Adams, Rex Bush, Carey Kelley
ALASKA	Mark Neidhold, Robert A. Campbell
ARIZONA	VACANT
ARKANSAS	Michael Fugett, Phillip L. McConnell
CALIFORNIA	Terry L. Abbott, Kevin Hanley
COLORADO	Jeffrey Wassenaar
CONNECTICUT	James H. Norman, Timothy M. Wilson, Will Britnell
DELAWARE	Thad McIlvain, Mark Tudor
DISTRICT OF COLUMBIA	Muhammad Khalid, Dawit Muluneh
FLORIDA	David O'Hagan, Frank Sullivan
GEORGIA	Russell McMurry, Brent Story, G. Andy Casey
HAWAII	Julius Fronda
IDAHO	Loren D. Thomas, Monica Crider
ILLINOIS	Scott E. Stitt
INDIANA	Jeff Clanton, Merrill E. Dougherty, John E. Wright
IOWA	Michael J. Kennerly, David L. Little, Deanna Maifield
KANSAS	James O. Brewer, Rod Lacy
KENTUCKY	Keith Caudill, Bradley S. Eldridge, Jeff D. Jasper
LOUISIANA	Nicholas Kalivoda, III, Chad Winchester
MAINE	Bradford P. Foley, Heath Cowan
MARYLAND	Kirk G. McClelland
MASSACHUSETTS	Stanley Wood, Jr.
MICHIGAN	Bradley C. Wieferich
MINNESOTA	John M. Chiglo, Mike Ginnaty
MISSISSIPPI	John M. Reese, Amy Mood, Richard Pittman
MISSOURI	David B. Nichols, Kathryn P. Harvey
MONTANA	Paul R. Ferry, Lesly Tribelhorn

NEBRASKA	James J. Knott, Ted Watson
NEVADA	Paul Frost, Kristena Shigenaga
NEW HAMPSHIRE	William Oldenburg
NEW JERSEY	Richard Jaffe, Richard Dunne
NEW MEXICO	Gabriela Contreras-Apodaca
NEW YORK	Daniel D'Angelo, Richard Lee
NORTH CAROLINA	Deborah M. Barbour, Jay A. Bennett, Art McMillan
NORTH DAKOTA	Roger Weigel
OHIO	Dirk Gross, James Young
OKLAHOMA	Tim Tegeler
OREGON	David Joe Polly, Steven R. Lindland
PENNSYLVANIA	Wayne Willey
PUERTO RICO	Luis Santos, José E. Santana-Pimentel
RHODE ISLAND	Robert Smith
SOUTH CAROLINA	Rob Bedenbaugh, Mark Lester, Mitchell D. Metts
SOUTH DAKOTA	Mark A. Leiferman
TENNESSEE	Jeff C. Jones, Carolyn Stonecipher
TEXAS	Mark A. Marek
UTAH	Lisa Wilson, Fred Doerhing, George Lukes
VERMONT	Kevin Marshia, Jesse Devlin
VIRGINIA	Robert H. Cary, Mohammad Mirshahi, Barton A. Thrasher
WASHINGTON	Pasco Bakotich, Terry L. Berends, Nancy Boyd
WEST VIRGINIA	Jason C. Foster, Dee Begley
WISCONSIN	Jerry H. Zogg
WYOMING	Tony Laird, Sandra Pecenka, Andrea Allen

ASSOCIATE MEMBER—Bridge, Port, and Toll

NJ TUR NPIKE AUTHORITY	J. Lawrence Williams
PORT AUTHORITY OF NY AND NJ	Scott D. Murrell

ASSOCIATE MEMBER—Federal

USDA FOREST SERVICE	Ellen G. LaFayette
---------------------	--------------------

ASSOCIATE MEMBER—International

ALBERTA	Moh Lali
BRITISH COLUMBIA	Richard Voyer
KOREA	Chan-Su “Chris” Reem
ONTARIO	Joe Bucik
SASKATCHEWAN	Sukhy Kent

Table of Contents

Chapter 1: Introduction.....	1-1
1.1 Design Imperative	1-1
1.2 Purpose.....	1-1
1.3 Scope.....	1-2
1.4 Definitions	1-2
 Chapter 2: Bicycle Planning	 2-1
2.1 Background	2-1
2.2 Why Planning for Bicycling is Important	2-1
2.3 Factors Influencing Bicycling Behavior	2-2
2.3.1 Trip Purpose	2-2
2.3.2 Level of User Skill and Comfort	2-4
2.4 Types of Transportation Planning Processes	2-6
2.4.1 Comprehensive Transportation Plans.....	2-6
2.4.2 Bicycle Master Plans	2-6
2.4.3 Transportation Impact/Traffic Studies.....	2-11
2.4.4 Small-Area and Corridor-Level Planning	2-12
2.4.5 Project Level Planning—Approvals.....	2-12
2.5 Planning Bicycle Transportation Networks	2-12
2.5.1 Deciding Where Improvements Are Needed.....	2-12
2.5.2 Practical (Opportunistic) Approach to Network Planning	2-14
2.5.3 Wayfinding for Bicycles	2-20
2.6 Technical Analysis Tools That Support Bicycle Planning	2-21
2.6.1 Data Collection and Flow Analysis	2-21
2.6.2 Quality of Service (or Level of Service) Tools	2-22
2.6.3 Safety Analysis	2-23
2.6.4 GIS-Based Data Collection/Network Planning.....	2-24
2.6.5 Bicycle Travel Demand Analysis.....	2-25
2.6.6 Cost-Benefit Analysis.....	2-26
2.6.7 Key Role of Public Input in the Process	2-26
2.7 Integrating Bicycle Facilities with Transit.....	2-27

Chapter 3: Bicycle Operation and Safety	3-1
3.1 Introduction	3-1
3.2 Design Vehicle	3-1
3.3 Traffic Principles for Bicyclists	3-4
3.4 Causes of Bicycle Crashes	3-6
3.4.1 Bicyclist Crash Studies	3-8
3.4.2 Overall Findings	3-8
3.4.3 Contributing Causes of Bicyclist-Motor Vehicle Crashes and Recommended Countermeasures.....	3-9
 Chapter 4: Design of On-Road Facilities.....	 4-1
4.1 Introduction	4-1
4.2 Elements of Design.....	4-1
4.3 Shared Lanes.....	4-2
4.3.1 Shared Lanes on Major Roadways (Wide Curb/Outside Lanes)	4-3
4.3.2 Signs for Shared Roadways	4-3
4.4 Marked Shared Lanes	4-4
4.5 Paved Shoulders.....	4-7
4.5.1 Shoulder Bypass Lanes.....	4-8
4.5.2 Rumble Strips.....	4-9
4.6 Bicycle Lanes	4-11
4.6.1 General Considerations	4-11
4.6.2 Bicycle Lanes on Two-Way Streets.....	4-12
4.6.3 Bicycle Lanes on One-Way Streets	4-12
4.6.4 Bicycle Lane Widths	4-14
4.6.5 Bicycle Lanes and On-Street Parking	4-16
4.7 Bicycle Lane Markings and Signs	4-17
4.7.1 Bicycle Lane Lines	4-17
4.7.2 Bicycle Lane Markings.....	4-18
4.7.3 Bicycle Lane Signs	4-21
4.8 Bicycle Lanes at Intersections.....	4-22
4.8.1 Right Turn Considerations	4-23
4.8.2 Left Turn Considerations	4-26
4.9 Retrofitting Bicycle Facilities on Existing Streets and Highways	4-28
4.9.1 Retrofitting Bicycle Facilities By Widening the Roadway	4-28
4.9.2 Retrofitting Bicycle Facilities Without Roadway Widening.....	4-29
4.10 Bicycle Boulevards	4-33
4.11 Bicycle Guide Signs/Wayfinding.....	4-34
4.12 Other Roadway Design Considerations	4-38

4.12.1	Railroad Grade Crossings	4-38
4.12.2	Obstruction Markings	4-40
4.12.3	Bridges, Viaducts, and Tunnels	4-41
4.12.4	Traffic Signals	4-43
4.12.5	Detection for Bicycles at Traffic Signals.....	4-47
4.12.6	Bicycles and Traffic Calming	4-51
4.12.7	Bicycles and Traffic Management	4-53
4.12.8	Drainage Grates and Utility Covers	4-55
4.12.9	Bicycle Travel on Freeways.....	4-56
4.12.10	Bicycle Travel Through Interchange Areas.....	4-57
4.12.11	Bicycle Travel at Roundabouts	4-63

Chapter 5: Design of Shared Use Paths 5-1

5.1	Introduction	5-1
5.1.1	Accessibility Requirements for Shared Use Paths.....	5-2
5.2	Elements of Design.....	5-2
5.2.1	Width and Clearance.....	5-3
5.2.2	Shared Use Paths Adjacent to Roadways (Sidepaths)	5-8
5.2.3	Shared Use with Mopeds, Motorcycles, Snowmobiles, and Horses	5-11
5.2.4	Design Speed.....	5-12
5.2.5	Horizontal Alignment.....	5-13
5.2.6	Cross Slope.....	5-15
5.2.7	Grade	5-16
5.2.8	Stopping Sight Distance	5-17
5.2.9	Surface Structure	5-25
5.2.10	Bridges and Underpasses.....	5-26
5.2.11	Drainage.....	5-28
5.2.12	Lighting.....	5-29
5.3	Shared Use Path Roadway–Intersection Design	5-30
5.3.1	Shared Use Path Crossing Types	5-30
5.3.2	Design of Mid-Block Crossings	5-31
5.3.3	Examples of Mid-Block Intersection Controls	5-38
5.3.4	Sidepath Intersection Design Considerations.....	5-42
5.3.5	Other Intersection Treatments	5-45
5.3.6	Additional Bicycle Crossing Considerations.....	5-49
5.4	Pavement Markings, Signs, and Signals.....	5-50
5.4.1	Pavement Markings	5-50
5.4.2	Signs.....	5-52
5.4.3	Signalized and Active Warning Crossings.....	5-54

Chapter 6: Bicycle Parking Facilities.....	6-1
6.1 Introduction	6-1
6.2 Planning for Bicycle Parking.....	6-1
6.3 Short-Term Bicycle Parking Facilities.....	6-2
6.3.1 Site Design	6-3
6.3.2 Rack Design	6-3
6.3.3 Considerations for Special Types of Racks.....	6-4
6.4 Long-Term Bicycle Parking Facilities	6-4
 Chapter 7: Maintenance and Operations.....	 7-1
7.1 Introduction	7-1
7.2 Recommended Maintenance Programs and Activities	7-1
7.2.1 Sweeping	7-2
7.2.2 Surface Repairs	7-2
7.2.3 Pavement Overlays	7-3
7.2.4 Vegetation	7-3
7.2.5 Traffic Signal Detectors.....	7-4
7.2.6 Signs and Markings	7-4
7.2.7 Drainage Improvements	7-4
7.2.8 Chip Sealing.....	7-5
7.2.9 Patching Activities	7-5
7.2.10 Utility Cuts	7-5
7.2.11 Snow Clearance	7-6
7.3 Operating Bikeways in Work Zones.....	7-6
7.3.1 Rural Highway Construction.....	7-7
7.3.2 Urban Roadway Construction	7-7
 Index	 I-1

List of Figures

Chapter 2

Figure 2-1	Typical Wayfinding Signs.....	2-20
------------	-------------------------------	------

