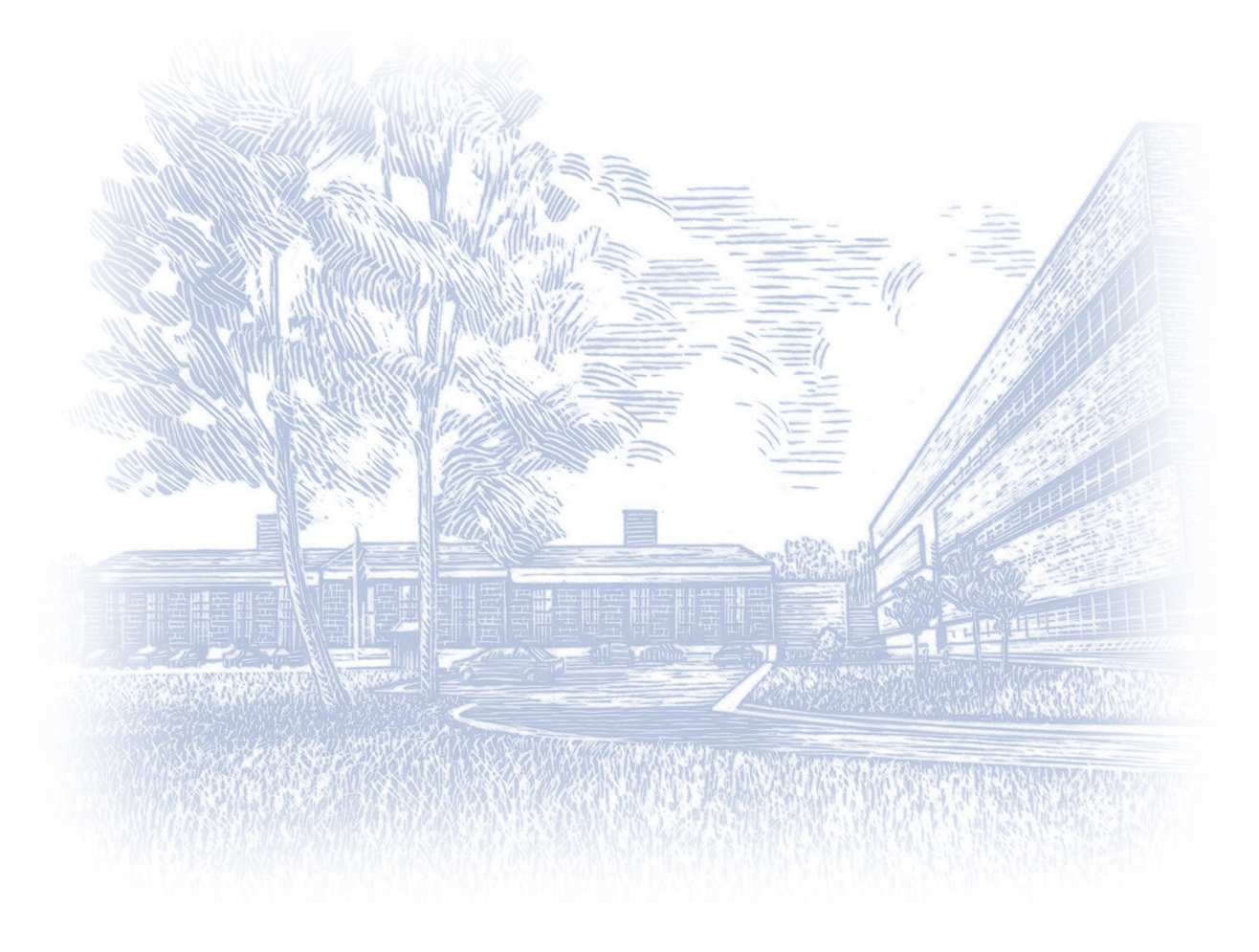
Guidebook on Methods to Estimate Non-Motorized Travel: Overview of Methods

Publication No.: FHWA-RD-98-165 **July 1999**



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Federal Highway Administration

Federal Highway Administration
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Foreword

This two-volume guidebook describes and compares the various methods and tools that can be used to forecast non-motorized travel demand or that otherwise support the prioritization and analyses of bicycle and pedestrian facilities. The guidebook is intended to be used by bicycle and pedestrian planners, technical staff, researchers, advocates, and others who may wish to estimate bicycle and pedestrian travel demand or to prioritize bicycle and pedestrian projects.

This second volume, *Supporting Documentation*, gives details on each method, including purpose, structure, input / data needs, assumptions, and real-world applications. This volume contains an extensive annotated bibliography of references on demand forecasting methods, supporting tools and techniques, and factors influencing the choice to walk or bicycle, as well as potential contacts in this field. The other volume, *Overview of Methods*, provides an overview of each of nineteen methods appropriate for forecasting and/or understanding pedestrian and bicycle travel demand.

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Technical Report Documentation Page

1. Report No. FHWA-RD-98-165	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle GUIDEBOOK ON METHODS TO ESTIMATE NON-MOTORIZED TRAVEL: OVERVIEW OF METHODS		**5. Report Date** July 1999
		6. Performing Organization Code
7. Author(s) WL Schwartz, CD Porter, GC Payne, JH Suhrbier, PC Moe, WL Wilkinson III		8. Performing Organization Report No.
9. Performing Organization Name and Address Cambridge Systematics, Inc. 150 Cambridge Park Dr., Ste 4000 Cambridge, MA 02140 Bicycle Federation of America 1506 21st St., NW, Ste. 200 Washington, DC 20036		**10. Work Unit No. (TRAIS)** 3A4B
		11. Contract or Grant No. DTFH61-92-C-00138
12. Sponsoring Agency Name and Address Federal Highway Administration Turner-Fairbanks Highway Research Center 6300 Georgetown Pike McLean, VA 22101-2296		**13. Type of Report and Period Covered** Final Report July 1, 1997 - February 28, 1999
		14. Sponsoring Agency Code
15. Supplementary Notes Contracting Officer's Technical Representatives (COTR's): Carol Tan Esse and Ann Do		
16. Abstract This guidebook provides a means for practitioners to better understand and estimate bicycle and pedestrian travel and to address transportation planning needs. The guidebook describes and compares the various methods that can be used to forecast non-motorized travel demand or that otherwise support the prioritization and analyses of non-motorized projects. These methods are categorized according to four major purposes: (1) demand estimation; (2) relative demand potential; (3) supply quality analysis; and (4) supporting tools and techniques. Discrete choice models, regional travel models, sketch plan methods, facility demand potential, bicycle compatibility measures, and geographic information systems are among the methods and tools described. *Overview of Methods* provides a concise overview for each available method, including some typical applications, pros and cons, and a quick reference guide on ease of use, data requirements,		

sensitivity to design factors, and whether widely used. In addition, it discusses general issues for consideration in forecasting non-motorized travel demand, such as the dimensions of travel behavior and factors influencing bicycling and walking, and identifies future needs in this area.

Supporting Documentation provides substantially more detail on the methods including purpose, structure, input/data needs, assumptions, and real-world applications. It also contains an extensive annotated bibliography of references on demand forecasting methods, supporting tools and techniques, and factors influencing the choice to walk or bicycle, as well as potential contacts in this field.

17. Key Words:	**18. Distribution Statement**
Bicycle, pedestrian, travel demand, forecasting methods, estimate.	No restrictions. This document is available to the public through the National Technical Information Services, Springfield, VA 22161

19. Security Classif.(of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) **Reproduction of form and completed page is authorized**

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Introduction

1.1 Purpose of Guidebook

The need for improved conditions for bicyclists and pedestrians has received increasing attention in recent years in transportation planning circles. Planners are recognizing a growing popular interest in bicycling and walking for health and recreation, the desire to promote alternatives to automobile travel for environmental reasons, and the need to provide safe and convenient travel options for the entire population. At the same time, the question of how many people will actually use new or improved bicycle and pedestrian facilities is gaining attention and importance. Planners and policy makers need to be convinced that the benefits of improvements are worth the costs. Furthermore, they want to know where to spend limited resources to get the most "bang for the buck" as measured by benefits to users.

This guidebook was developed in response to the need to predict bicycle and pedestrian or "non-motorized" travel. The guidebook is intended to provide a means of addressing the following related questions:

- If we build a new bicycle or pedestrian facility, how many people will use it?
- If we improve an existing facility or network, how many additional people will choose to walk or bicycle?
- What types and combinations of improvements will have the greatest impact on increasing non-motorized travel?
- How will improvements to non-motorized travel conditions affect motor vehicle use?

The guidebook describes and compares the various methods that have been developed to predict future levels of bicycle and pedestrian travel, i.e., "travel demand." The guidebook also discusses other quantitative methods that support demand forecasting but do not actually predict future demand. These include (1) analyses of the *potential* market for bicycling and walking; (2) " level of service" measures and "environment factors" which describe the quality of the *supply* of bicycle and pedestrian facilities; and (3) supporting tools and techniques such as Geographic Information Systems (GIS) and preference surveys. The guidebook is intended to be used by bicycle and pedestrian planners, technical staff, researchers, advocates, and others who may wish to apply these methods to estimate bicycle and pedestrian travel demand and/or to prioritize bicycle and pedestrian projects.

Figure 1.1: If We Build a New Bicycle or Pedestrian Facility, How Many People Will Use It?

While all of these methods focus on non-motorized travel, some important distinctions in scope can be identified. Some methods are directed specifically at either bicycle or pedestrian travel, while others are generally relevant to both. Some methods focus on demand for a specific facility, such as a bicycle lane or shared-use trail, while others focus on travel over an entire area, such as a city or census tract. Finally, the methods differ in the extent to which they consider trips made for recreational, as opposed to utilitarian, purposes(2).

The guidebook is based on an extensive international review of both published and unpublished sources. Most of the methods were developed in the United States and Europe, but examples are also included from Japan, Australia, and South America. While it is doubtless that some relevant sources and methodologies have been overlooked, the guidebook should serve as a reasonably complete review of methods currently available to the bicycle and pedestrian planner.

1.2 The Importance of Forecasting Demand

There are many compelling reasons both to apply existing methods of forecasting bicycle and pedestrian travel and to advance the state-of-the-practice in this area. If properly done, demand forecasting has a variety of uses including:

- Estimating the benefits of a proposed project, such as number of users served, reductions in automobile emissions and energy consumption, or time and cost savings to travelers;
- Prioritizing projects based on the greatest benefit to existing users or on the greatest payoff in attracting new bicyclists or walkers;
- Planning bicycle or pedestrian networks and identifying and correcting deficiencies in existing networks, based on desired travel patterns and facility characteristics; and
- Planning for bicycle and pedestrian safety by developing exposure information for crash/safety models. In the United States in particular, two recent developments underscore the importance of quantifying demand:

- The 1994 U.S. Supreme Court *Dolan vs. Tigard* decision. This decision mandates that local jurisdictions quantify proposed bicycle project benefits when the project involves private land dedications under master plans.
- The 1998 passage of the Transportation Equity Act for the 21st Century (TEA-21). TEA-21 continues and expands provisions of its predecessor, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), to improve facilities and safety for bicycles and pedestrians. TEA-21 places an emphasis on quantifying the air quality and congestion alleviation benefits of projects, including bicycle and pedestrian projects to receive funding under the Congestion Mitigation and Air Quality (CMAQ) program(3). TEA-21 also adds "bicycle transportation and pedestrian walkways" to the list of eligible projects for National Highway System Funds and expands eligibility for funding under other programs(4). Estimates of the benefits of bicycle and pedestrian projects will be useful in competing for funding under these programs.