Chapter 3

Figure 3-1	Bicyclist Operating Space.....	3-2
Figure 3-2	Typical Bicycle Dimensions	3-3
Figure 3-3	Common Maneuvers for Bicyclists Turning Left at an Intersection	3-7

Chapter 4

Figure 4-1	“Share The Road” Sign Assembly	4-3
Figure 4-2	Bicycles “May Use Full Lane” Sign.....	4-3
Figure 4-3	“Wrong Way—Ride With Traffic” Sign Assembly	4-4
Figure 4-4	Shared-Lane Marking	4-5
Figure 4-5	Typical Shared-Lane Marking Cross Section on Street with Parking.....	4-6
Figure 4-6	Typical Shared-Lane Marking Cross Section on Street with No On-Street Parking.....	4-6
Figure 4-7	Shoulder Bypass Lane	4-8
Figure 4-8	Rumble Strips	4-9
Figure 4-9	Rumble Strip Design Parameters.....	4-10
Figure 4-10	Example of Paved Shoulder Designated as Bicycle Lane	4-11
Figure 4-11	Shared-Lane Marking and Bike Lane on Steep Street	4-12
Figure 4-12	Typical Markings for One-Way Street Designed for Two-Way Bicycle Travel	4-13
Figure 4-13	Typical Bike Lane Cross Sections	4-15
Figure 4-14	Example of Bike Lane Adjacent to Parallel Parking	4-16
Figure 4-15	Example of Bike Lane Adjacent to Back-in Diagonal Parking.....	4-17
Figure 4-16	Typical Bike Lane Pavement Markings.....	4-19
Figure 4-17	Bike Lane Symbol Markings	4-20
Figure 4-18	Example of Symbol Placement to Avoid Premature Wear.....	4-21
Figure 4-19	Bike Lane Sign.....	4-22
Figure 4-20	Examples of Bike Lanes Approaching Right-Turn-Only Lanes (With and Without Parking).....	4-24

Figure 4-21	Example of Bike Lane with Through Lane Transitioning to Right-Turn-Only Lane.....	4-25
Figure 4-22	Example of Bike Left-Turn-Only Lane.....	4-27
Figure 4-23	Example of Road Diet.....	4-31
Figure 4-24	Road Diet—Before and After.....	4-32
Figure 4-25	D11 Series Bicycle Route Signs.....	4-34
Figure 4-26	Wayfinding Signs.....	4-35
Figure 4-27	Typical Bicycle Guide Signage Layout.....	4-37
Figure 4-28	Correction for Skewed Railroad Grade Crossing—Separate Pathway	4-39
Figure 4-29	Correction for Skewed Railroad Grade Crossing—Widened Shoulder ..	4-40
Figure 4-30	Obstruction Marking.....	4-41
Figure 4-31	Diagonal Quadrupole Loop Detector	4-48
Figure 4-32	Conventional Quadrupole Loop Detector	4-48
Figure 4-33	Typical Bicycle Detector Pavement Marking	4-49
Figure 4-34	Bicycle Detector Pavement Marking and Sign	4-49
Figure 4-35	Examples of Bicycle-Friendly Approach Profiles for Speed Humps and Speed Tables.....	4-51
Figure 4-36	Curb Extensions	4-53
Figure 4-37	Choker with Bicycle Access.....	4-55
Figure 4-38	Bicycle-Compatible Drainage Grates.....	4-56
Figure 4-39	Example of Bike Lane on the Crossroad at a Freeway Interchange.....	4-58
Figure 4-40	Single-Point Diamond Interchange (SPDI).....	4-59
Figure 4-41	Option 1—Bike Lane and Free-Flow Merging Roadway.....	4-61
Figure 4-42	Option 2—Bike Lane and Free-Flow Merging Roadway	4-61
Figure 4-43	Example of Bike Lane and Diverging Roadway on an Arterial Street....	4-62
Figure 4-44	Typical Layout of Roundabout with Bike Lanes (4)	4-64

Chapter 5

Figure 5-1	Typical Cross Section of Two-Way Shared Use Path on Independent Right-of-Way	5-4
Figure 5-2	Minimum Width Needed to Facilitate Passing on a Shared Use Path	5-4
Figure 5-3	Safety Rail Between Path and Adjacent Slope.....	5-7
Figure 5-4	Sidepath Conflicts.....	5-10
Figure 5-5	Shared Use Path with Separate Unpaved Equestrian/Jogger Path.....	5-12
Figure 5-6	Minimum Stopping Sight Distance vs. Grades for Various Design Speeds—Ascending Climbing Grade.....	5-18
Figure 5-7	Minimum Stopping Sight Distance vs. Grades for Various Design Speeds—Descending Climbing Grade	5-19

Figure 5-8	Minimum Length of Crest Vertical Curve Based on Stopping Sight Distance.....	5-21
Figure 5-9	Diagram Illustrating Components for Determining Horizontal Sight Distance.....	5-23
Figure 5-10	Minimum Lateral Clearance (Horizontal Sightline Offset or HSO) for Horizontal Curves	5-24
Figure 5-11	Bridge Railing.....	5-27
Figure 5-12	Example of Bridge Structures	5-28
Figure 5-13	Mid-block and Sidepath Crossings Relative to Intersection Functional Area	5-31
Figure 5-14	Crossing Angle.....	5-32
Figure 5-15	Yield Sight Triangles.....	5-35
Figure 5-16	Minimum Path-Walkway Sight Triangle.....	5-37
Figure 5-17	Example of Mid-block Path–Roadway Intersection—Path is Yield Controlled for Bicyclists.....	5-39
Figure 5-18	Example Midblock Path–Roadway Intersection—Roadway is Yield Controlled	5-40
Figure 5-19	Example of Mid-block Path–Roadway Intersection—Path is Stop Controlled for Bicyclists.....	5-19
Figure 5-20	Example Mid-block Path–Roadway Intersection—Roadway is Stop Controlled	5-42
Figure 5-21	Bollard Approach Markings	5-47
Figure 5-22	Crossing Island	5-48
Figure 5-23	Advance Yield Signs and Markings.....	5-52
Figure 5-24	Advance Warning Assembly Example.....	5-53
Figure 5-25	Mode-Specific Guide Signs	5-54

Chapter 6

Figure 6-1	Directional Signage for Bicycle Storage	6-2
Figure 6-2	Example of “Inverted U” Bicycle Rack.....	6-3

List of Tables

Chapter 2

Table 2-1	Recreational Trips vs. Utilitarian Trips.....	2-4
Table 2-2	Casual/Less Confident vs. Experienced/Confident Riders	2-5
Table 2-3	General Considerations for Different Bikeway Types	2-17

Chapter 3

Table 3-1	Key Dimensions	3-3
Table 3-2	Key Performance Criteria.....	3-4

Chapter 4

Table 4-1	Formula for Determining Taper Length for Obstruction Markings.....	4-41
Table 4-2	Standing Bicycle Crossing Time	4-44
Table 4-3	Bicycle Minimum Green Time Using Standing Bicycle Crossing Time	4-45
Table 4-4	Rolling Bicycle Crossing Time Considering Braking Distance	4-46
Table 4-5	All-Red and Extension Time Using Rolling Bicycle Crossing Time	4-47

Chapter 5

Table 5-1	Minimum Radius of Curvature Based on Lean Angle	5-14
Table 5-2	Minimum Radii for Horizontal Curves on Paved, Shared Use Paths at 20-Degree Lean Angle	5-14
Table 5-3	Minimum Radius of Curvature Based on Superelevation	5-15
Table 5-4	Minimum Stopping Sight Distance	5-17
Table 5-5	Length of Crest Vertical Curve to Provide Sight Distance	5-20
Table 5-6	Horizontal Sight Distance.....	5-23
Table 5-7	Length of Roadway Leg of Sight Triangle.....	5-35
Table 5-8	Length of Path Leg of Sight Triangle.....	5-36
Table 5-9	Taper Length	5-49

1

Introduction

1.1 DESIGN IMPERATIVE

Bicycle travel has played a historic role in transportation. Even before the invention of the automobile, the League of American Wheelmen promoted improved traveled ways.

Bicycling is recognized by transportation officials throughout the United States as an important transportation mode. A policy statement, released in early 2010 by the U.S. Department of Transportation, emphasizes the needs and requirements to integrate bicycling (and walking) into transportation systems (4). Over a quarter of the population in the United States, over the age of 16 rides bicycles (3). Nationwide, people are recognizing the convenience, energy efficiency, cost effectiveness, health benefits, economic development, and environmental advantages of bicycling.

Local, state, and federal agencies are responding to the increased use of bicycles by implementing a wide variety of bicycle-related projects and programs. This interest in bicycle transportation calls for an understanding of bicycles, bicyclists, and bicycle facilities. This guide addresses these issues and clarifies the elements needed to make bicycling a more safe, comfortable, and convenient mode of transportation.

All roads, streets, and highways, except those where bicyclists are legally prohibited, should be designed and constructed under the assumption that they will be used by bicyclists. Therefore, bicyclists' needs should be addressed in all phases of transportation planning, design, construction, maintenance, and operations (1). All modes of transportation, including bicycles, should be jointly integrated into plans and projects at an early stage so that they function together effectively.

1.2 PURPOSE

Bicyclists should be expected on roadways, except where prohibited, and on shared use paths. Safe, convenient, well-designed, well-maintained facilities, with low-crash frequencies and severities, are important to accommodate and encourage bicycling.

Photo courtesy of Alaska DOT.

This guide provides information on how to accommodate bicycle travel and operations in most riding environments. It is intended to present sound guidelines that result in facilities that meet the needs of bicyclists and other highway users. Sufficient flexibility is permitted to encourage designs that are sensitive to local context and incorporate the needs of bicyclists, pedestrians, and motorists. However, in some sections of this guide, suggested minimum dimensions are provided. These are recommended only where further deviation from desirable values could increase crash frequency or severity.

This guide has been updated from the previous guide published in 1999. The fact that new guidance is presented herein does not imply that existing bicycle facilities are inadequate or unsafe, nor does it mandate the initiation of improvement projects. The intent of this document is to provide guidance to designers and planners by referencing a recommended range of design values and describing alternative design approaches. Good design practice involves engineering cost-effective solutions that balance safety and mobility for all transportation modes, along with preservation of scenic, aesthetic, historic, cultural, and environmental resources. This guide is therefore not intended to be a detailed design or traffic engineering manual that could supersede the need for application of sound principles by the knowledgeable design or traffic engineering professional.

1.3 SCOPE

This guide provides information on the physical infrastructure needed to support bicycling. Facilities are only one of several elements essential to a community's overall bicycle program. Bicycle safety education and training, encouraging bicycle use, and enforcing the rules of the road as they pertain to bicyclists and motorists should be combined with engineering measures to form a comprehensive approach to bicycle use. Information on other elements of an overall bicycle program can be obtained from state or local bicycle coordinators and other publications.

The provisions for bicycle travel are consistent with, and similar to, normal highway engineering practices. Signs, signals, and pavement markings for bicycle facilities are presented in the *Manual on Uniform Traffic Control Devices* (MUTCD) (2), which should be used in conjunction with this guide. If there is a discrepancy between the content of this guide and the current edition of the MUTCD, then the MUTCD supersedes this guide for that case. For construction of bicycle facilities, applicable state and local construction specifications should be used.

1.4 DEFINITIONS

Bicycle—A pedal-powered vehicle upon which the human operator sits. The term “bicycle” for this publication includes three- and four-wheeled human-powered vehicles, but not tricycles for children. In some states, a bicycle is considered a vehicle, while in other states it is not.