All of these reasons underscore the need to apply available demand forecasting methods and to continually advance these methods. Forecasts of demand provide a much needed complement to other considerations, such as improvements to safety and convenience for existing users, in planning bicycle and pedestrian facilities.

Nevertheless, many people in the bicycle and pedestrian planning and advocacy communities are skeptical of demand forecasting, and raise valid points about its limitations. Skeptics argue that the factors influencing non-motorized travel are largely attitudinal and cannot be easily described or quantified in models. They further believe that comprehensive efforts to improve facilities, policies, and social attitudes toward bicycling and walking are required, and that such measures would result in significant mode shifts that would not be predicted by existing models. Others take the philosophical viewpoint that conditions for bicyclists and pedestrians should be improved simply as a matter of fairness to existing users, regardless of whether new users would be attracted. Still others are concerned that a focus on predicting demand will divert much needed energy away from the actual implementation of bicycle and pedestrian improvements.

These arguments, although valid, should not detract from the usefulness of forecasting bicycle and pedestrian travel demand. A simple "if you build it, they will come" attitude is not sufficient given that resources for implementing projects are limited. Existing forecasting methods, even given their limitations, can help allocate resources toward the *most* beneficial projects and can help determine which improvements will attract the most new users. Furthermore, future developments have the potential to greatly increase the accuracy and usefulness of these methods. While qualitative assessment based on experience and judgment will continue to play a key role in identifying projects with the greatest benefits, quantitative methods can become increasingly useful in providing information for planning and decision making.

1.3 How to Use This Guidebook

This guidebook consists of two parts: *Overview of Methods* and *Supporting Documentation*. *Overview of Methods* provides a concise overview of the available methods and of general issues for consideration in forecasting demand for non-motorized travel. *Supporting Documentation* provides substantially more detail on the methods described in the guidebook and identifies sources and real-world applications for the methods.

The contents of *Overview of Methods* include:

- Section 2.0- An introduction to non-motorized travel demand forecasting, including ways in which travel behavior can change, general approaches to travel demand forecasting, factors specifically

influencing bicycle and pedestrian travel, and differences in forecasting bicycle vs. pedestrian travel.

- Section 3.0 - An introduction to 11 classes of methods, and a one-page overview of each which includes a description, typical applications, advantages, and disadvantages. Section 3.0 also contains a summary of key characteristics and uses of each method as well as a guide to choosing an appropriate method for a specific purpose.
- Section 4.0 - A summary of this guidebook and a discussion of the limitations of existing forecasting methods and future research needs for improving non-motorized demand forecasting.

Supporting Documentation includes:

- Section 1.0 - A description of the research methodology and a categorization of the methods according to their major purposes.
- Section 2.0 - An in-depth, structured description (e.g., purpose, structure, inputs/data needs, assumptions) of each method along with evaluative criteria. Multiple variations on some methods are included, as well as specific examples and real-world applications.
- Section 3.0 - An annotated bibliography of references on demand forecasting methods, supporting tools and techniques, and factors influencing the choice to walk or bicycle.
- Section 4.0 - A list of individuals and organizations contacted in developing this guidebook.

[1]Bicycling and walking are the most common forms of non-motorized travel in most countries and the term "non-motorized" is used herein to refer collectively to bicycle and pedestrian travel. Nevertheless, the term "non-motorized" could also refer to many other forms of travel such as in-line skating, skateboarding, or horseback riding. The methods discussed in this document may be applicable to these other forms of non-motorized travel although specific applications have not been identified.
[2]A significant weakness of existing methods is that none differentiate explicitly between utilitarian and recreational travelers. The two travel markets have very different characteristics and needs, and a greater focus on these distinctions would help improve the accuracy and usefulness of travel forecasting methods in the future.
[3]Title I, Sections 1110.
[4]Title I, Sections 1106 and 1202.

Introduction To Non-Motorized Travel Forecasting

2.1 Dimensions of Travel Behavior

The objective of travel demand forecasting is to predict changes in travel behavior and transportation conditions as a result of proposed transportation projects, policies, and future changes in socioeconomic and land use patterns. For non-motorized forecasting in particular, the objective is generally to predict the change in the number or characteristics of bicycle, pedestrian, or vehicle-trips as a result of facility improvements or policy changes which are designed to make bicycling or walking more attractive. In addition to affecting overall levels of non-motorized travel, changes in non-motorized travel conditions may affect travel behavior in a variety of ways:

- Trip making. A high-quality walking and bicycling environment is likely to increase total person travel, while a poor quality environment may lead some people to choose not to travel.
- Trip location. A high-quality pedestrian and bicycling environment may cause changes in the choice of destinations, e.g., diverting travel from more distant automobile-accessible areas to closer-by pedestrian-oriented locations.
- Mode choice. Changes in the quality of the travel environment may spur changes not only in the number of people who walk and bicycle, but also decrease the propensity to use public transportation, rideshare, or to drive an automobile.
- Route choice. Changes in the quality of the travel environment may spur changes in the use of various routes by pedestrians and bicyclists.
- Trip scheduling. The quality of the travel environment may vary by time-of-day (e.g., with changes in on-street parking regulations or non-peak-period traffic restrictions) and may also affect trip scheduling of motorized travel. For example, bicyclists may choose to make trips when there is less motor vehicle traffic.
- Land use. Changes in the travel environment may spur changes in land use over a period of several years or more, with some locations becoming more or less desirable for certain types of uses. For example, pedestrian-friendly urban environments may be more attractive, thus increasing development in these areas.
- Distribution of effects. Changes in the pedestrian and bicycling environment are likely to have widely varying effects on different segments of the population. For example, some types of improvements will primarily benefit recreational users while others will benefit those for whom bicycling or walking is the primary means of transportation.

Figure 2.1: **A High-Quality Walking Environment May Cause Changes in the Choice of Destinations**

2.2 Perspectives on Modeling Travel Behavior

A variety of forecasting methods has been developed to predict changes in travel behavior. Forecasting methods are generally founded on theoretical models and then verified by empirical studies, which describe how people change their behavior in response to changes in the major factors which influence this behavior.

Travel behavior, including non-motorized behavior, may be studied or modeled from two perspectives:

- The aggregate perspective. Aggregate studies look at travel from an areawide perspective. They attempt to relate characteristics of an area (e.g., population, employment, or average income) to travel characteristics of that area (e.g., average number of trips per household, or the number or percent of trips made by foot or bicycle). In the context of non-motorized travel, these studies may also look at characteristics of specific facilities (e.g., roadway and sidewalk width or type) in conjunction with characteristics of the surrounding area (e.g., population density, or number of students) to predict the number of people using the facility.
- The disaggregate or individual perspective. Disaggregate studies look at travel decisions from the perspective of the individual. The individual's personal characteristics (e.g., age, gender, attitudes, beliefs) interact with the travel options available to them (e.g., time, cost, comfort of competing modes). To predict overall demand, models of individual behavior are applied across a population with known characteristics.

Each approach has its advantages and disadvantages. Aggregate-level methods tend to be relatively easy to apply, with readily available data sources and computational methods, and can be useful for sketch-planning purposes. Disaggregate-level methods are more complicated to develop but can be much more effective at predicting behavior changes. This is because they explain individual choices rather than making generalizations based on overall population characteristics.

2.3 The Four-Step Urban Transportation Planning Process

Variations on both the aggregate and disaggregate approaches can be developed and applied as stand-alone travel demand forecasting methods, appropriate for specific purposes. Alternatively, a set of methods can be applied in conjunction with each other to create a larger modeling framework. The four-step Urban Transportation Planning Process (UTPP) (Weiner, 1997), first developed in the 1950s to forecast automobile travel and now applied in urban areas throughout the world, is an example of such a framework. To predict how travel patterns will change as a result of future changes in land use patterns and the transportation system, this framework integrates models of various aspects of travel behavior (e.g., trip-making or mode choice) with spatial information on land use patterns and the transportation network.

The UTPP is important to understand because it is widely used in transportation planning and because of its potential for integrating bicycle and pedestrian with automobile and transit travel forecasting. The basis for UTPP models is the division of the urban area into traffic analysis zones (TAZs), which may correspond to census tracts, and the definition of a network of transportation facilities connecting the zones (figure 2.1). The network is described by the time and cost of travel, for each mode, between each pair of zones. Inputs include proposed future transportation networks and forecast population and employment characteristics by zone. A four-step process is then used to forecast travel:

1. Trip generation - Total trips generated by persons that start and end in each zone are predicted, based on the population, employment, household characteristics, etc., of the zone;

2. Trip distribution - The trips are distributed among pairs of zones, usually based on a gravity model which distributes trips in inverse proportion to the distance between zones;

3. Mode choice - The trips are allocated among the available travel modes, based on relative characteristics (usually time and cost) of the modes; and

4. Network assignment - The trips are assigned to specific links (road segments) in the transportation network, generally based on the shortest time path between two zones.

The different stages of the process may include both aggregate and disaggregate behavior models. In addition, these models have sometimes been modified to incorporate additional travel behavior factors, such as feedback from later steps to earlier steps (e.g., congestion influencing trip generation and mode choice) or variations in travel by time of day.

The UTPP framework has primarily been applied to automobiles and transit but is increasingly being modified to include bicycles and pedestrians. Non-motorized modes can be incorporated in the models in various ways. For example, a bicycle or pedestrian network can be defined. Bicycling and walking can be included as modes in the mode choice model. The advantages and limitations of this framework for modeling non-motorized travel are discussed more fully under the specific entries on "Regional Travel Models"in Section 3.0 and in the *Supporting Documentation*.

2.4 Factors Specifically Influencing Bicycling and Walking

Standard travel demand modeling procedures generally predict total trip-making and mode choice based on a limited number of variables, such as household characteristics and the time and cost of competing

modes. These factors, however, only partially explain the decision to bicycle or walk. Development of non-motorized travel forecasting methods requires consideration of a range of factors specific to non-motorized modes. From an individual perspective, personal factors, environmental factors, and trip characteristics interact to determine whether a trip is made by bicycle, foot, or other mode. The specific factors which are important vary depending on whether the mode being discussed is bicycling or walking.

If behavior studies are performed from an aggregate-level perspective, factors must be identified which proxy for the personal and environmental factors seen from the individual's perspective. For example, median income of an area may represent household income, or average vehicle travel speeds and parking costs in a city may serve as a proxy for the time and cost of travel by automobile for a particular trip. Figure 2.2 presents a framework for how a general set of factors, including facility design factors, interact to affect non-motorized travel levels, both overall and for specific facilities (links) in a network. These factors are described in table 2.1.

Regardless of whether models are developed at the disaggregate or aggregate level, it is important to remember that decision making ultimately occurs at the individual level and that a forecasting procedure should approximate the individual decision-making process as closely as possible.