Bicycle Boulevard—A street segment, or series of contiguous street segments, that has been modified to accommodate through bicycle traffic and minimize through motor traffic.

Bicycles Facilities—A general term denoting improvements and provisions to accommodate or encourage bicycling, including parking and storage facilities, and shared roadways not specifically defined for bicycle use.

Bicycle Lane or Bike Lane—A portion of roadway that has been designated for preferential or exclusive use by bicyclists by pavement markings and, if used, signs. It is intended for one-way travel, usually in the same direction as the adjacent traffic lane, unless designed as a contra-flow lane.

Bicycle Level of Service (BLOS)—A model used to estimate bicyclists' average perception of the quality of service of a section of roadway between two intersections.

Bicycle Locker or Bike Locker—A secure, lockable container used for individual bicycle storage.

Bicycle Network—A system of bikeways designated by the jurisdiction having authority. This system may include bike lanes, bicycle routes, shared use paths, and other identifiable bicycle facilities.

Bicycle Rack or Bike Rack—A stationary fixture to which a bicycle can be securely attached.

Bicycle Route or Bike Route—A roadway or bikeway designated by the jurisdiction having authority, either with a unique route designation or with Bike Route signs, along which bicycle guide signs may provide directional and distance information. Signs that provide directional, distance, and destination information for bicyclists do not necessarily establish a bicycle route.

Bicycle Wheel Channel—A channel installed along the side of a stairway to facilitate walking a bicycle up or down the stairs.

Bikeway—A generic term for any road, street, path, or way which in some manner is specifically designated for bicycle travel, regardless of whether such facilities are designated for the exclusive use of bicycles or are to be shared with other transportation modes.

Highway—A general term denoting a public way for purposes of vehicular travel, including the entire area within the right-of-way.

Independent Right-of-Way—A general term denoting right-of-way outside the boundaries of a conventional highway.

Rail-Trail—A shared use path, either paved or unpaved, built within the right-of-way of a former railroad.

Rail-with-Trail—A shared use path, either paved or unpaved, built within the right-of-way of an active railroad.

Right-of-Way—A general term denoting land, property or interest therein, usually in a strip, acquired for or devoted to transportation purposes.

Right of Way (Assignment)—The right of one driver or pedestrian to proceed in a lawful manner in preference to another driver or pedestrian.

Roadway—The portion of the highway, including shoulders, intended for vehicular use.

Recumbent Bicycle—A bicycle with pedals at roughly the same level as the seat where the operator is seated in a reclined position with their back supported.

Roundabout—A type of circular intersection that provides yield control to all entering vehicles and features channelized approaches and geometry to encourage reduced travel speeds through the circular roadway.

Rumble Strips—A textured or grooved pavement treatment designed to create noise and vibration to alert motorists of a need to change their path or speed. Longitudinal rumble strips are sometimes used on or along shoulders or center lines of highways to alert motorists who stray from the appropriate traveled way. Transverse rumble strips are placed on the roadway surface in the travel lane, perpendicular to the direction of travel.

Shared Lane—A lane of a traveled way that is open to both bicycle and motor vehicle travel.

Shared-Lane Marking—A pavement marking symbol that indicates an appropriate bicycle positioning in a shared lane.

Shared Roadway—A roadway that is open to both bicycle and motor vehicle travel.

Shared Use Path—A bikeway physically separated from motor vehicle traffic by an open space or barrier and either within the highway right-of-way or within an independent right-of-way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers, and other non-motorized users. Most shared use paths are designed for two-way travel.

Shoulder—The portion of the roadway contiguous with the traveled way that accommodates stopped vehicles, emergency use, and lateral support of subbase, base, and surface courses. Shoulders, where paved, are often used by bicyclists.

Sidewalk—That portion of a street or highway right-of-way, beyond the curb or edge of roadway pavement, which is intended for use by pedestrians.

Sidelpath—A shared use path located immediately adjacent and parallel to a roadway.

Traveled Way—The portion of the roadway intended for the movement of vehicles, exclusive of shoulders and any bike lane immediately inside of the shoulder.

Unpaved Path—Path not surfaced with a hard, durable surface such as asphalt or Portland cement concrete.

REFERENCES

1. AASHTO. *A Policy on Geometric Design of Highways and Streets*. American Association of State Highway and Transportation Officials, Washington, DC, 2011.
2. FHWA. *Manual on Uniform Traffic Control Devices*. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2009.
3. National Highway Traffic Safety Administration, Bureau of Transportation Statistics. *National Survey of Pedestrian and Bicyclist Attitudes and Behaviors*. U.S. Department of Transportation, Washington, DC, 2002.
4. U.S. Department of Transportation. *Policy Statement on Bicycle and Pedestrian Accommodation Regulations and Recommendations*. Washington, DC, March 2010.
<http://www.dot.gov/affairs/2010/bicycle-ped.html>



Bicycle Planning

2.1 BACKGROUND

Bicycling is a healthy, low cost mode of travel that is available to nearly everyone. Bicycling is also one of the most energy-efficient forms of transportation available. Since bicycling emits no pollution, needs no external energy source, and uses land efficiently, it effectively moves people from one place to another without adverse environmental impacts. For communities working to address a wide range of issues from traffic congestion to climate change, bicycling is a transportation solution that works at both local and global levels.

Surveys show that people support bicycling because it makes neighborhoods safer and friendlier, saves on transportation costs, provides a way to routinely get physical activity, and reduces transportation-related environmental impacts, emissions, and noise. Bicycling increases the flexibility of the transportation system by providing additional mobility options, especially for short-distance trips that are considered too long to walk. Bicycle transportation is particularly effective in combination with transit systems, as when used together, each expands the range of the other mode.

2.2 WHY PLANNING FOR BICYCLING IS IMPORTANT

As communities throughout the United States face new challenges, bicycling provides a solution to many different concerns. Since the bicycle is an appropriate vehicle for many trips, it can play a significant role in sustainable land-use planning, transportation, recreation, and economic development initiatives. Particularly in urban and suburban centers, where a large percentage of trips are shorter than two miles in length, bicycling can serve as part of a comprehensive approach to alleviate traffic congestion and provide flexible, convenient, and affordable travel options. Bicycling is also very compatible with transit system development, and can effectively expand the area served by each transit stop.

Like other users of the transportation system, bicyclists need access to jobs, goods and services, recreational activities, and other destinations. Planning for existing and potential bicycle use should

be integrated into and coordinated with the overall transportation planning process. Transportation improvements can provide an opportunity to enhance the safety and convenience of bicycle travel.

Improvements made for bicyclists often result in better conditions for other transportation users. For instance, paved shoulders, wide curb lanes, and bike lanes not only provide improved conditions for bicyclists, but also increase motorist comfort. However, these can increase crossing distances for pedestrians. Between intersections, bike lanes and paved shoulders result in more consistent separation between bicyclists and passing motorists. Bike lanes improve sight distance for motorists at driveways and provide a buffer area between sidewalks and traffic lanes, making streets more comfortable for pedestrians. Communities that have improved conditions for bicycling have seen positive results for all users.

Plans for implementing bicycle projects often need supportive policies in a community's general plan, master transportation plan, zoning ordinances, and subdivision regulations. These may need to be amended to support bicycle-compatible roadway design, encourage shared use path connections between neighborhoods, require bicycle parking, and create land-use policies that keep destinations closer to home and work.

Providing for bicycling touches on many different aspects of community planning, and a good bicycle plan reflects this dynamic. Depending on the community, a bicycle plan may involve many diverse aspects, such as signal timing and progression, safety education, building codes and parking facility design, land-use policies, school busing policies, social marketing to promote flexible transportation options, roadway maintenance and transit access, and many others.

2.3 FACTORS INFLUENCING BICYCLING BEHAVIOR

Many characteristics have been used to classify different types of bicycle riders. Among the most common are comfort level, physical ability, and trip purpose. These characteristics can be used to help develop generalized profiles of various bicycle user types. People will not fit into a single category, and a rider's profile may change in a single day; for example, as a commuter switches to a parent who takes a child for a recreational ride. Still, these profiles provide a way to gauge approximate level of comfort on and preference for specific facility types.

2.3.1 Trip Purpose

Utilitarian/Nondiscretionary

Utilitarian or nondiscretionary trips are trips that are needed as part of a person's daily activities. These commonly include commute trips to work or school, work-related non-commute trips, shopping and errands, or taking a child to school. Depending on the length of trip and quality of bicycling conditions on transportation facilities, among other factors, bicycling trips can replace or seamlessly link with other transportation modes such as transit or motor vehicle trips.

While some people may choose to bicycle for transportation, others may use bicycles for utilitarian trips because they do not have access to an automobile or possess a driver's license, have no transit available, or are otherwise dependent upon bicycling.

School trips are a special type of utilitarian trip that involve younger riders and call for careful attention to their characteristics. School children can and do use the transportation system to bicycle to and from school. There is significant variation in their size and ability. It is important to

take into account the type of school (i.e., high, middle, or elementary school) that will be served and the roadway(s) that access it (e.g., is it an elementary school accessible from a local residential street or is it a large or regional high school accessible from an arterial). School policies such as those that provide students with information about preferred bike routes and bicycle safety education are also important to consider. Even so, most children will not have the same understanding of the rules of the road as adult bicyclists, so facilities planned near schools may need special accommodations to provide for the needs of young bicyclists.

Recreation/Discretionary

Recreational and discretionary trips include trips made for exercise and/or leisure. Recreational users cover all age groups from children to adults to senior citizens, and will have varying levels of comfort when riding in traffic. Recreational trips can range from short trips within a neighborhood, to long rides lasting several hours and covering many miles. Children will generally ride within their neighborhood, with friends or parents, and on streets, sidewalks, or shared use paths. Adult recreational trips cover a wide range depending on the user's comfort and fitness level, with average adult users looking for moderate to slow-paced riding on quiet streets or shared use paths. A smaller number of adult bicyclists go on long-distance recreational trips, sometimes in groups or as part of a bike club, seeking out scenic and/or challenging terrain for sport and fitness, and sometimes at higher speeds.

Mountain bicyclists fall into the category of recreational riders but are considered a unique and independent group due to their regular use of natural surfaces in addition to paved surfaces. Mountain bikes are generally designed for use on both types of surfaces. This guide will cover the use of mountain bikes for recreational or utilitarian travel on paved surfaces but does not discuss mountain bike use on narrow or single track natural surfaces.

Utilitarian vs. Recreation

It is difficult to differentiate between utilitarian and recreational bicycling because the same transportation system can be used for both purposes. Just as roads are designed for various motor vehicle trip purposes, roads and pathways should be designed to facilitate various bicycle trip purposes.

People who use a bike for transportation get exercise they may not have otherwise had time for, or that would have taken additional time and expense, such as going to a fitness center. Unlike driving, which is typically not viewed as a recreational activity but rather as a means to an end, many people choose to bicycle because it achieves more than a single purpose, such as exercising while reaching a destination. Bicycling is a multifaceted recreational activity for millions of people nationwide, young and old, cutting across many socioeconomic and demographic categories. Some users may never go beyond recreational rides on shared use paths or low-volume roads, while others may advance their skills and become bicycle commuters. That is why understanding and planning for the needs and abilities of all bicycle users is important for designing successful bicycle networks.

Table 2-1 outlines common characteristics of recreational and utilitarian trips. The descriptions below provide a general idea of typical differences between trip purposes; however it should be noted that some trips combine purposes and do not fall into these distinct categories.