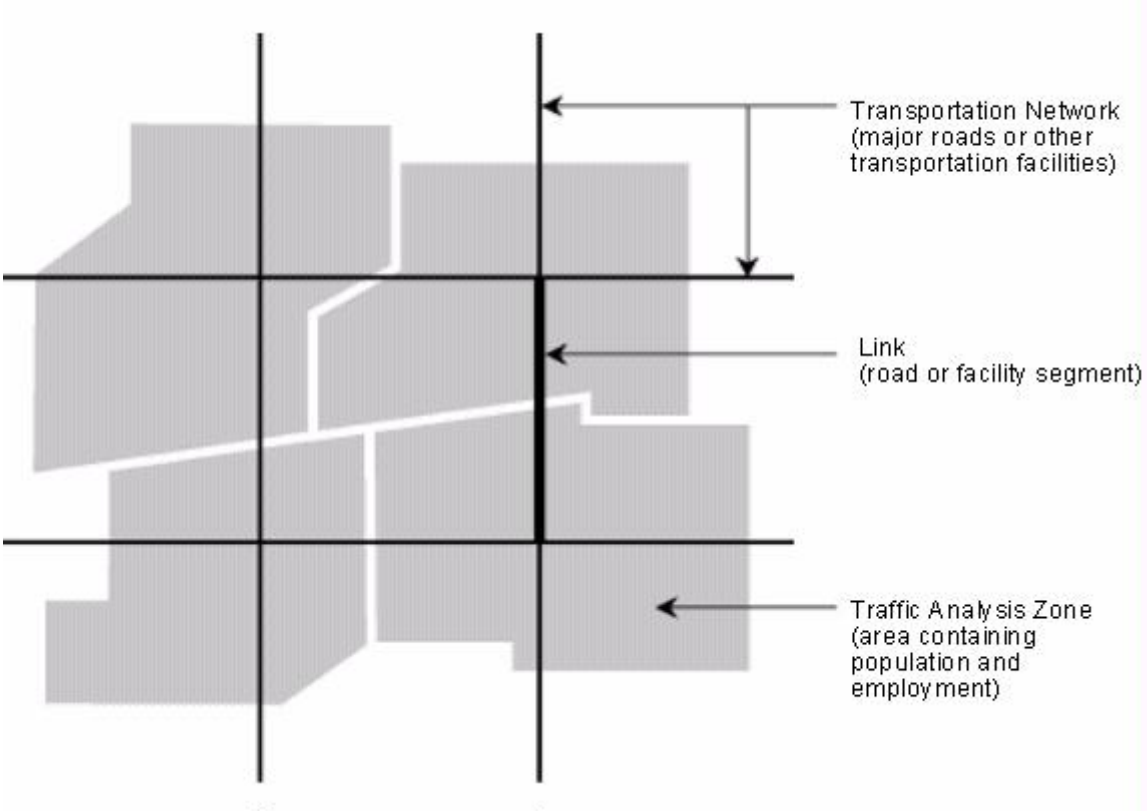


Figure 2.2: Structure of Regional Travel Model

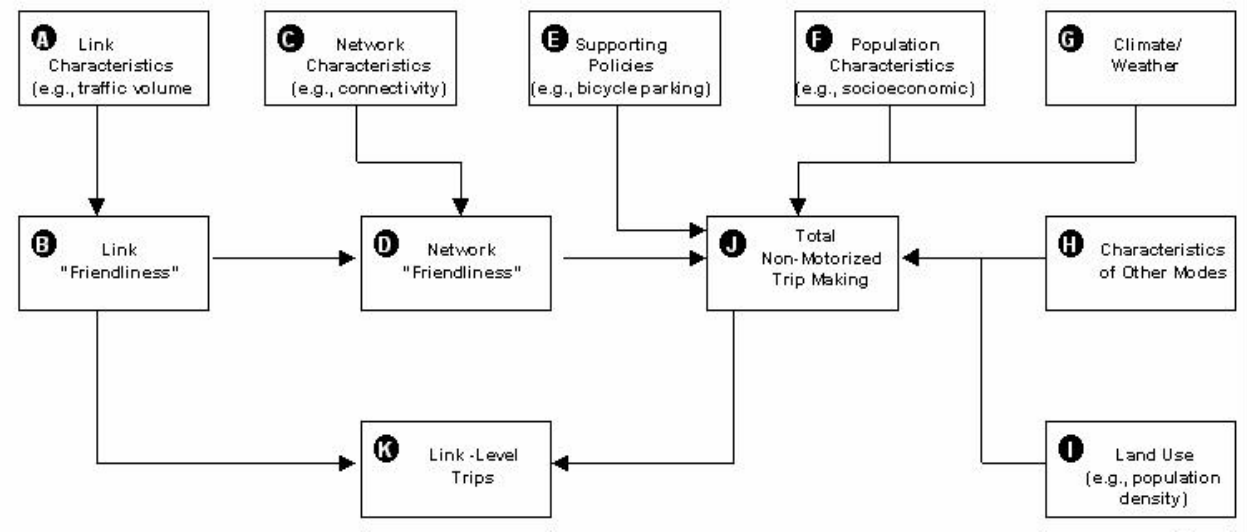


Figure 2.3: Relationship of Factors Influencing Non-Motorized Travel

Table 2.1 - Description of Factors Influencing Non-Motorized Travel.

Box	Variable	Description
A.	Link Characteristics	Measurable characteristics of a link in a road or path network (e.g., traffic volume, lane width, or pavement quality).
B.	Link "Friendliness"	The overall acceptability of a link as a bicycle or pedestrian route - a function of link characteristics. Also varies by user characteristics (e.g., experienced vs. novice bicyclist).
C.	Network Characteristics	Characteristics of a network of links (e.g., connectivity) which determine its overall acceptability or "friendliness" to the user.
D.	Network "Friendliness"	A general measure of how acceptable the local road/path network is for bicycling or walking.
E.	Supporting Policies	Other programs, policies, facilities, etc., which affect the acceptability of bicycling or walking (e.g., bicycle parking, showers/lockers, and educational programs).
F.	Population Characteristics	Characteristics of the local population which relate to likelihood of bicycling or walking (e.g., socioeconomic characteristics, or attitudes).
G.	Climate/Weather	General propensity to walk or bicycle, as a function of climate/weather. This might be considered a constant for a given area/region.
H.	Characteristics of Other Modes	Relative travel times and costs of bicycling or walking vs. other modes, as well as safety, comfort, or other factors which influence choice of mode. Policy variables might include parking pricing, transit service improvements, etc.
I.	Land Use	Density and distribution characteristics of population, employment, shopping, and other activities which affect where people travel, how many trips are generated, trip length, etc.

J.	Total Non-Motorized Trip Making	Overall level of non-motorized trip making in an area as a result of the above factors.
K.	Link-Level Trips	Non-motorized trips on a specific facility or link as a function of local trip generation/distribution characteristics and route choice based on link "friendliness."

Finally, it should be kept in mind that the factors shown in table 2.1 may influence an individual's travel behavior decisions at a variety of stages, not just on a trip-by-trip basis. For example, the individual must first decide to even consider bicycling or walking as a viable travel option. Only when this is done does the question of whether to bicycle or walk for a particular trip become relevant.

2.5 Differences in Forecasting Bicycle vs. Pedestrian Travel

Bicycle and pedestrian travel are collectively referred to throughout this guidebook as non-motorized travel, and each class of forecasting methods discussed is generically applicable to both. Nevertheless, significant differences exist between the two modes, both in terms of travel characteristics and factors influencing the decision process. These differences are apparent in the specific examples of the methods, most of which were developed for either bicycles or pedestrians, as discussed in the supporting documentation of this guidebook. Some of the most significant differences include:

Pedestrian trips are generally shorter than bicycle trips. This is important because appropriate analysis methods may depend on the spatial scale of analysis. For example, an analysis of pedestrian conditions may consider every block in a small area, while an analysis of bicycle conditions may focus on through bicycle routes.

A large percentage of pedestrian trips are actually trips to access other modes, including the automobile or transit. Bicycle trips, in contrast, are primarily stand-alone trips (although bicycle access to transit is an important type of non-motorized travel). Therefore, local pedestrian travel will largely result from automobile and transit trips rather than replacing these trips, and modeling transit vs. auto mode choice will be relevant to predicting pedestrian travel. Conversely, pedestrian access factors will be important in predicting transit vs. auto mode choice, since the quality of the environment for walking may influence the decision to use transit.

Perhaps most significantly, the decision to ride a bicycle involves a greater conceptual leap than the decision to walk. Everyone is a pedestrian, but not everyone is a bicyclist. Insights from the public health and social marketing fields suggest that the decision to even consider riding a bicycle is a multi-staged process involving a variety of interacting personal, social, and environmental factors. The choice to bicycle for a particular trip depends not only on the specific characteristics of that trip but on the individual's attitude toward and willingness to bicycle. While attitudinal research gives important insights into pedestrian and transit travel choices as well, its implications are perhaps most significant for bicycle travel.

Guide To Available Methods

3.1 Overview of Methods

This section describes eleven types of quantitative methods that can be used to forecast non-motorized travel demand or that otherwise support the prioritization and analysis of non-motorized projects. These methods are categorized according to four major purposes, as shown and described in table 3.1. Figure 3.1 illustrates how these four purposes relate to each other to support demand estimation. Following the overview, section 3.2 summarizes key characteristics of the methods. Section 3.2 also suggests appropriate methods according to specific purpose such as forecasting the number of new users of a bicycle/pedestrian trail.

Table 3.1 Categorization of Available Methods.

Purpose	Method	Description
Demand Estimation.		Methods that can be used to derive quantitative estimates of demand.
	Comparison Studies	Methods that predict non-motorized travel on a facility by comparing it to usage and to surrounding population and land use characteristics of other similar facilities.
	Aggregate Behavior Studies	Methods that relate non-motorized travel in an area to its local population, land use, and other characteristics, usually through regression analysis.
	Sketch Plan Methods	Methods that predict non-motorized travel on a facility or in an area based on simple calculations and rules of thumb about trip lengths, mode shares, and other aspects of travel behavior.
	Discrete Choice Models	Models that predict an individual's travel decisions based on characteristics of the alternatives available to them.
	Regional Travel Models	Models that predict total trips by trip purpose, mode, and origin/destination and distribute these trips across a network of transportation facilities, based on land use characteristics such as population and employment and on characteristics of the transportation network.

Table 3.1 Categorization of Available Methods (continued)

Purpose	Method	Description
Relative Demand Potential		Methods that do not predict actual demand levels, but which can be used to assess potential demand for or relative levels of non-motorized travel.
	Market Analysis	Methods that identify a likely or maximum number of bicycle or pedestrian trips that may be expected given an ideal network of facilities.
	Facility Demand Potential	Methods that use local population and land use characteristics to prioritize projects based on their relative potential for use.
Supply Quality Analysis		Methods that describe the quality of non-motorized facilities (supply) rather than the demand for such facilities. These may be useful for estimating demand if demand can be related to the quality of available facilities.
	Bicycle and Pedestrian Compatibility Measures	Measures that relate characteristics of a specific facility such as safety to its overall attractiveness for bicycling or walking.
	Environment Factors	Measures of facility and environment characteristics at the area level that describe how attractive the area is to bicycling or walking.
Supporting Tools and Techniques		Analytical methods to support demand forecasting.
	Geographic Information Systems	Emerging information management tools, with graphic or pictorial display capabilities, that can be used in many ways to evaluate both potential demand and supply quality.
	Preference Surveys	Survey techniques that can be used on their own to determine factors that influence demand, and that also serve as the foundation for quantitative forecasting methods such as discrete choice modeling.

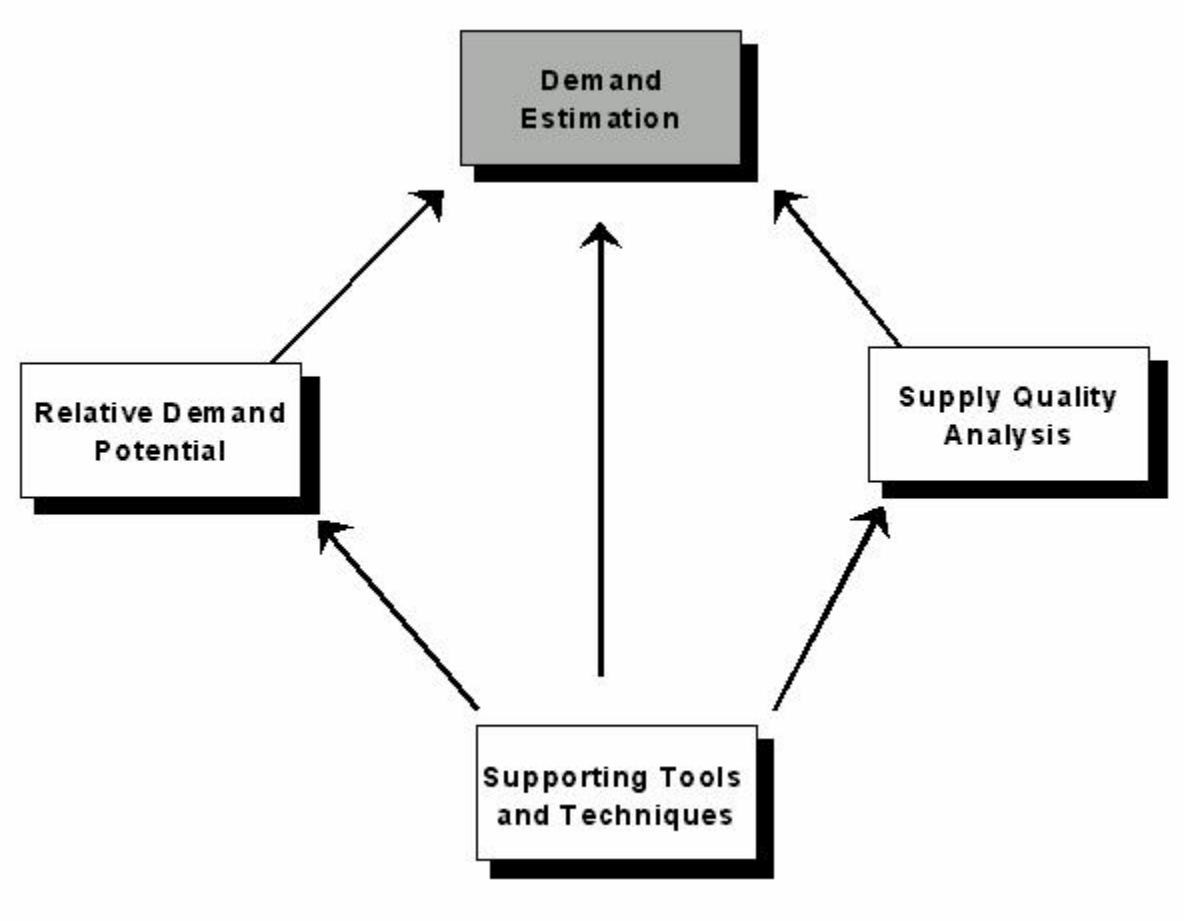


Figure 3.1: Relationship of Methods Supporting Demand Estimation

For each of the 11 methods, a one-page summary is provided which includes an overview of the method, typical applications, advantages and disadvantages, and one or two real-world examples. Each summary also includes a quick reference guide, which provides a subjective rating of the method for five factors as described below. The ratings are provided only as a general assessment of the method's capabilities, and the quality of specific applications of each of these methods may vary. More detail on the specific ratings for each method is given in table 3.2, which follows the individual method overviews.

The five factors and criteria used to rate the factors are as follows:

- Ease of Use - "Easy" if the method could be applied by a layperson with basic research and data analysis capabilities; "difficult" if the method requires extensive specialized training to understand and apply.
- Data Requirements - "Minimal" if the method primarily uses existing data that can easily be collected and evaluated; "extensive" if it requires significant new data collection efforts.
- Accuracy - "Low" if forecasts have not corresponded well to observations; "high" if forecasts have been found to closely reflect actual demand.

- Sensitivity to Design Factors - "Low" if the method cannot assess the impacts of specific design factors on demand; "high" if the method can assess the impacts of multiple factors and the interactive effects of these factors.
- Widely Used - "No" if only a few applications have been identified; "yes" if the method has been widely used in practice.

Finally, the overview page indicates whether the method can be used to predict demand at the facility level, area/regional level, or both. Facility-level methods predict the number of users of a specific facility such as a non-motorized trail, bicycle lane, or pedestrian bridge. Area-level methods predict total bicycle or pedestrian trips for an entire area such as a city, census tract, or other geographic area.

Section 2.0 of *Supporting Documentation* presents a more indepth, structured description of each method as well as specific variations and applications of the method. Section 3.0 contains bibliographic references for the real-world examples highlighted in this section. Section 4.0 identifies useful contacts, including individuals and organizations, in the area of non-motorized travel estimation.

Demand Estimation:

Aggregate Behavior Studies

☐ Facility Level

☒ Area/Regional Level

Quick Reference Guide

Ease of Use:	easy	difficult
Data Requirements:	minimal	extensive
Accuracy:	low	high
Sensitivity to Design Factors:	low	high
Widely Used:	no	yes

Overview	The simplest form of demand forecasting, comparison studies compare usage levels before and after a change (such as a facility improvement), or compare travel levels across facilities with similar characteristics. The results of a comparison study can be used to predict the impacts on non-motorized travel of a similar improvement in another situation, assuming that all other influencing factors are roughly the same between the two situations.
Typical Applications	Before-and-after studies have been widely used in Europe to assess the mode choice impacts of programs to improve bicycle and pedestrian facilities. Some studies have focused on the change in mode split for an urban area as a whole, after a city-wide pro- gram of improvements. Others have focused on specific facilities, conducting user counts both before and after an improvement to the facility. Comparison studies have also been performed in the United States, using counts from existing trails to forecast the number of users on a new trail.
Advantages	This method is simple to understand and relatively easy to apply.
Disadvantages	Comparison studies only provide a rough estimate of demand for proposed facilities. Unless very carefully designed, comparison studies may not control for other factors unrelated to the facility improvement which may affect usage levels. It is often difficult to find truly comparable facilities. Because of possible differences in situations, trans- transferring results from one situation to another may lead to incorrect usage forecasts.

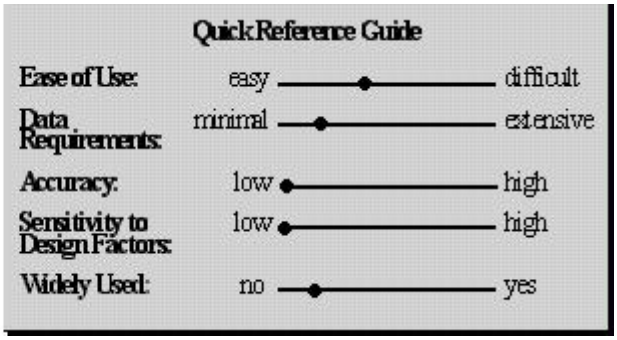
Central Massachusetts Rail Trail Bikeway
To estimate the potential usage of a proposed rail trail in Massachusetts, planning staff conducted bicycle counts on an existing trail which has characteristics similar to the proposed facility. These counts were then factored based on the ratio of total population within the corridors surrounding the two facilities to predict total trips on the proposed facility. Total volumes were distributed throughout the proposed corridor based on the population of communities along the corridor. An alternative method was also applied in which usage of the existing trails was factored by the ratio of bicycle commuting mode share in the two corridors, as determined from census data (Lewis and Kirk, 1997).

Comparison of Trails in Australia
Wigan (1997) compared the characteristics of users and the surrounding population on two existing facilities in Australia. Trail users were surveyed regarding mode of access to the trail, access distance, and personal characteristics. Data on population in the surrounding area were also analyzed. The results indicate that the Lower Yarra trail attracted more users from a wider range of distances than the Lower Maribrynong, despite similar levels of surrounding population. The authors concluded that with better signage, improved linkages, and promotional efforts for the Lower Maribrynong facility, usage could be comparable to the Lower Yarra trail.

Demand Estimation:

Aggregate Behavior Studies

- ☐ Facility Level
- ☒ Area/Regional Level



Overview Aggregate behavior studies involve the development of models to predict mode split and/or other travel behavior characteristics for an aggregate population, such as residents of a census tract or metropolitan area. Prediction is based on characteristics of the population and of the area. An example of an aggregate model is an equation to predict the percentage of trips taken by bicycle in individual census tracts in a metropolitan area, based on the average income of the tract and on the total length of bike-ways in the tract.

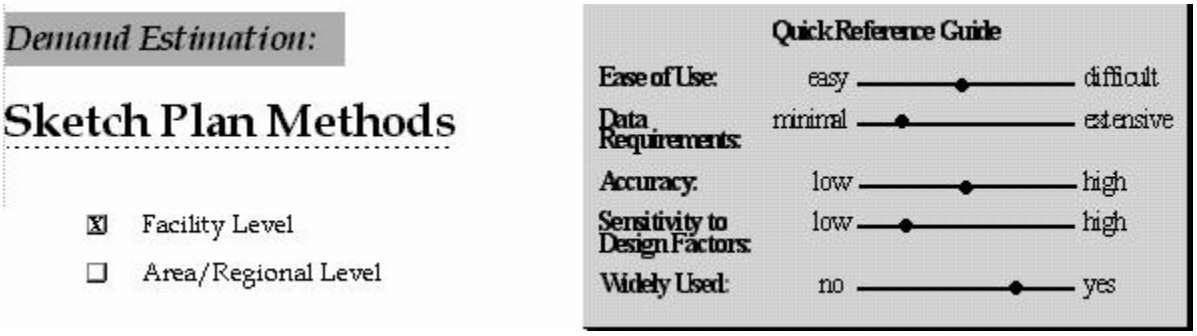
Typical Applications Aggregate behavior studies have been conducted in the United States and the United Kingdom, primarily utilizing census data and other readily available data sources to predict work-trip mode split at a tract, city, or metropolitan-area level.

Advantages Aggregate behavior models have isolated some factors that can be related to non- motorized travel and have developed quantitative relationships between these factors and modal split. Also, the results of these studies are potentially useful for the trip generation component of regional travel models which include non-motorized modes.

Disadvantages Aggregate behavior models have generally had low explanatory power and have not been successful at predicting mode splits when applied to other areas. Predicting behavior at an aggregate level suffers from a number of significant difficulties, including: (1) aggregate level data can mask significant variances within a population which affect behavior, e.g., the average income of a census tract may be much less important than the distribution of income; (2) the method ignores the impact of factors which are not readily available, such as attitudinal factors; (3) the primary data source on trips at a zonal/aggregate level is the census, which looks only at work trips; and (4) the available data generally do not include environmental variables which describe the overall quality of the area for bicycling or walking, the overall quality of alternative modes, etc.

Bicycle Journey-to-Work in the UK
Ashley and Banister (1989) used UK census and other data to (1) evaluate factors influencing cycling to work, (2) develop a model to predict the proportion of residents in a ward bicycling to work, and (3) test the model. The authors used regression analysis to test the effects of various factors on the proportion of ward residents cycling to work. Factors tested included personal characteristics, trip distance, avail- ability of cycling facilities, avail- ability of other modes, modes, traffic levels, and local climate and topography.