Table 2-1. Recreational Trips vs. Utilitarian Trips

Recreational Trips	Utilitarian Trips
Directness of route not as important as visual interest, shade, protection from wind.	Directness of route and connected, continuous facilities more important than visual interest.
Loop trips may be preferred to backtracking; start and end points are often the same.	Trips generally travel from residential to schools, shopping, or work areas and back.
Trips may range from under a mile to over 50 miles.	Trips generally are 1–10 miles in length.
Short-term bicycle parking is needed at recreational sites, parks, trailheads, and other recreational activity centers.	Short-term and long-term bicycle parking is needed at stores, transit stations, schools, and workplaces.
Varied topography may be desired, depending on the fitness and skill level of the bicyclist.	Flat topography is desired.
(Individuals) May be riding in a group.	(Individuals) Often ride alone.
(Individuals) May drive with their bicycles to the starting point of a ride.	Use bicycle as primary transportation mode for the trip; may transfer to public transportation; may or may not have access to a car for the trip.
Typically occur on the weekend or on weekdays before morning commute hours or after evening commute hours.	Some trips occur during morning and evening commute hours (commute to school and work), but in general bicycle commute trips may occur at any hour of the day.

2.3.2 Level of User Skill and Comfort

Another way to look at user types is by comfort and skill level. Rider age often influences comfort and skill level.

Rider Age

Adults do not have uniform cognitive and perceptual abilities. However, in comparison to children, adults generally can start and stop movement of their bicycle more quickly, are more visible to motorists, can interpret directionality of sounds with greater accuracy, and have a greater awareness of potential conflicts. In addition, most adults also operate motor vehicles and have the advantage of understanding the “rules of the road” from a driver’s perspective. Seniors are a special type of adult rider, who may ride at a slower pace and have longer reaction times when faced with sudden conflicts or objects in their path.

Children have a wide range of skills and cognitive capabilities. Generally, children are slower in recognizing and responding to rapidly changing situations. This leads to the possibility of crashes in common situations that children face when riding bicycles, such as crossing streets.

Children tend to:

- Have a relatively narrow field of vision.
- Have difficulties accurately judging the speed and distance of an approaching vehicle.
- Assume the driver of a motor vehicle can see them if they can see the vehicle.
- Have difficulty concentrating on more than one thing at a time.
- Have difficulty understanding risks.

- ➡ Have difficulty determining the direction of auditory input.
- ➡ Have little experience with the rules of the road because they do not drive motor vehicles.

These are development characteristics which change as children mature.

Experienced and Confident

This group includes bicyclists who are comfortable riding on most types of bicycle facilities, including roads without any special treatments for bicyclists. This group also includes utilitarian and recreational riders of many ages who are confident enough to ride on busy roads and navigate in traffic to reach their destination. However, some may prefer to travel on low-traffic residential streets or shared use paths. Such bicyclists may deviate from the most direct route to travel in their preferred riding conditions. Experienced bicyclists may include commuters, long-distance road bicyclists, racers, and those who regularly participate in rides organized by bicycle clubs.

Casual and Less Confident

This group includes a majority of the population, and includes a wide range of people: (1) those who ride frequently for multiple purposes; (2) those who enjoy bicycling occasionally but may only ride on paths or low-traffic and/or low-speed streets in favorable conditions; (3) those who ride for recreation, perhaps with children; and (4) those for whom the bicycle is a necessary mode of transportation. In order for this group to regularly choose bicycling as a mode of transportation, a physical network of visible, convenient, and well-designed bicycle facilities is needed. People in this category may move over time to the “experienced and confident” category. Table 2-2 outlines general characteristics of experienced versus casual bicyclists.

Table 2-2. Casual/Less Confident vs. Experienced/Confident Riders

Experienced/Confident Riders	Casual/Less Confident Riders
Most are comfortable riding with vehicles on streets, and are able to navigate streets like a motor vehicle, including using the full width of a narrow travel lane when appropriate and using left-turn lanes.	Prefer shared use paths, bicycle boulevards, or bike lanes along low-volume, low-speed streets.
While comfortable on most streets, some prefer on-street bike lanes, paved shoulders, or shared use paths when available.	May have difficulty gauging traffic and may be unfamiliar with rules of the road as they pertain to bicyclists; may walk bike across intersections.
Prefer a more direct route.	May use less direct route to avoid arterials with heavy traffic volumes.
Avoid riding on sidewalks. Ride with the flow of traffic on streets.	If no on-street facility is available, may ride on sidewalks.
May ride at speeds up to 25 mph on level grades, up to 45 mph on steep descents.	May ride at speeds around 8 to 12 mph.
May cycle longer distances.	Cycle shorter distances: 1 to 5 miles is a typical trip distance.

2.4 TYPES OF TRANSPORTATION PLANNING PROCESSES

The field of transportation planning has evolved over 20 years to reflect a growing body of experience, literature, and lessons learned nationwide. Bicycling has been integrated into planning processes throughout the country, in places large and small, including urban, suburban, and rural areas. This section of the guide covers the following types of planning processes:

- Comprehensive Transportation Plans
- Bicycle Master Plans
- Transportation Impact/Traffic Studies
- Small-Area and Corridor-Level Planning
- Project-Level Planning

2.4.1 Comprehensive Transportation Plans

Comprehensive or master transportation plans should include a bicycling component. These include Long-Range Transportation Plans, Highway System Plans, Highway Safety Plans, and Transportation Demand Management (TDM) Plans. The bicycle component of these plans should be of a similar level of detail as the motor vehicle components; for example, identifying specific short-term and long-term improvements, establishing funding priorities, and addressing policy issues. Public meetings for these plans should be designed to solicit input on bicyclists' needs and priorities, as well as input on all other modes. These plans should also provide recommendations for improving bicycle/transit connections.

In some cases, the bicycle element of the master transportation plan is a condensed version of a separate bicycle master plan (see below) and/or may incorporate the separate bicycle master plan by reference. Where this is the case, it is still important for the bicycle component to provide the same level of detail as the other modal elements of the plan.

2.4.2 Bicycle Master Plans

The purpose of a stand-alone bicycle plan is to identify the projects, policies, and programs that are needed in order to fully integrate bicycling as a viable mode of transportation within a community. Bicycle plans prepared by a state department of transportation (DOT) are often more focused on policy issues, while bicycle plans that are completed by local or regional agencies may focus on bicycle network planning, as well as policies and design practices that support bicycling.

A good bicycle plan starts from each community's current stage—some communities may be just beginning ("starting from scratch") while others may be at a more advanced stage. It should address policy, infrastructure, and programming. For a community that is embarking upon bicycle planning for the first time, the focus may be on winning support for initial projects that will generate significant use or result in visible safety improvements, and help to build momentum for subsequent projects. For a community that has already implemented a partial bicycle network and has a growing number of engaged and active bicyclists, the focus may be on more challenging projects and programs. And for those communities in a more advanced stage with transportation systems that largely meet the needs of bicyclists, well-defined policies, new education and outreach programs, and a focus on critical gaps in the network may be appropriate. All communities should address policies that encourage and support bicycle trips.

A bicycle plan should be tailored to the unique conditions of the community which it serves. Bicycle plans for cities, suburbs, counties, regions, and states all differ significantly, depending on many factors including span of control (e.g., which roads or corridors are controlled or managed by the government entity), political support, available funding, and level of community engagement. Bicycle plans exist for every type of community: urban, suburban, rural, mountain, and resort. In fast-growing communities, bicycle plans may concentrate on policies, standards, and code language to guide future development, whereas plans for more built-out communities may be more concerned with the retrofitting of bicycle improvements at existing locations and analysis of potential off-street corridors.

A bicycle plan helps guide transportation departments to implement or improve bikeways and make other improvements to bicycling conditions as part of their routine roadway maintenance and “3R” (resurfacing, restoration, or rehabilitation) activities. For example, a routine pavement overlay may provide a convenient opportunity to add or improve bike lanes or paved shoulders, or consider changes to pavement markings that will improve bicycling conditions. When signals are upgraded, it is a good time to add bicycle-sensitive detectors. A bicycle plan can and should deal with the immediate needs for short-term improvements, balanced with longer term projects that could be decades from realization.

Public Process

To develop a plan that will enjoy community support, the process should include opportunities for the public, stakeholders, and other interest groups to participate and be heard. Public input should include a combination of strategies, such as public workshops, hearings, notices in the media, outreach events, and the formation of a Bicycle Advisory Committee. Effective committees report their findings to agencies and elected officials; are attended by transportation and enforcement officials, and welcome diverse viewpoints. Potential committee members may include planners, engineers, health and/or safety advocates, educators, business leaders, law enforcement personnel, bicycling advocacy groups, transit personnel, people with disabilities, elderly, and people who are economically disadvantaged. Local officials (elected and staff), who are responsible for implementation should participate in the process.

Outreach should be conducted to target and draw out the opinion of a broad cross section of the community, including experienced, casual, and novice bicyclists of all ages. These efforts could include a website, mailed surveys, school visits, or community bicycling audits to document bicycling resources and/or opportunities.

Coordination with Other Documents and Planning Processes

The plan should be coordinated with regional (county and Metropolitan Planning Organization) and state transportation plans (such as modal plans or corridor plans). While bicycle transportation may not always be the primary focus of these plans, the bicycle mode should be taken into consideration and should be addressed in an appropriate level of detail. For example, the implementation of bicycle recommendations often involves revisions to land development regulations, roadway design standards, and standard design details. These documents are typically updated on a periodic basis and these updates should address the travel needs of bicyclists where appropriate and as recommended in the bicycle master plan. Coordination is also needed with funding programs (such as the annual capital improvements program), and planning documents of other agencies (such as transit, and parks and recreation).

Phasing of Infrastructure Improvements

A phasing plan sets forward a strategy for improving conditions for bicycling over time, reflecting political realities, future development, funding opportunities, corridor constraints, and technical challenges. By identifying projects to be implemented in the short-, medium- and long-term, jurisdictions can focus initially on projects that are low-cost or need minimal infrastructure work, while simultaneously starting to plan, design, and seek funding and support for longer-term, more complex projects.

Short-term projects. Short-term projects can help to create early success and show significant progress in plan implementation. These projects are generally low-cost and easy to implement. Examples include traffic signal timing and/or detection adjustments; shared lanes; adjusting lane widths when restriping existing streets to create wide right lanes or bike lanes; removing travel lanes or parking and redistributing space to accommodate bike lanes; road repaving that includes bike lanes or paved shoulders; or installation of wayfinding signage or shared lane markings. These strategies will be discussed in more detail in the design chapters.

Medium-term projects. Medium-term projects may include major street repaving, facility reconstruction such as moving curbs, or funding as part of other capital improvement programs. These projects generally undergo a detailed infrastructure design study, are more complex to implement, and need time to secure funding and potentially right-of-way. Medium-term projects may also be those that only occur with new facility construction or old facility rehabilitation.

Long-term projects. Long-term projects generally represent investments of major capital funds; these projects are complex from a design or political standpoint. Examples can include bicycle bridges, elevated crossings, or underpass-style tunnels. These projects can be developed through new facility construction or facility rehabilitation.