Bicycle Mode Split in U.S. Cities
Nelson and Allen (1997) conducted a cross-sectional analysis of 18 U.S. cities to predict work trip bicycle mode split (from census data) based on weather, terrain, number of college students, and per capita miles of bikeway facilities. A positive association was found between the presence of bikeway facilities and bicycle work trip mode split.



Overview Sketch plan methods can be defined as a series of simple calculations to estimate the number of bicyclists or pedestrians using a facility. These methods generally rely on data that already exist or can be collected with relative ease (such as census and land use data), and can be combined with behavioral assumptions derived from other studies. Sketch plan methods vary widely in their specific approaches and in their level of sophistication.

Typical Applications A variety of pedestrian sketch-plan methods have been developed to estimate pedestrian volumes under existing and future conditions in a pedestrian activity area, such as a central business district or shopping center. These methods generally use pedestrian counts and regression analysis to predict pedestrian volumes as a function of adjacent land uses and/or indicators of transportation trip generation (parking capacity, transit volumes, traffic movements, etc.) Alternatively, data on surrounding population and employment may be combined with assumed trip generation and pedestrian mode shares to estimate levels of pedestrian traffic. At least one bicycle sketch plan method has also been applied to predict usage of a new bicycle lane in Seattle. This method relies on census data and simple travel survey data to estimate the travel impact of the project.

Advantages Sketch plan methods tend to be relatively simple to understand and to apply. If the methods and data are selected carefully, they may give reasonable estimates of the number of users of a proposed facility. These methods are best for developing rough estimates for planning purposes and for comparing potential usage levels among facilities or areas to prioritize actions.

Disadvantages Sketch plan methods tend to rely on limited local data and on general assumptions about behavior. Therefore, they can be imprecise and may not account well for specific local conditions such as characteristics of the facility, network, surrounding population, destinations, or competing modes of travel. In addition, methods and assumptions developed for specific applications may not always be relevant to applications in other geographical areas.

Estimating Pedestrian Corridor Activity
Matlick (1996) describes a method to determine the level of pedestrian activity in 0.8 km buffer areas in specific corridors. A variety of sources was used to estimate activity within the corridor: population, mode split, and trip characteristics from census and National Personal Transportation Survey data; land use data from local data bases; and estimates of school and transit trips.

Estimating Peak Pedestrians per Hour
Ercolano (1997) describes a method that determines site, corridor, and subarea pedestrian per hour volumes using local vehicle per hour turning movements and mode share census data (at a minimum). Other features of this method include the ability to estimate sidewalk and intersection trips and the ability to adjust trips based on completeness of pedestrian infrastructure and climatic conditions.

Demand Estimation:

Discrete Choice Models

- [X] Facility Level
- [X] Area/Regional Level

Quick Reference Guide

Ease of Use:	easy	difficult
Data Requirements:	minimal	extensive
Accuracy:	low	high
Sensitivity to Design Factors:	low	high
Widely Used:	no	yes

Overview A discrete choice model predicts a decision (choice of mode, choice of route, etc.) made by an individual as a function of any number of variables, including factors that describe a facility improvement or policy change. The model can be applied across a population to estimate the total number of people who change their behavior in response to an action. The model can also be used to derive elasticities, i.e., the percent change in bicycle or pedestrian travel in response to a given change in any particular variable.

Typical Applications Discrete choice models are widely used by regional travel modelers to predict auto vs. transit mode choice. Mode choice models have also been developed that include bicycling and walking as options; a model was recently developed in Chicago to predict the impacts of pedestrian and bicycle improvements on transit access mode (see sidebar). Discrete route choice models have also been developed for bicyclists which model bicyclists preference for various facility design features when selecting a route.

Advantages Discrete choice models based on local survey data are the most accurate tool available for predicting travel behavior impacts. These models can be a powerful tool for isolating and quantifying the effects of specific factors, both personal and environmental, on travel behavior. They can also be used to

examine the interaction of each factor with other factors, e.g., whether age has an impact on the type of facility preferred.

Disadvantages Development of a discrete choice model generally requires the collection of extensive survey data and requires expertise in discrete choice modeling techniques. Also, since the number of factors (facility design, personal, etc.) which can be considered in any particular modeling exercise is limited, it is not possible to identify or control for all factors which may influence behavior. Furthermore, a model developed for a specific situation may not be applicable to other situations if important factors not considered in the model differ between the two situations.

Transit Access Mode Choice in Chicago
The Chicago Regional Transit Authority recently developed a set of discrete choice models to predict the impacts on transit access mode of bicycle and pedestrian improvements to rail station areas in Chicago. Surveys to determine existing commuters mode choice, station access distance, and other characteristics were used in conjunction with visual simulation surveys to estimate whether people would shift to non-motorized access modes as a result of various improvements. Bicycle improvements tested included removal of debris, provision of parking, slowing of traffic, and development of curb lanes, paths, and bicycle routes. Pedestrian improvements tested included sidewalks, recreation paths, slowing of traffic, and various improvements to intersection crossings (Wilbur Smith Associates, 1997).

Overview Regional travel models, commonly referred to as four-step travel demand models, use existing and future land use conditions and transportation network characteristics, in conjunction with models of human behavior, to predict future travel patterns. These models are described in more detail in section 2.4 of this overview and section 2.8 of the supporting documentation.

Typical Applications Traditionally, regional travel models have been oriented toward predicting trips by automobile and transit. However, a number of models in the United States, Canada, and Europe have recently been modified to estimate non-motorized mode splits based on ratings of the pedestrian friendliness or bicycle friendliness of individual zones. Some models have also been modified to include bicycle and/or pedestrian facility networks and to predict the route choice impacts of improving or adding facilities. Models have also been developed specifically for bicycle or pedestrian travel. For example, in the 1970s pedestrian demand models were developed for various commercial business districts in the United States. These models related pedestrian trips to land uses at a block level and assigned trips between blocks based on characteristics of the pedestrian network.

Advantages Regional travel models have been developed for all major urban areas in the United States. The regional travel model structure provides an integrated framework for analyzing travelers choices between modes. Given sufficient data collection and enhancements to the model structure, regional travel models could serve as a powerful tool for analyzing bicycle and pedestrian travel. Regional travel models can also serve as a source of data, such as total trips generated in an area, which are useful for other bicycle or pedestrian modeling or sketch-planning efforts.

Disadvantages The current generation of regional travel models was developed at a spatial scale appropriate for automobile rather than bicycle or pedestrian travel. Also, incorporation of non-motorized modes may require significant data collection to create a zone-level "environment factor" or develop a network of bicycle and pedestrian facilities. Current regional travel models also do not consider trips made for the sole purpose of recreation. Finally, the development and modification of travel models require considerable expertise and the use of specialized software packages.

Edmonton Transport Analysis Model (Canada)
The Edmonton Transport Analysis Model recently developed for the Edmonton, Canada region includes both walk and bicycle as separate modes and also includes bicycle network characteristics in determining mode choice. Links in the network model can be coded in three ways: bicycle path, bicycle lane, or mixed traffic. Bicycle travel time on each link is adjusted by a factor representing the relative onerousness of bicycling by facility type. These factors are derived from a hypothetical choice survey of bicyclists in which bicyclists are asked to choose between different routes based on distance, facility type, and other factors (Hunt, Brownlee, and Doblanko, 1997).

Relative Demand Potential:

Market Analysis

☐ Facility Level

☒ Area/Regional Level

Quick Reference Guide

Ease of Use:	easy		difficult
Data Requirements:	minimal		extensive
Accuracy:	low	**not rated**	high
Sensitivity to Design Factors:	low		high
Widely Used:	no		yes

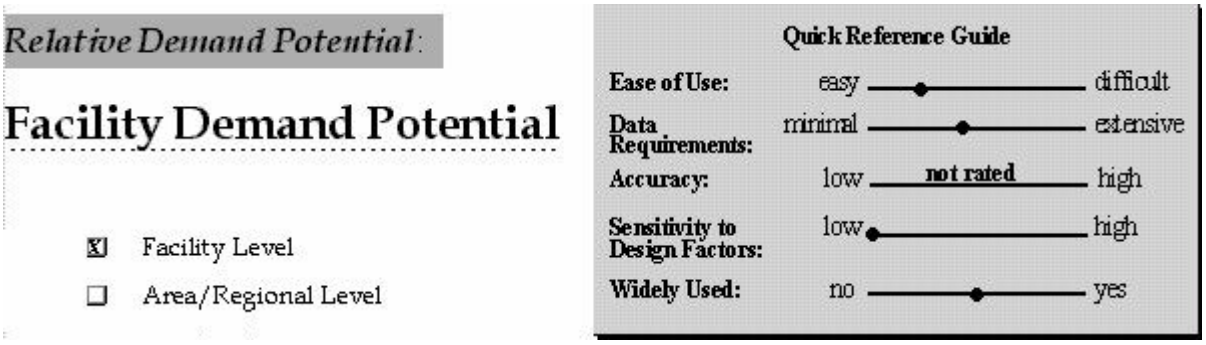
Overview This is a general approach which estimates the maximum potential number of trips by bicycle or walking in an area, based on (1) current trip length distributions, usually by trip purpose; (2) rules of thumb on the maximum percentage of bicycling or walking trips by trip distance and purpose; and/or (3) the percentage of the population likely to switch to bicycling or walking, based on identifying a target market of bicyclists or walkers according to commute distance, demographic characteristics, etc. An ideal network of facilities is assumed, i.e., this method estimates how many trips might take place if the quality of facilities was not an issue.

Typical Applications Market analysis is a relatively common approach that can be applied in many different ways, with varying levels of detail. Some studies have taken aggregate data on trip lengths by purpose for an area and applied a rule of thumb about the maximum bicycle or walk trip length, in conjunction with a best guess as to the likely mode share diversion, to estimate the potential bicycle or walk mode share. Others have focused on defining the demographic characteristics of people most likely to walk or bicycle, and subsequently using demographic information for an area, in conjunction with trip length distributions, to obtain an overall maximum potential mode split under ideal conditions.

Advantages Market analysis methods generally define an "upper bound" on the number of trips by cycling or walking and may therefore give municipalities a target to shoot for in developing plans to improve facilities city-wide. This type of analysis can also be helpful in identifying areas of greatest potential demand, as an aid to prioritizing projects.

Disadvantages Market analysis methods are intended only to achieve rough estimates of the maximum number of trips that could be diverted to bicycling or walking. The methods are not useful for estimating changes in demand in response to an improvement, and they shed little light on factors affecting the decision to walk or bicycle.

Market for Bicycle Commuting in the San Francisco Bay Area
Deakin (1985) defined a demographic target group for Bay Area commuter bicycling, based on data from the Bay Area Travel Survey, a review of the literature, and interviews with local and state officials. Her market was defined as employed full-time, under 40 years old, travels less than 11.3 km one-way to work, drives alone during the peak period, and owns a bike suitable for commuting. She used these criteria to estimate a reasonable upper bound on the size of the potential bicycle commuter market.



Overview Measures of potential demand have been developed for both bicycle and pedestrian facilities for the purpose of prioritizing facility improvements according to areas of highest potential demand. Demand potential is measured based on characteristics and levels of the surrounding population, trip generators, as well as other environmental factors such as topography and the quality of connecting facilities.

Typical Applications Measures for both bicycle and pedestrian facility demand potential have been developed and applied to prioritize improvements (see sidebar).

Advantages Measures of potential demand can be a useful aid to prioritizing locations for improvements, particularly when applied in conjunction with measures of supply or facility quality to identify areas of both high potential demand and significant deficiencies. In addition, these measures can frequently be constructed from readily available data sources such as the census and local land use data bases.

Disadvantages Measures of potential demand only indicate relative levels of demand between areas, rather than predict the actual number of users of a facility. They do not indicate the extent to which usage is likely to increase as the result of a particular improvement, and they do not indicate which improvements to a specific facility or area should be given the highest priority. Also, the factors used in constructing the index may or may not be good indicators of the true potential demand for the facility.

Latent Demand Score
A Latent Demand Score (LDS) technique has been developed to estimate the latent or potential demand for bicycle travel assuming the existence of a bicycle facility. Trips are estimated based on the size and proximity of population and activity centers to the proposed facility, using Geographic Information System (GIS) analysis tools. The LDS has been applied in a number of cities with the purpose of prioritizing existing bicycle facility improvements

Pedestrian Potential Index
A Pedestrian Potential Index has been developed and applied in Oregon to prioritize locations for pedestrian improvements. The index uses three main factors: (1) proximity factors that refer to pedestrian generators such as schools, transit or neighborhood shopping; (2) environmental factors such as mixed use and street connectivity; and (3) policy factors that identify certain areas as critical for pedestrians. The index has been

or new bicycle facility improvements or new bicycle facilities. (Landis, 1996). The LDS may be combined with bicycle level of service measures.

applied in conjunction with a Deficiency Index to identify areas with both high potential demand and significant deficiencies. (City of Portland, 1997).

Supply Quality Analysis:

Bicycle and Pedestrian Compatibility Measures

☒ Facility Level

☐ Area/Regional Level

Quick Reference Guide

Ease of Use:	easy	difficult
Data Requirements:	minimal	extensive
Accuracy:	low — **not rated**	high
Sensitivity to Design Factors:	low	high
Widely Used:	no	yes

Overview A variety of compatibility measures have been developed to indicate the suitability of a particular facility for bicycle or pedestrian travel. These measures have been given names such as "Level of Service," "Stress Level," "Compatibility Index," and "Interaction Hazard Score." The measures combine factors such as motor vehicle traffic volume and speeds, lane or sidewalk width, pavement quality, and pedestrian amenities into an index of overall suitability for travel. The measures can be used alone or in conjunction with measures of potential demand to prioritize facilities for improvements.

Typical Applications Compatibility measures have been used in a number of cities to rank facilities for purposes of prioritizing projects. For example, Orange County, NC, has applied the Bicycle Stress Level index to determine the suitability of their planned bicycle routes. Level-of- service measures have also been applied in conjunction with the Latent Demand Score to prioritize projects in various urban areas in Florida. Oregon has developed a Deficiency Index which it uses in conjunction with potential demand indicators to rank and prioritize pedestrian facilities.

Advantages Compatibility measures can serve as a useful means of prioritizing facilities for improvement as well as determining which improvements will be most beneficial. Compatibility measures may also become a key component of non-motorized travel demand forecasting, if relationships can be developed between the indices and individuals' likelihood of making a bicycling or walking trip.

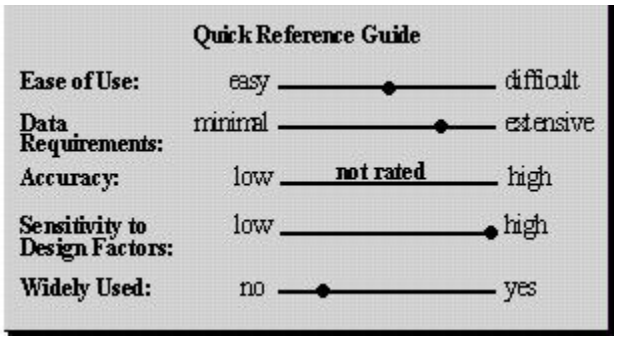
Disadvantages Existing indices primarily rate individual segments rather than describing the overall compatibility of a route. They cannot account for the effects of intersections and other discontinuities, and they do not sufficiently describe the overall compatibility of a route made up of different segments with different ratings. Also, the indices may not include all relevant factors (or may require significant data collection to do so), and they may not properly reflect perceptions if not validated through surveys. In addition, they do not predict the actual number of trips on the segment.

Bicycle Compatibility Index
The Federal Highway Administration has recently developed a bicycle compatibility index (BCI) to describe the compatibility of a facility for cycling (FHWA, 1998). The BCI uses a formula based on traffic volume, speed, lane width, and other indicators of bicyclist stress to rank a road segment for compatibility on a scale of 1 to 6, which is then equated to a level-of-service (LOS) rating. Qualitative adjustment factors were developed to consider instances of high volumes of trucks or buses, right-turning vehicles, and vehicles turning into and out of driveways. The index was developed using a video survey methodology which asked participants to rate their comfort level on various videotaped facilities.

Supply Quality Analysis:

Environment Factors

- ☐ Facility Level
- ☒ Area/Regional Level



Overview Pedestrian and bicycle environment factors describe the friendliness of an area (such as a city block, census tract, or traffic analysis zone) for walking and/or bicycling. The factors are quantitative and may be a composite of a number of quantitative descriptors and subjective factors. Examples of factors considered include lane or sidewalk width, street continuity, topography, and the aesthetic quality of the environment.

Typical Applications Pedestrian and bicycle environment factors have been developed primarily for use in regional travel models. A pedestrian environment factor has been developed and applied to the regional travel model in Portland, OR and modified versions have been applied in Sacramento, CA and Washington, DC. Montgomery County, MD, has developed a different pedestrian/bicycle environment factor for use in its travel model. A transit friendliness factor describing the quality of pedestrian access to transit has been developed in Washington State.

Advantages Considerable research has been performed recently on factors that make areas inviting to pedestrians, and much of this knowledge has been incorporated in the current generation of environment factors. The factors have been found to enhance the performance of travel models in Portland, OR and Montgomery County, MD particularly for predicting vehicle trips from an area. These factors may also be useful in prioritizing areas for improvements, based on the relative ratings of individual areas.

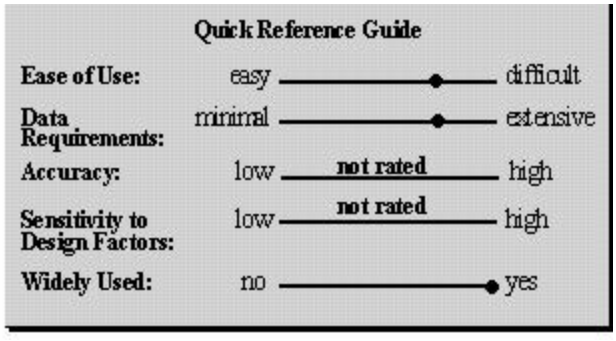
Disadvantages Environment factors are frequently based on subjective ratings and their performance at predicting actual variations in travel behavior has not yet been widely validated. Also, separate bicycle environment factors have not been developed; the ability of these or of combined pedestrian/bicycle factors to predict bicycle trip activity has not yet been tested. In addition, environment factors require considerable field data collection to develop for a specific area.

Portland, OR, Pedestrian Environment Factor
Portland's Pedestrian Environment Factor (PEF), developed for use in its regional travel model, includes four elements: sidewalk availability, ease of street crossing, connectivity of street/sidewalk system, and terrain. Each traffic analysis zone is ranked for each element on a scale of zero to three, with higher numbers representing higher quality pedestrian environments, so the overall PEF can range from 0 to 12 (1,000 Friends of Oregon, 1992 - 1997).

Supporting Tools and Techniques:

Geographic Information Systems

- ☒ Facility Level
- ☒ Area/Regional Level



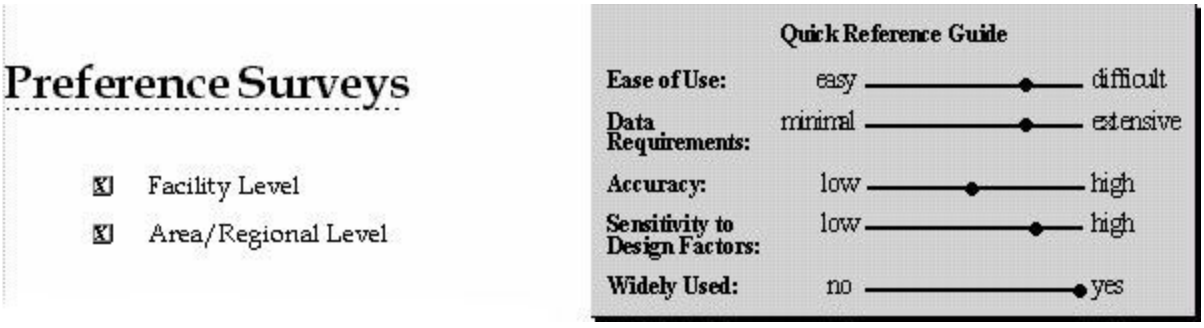
Overview Geographic Information Systems (GIS) relate environmental and population data in a spatial framework, using location points, lines (commonly roadway links and corridors), corridors), and polygons (surface areas and analysis zones). GIS are employed as a mechanism for the physical inventory of transportation facilities; as a planning tool to relate available environmental, personal transportation and household characteristics data; as a spatial analysis tool for calculating distances and areas; as a network performance monitor; and as a vehicle for the graphic display of data and analysis in a geographic context.

Typical Applications GIS have been used in non-motorized planning to inventory and evaluate facilities such as roads and sidewalks; establish spatial relationships between roadway network links, features such as activity centers, and area population characteristics; compare and display current conditions with projected travel and conditions; assess total network performance and identify optimal routes; produce printed maps; and develop network measures (e.g. street density and connectivity) and land use measures (e.g., mix of residential, office, and retail) which can be related to the likelihood of walking or bicycling.

Advantages GIS can greatly increase the ease of analyzing data relevant to non-motorized travel forecasting. For example, a corridor surrounding a facility can be defined and the characteristics of the population within the corridor easily identified. GIS allows development of spatial measures and analysis of data relationships which might otherwise be prohibitively time-consuming or impossible. The display capabilities of GIS are also valuable for conveying information to policymakers and the public.

Disadvantages GIS require considerable user skill as well as specialized software to develop, although future developments will make them more accessible to laypersons. Also, since GIS can only manage and analyze data, the data must still be collected through other means.

Warwick, RI, Bicycle Network Study
A Bicycle Network Study in Warwick, RI, was assisted by GIS methods. Trip generation estimates were calculated as a function of employment, school enrollment, and total population for traffic analysis zones adjacent to the bicycle network. Composite trip generation scores were then attributed to network segments within the areas of influence of trip generators. The results of this analysis were compared to the existing designated bicycle route network. Alternative route designations were suggested where an undesignated roadway link's potential scored higher than a parallel or adjacent designated route (Beltz and Burgess, 1997).



Overview Using survey research techniques, preference surveys (also known as stated preference surveys) focus on the choices that people would make given discrete alternatives. Respondents are asked to express an attitude or make a choice as to how they would act under certain conditions. Two basic types of preference surveys exist. Attitudinal surveys ask respondents directly how they would respond to various actions (e.g., would they bicycle if bike lanes were available), or ask them to rate their preferences for various improvements. Hypothetical choice surveys require respondents to make choices

between hypothetical alternatives with varying attributes, and survey results are then used to develop models of behavior.