To develop a phasing plan, several issues should be considered:

- **Bicycle Travel Demand:** To what degree will the bikeway generate significant usage? How many trip generators are within close proximity of the project, such as residential areas, schools, parks, transit centers, employment and commercial districts, churches, and park-and-ride facilities? There are several methods for forecasting bicycle travel demand, as described in Section 2.6.
- **Route Connectivity and Directness:** To what degree does this alternative fill in a missing gap in the bicycle network, or make a critical connection to a transit facility or other key destination?
- **Crash/Conflict Analysis:** Does the proposed improvement have the potential to alleviate a specific concern, such as an intersection with a history of bicycle crashes or conflicts?
- **Barriers:** How well does the alternative overcome barriers to bicyclists in the current transportation system? Barriers could include railroads, waterways, hills, canyons, and freeways. Bridges, overpasses, interchanges, and intersections that do not meet the needs of bicyclists can also be barriers.
- **Ease of Implementation:** How difficult will it be to implement this project? This criterion takes into account right-of-way, topographical, environmental, political, and economic constraints.

- ➔ **System Integration:** How well does the alternative link with other transportation modes? This criterion assesses how the proposed improvement fits within the overall transportation system and how it affects multimodal transportation.

Typical Plan Contents

A well-developed bicycle plan is comprehensive and should cover some, if not all, of the following topics (not necessarily in this order):

Introduction

The introduction of the plan lays a foundation and sets the context for the plan. It should provide a brief overview of the history and current status of bicycling in the jurisdiction, may discuss current or previous planning efforts that support bicycling, provide data on current levels of bicycling (along with historical data if available), and any other information that is needed to lay a foundation for the plan.

Vision, Goals, and Objectives

This section establishes what the plan hopes to accomplish. The vision statement should describe the jurisdiction in the future, once the goals and objectives have been fulfilled. Goals should be broad statements that address key focus areas, such as mobility, health, and the environment. Objectives identify more specific strategies for accomplishing the vision and goals.

Benchmarks or Performance Indicators

Benchmarks should be set in such a way that jurisdictions can measure results. In order to set a baseline for performance measures, collection of initial data may be needed (see Section 2.6.1). Performance measures should be as simple as practical, and should be fairly easy to measure. In some cases, existing data collection processes (such as roadway inventories) can be adjusted to collect data relevant to bicycle performance measures (i.e., shoulder width and pavement condition). Examples of benchmarks include the number of bikeway miles implemented, mode share percentage, rate of bicycle-motor vehicle crashes as compared to the number of bicycle trips, total number of bicycle-motor vehicle crashes, number of bike parking spaces, bike usage on a particular corridor, percentage of children bicycling to school, and others. Inclusion of outcome-oriented performance measures (such as usage counts and crash rates) is desirable to check effectiveness of current programs; purely inventory-oriented performance measures may not detect issues that need to be addressed.

Existing Conditions

The overview of existing conditions should take stock of the transportation infrastructure. The existing conditions analysis should include a general assessment of streets, roads, and highways by function, type, ownership, traffic volumes and speeds, width, and condition, as well as an inventory of existing bikeways, including shared use paths and trails outside the street system. Other items include bicycle parking conditions (quality, quantity, and location); crash data; proposed developments that may have a significant impact on bicycling; bike-transit integration (availability of bicycle racks on buses and policies regarding bicycles on transit vehicles); and education, encouragement, and enforcement efforts.

Recommended Bicycle Facilities

This component is discussed in more detail in the next section. Recommendations should reflect the community's needs, as well as the feasibility of projects in specific roadway corridors. An opportunistic approach is wise—the majority of bike plans recommend new facilities in locations where other roadway projects (such as repaving and shoulder widening) offer opportunities to implement bikeways less expensively. Projects should be identified in sufficient detail such that they can be integrated into a local capital improvement plan or advanced to a design phase. This should include, at a minimum, roadway name, beginning and end points, bikeway or improvement type, a description of the work needed, and the estimated cost. Bicycle parking needs can also be identified, as well as standards for placing bicycle parking facilities (see Chapter 6 for more information).

Recommended Policies/Design Guidelines

Recommendations for policy changes are a standard component of most bicycle master plans. This includes zoning and land development policies that support bicycling (such as higher densities of mixed-use development, neighborhood design that provides a high level of bicycle connectivity, bicycle parking ordinances, the need for commuter support facilities such as showers, etc.) Some bicycle plans also include design guidance that clarifies the jurisdiction's expectations in terms of bicycle facility design. This can be particularly helpful if the jurisdiction's current design guidelines do not address bicycle facilities; however, ultimately the goal should be to integrate bicycle design standards into other existing documents that cover roadway design, local subdivision and development codes, or other appropriate sources.

Recommended Education and Encouragement Programs

This section of the plan is very important, as there are typically many opportunities to improve conditions for bicyclists by improving behaviors. The education component should address issues such as bicycling-related information on appropriate jurisdictional websites; improvements in driver education programs and driver handbooks; routine inclusion of bicycle-related questions on driver license exams; safety information messages for motorists and bicyclists; and bicyclist training programs for children, youth, and adults. Education programs can help dispel myths, encourage courteous and lawful behavior among motorists and bicyclists of all ages, enhance the skill level of bicyclists, and improve motorist awareness. Education programs can be administered through a number of different agencies and interest groups, such as police departments, schools, libraries, bicycle clubs, and parks and recreation departments. The encouragement component can include commuter support programs and incentives, promotional activities oriented to neighborhoods and local business districts (e.g., a “shop by bike” program), campaigns to promote use of bicycles with transit, rides organized to introduce (or publicize benefits of) bicycling to a wider audience, and other activities to promote the more widespread practical application of bicycling (e.g., a “bike to work” program).

Enforcement Programs

This section of the plan should provide an overview or summary of enforcement of motorist and bicyclist violations and assess the need for improved enforcement of violations. This section should also address training of enforcement personnel to improve their understanding of the rights and responsibilities of bicyclists and duties of motorists towards bicyclists.

Implementation plan

This section should address short-, medium- and long-term recommendations, and should provide a phasing plan as described above. Short-term projects should include planning-level cost estimates for budgetary purposes. Funding sources should be identified, such as local or state transportation improvement programs, special federal funding programs, local capital improvement budgets, grants, and others. All types of projects—both infrastructure and non-infrastructure (such as education and encouragement programs) should be included in the phasing plan. For some plans, it may also be desirable to identify the agencies that are responsible for implementing the recommendations, and after project implementation it is important to evaluate improvements to determine if they achieved their desired results.

2.4.3 Transportation Impact/Traffic Studies

Transportation impact studies attempt to disclose information to stakeholders about potential impacts and benefits of new development. Although many studies in the past focused exclusively on motor vehicle impacts, today agencies have access to resources that can be used to measure the impacts on bicyclists (see Section 2.6). The National Environmental Policy Act (NEPA), the federal law governing environmental analysis, and many state environmental laws require a full disclosure of all transportation impacts, not just motor vehicle traffic impacts.

Thorough traffic studies evaluate impacts to all modes, including pedestrians, bicyclists, and transit, in addition to a discussion of on-site circulation and support facilities. Impacts to bicyclists are considered significant if:

- **A project disrupts existing bicycle facilities.** This can include adding new vehicular or bicycle traffic to an area experiencing safety concerns or a new development adjacent to an existing sensitive use, such as a school or park. Particular attention should be paid to on-street bicycle facilities on roadways with proposed driveways, and roadway widening or intersection improvements intended to augment motor vehicle capacity, which may reduce or eliminate shoulders or bike lanes.
- **A project interferes with proposed bicycle facilities.** This includes failure to dedicate right-of-way for planned on- and off-street bicycle facilities included in an adopted bicycle master plan, or failure to contribute toward construction of planned bicycle facilities along the project's frontage. Other examples are: a new roadway that severs a planned pathway connection, particularly when grade separation is desirable but is not planned for in advance, or a road design that constrains the inclusion of bicycle facilities or other bicycling improvements.
- **A project conflicts with adopted bicycle system plans, guidelines, policies, or standards.** This can include project designs that are in conflict with policy language, such as bicycle directness, connectivity, and network completeness.

Another consideration for bicycles in traffic studies is the evaluation of future off-site improvements to determine secondary impacts to bicycles. Impact studies typically include a set of improvements designed to reduce impacts to the transportation system. For example, a project may call for acceleration or deceleration lanes at a new driveway to reduce crashes and/or improve capacity. Thorough transportation impact studies explicitly analyze and mitigate secondary impacts on bicycling.

2.4.4 Small-Area and Corridor-Level Planning

Transportation plans that focus on specific roadway corridors should incorporate the needs of bicyclists along with all other users. The presumption in preparing these plans is that the needs of bicyclists will be included as a routine matter, and the decision to not accommodate them should be the exception rather than the rule.

During the development of small-area plans and corridor plans, bicycle access along and across roadways should be planned. An opportunistic approach should be used to incorporate improvements with the potential to reduce crashes for bicyclists along with other planned roadway improvements (see Section 2.5.2). In some cases, a roadway corridor or bridge replacement/reconstruction plan may create an opportunity to provide a new bicycle facility that does not necessarily connect to bikeways on either end of the corridor. However, bicycle accommodations should still be provided and should be designed with logical termini, because all bicycle networks begin with incremental improvements that eventually result in a connected network and transportation system that meet bicyclists' travel needs.

2.4.5 Project Level Planning—Approvals

Once a specific project is identified, key considerations become the types of approvals needed or desired to move the project to construction. Approvals needed by affected government agencies, stakeholders, and the general public should be identified early in the project development process. In some cases, projects require approval at the national level under NEPA. There are several factors that trigger the need for NEPA approval, most commonly the use of federal funding or impacts to federal lands. In many instances, whether or not NEPA approval is needed, state and local environmental approvals as well as other permits may be required. Often times these approvals require regular updates to, and input from, the general public and key stakeholders.

During the project development and/or approval process, there is often a need to develop and evaluate design alternatives. In some cases, NEPA approval requires the evaluation of all practical alternatives that accomplish the purpose and need of the project. Analytical tools (see Section 2.6) can aid in evaluating alternatives by comparing relatively small differences in design and presenting them in a format that is relatively easy to understand.

2.5 PLANNING BICYCLE TRANSPORTATION NETWORKS

The core element of a bicycle plan will be the bicycle transportation network, composed of a connected, comprehensive system of paved shoulders, bike lanes, shared lanes, bicycle boulevards, bike routes, and shared use paths. This section describes how to develop a bicycle network plan.

2.5.1 Deciding Where Improvements Are Needed

All roadways should be accessible by bicycle, except where bicycle travel is specifically prohibited. Whenever roads are reconstructed or constructed, appropriate bikeways should be included to accommodate bicyclists' needs. However, technical, political, and financial realities may mean that not all roads can be immediately retrofitted or designed with the best or most appropriate bikeway. Thus, choices should be made regarding which improvements receive priority, and what level of accommodation each roadway will receive. Making these choices is both an art and a science. The science relies on use of standards, guidelines, and technical analysis tools, while the art

integrates local knowledge, engineering judgment, and public input. Technical guidance on the design of different bikeways is provided in Chapters 4 and 5 of this guide.

Factors to consider when deciding where improvements are needed to develop a connected bicycle transportation network include:

- **User Needs**—Balancing the full range of needs of current and future bicyclists.
- **Traffic Volumes, Vehicle Mix, and Speeds**—Motor vehicle traffic volumes, vehicle mix, speeds, and driveways should be considered along with the roadway width. Some bicyclists will avoid roadways with high speeds and high volumes of traffic and many driveways unless they are provided with a facility that offers some degree of separation from traffic. Also, some bicyclists will avoid roadways with high truck volumes. By contrast, people who regularly use a bicycle for transportation often use main roadways because their directness and higher priority at intersections typically make them more efficient routes. In many cases, the best approach is to improve the arterial roadway to accommodate bicyclists, but to also provide a parallel route along streets with lower speeds and traffic volumes that is convenient to follow and offers a similar level of access to destinations. High traffic volumes and speeds should not be used as justification for not accommodating bicyclists because many of these roadways are the only ones that connect parts of communities.
- **Overcoming Barriers**—Overcoming constraints and physical barriers such as freeways or waterways should be a top priority when developing a bicycle network. A single major barrier (e.g., difficult intersection, bridge without bike lanes or paved shoulder) can render an otherwise attractive bikeway undesirable. Input from local bicyclists, along with a field analysis of major highway crossings, railroads, and river crossings, can help to identify major barriers. Barriers can also include difficulties for bicyclists in utilizing other modes of transportation to link trips.
- **Connection to Land Uses**—Bikeways should allow bicyclists to access key destinations. They should connect to employment zones, parks, schools, shopping, restaurants, coffee and ice cream shops, sports facilities, community centers, major transit connections, and other land uses that form the fabric of a community.
- **Directness of Route**—A bikeway should connect to desirable locations with as few detours as practical. For example, does a bicyclist have to travel out of his or her way on a route with many turns to reach a freeway overpass? Multiple turns can disorient a rider and unnecessarily complicate and lengthen a trip.
- **Logical Route**—Does the planned bicycle network make sense? A network should include facilities that bicyclists already use, or have expressed interest in using.
- **Intersections**—Bikeways should be planned to allow for as few stops as practical, as bicycling efficiency is greatly reduced by stops and starts. If bicyclists are required to make frequent stops, for example, along streets with stop signs every block, they may avoid the route or disregard traffic control devices. Signalized intersections with very short green times (such as those on low-priority streets) can lead to disregard for traffic

control. At major streets, crossings should be carefully planned and managed to reduce crashes and improve operations for all travelers and modes. Each additional intersection can present a potential for additional crashes.

- **Aesthetics—Scenery** is an important consideration along a facility, particularly for a facility that will serve a primarily recreational purpose. Trees can also provide cooler riding conditions in summer and can provide a windbreak. Bicyclists tend to favor roads with adjacent land uses that are attractive such as campuses, shopping districts, and those with scenic views.
- **Spacing or Density of Bikeways**—A bicycle network should be planned for maximum use and comfort, and thus should provide an appropriate density relative to local conditions. Some bicycle network plans have set a goal to provide a bikeway within one-fourth of a mile of every resident.
- **Safety**—Analysis of crash data and reviews of crash reports may also aid in identifying where improvements to the bicycle transportation network are recommended based upon safety experience.
- **Security**—Security issues are important to consider especially for sections of shared use paths that are not visible from roads and neighboring buildings.
- **Overall Feasibility**—Decisions regarding the location of new bikeways may also include an overall assessment of feasibility given physical or right-of-way constraints, as well as other factors that may impact the cost of the project. While funding availability may influence decisions, it is essential that a lack of funds not result in a poorly-designed or constructed facility. The decision to implement a bicycle network plan should also be made with a conscious, long-term commitment to a proper level of maintenance. Facility selection should seek to maximize user benefit per dollar funded. Cost-benefit analysis is covered in Section 2.6.6.

While every street will serve as a bicycle facility to some extent, concentrating bicycle trips along specially treated corridors can help to attract new bicyclists and reduce crashes for all modes.

A context sensitive design approach is important in all aspects of roadway design. Simply applying standards, without understanding how they will function, the local context, or the future design intent, can lead to inappropriate and underused facilities. A core value of context sensitive solutions is to provide an effective facility for both the user and the surrounding community and a project built in harmony with adjacent land uses, preserving important environmental, historic, and aesthetic features of the area. Context sensitive designs should address the needs of bicyclists and should support measures that reduce the impact of motor vehicles on the environment.

2.5.2 Practical (Opportunistic) Approach to Network Planning

Many of the most successful bike plans have been implemented through a pragmatic approach involving phasing of improvements and opportunistic partnerships with other projects and government departments/agencies. Examples of this type of approach include:

- Bike lane implementation as part of resurfacing, reconstruction, and routine maintenance overlays. Many communities have coordinated their bikeway plans and their street repaving programs to create bike lanes through the reallocation of street space during routine paving projects.
- “Complete Streets” Policies. Integration of bikeways in routine public works projects including highway and transit projects. Cost-effective improvements can be made by systematically including bikeways in projects as a matter of policy.
- Bikeway implementation via private-sector development activity. New developments, including mixed-use projects, residential developments, and urban infill projects provide significant opportunities for including bikeways in the local planning process.
- Bikeway implementation in coordination with major capital projects. Bikeways can successfully be included in bridges, freeways, light rail projects, transit stations, and other capital projects.
- Development of shared use paths in corridors with utilities or other infrastructure improvements. Co-location of water, sewer, communications, power, and other utilities can create cost-sharing and revenue opportunities for bikeways.
- Rails-to-Trails and Rails-with-Trails Projects. Active, abandoned, and rail-banked corridors are frequently used to create shared use paths.
- Training for maintenance bureaus, planning boards, utility managers, school districts, transit districts, and other agencies so that they are aware of the opportunity to implement bicycle facilities as part of their routine activities.

Choosing an Appropriate Facility Type

Although incorporating bicyclists’ needs into the design of major transportation corridors can be challenging, the reality of planning bikeways in built environments means that roadways constitute the majority of a bicycle network. Whenever streets are constructed or reconstructed, appropriate provisions for bicyclists should be included consistent with federal policy. Technical information on the design of different bikeways is provided in Chapters 4 and 5. The bikeway design options are:

- Shared lanes,
- Marked shared lanes,
- Paved shoulders,
- Bike lanes,
- Bicycle boulevards, and
- Shared use paths.

Bike routes are not included in the list above because they represent a designation, rather than a facility type. See Section 2.5.3 on “Wayfinding for Bicycles.”

Considerations

The best application of each of these facilities combines experience with data analysis, engineering judgment, and budget constraints. Across the nation, state and local guidelines vary considerably depending on local preferences, experience, and conditions. Thus, this guide does not provide strict rules as to when to employ a bike lane versus a shared lane.

However, the urban centers in the United States that have seen the highest levels of bicycle use are those that have built a network of bike lanes and shared use paths as the backbone of their system. A very effective tool for encouraging bicycling is to provide a visible network of bikeways; it is harder (though not impossible) to attract people to use something not readily apparent. Selection of an appropriate bikeway should be based on the following information:

- Road function (arterial, local),
- Traffic volume,
- Speed,
- Traffic mix (e.g., truck percentage),
- Expected users (e.g., is one type of user expected to dominate, such as children bicycling to school),
- Road conditions (lane widths, total roadway width, conditions at intersections, and parking demand),
- Driveways or access points,
- Topography,
- Existing and proposed adjacent land uses, and
- Cost.

Bicycle quality of service tools (see Section 2.6.2) can be helpful in determining the appropriate facility choice, as they combine several of the factors listed above and can be used to determine the amount of lateral separation that is needed between bicycles and motor vehicles at increasing speeds. However, facility choice should also be appropriate given the type of street or corridor involved, and the potential for conflicts at intersections. Table 2-3 outlines general considerations for each facility type.

Multiple Facility Types on a Single Corridor

Corridors that effectively accommodate bicyclists often combine multiple facility types, each type being used where appropriate. For example, a shared use path can connect to a bicycle boulevard to create a continuous corridor. A corridor may start with bike lanes, travel along a bicycle boulevard, and then transition back to bike lanes. Throughout the network, transitions between facility types should be functional and intuitive.

As indicated in Table 2-3, shared use paths can range from short inter-street connections to long corridor routes. Shared use paths can attract new users, and can be an asset in connecting neighboring jurisdictions and providing community cohesion. To be successful, access via the local street network is crucial, with appropriate bikeways available on those connecting streets.

Table 2-3. General Considerations for Different Bikeway Types

Type of Bikeway	Best Use	Motor Vehicle Design Speed	Traffic Volume	Classification or Intended Use	Other Considerations
Shared lanes (no special provisions)	Minor roads with low volumes, where bicyclists can share the road with no special provisions.	Speeds vary based on location (rural or urban).	Generally less than 1,000 vehicles per day.	Rural roads, or neighborhood or local streets.	Can provide an alternative to busier highways or streets. May be circuitous, inconvenient, or discontinuous.
Shared lanes (wide outside lanes)	Major roads where bike lanes are not selected due to space constraints or other limitations.	Variable. Use as the speed differential between bicyclist and motorists increases. Generally any road where the design speed is more than 25 mph.	Generally more than 3,000 vehicles per day.	Arterials and collectors intended for major motor vehicle traffic movements.	Explore opportunities to provide marked shared lanes, paved shoulder, or bike lanes for less confident bicyclists.
Marked shared lanes	Space-constrained roads with narrow travel lanes, or road segments upon which bike lanes are not selected due to space constraints or other limitations.	Variable. Use where the speed limit is 35 mph or less.	Variable. Useful where there is high turnover in on-street parking to prevent crashes with open car doors.	Collectors or minor arterials.	May be used in conjunction with wide outside lanes. Explore opportunities to provide parallel facilities for less confident bicyclists. Where motor vehicles allowed to park along shared lanes, place markings to reduce potential conflicts with opening car doors.

Table 2-3. General Considerations for Different Bikeway Types (continued)

Type of Bikeway	Best Use	Motor Vehicle Design Speed	Traffic Volume	Classification or Intended Use	Other Considerations
Paved shoulders	Rural highways that connect town centers and other major attractors.	Variable. Typical posted rural highway speeds (generally 40–55 mph).	Variable.	Rural roadways; inter-city highways.	Provides more shoulder width for roadway stability. Shoulder width should be dependent on characteristics of the adjacent motor vehicle traffic, i.e. wider shoulders on higher-speed and/or higher-volume roads.
Bike lanes	Major roads that provide direct, convenient, quick access to major land uses. Also can be used on collector roads and busy urban streets with slower speeds.	Generally, any road where the design speed is more than 25 mph.	Variable. Speed differential is generally a more important factor in the decision to provide bike lanes than traffic volumes.	Arterials and collectors intended for major motor vehicle traffic movements.	Where motor vehicles are allowed to park adjacent to bike lane, provide a bike lane of sufficient width to reduce probability of conflicts due to opening vehicle doors and objects in the road. Analyze intersections to reduce bicyclist/motor vehicle conflicts.

Table 2-3. General Considerations for Different Bikeway Types (continued)

Type of Bikeway	Best Use	Motor Vehicle Design Speed	Traffic Volume	Classification or Intended Use	Other Considerations
Bicycle boulevards	Local roads with low volumes and speeds, offering an alternative to, but running parallel to, major roads. Still should offer convenient access to land use destinations.	Use where the speed differential between motorists and bicyclists is typically 15 mph or less. Generally, posted limits of 25 mph or less.	Generally less than 3,000 vehicles per day.	Residential roadways.	Typically only an option for gridded street networks. Avoid making bicyclists stop frequently. Use signs, diverters, and other treatments so that motor vehicle traffic is not attracted from arterials to bicycle boulevards.
Shared use path: independent right-of-way	Linear corridors in greenways, or along waterways, freeways, active or abandoned rail lines, utility rights-of-way, unused rights-of-way. May be a short connection, such as a connector between two cul-de-sacs, or a longer connection between cities.	N/A	N/A	Provides a separated path for non-motorized users. Intended to supplement a network of on-road bike lanes, shared lanes, bicycle boulevards, and paved shoulders.	Analyze intersections to anticipate and mitigate conflicts between path and roadway users. Design path with all users in mind, wide enough to accommodate expected usage. On-road alternatives may be desired for advanced riders who desire a more direct facility that accommodates higher speeds and minimizes conflicts with intersection and driveway traffic, pedestrians, and young bicyclists.