Typical Applications Attitudinal surveys have been widely used to estimate the potential impacts of bicycle and pedestrian improvements and to determine relative preferences for such improvements. Hypothetical choice surveys are generally used to develop discrete choice models and to estimate the relative importance of each attribute (time, cost, presence of bike lanes, etc.) in common terms.

Advantages Attitudinal surveys are relatively easy to design and implement. They can also be good tools for evaluating relative preferences and for estimating the maximum possible response to an action. Hypothetical choice surveys, if carefully designed, can be used to develop relatively accurate models of behavior and to give quantitative information on the relative importance which people place on various factors.

Disadvantages Attitudinal surveys often significantly overestimate the response to a bicycle or pedestrian improvement, since people tend to be more likely to state that they will change their behavior than to actually do so (Goldsmith, 1992). Therefore, they are not well-suited for predicting actual shifts in travel demand. While hypothetical choice surveys overcome many of the limitations of attitudinal surveys, they must be designed carefully and require considerable time and expertise to implement. Both types of preference surveys suffer from the further drawback that people may not have any real-world experience with the choices they are asked to make, and may therefore be unable to indicate their preferences or actions with accuracy.

Transit Access Mode Choice in Chicago
The Chicago Regional Transit Authority (RTA) surveyed transit and auto users to determine reasons why they did not currently walk or bicycle to a transit station. (These surveys were also used to develop models of individual behavior, as described under Discrete Choice Models.) Respondents were asked to identify specific reasons for not bicycling or walking, such as lack of secure parking, dangerous traffic conditions, or inadequate sidewalks or path-ways. Two different survey methods were employed: an intercept survey in which respondents were asked directly to rate factors, and an interactive video survey in which respondents were asked to make tradeoffs between vari-

3.2 Key Characteristics and Uses of Each Method

This section summarizes key characteristics of the methods and suggests appropriate methods according to specific purpose such as forecasting the number of new users of a bicycle/pedestrian trail. More specifically, table 3.2 summarizes key characteristics of each of the 11 methods, providing more detail on the factors (e.g., ease of use and data requirements) rated in the quick reference guide for each method.

Tables 3.3 through 3.6 are intended as a guide for practitioners who need to choose the most appropriate method for a specific situation. Each table lists a specific purpose for which non-motorized demand forecasting methods may be applied and suggests which methods are most appropriate for that purpose. Generally the methods are ordered from simpler to more complex in Tables 3.3 - 3.5. For each of these methods, the table describes the specific way in which the method would be applied and identifies major advantages and disadvantages of using the method for the given purpose. These purposes include:

Table 3.3 - estimating the number of users of a new facility;

Table 3.4 - estimating the number of new bicycle or pedestrian trips area-wide, as a result of facility or network improvements;

Table 3.5 - prioritizing design features for a specific facility; and

Table 3.6 - prioritizing facilities for improvement.

**Figure 3.2: If Sidewalks Were Built Here,
How Many People Would Use Them?
How Far Up on the Priority List is This Project?**

Table 3.2 - Key Characteristics of Available Methods.

Method	Ease of Use	Data Requirements	Accuracy	Sensitivity to Design Factors	Where Used
Demand Estimation					
Comparison Studies	Simple to understand and relatively easy to apply	Requires facility user counts; data on surrounding population and land uses are optional	May provide rough estimates of demand if truly comparable case studies can be found. Accuracy has not been formally tested.	Relatively low; requires identification of comparable facilities within a comparable environment	Massachusetts; Netherlands; Germany; Australia
Aggregate Behavior Studies	Requires simple statistical analysis skills	Varies; can use existing sources such as census and local land use data bases	Models have generally had low explanatory power and have not been transferable	Low, since detailed information on facilities has generally not been collected	UK; Berkeley, CA
Sketch Plan Methods	Methods are relatively simple to apply	Varies; can use existing sources such as census and	Varies by method; some methods may give reasonable	Low; rely on general assumptions	Seattle, WA (bicycle); New York City, NY; Plattsburgh, NY;

		local land use data bases	estimates others have not been formally tested		Milwaukee, WI; Toronto and Montreal, Canada (pedestrian)
Discrete Choice Models	Knowledge of statistical analysis and specialized survey and modeling techniques is required	Usually requires survey data collection specific to situation being analyzed	Can be relatively accurate in predicting impacts of specific actions	High, although only limited number of factors can be considered at once	Wisconsin; California, Chicago, IL; Raleigh, NC
Regional Travel Models	Requires established capabilities for travel demand modeling	May require additional data collection on bicycle and pedestrian travel patterns and/or facility characteristics	Including bikes/peds has improved performance of some models at predicting auto and transit trips	Potentially high; limited by data availability and tradeoff information	Portland, OR; Montgomery County, MD; Sacramento and San Francisco, CA; Edmonton, Canada; Leicester, UK; Netherlands

Relative Demand Potential

Method	Ease of Use	Data Requirements	Accuracy	Sensitivity to Design Factors	Where Used
Market Analysis	Methods are relatively simple to apply	Data required on trip length distributions (from travel survey or regional travel model); other population data may be needed	Untested. Methods are designed to predict an upper bound under ideal conditions	Low; assumes ideal network of facilities	San Francisco, CA; Chicago, IL; Bend, OR; Minneapolis, MN; Europe
Facility Demand Potential	Methods are relatively simple to apply	Data required on local population and land use, some methods require trip distributions by length and purpose	Attempts to apply Latent Demand Score in practice have had mixed results	Low; assumes ideal network of facilities	(Pedestrian Potential Index); Florida; Birmingham, AL; Philadelphia, PA; Portland, OR (pedestrian)
Supply Quality Analysis					
Bicycle and Pedestrian Compatibility Measures	Methods vary but are generally relatively simple to apply	Requires data on facility characteristics; some may exist, others may need to be collected, depending on method	Has not been tested with respect to forecasting demand	High; factors included depend on specific index	Orange County, NC; Gainesville, FL; Buffalo, NY; Ames, IA
Environment Factors	Relatively simple to apply; may require judgment in	Generally requires field data collection on facility/ environmental characteristics	Have improved performance of some regional travel models at	High; factors included depend on	Portland, OR; Montgomery County, MD; Sacramento, CA

	developing ratings		predicting auto, transit trips	specific index	
Supporting Tools and Techniques					
Geographic Information Systems	Generally requires specialized knowledge of GIS analysis techniques	GIS can manage and analyze a wide variety of data based on availability and needs	Has potential to improve accuracy of forecasting methods	Potential to store information on a variety of facility design factors	Portland, OR; Seattle, WA; Buffalo, NY; Warwick, RI; Orange County, CA; Fort Collins, CO; Buffalo, NY; Ames, IA
Preference Surveys	Requires knowledge of survey research techniques; may require specialized survey design and analysis skills	Requires survey data collection	Performance depends on quality of survey design and implementation	Variety of design factors can be considered in survey	Widespread

Table 3.3 - Methods for Estimating the Number of Users of a New Facility.

Method	Specific Application	Major Advantages or Drawbacks
Comparison Study	Look at usage on comparable facility	May be difficult to find truly comparable situation
Sketch-Plan Method	Look at local population, trip generators, non-motorized work trip percentages for area around facility to estimate potential trips	Easy way to get a rough estimate of potential usage; however, difficult to consider factors such as non-work trips, whether facility serves local travel patterns, existence of supporting facilities/network, etc.
Preference Survey (Attitudinal)	Survey local residents and commuters as to whether they would use the facility	Will give relative indication of interest, but will generally overstate actual likelihood of using facility
Preference Survey (Hypothetical Choice) and Discrete Choice Model	Conduct survey of whether people would use facility under various scenarios; develop behavior model to predict usage	A carefully-designed hypothetical choice survey may be the most accurate method but is also resource-intensive
Regional Travel Model	Modify existing regional travel model to include new facility	Requires travel model which already includes bicycling/walking networks; will not capture recreational travel

Table 3.4 - Methods for Estimating the Number of New Bicycle or Pedestrian Trips Area-wide as a Result of Facility or Network Improvements.

Method	Specific Application	Major Advantages or Drawbacks
Preference Survey (Attitudinal)	Survey residents to ask if they would choose to walk or bicycle given improvements	Survey results tend to overstate willingness to change mode of travel
Aggregate Behavior Study	Develop relationship between levels of non-motorized trip-making and overall facility/network characteristics, based on data from other cities/areas	Requires data on many cities or areas which includes indicators of non-motorized trip making as well as information on existing facilities/ networks comparable to the improvements being considered locally
Preference Survey (Hypothetical Choice) and Discrete Choice Model	Conduct survey of whether people would bicycle or walk under various city-wide improvement scenarios; develop behavior model to predict usage	A carefully-designed hypothetical choice survey may be relatively accurate but is also resource-intensive
Regional Travel Model	Modify pedestrian/bicycle environment factors or network links in regional travel model	Requires travel model which already includes bicycling/walking environment factors and/or networks, and that these networks include facility characteristics that are desired to be improved; models must also be based on data relating behavior responses to design improvements

Table 3.5 - Methods for Prioritizing Design Features for a Specific Facility.

Method	Specific Application	Major Advantages or Drawbacks
Supply Quality Analysis	Compare improvements in quality rating as a result of various design improvements	Good for identifying facility deficiencies and most effective improvements, but using this technique alone does not predict benefits in terms of new users
Preference Survey (Attitudinal)	Ask local residents, employees, bicyclists, pedestrians, etc., which design improvements are highest priority	Responses may vary depending on population surveyed; for example, just surveying existing users will not indicate number of new users attracted to facility as a result of improvements
Preference Survey (Hypothetical Choice) and Discrete Choice Model	Conduct survey to determine relative-preference for facility improvements, and build model to determine likely number of new users	Determining who to survey can be a problem; however, can actually predict benefits of each improvement based on change in usage as well as benefits to existing users
Regional Travel Model	Modify facility travel times to reflect proposed new facilities or	Considers most types and origins/destinations of trips. However,

	design improvements, to determine travel-time equivalent benefits to existing users and number of new users	requires that the travel network is coded with the bicycle or pedestrian facility design features to be analyzed, and that the valuation of travel time by bicycle or foot has been related to these design features.

Table 3.6 - Methods for Prioritizing Facilities for Improvement.

Method	Specific Application	Major Advantages or Drawbacks
Supply Quality Analysis	Rate facilities based on existing bicycle or pedestrian compatibility, environment factors, or deficiency indicators; prioritize according to ratings	Does not look at existing or potential demand/usage on facilities
Preference Survey (Attitudinal)	Ask local residents, employees, bicyclists/ pedestrians, etc., which are highest priority facilities to improve	Responses may vary depending on population surveyed; for example, just surveying existing users will not indicate number of new users attracted to facility; need to survey population of potential users as well
Facility Demand Potential	Look at potential demand for facility based on surrounding population, land uses, etc., and prioritize according to highest potential	Serves as a good basis for prioritization assuming that measures of potential demand are proportional to actual future demand across projects.
Combination of Facility Demand Potential and Supply Quality Analysis	Rate facilities both on potential demand and existing quality; prioritize facilities with highest potential and lowest quality	Combines strengths of both methods; however, still does not indicate actual number of new users

Conclusions And Future Needs

4.1 Conclusions

A bicycle or pedestrian planner wishing to estimate future levels of non-motorized travel has a number of options. These include comparisons of proposed projects with usage on similar existing projects, calculations based on census and other available local data and assumptions, aggregate and disaggregate behavior models to predict travel choices, and inclusion of bicycle and pedestrian factors in existing regional travel models. Alternatively, the planner may choose to look at measures of the *potential* market for bicycling or walking, rather than explicitly forecasting demand. The planner may also use these measures in conjunction with measures of the *quality* of facilities supplied to prioritize improvements where they are most needed. Finally, these methods can be enhanced by tools and techniques such as GIS and preference surveys of travelers.

In addition, planners may develop combinations of existing and new approaches. Bicycle and pedestrian travel demand forecasting is an evolving field, and creative thought is needed by those who are confronted with planning needs in the real world. The best approach for any particular situation will depend on available knowledge, data, financial, and technical resources, as well as the specific purpose for which the demand forecasts are being developed.

Finally, planners should be aware of the limitations as well as the advantages of existing methods, and should supplement quantitative forecasts with the judgment of local practitioners and advocates when planning projects. Despite limitations, however, the methods discussed in this guidebook can provide valuable information, both for estimating the benefits of proposed projects and for prioritizing projects and improvements to achieve the greatest benefits to users.

4.2 Future Needs

As a result of developing this guidebook, a number of areas have been identified in which additional research and methodological development could be particularly useful. These suggestions are presented so that users of this guidebook can consider the limitations of existing knowledge when developing their own methods, collecting data, and conducting research. Recommended future efforts include:

- Development of a manual for bicycle and pedestrian sketch-planning. In the short term, practitioners with neither the resources nor the expertise to conduct an indepth forecasting study need a simple yet effective set of tools and data for estimating future demand.
- Further research on factors influencing non-motorized travel behavior. Ongoing research into the specific factors that influence decisions to bicycle and walk will improve the quality of both sketch-planning and more advanced modeling techniques.Research should focus not just on identifying specific factors but on how these factors interact and how they can be modeled to assist in forecasting bicycle or pedestrian travel for specific projects.
- Integration of bicycle and pedestrian considerations into mainstream transportation models and planning. Future improvements to regional travel models hold great promise to improve the quality of non-motorized travel modeling, if these modes are included in travel model development efforts. Inclusion of these modes will also help place bicycles and pedestrians on a "level playing field" with motorized modes in transportation planning.

Development of a Manual for Bicycle and Pedestrian Sketch-Planning

In the absence of better methods, practitioners who need to estimate usage on a non-motorized facility generally resort to back-of-the-envelope calculations based on readily available data and rules of thumb on travel behavior. These methods are somewhat crude and generally have not been tested for accuracy, but nevertheless may be the best that is possible given limitations on data, resources, and expertise.

Development of a sketch-planning manual for bicycle and pedestrian forecasting would improve the state of practice in this area and could be widely used by bicycle and pedestrian planners. Such a manual would include methods and supporting data for developing local estimates of demand. Specific elements of the manual might include:

- A summary of available bicycle and pedestrian travel characteristics, including trip length distributions by type of trip, personal and household characteristics of travelers, etc.;
- A summary of studies that have evaluated the effects of various bicycle or pedestrian facility or policy improvements on non-motorized travel;
- Identification and description of existing data sources, such as the census, travel surveys, and land use data bases, which can support the estimation of non-motorized travel demand;
- Guidelines for collecting local data, including user counts and surveys of existing and potential users;
- Applications of new technologies, including GIS methods and Intelligent Transportation System (ITS) technologies, for data collection and analysis; and
- A set of back-of-the-envelope procedures for using these various data sources to obtain rough estimates of demand.

The sketch-planning techniques could, at a minimum, draw from techniques that already have been developed by practitioners and identified in this guidebook. Ideally, such techniques would be further developed and tested in practice to ensure that they are applicable to a variety of areas and that they give reasonable results.

Additional research useful for this type of guidebook might include further analysis of data sources, such as trail user counts and surveys in conjunction with other trail-related data, to look for patterns in facility usage and to provide information useful for the planning of comparable facilities.

Research on Factors Influencing Non-Motorized Travel Behavior

Along with the short-term documentation of planning methods and data for practitioners, more fundamental research is needed into the factors influencing non-motorized travel behavior and how these factors can be modeled to support demand forecasting. Particular attention should be given to identifying factors that are both of significance in predicting non-motorized travel behavior and that can be collected or created with relative ease from existing data sources or future survey efforts. Factors should be investigated that can be useful in a variety of forecasting methodologies ranging from sketch-planning techniques to travel demand and network modeling. Focusing on the *individual* traveler as the unit of analysis, rather than on aggregate-level studies, will provide richer information that will be useful not only for improvements to current efforts but to future modeling efforts such as activity-based analysis and microsimulation.

Facility design characteristics. Significant research has focused on developing quantitative measures of the quality or compatibility of facilities for bicyclists and pedestrians. The next step is to integrate these measures into methods of forecasting travel demand. Research is needed into how to aggregate facility-level compatibility measures, such as the Bicycle Compatibility Index, into an overall route or network compatibility measure, including facilities of varying quality as well as intersections and other discontinuities. Ultimately, the overall route or set of route options, rather than just individual facility characteristics, determines whether or not the bicyclist or pedestrian makes the trip.

Environment factors. Area-level environment factors that describe, or act as a proxy for, the relative attractiveness of bicycling or walking at an area/zonal level are potentially useful and should be further developed and tested. Pedestrian environment factors should be further refined and tested to verify their predictive capability. (Efforts in this area should build on recent research relating neighborhood design factors to levels of walking.) Bicycle environment factors also should be developed and tested for predictive capability. Other possibilities include the quality or impedance of alternative modes (traffic

speeds, LOS, cost of parking, etc.) and the potential demand based on trip-end characteristics (population, employment, special generators, etc.). These factors should be useful both in sketch-planning techniques and in regional travel models where the scale of resolution is too coarse to model every facility in the network.

Attitudinal and perceptual factors. The relative importance of attitudinal and perceptual factors in the choice to walk or bicycle, as well as their potential uses in modeling, should be investigated. While gathering such data requires additional collection efforts, factors of this type have been found to be highly significant in determining travel behavior. Research in this area should focus on (1) which factors are most important; (2) how they can best be described/standardized; (3) what level of resources are required to collect these data on an ongoing basis; (4) how the factors may change over time; (5) how they can most effectively be influenced; and (6) how they can be integrated into modeling/forecasting techniques to predict the impacts of various policies. Research in this area can build on behavioral research from the public health field, as well as on existing studies of attitudes and perceptions regarding bicycling and walking.

Factors influencing recreational travel. None of the methods discussed in this guidebook make an explicit distinction between recreational and utilitarian travel. Many aggregate-level methods consider both types implicitly by looking at overall travel on a facility, while others such as regional travel models consider only utilitarian trip-making. Forecasting *recreational* travel at the individual or disaggregate level requires a different analysis framework, involving lifestyle and activity patterns, than is generally used in transportation modeling. Approaches from the public health arena that model the decision to exercise as a function of various personal/attitudinal characteristics and social factors should be helpful for incorporating recreational travel in transportation modeling.

Figure 4.1: Models Need to be Capable of Modeling Both Utilitarian and Recreational Travel.

Market research. Marketers in competitive industries have long recognized that marketing success depends on targeting the right customer with the right product. State-of-the-art techniques from the field of market research can be used to better identify the "market segments" for non-motorized travel, the travel characteristics of each market segment, and the facility design factors that are important in attracting increased usage from each segment. The trip and personal characteristics of recreational travelers, for example, should be differentiated from those of utilitarian travelers, while utilitarian users may be further distinguished as necessity vs. discretionary, commute vs. non-commute, etc. While some research has been conducted in defining non-motorized market segments, planners have not adequately

identified the differences in techniques required for identifying the needs and predicting the behavior of these various groups.

Integration of facility/environment, policy, and personal/attitudinal variables into an overall modeling framework. Insights from the public health and social marketing fields suggest that personal attitudes and beliefs interact strongly with environmental and policy variables to influence travel behavior and mode choice, particularly for bicycling. Accurate forecasting of bicycle travel will require integrating these variables into a modeling framework which can include personal/attitudinal variables, and which can account for the fact that the effects of facility/environmental improvements will depend on (as well as influence) the levels of these other variables.

Integration of Bicycle and Pedestrian Considerations into Mainstream

Transportation Models and Planning

As a final recommendation, further development of modeling techniques and data sources is needed to better integrate bicycle and pedestrian travel into mainstream transportation models and planning activities. Regional travel models have the unique advantage of representing an integrated framework for predicting travel decisions, considering all trips and modal options, as well as personal and household characteristics, within the spatial structure of the surrounding area. Furthermore, they are widely used and accepted as demand forecasting methods for automobile and transit planning. Improvements to existing models should significantly increase their usefulness for analyzing non-motorized policies and facility improvements. Specific near-term and long-term improvements might include:

Data collection on bicycle and pedestrian travel. A general need for all types of bicycle and pedestrian planning is better data on trip and personal characteristics of travelers. Household travel surveys performed for modeling purposes are a potentially effective means of collecting these data. While data on non-motorized trips are increasingly being collected in these surveys, surveys must be designed carefully to ensure that all non-motorized trips are reported. Also, since there are generally few reported bicycle trips, additional means of collecting data on bicycle trips, such as supplemental stated preference surveys, may be required. The potential for non-motorized data collection using emerging ITS information technologies should also be investigated.

Spatial scales of models. The scale at which travel is modeled should be refined to be more relevant to the short distances involved in bicycle and pedestrian travel. Improvements in computational power and in data management tools will make it easier to analyze smaller-scale networks of bicycle and pedestrian facilities rather than just major roadways.

Facility design factors. For travel models in which bicycle and pedestrian networks can be accurately represented, the most important design variables for predicting mode and route choice should be identified and included in the network link characteristics in the model. This will require quantifying tradeoffs between these variables and link travel time or distance. Travel time penalties also need to be developed for major intersections or other discontinuities in the network. The validity of aggregating link-level factors across routes and networks to produce an overall "utility" or "compatibility" should be tested. In addition, the potential for transferring preferences for facility design from studies conducted in one area to other areas, to avoid the need for locally-specific surveys, should be investigated.

Environment factors. For regional models in which zones are too large to model local non-motorized networks, further development and testing of zone-level environment factors are needed to validate the usefulness of these models for analyzing non-motorized travel. These efforts can build on the outcomes of basic research into these factors and can also utilize GIS data bases and analysis techniques to develop better factors. In addition, environment factors should be developed for bicycles as well as pedestrians.

Other environmental and policy variables critical to non-motorized modeling. Factors such as the presence of bicycle parking and workplace showers and lockers may be just as important as facility and network design factors in determining the decision to walk and particularly to bicycle. Methods should be investigated for collecting data on these factors; describing them in a way in which they can be included in travel models; and verifying the relationship of the identified factors with levels of non-motorized travel.

Modeling behavioral change in multiple stages. Methods and data requirements for modeling bicycle use in multiple stages should be investigated. Multi-stage behavior models may improve forecasting efforts because the individual must first decide to even consider bicycling or walking as a viable travel option. Only when bicycling or walking is regarded as a viable option does the question of whether to bicycle or walk for a particular trip become relevant. These methods should be tested for improving the sensitivity and predictive power of travel models. The results of research into attitudinal and perceptual factors, as well as modeling approaches from the public health and market research areas, can inform this process.

Inclusion of recreational travel. To be useful for modeling non-motorized travel particularly on separate facilities, travel models will need to be capable of modeling recreational as well as utilitarian travel. Advances in activity-based modeling, which looks at personal and household activity patterns rather than simply trip-making patterns, may be useful in this effort. Research and methods from the public health arena are also relevant to modeling recreational travel.