Table 2-3. General Considerations for Different Bikeway Types (continued)

Type of Bikeway	Best Use	Motor Vehicle Design Speed	Traffic Volume	Classification or Intended Use	Other Considerations
Shared use path: adjacent to roadways (i.e., sidepath)	Adjacent to roadways with no or very few intersections or driveways. The path is used for a short distance to provide continuity between sections of path on independent rights-of-way.	The adjacent roadway has high-speed motor vehicle traffic such that bicyclists might be discouraged from riding on the roadway.	The adjacent roadway has very high motor vehicle traffic volumes such that bicyclists might be discouraged from riding on the roadway.	Provides a separated path for nonmotorized users. Intended to supplement a network of on-road bike lanes, shared lanes, bicycle boulevards, and paved shoulders. Not intended to substitute or replace on-road accommodations for bicyclists, unless bicycle use is prohibited.	Several serious operational issues are associated with this facility type. See Sections 5.2.2 and 5.3.4 for additional details.

2.5.3 Wayfinding for Bicycles

Developing a bicycle wayfinding system that provides clear user information and navigational instructions is a complex endeavor in which the planner or designer must carefully consider the routes that bicyclists prefer, balancing the need for good bicycling conditions with the need for direct access to destinations. Input from local bicyclists can be very helpful when planning new bicycle routes. In general, it is advisable to start with a single route, or a simple network, and then build upon the network over time, rather than to attempt to implement an extensive network of multiple, interconnecting routes all at once.

To achieve a successful wayfinding system, the planner should conduct careful field work to identify effective routes and determine where signs should be placed, so that bicyclists following routes do not go off course. It is very important for the route planner to approach the task from the perspective of the bicyclist who will be following the signs to reach their destination.

Part 9 of the MUTCD (2) provides the basic guidelines for design of wayfinding signage systems for bicycle networks. This includes three types of bicycle route designation and guide signs (see Figure 2-1), including D Series Route signs, M1-8 Series Route Signs, and M1-9



Figure 2-1. Typical Wayfinding Signs

Route Signs. Section 4.11 provides additional information on bicycle guide/wayfinding signs. Colored pavement is another wayfinding strategy that can be used, especially in urban areas. Section 4.7.2 provides more details on the use of colored pavement.

Many communities find that a wayfinding system for bicycles is a component of a bicycle network that enhances other encouragement efforts, because it provides a visible invitation to new bicyclists, while also encouraging current bicyclists to explore new destinations.

2.6 TECHNICAL ANALYSIS TOOLS THAT SUPPORT BICYCLE PLANNING

A number of technical analysis tools exist to help with planning bikeways, bicycle networks, and roads without bikeways. These will be addressed in the following sections, and include:

- Data collection and flow analysis,
- Quality of service tools,
- Safety analysis,
- Bicycle travel demand analysis,
- GIS-based data collection/network planning, and
- Cost-benefit analysis.

The models and tools described in this section provide planners and decision-makers with methods of synthesizing large amounts of complex information. They can also provide useful graphical tools to communicate conditions and opportunities. No one model or tool solves all problems or answers all questions; each can provide assistance to the planning effort in a different way.

2.6.1 Data Collection and Flow Analysis

Many of the demand projection techniques described below either need, or would benefit from, bicyclist count data. Cities routinely collect, analyze, and use various data on motor vehicle traffic (e.g., average daily volumes, peak hour volumes, turning movements, and speed) to determine such items as number of travel or turn lanes, and signal timing. Similarly, bike-related data collection is an important part of understanding, planning, and operating a bicycle network. Bicycle counts should be considered at the state, regional, and local levels to complement bicycle planning and performance measurement. Bike counts and movement analysis can be used for the following:

- To identify corridors where current use and potential for increased use is high.
- To understand patterns of usage both before and after a facility is installed.
- To forecast bicycle travel demand (see Section 2.6.5) to and from colleges, universities, schools, parks, and employment centers.
- To track community-wide bicycle use over time, on particular corridors, as part of multimodal trips, or in response to specific factors, such as increasing density of bike-ways (this can include bicycle counts on specific roadways, as well as tracking bike-on-bus boardings or bike parking usage).
- To project increases in bicycle use in future years.

- To analyze specific travel patterns, such as bicyclists' positioning or movements at intersections, sidewalk usage, compliance with traffic control devices, use of hand signals, and interaction with motorists.
- To analyze equipment trends such as the wearing of helmets and use of front or rear lights and reflectors. Such an analysis can be helpful in determining if a campaign to encourage helmet use, for example, was successful.
- To analyze demographic trends, such as male versus female or rider age.

By conducting counts over several years, event-specific spikes will be less likely to skew the results. Counts taken in multiple seasons can help to determine seasonal fluctuation. In addition, existing conditions should be taken into account when conducting bicycle counts to estimate facility usage. The condition of the bicycle environment can be a deterrent to bicyclists that might otherwise use a particular corridor, and thus not to be counted. Per the direction of the Institute of Transportation Engineers (ITE) *National Bicycle and Pedestrian Documentation Project* (8), a bicycle count methodology has been established that will give jurisdictions across the nation access to a rich dataset for analysis. For count forms and directions, refer to the *National Bicycle and Pedestrian Documentation Project* website (8).

2.6.2 Quality of Service (or Level of Service) Tools

Quality of service (or Bicycle Level of Service [Bicycle LOS]) tools can be used to inventory and evaluate existing bicycling conditions, or to forecast future conditions for bicycling under different roadway design scenarios. A variety of bicycle compatibility criteria have been developed since the early 1990s to quantify how compatible a roadway is for accommodating safe and efficient bicycle travel. More information on this topic can be found in the *Highway Capacity Manual* (11). Applications of these models include:

- Documenting current conditions on an existing roadway.
- Documenting current conditions on an existing shared use path.
- Conducting a benefits comparison among proposed bikeway/roadway cross sections.
- Identifying roadway restriping or reconfiguration opportunities to improve bicycling conditions.
- Prioritizing and programming roadway corridors for bicycle improvements.
- Creating bicycle suitability maps.
- Documenting improvements in a corridor or system-wide bicycling conditions over time (typically means data to be managed in a GIS environment).
- Determining impacts of proposed roadway projects on bicyclists.

Although the term Level of Service (LOS) implies similarity to the vehicular intersection delay rating system established in the *Highway Capacity Manual*, Bicycle LOS evaluates bicyclists' perceived safety and comfort with respect to motor vehicle traffic while traveling in a roadway corridor. To evaluate Bicycle LOS, a mathematical equation is used to estimate bicycling conditions in a shared roadway environment (9). This modeling procedure calculates a user comfort rating (A through F, A being the best and F, the worst), from such factors as curb lane width, bike lane

widths and striping combinations, traffic volumes, pavement surface condition, motor vehicle speeds, presence of heavy vehicle traffic, and on-street parking.

Bicycle LOS provides a score for each roadway that indicates how comfortable a “typical” adult bicyclist would feel while riding along that roadway during peak travel conditions. Some bicyclists may feel more or less comfortable than the Bicycle LOS calculated for a roadway. A poor Bicycle LOS grade does not mean that bikes should be prohibited on a roadway, rather it means that the roadway is a candidate for improvements to better accommodate bicyclists.

It is important to distinguish between a segment-based and intersection-based LOS. The models discussed above do not address intersection LOS. Intersections can be significant barriers to bicycling, and a corridor with relatively high Bicycle LOS along its segments can be less suitable due to intersections that have a low Bicycle LOS. Factors that impact intersection LOS for bicycles include lane widths, motor vehicle speeds, crossing distance, signal timing, and conflicts with turning vehicles.

The detailed knowledge of local bicyclists and bicycle planners should be used to corroborate Bicycle LOS model results. The Bicycle LOS model provides a means to quantify the perceived safety and comfort of bicyclists. Perceived safety and comfort of bicyclists often serves as a surrogate for the crash experience of bicyclists when crash data are not available. To measure the actual safety of bicyclists, analysis of bicycle crash data is needed.

2.6.3 Safety Analysis

Analysis of crash trends, particularly at intersections or along corridors where most bicycle-motor vehicle related crashes occur, is one of several factors that are helpful when selecting and designing appropriate bikeways (see Section 2.5.1). By analyzing crash data, planners seek to target specific areas, understand the combination of conditions that could be creating high crash rates, profile corridors with high crash rates, compare the characteristics of one bikeway or potential bikeway to another, and focus attention most effectively. When using crash data to determine potential locations for improvements to reduce crash frequency or severity, it is important to review at least three years of data in order to account for anomalies that might occur in a single year. However, there are several limitations associated with crash data, as well as difficulties accessing data. They include:

- Bicycle-related crashes are generally underreported, especially those resulting in only minor injuries (10).
- Crash data fails to capture locations characterized by frequent near-misses.
- Bicycle count and exposure data is often lacking so it is difficult to calculate a crash rate.
- Crash databases typically only include bicycle-motor vehicle crashes; bicycle crashes that do not involve a motor vehicle (e.g., bicycle crashes influenced by poor surface conditions) and bicycle crashes that occur on shared use paths typically are not recorded in crash databases.
- Non-traditional data sources, such as hospital records, may help create a more comprehensive picture of crashes at a location or along a corridor, but are time consuming to collect and analyze (10).

- Existing data can be difficult to interpret, is often scattered through different systems and departments, and does not always yield enough crashes at a single location to produce statistically reliable results.
- If the data has not been sorted and mapped (such as through the *Pedestrian and Bicycle Crash Analysis Tool* described below), the process of analyzing data can involve significant effort.
- Depending upon the methods used to report bicycle crashes, it can be difficult to determine the actual location or cause of the crash, or to glean other helpful information (such as the age of the bicyclist, or whether the bicyclist was wearing a helmet).

Pedestrian and Bicycle Crash Analysis Tool

The *Pedestrian and Bicycle Crash Analysis Tool* (PBCAT) is a software product developed by the Federal Highway Administration that can be used to develop and analyze a database containing details associated with crashes between motor vehicles and pedestrians or bicyclists (5), (6). The database is typically built using detailed crash reports, which are generated by law enforcement agencies. PBCAT is a valuable tool, because in addition to identifying crash locations, it identifies the crash type (among a list of common reasons for crashes) and recommended countermeasures. During project planning, PBCAT can help to identify specific locations where additional design measures may be needed to reduce bicycle crash frequencies. More information on PBCAT can be found at the Pedestrian and Bicycle Information Center website (3).

Intersection Safety Index

The *Bicycle Intersection Safety Index* can be used to evaluate individual intersection approaches and crossings (1). This method helps determine which intersections or approach legs should be prioritized for further evaluation and may be helpful for prioritizing improvements to reduce crash frequency and severity. The safety index score is based on a number of measurable characteristics of the intersection (number of lanes, configuration of turn lanes, presence of bike lane, type of traffic control, and traffic volume among others). More information on the *Bicycle Intersection Safety Index* can be found at the Pedestrian and Bicycle Information Center website (4).

2.6.4 GIS-Based Data Collection/Network Planning

Geographic Information Systems (GIS) are a useful tool during the development of a bicycle network plan. GIS mapping enables the planner to combine a visual representation of a bicycle network with large quantities of background data that are needed for each individual roadway or pathway segment within the network. This enables a level of comprehensive analysis that is more efficient and enables the planner to track progress over time as roadways are improved with new bicycle facilities.

GIS mapping is typically used to catalogue essential data that is collected either from other databases (such as average daily traffic or traffic speeds), from aerial photography (such as presence of a shoulder on the roadway), or through field data collection (such as pavement condition or lane widths). GIS mapping can also be used to develop network maps that indicate the type of facility that is recommended for each roadway segment, as well as the proposed method of accomplishing the improvement (such as lane width reductions, addition of new pavement, etc.). Analysis in a GIS-based environment is needed in order to apply systematic evaluation tools such as Bicycle LOS. Crash data can also be analyzed efficiently in a GIS database by looking at different layers

of data; for example, a planner can view the locations of crashes on a map along with background information on each crash (fault, time of day, age of bicyclist, etc), and the map can display transit routes and stops.

2.6.5 Bicycle Travel Demand Analysis

Understanding existing and potential levels of bicycling is important in bikeway planning, particularly if there is a need to prioritize among many potential capital investments in bicycle infrastructure. Measuring demand is less important when opportunities arise to incorporate the needs of bicyclists in roadway resurfacing and rehabilitation projects, since routine accommodations for bicycling should be a standard operating procedure.

Evaluating bicycle travel demand shares some similarities to motor vehicle travel demand modeling. Both forecast future needs based on objective data inputs. However, bicycle travel demand should also account for latent demand (demand that is not apparent, but underlying) because existing conditions on a roadway are often a significant deterrent to travel. Therefore, bicycle travel demand methods make assumptions regarding how many people would choose to bicycle along a given corridor if conditions were conducive to bicycling. This is, at best, a very inexact science due to the many other casual factors involved in the decision to ride a bicycle. Those factors include the level of connectivity of the overall bicycle network, the availability of needed modal connections, availability of bicycle parking, typical trip lengths, and seasonal variations.

Compared to the vast amount of data collected for motor vehicles, there are virtually no widely-accepted sources of data available to evaluate the demand for bicycling. The *ITE Trip Generation Manual* (7) is widely used for data on trip generation, distribution, and other motor vehicle considerations; however, no such system exists for bicycles.

Choosing the correct tool to measure latent demand is dependent upon the study's purpose, availability of data, ease of analysis, desired accuracy, sensitivity to design factors, and whether the target of the evaluation is a single facility or an entire network. The tools vary in their qualitative versus quantitative approach to bicycle travel demand. The former depends on logic, examples, public input, and experience, while numbers will drive the latter. The qualitative approach generally involves less time and little data collection, while a quantitative approach may involve a high level of demographic data collection, user and household surveys, and proficiency with data and statistical analysis.

Types of travel demand analysis include:

- Comparison studies
- Sketch plan methods
- Market analysis/land use models
- Discrete choice survey models

Comparison Studies

This type of study involves comparing an existing facility with a proposed one. Adjustments for demographic and land use differences can refine the study. Steps include creating a list of comparable facilities and analyzing their similarities to the project location in terms of land use types, population density; income; availability of alternative routes; and presence of schools, retail shops, parks, employment, transit availability, and network continuity. When the comparison facility

is selected, counts conducted will determine the level of use. Adjusting for differences between the two locations completes the process. An ideal case study will have data taken before and after implementation to compare expected with actual increases in bicycling. This method works well when similar facilities for comparison exist within the region or market.

Sketch Plans

Sketch plan methods depend on rules of thumb and simple calculations to derive a demand estimate. For example, many communities need a demand estimate for a proposed trail or bikeway as part of a funding request. This method uses regional or national datasets including the National Census, Journey to Work data, or the National Household Trip Survey to establish a baseline of potential corridor users. Refinements are then made based on a variety of factors, such as percentage of students or youth within the corridor area, seasonal variations, bike-transit trips, or utilitarian trips. Sketch plan methods are typically less reliable than other methods, such as comparison studies or market analysis tools.

Market Analysis/Land Use Tools

Modeled after land-use projection tools, these GIS-based approaches analyze demographic and land-use conditions to evaluate existing conditions and project future potential bicycle demand across a zone or community. Factors analyzed include street connectivity, destination land uses, topography, barriers, crash statistics, demographic data, and bicycle network density and quality. By comparing these existing conditions to perfect or “ideal” conditions, practitioners can match improvements to areas with the highest potential demand.

Discrete Choice Models

Discrete choice models rely on surveys to ask people to catalogue their trips or predict their travel behavior if conditions were to change. They can be used to measure mode split based on the cost of travel time, fiscal cost, and convenience and can feed into regional travel models.

2.6.6 Cost-Benefit Analysis

Planning agencies can use cost-benefit analysis to quantify the impacts of bicycle facilities and discuss them in easily understood terms. Costs are generally divided into one-time capital construction costs and ongoing annual operating costs. Application of a cost-benefit methodology to bicycle projects can allow comparison to motor vehicle and transit projects. A comparative cost-benefit analysis of planned bikeways can help prioritize projects that will have a high benefit-to-cost ratio. A cost-benefit analysis tool for bicycle facilities can be found at the Pedestrian and Bicycle Information Center website (13).

2.6.7 Key Role of Public Input in the Process

All of the tools described above contribute to the planning process. However, no tool is a substitute for public input. Bicyclists in the community have the best knowledge of current conditions as well as specific opinions on areas that need new facilities or current facilities that need improvement. Opinions and feedback of interested users who do not ride extensively (or at all) should also be sought to provide input regarding which facilities or programs they need in order to start riding. Therefore, it is important to identify ways to gain feedback from both bicyclists and non-bicyclists in the community.

2.7 INTEGRATING BICYCLE FACILITIES WITH TRANSIT

The relative ease of access to transit often determines a traveler's decision whether or not to ride transit. Programs that educate the public about connections between bicycling and transit can promote both modes simultaneously. Linking bicycles with transit overcomes such barriers as lengthy trips, personal security concerns, poor weather, and riding at night or up hills.

Safe and convenient routes that serve bicyclists should be viewed as essential support strategies in increasing transit ridership. The “catchment” area for bicycle-to-transit trips is typically two to three miles. This is the area within which bicyclists will choose to bicycle to or from transit as a segment of a longer trip. There are four main components of bicycle-transit integration:

1. Facilitating bicycle access on transit vehicles;
2. Offering bicycle parking at transit locations;
3. Improving bikeways to transit; and
4. Promoting usage of bicycle and transit programs.

Bicycle transport on transit vehicles should include access during all hours of operation with enough spaces to meet the demand. A number of parking and bicycle-on-transit storage systems are available and in use. Transit stations should allow easy access for bicyclists; this may include installation of an elevator, retrofitting a staircase with a bicycle wheel channel, or providing access by ramps.

On highways and streets, combined bicycle and transit facilities, such as shared lanes or bike lanes adjacent to transit corridors, sometimes create design challenges for practitioners. As the bus pulls into a conventional, sidewalk stop, it crosses the area where bicyclists are most likely to ride (whether there is a designated bike lane or not). Bicyclists then typically pass the bus on the left. Once the bus has completed on- and off-boarding passengers, it crosses into the travel lane and the cycle repeats itself at each subsequent stop. This “leap-frog” effect is a fact of urban bicycle travel and is sometimes difficult to avoid; however, effective countermeasures include proper pavement markings for bike lanes at bus stops, provision of bike lanes on the left-hand side of the roadway on one-way streets, combined bus/bike lanes, added training for bus drivers, and educational materials for bicyclists (which can be displayed on the outside of the bus).

Bicycle parking at transit stops and stations should be well promoted and secure, with enough spaces available to meet the demand. Ideally, parking will include both short-term and long-term facilities.

Bicycle and transit integration continues to expand. Other areas of potential growth in bicycle and transit integration include:

- Emerging ways of accommodating bicycles on transit, such as high-capacity, on-bus bicycle racks, bicycle-on-vanpool services, and new methods for storing bicycles on rail cars.
- Emerging techniques for storing bicycles at transit hubs, such as high-capacity bike parking at transit stations and full-service staffed bicycle parking.
- Better access for bicyclists within transit stations and wayfinding signs for navigation to and from transit stations.
- More on-road bicycle and transit facilities, such as shared bus/bicycle streets and lanes.

- New methods of bicycle and transit education, such as on-bus bicycle rack demonstrations for bicyclists and share-the-road training for bus drivers.
- More coordination with local jurisdictions to provide bicycle access improvements in areas around transit stops and including bicycle access information on transit maps.
- Adjusting routes to maximize bicycle usage.
- New performance measures for evaluating the effectiveness of bicycle services.

Many transit agencies throughout the United States have participated in local bicycle planning efforts and interface with bicycle advocacy organizations. Many view efforts to better accommodate bicyclists as positive public marketing components and as a method of increasing the viability of transit (12). Integrating transit and bicycling involves bringing bicycle advocates, transit providers, local agencies, and state DOTs together to plan routes, intersections, and facilities jointly to address all potential transportation issues. This allows the owner and operator of the transportation facilities to incorporate bicycle and transit needs simultaneously to decrease the likelihood that the different modes will conflict with each other.

REFERENCES

1. Carter, D. L., W. W. Hunter, C. V. Zegeer, J. R. Stewart, and H. F. Huang. *Bicyclist Intersection Safety Index*. In *Transportation Research Record*, Vol. 2031. Washington, DC, 2007.
2. FHWA. *Manual on Uniform Traffic Control Devices*. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2009.
3. FHWA. *The Pedestrian and Bicycle Crash Analysis Tool* (PBCAT). Federal Highway Administration, U.S. Department of Transportation and the University of North Carolina Highway Research Center. <http://www.walkinginfo.org/facts/pbcats/index.cfm>
4. FHWA. *Pedestrian and Bicyclist Intersection Safety Indices*. Federal Highway Administration, U.S. Department of Transportation and the University of North Carolina Highway Research Center. <http://www.walkinginfo.org/library/details.cfm?id=2802>
5. Harkey, D. L., J. Mekemson, M. C. Chen, and K. Krull. *Pedestrian and Bicycle Crash Analysis Tool*. FHWA-RD-99-192. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1999.
6. Harkey, D. L., S. Tsai, L. Thomas, and W. W. Hunter. *Pedestrian and Bicycle Crash Analysis Tool (PBCAT): Version 2.0 Application Manual*. FHWAHRT-06-089. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2006.
7. ITE. *ITE Trip Generation Manual*, Eighth Ed. Institute of Transportation Engineers, Washington, DC, 2008.
8. ITE. *National Bicycle and Pedestrian Documentation Project*. Institute of Transportation Engineers, Washington, DC. <http://bikepeddocumentation.org>

Chapter 2: Bicycle Planning

9. Landis, B. *Real-Time Human Perceptions: Toward a Bicycle Level of Service*. In *Transportation Research Record 1578*. TRB. National Research Council, Washington, DC, 1997.
10. Stutts, J. C. and W. W. Hunter. *Injuries to Pedestrians and Bicyclists: An Analysis Based on Hospital Emergency Department Data*. FHWA-RD-99-078. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1997.
11. TRB. *Highway Capacity Manual*. Transportation Research Board, Washington, DC, 2010.
12. TRB. *Synthesis 62: Integration of Bicycles and Transit: A Synthesis of Transit Practice*. Transportation Research Board, Transit Cooperative Research Program, TRB, Washington, DC, 2005.
13. University of North Carolina Highway Research Center. *Benefit–Cost Analysis of Bicycle Facilities*. <http://www.bicyclinginfo.org/bikecost>