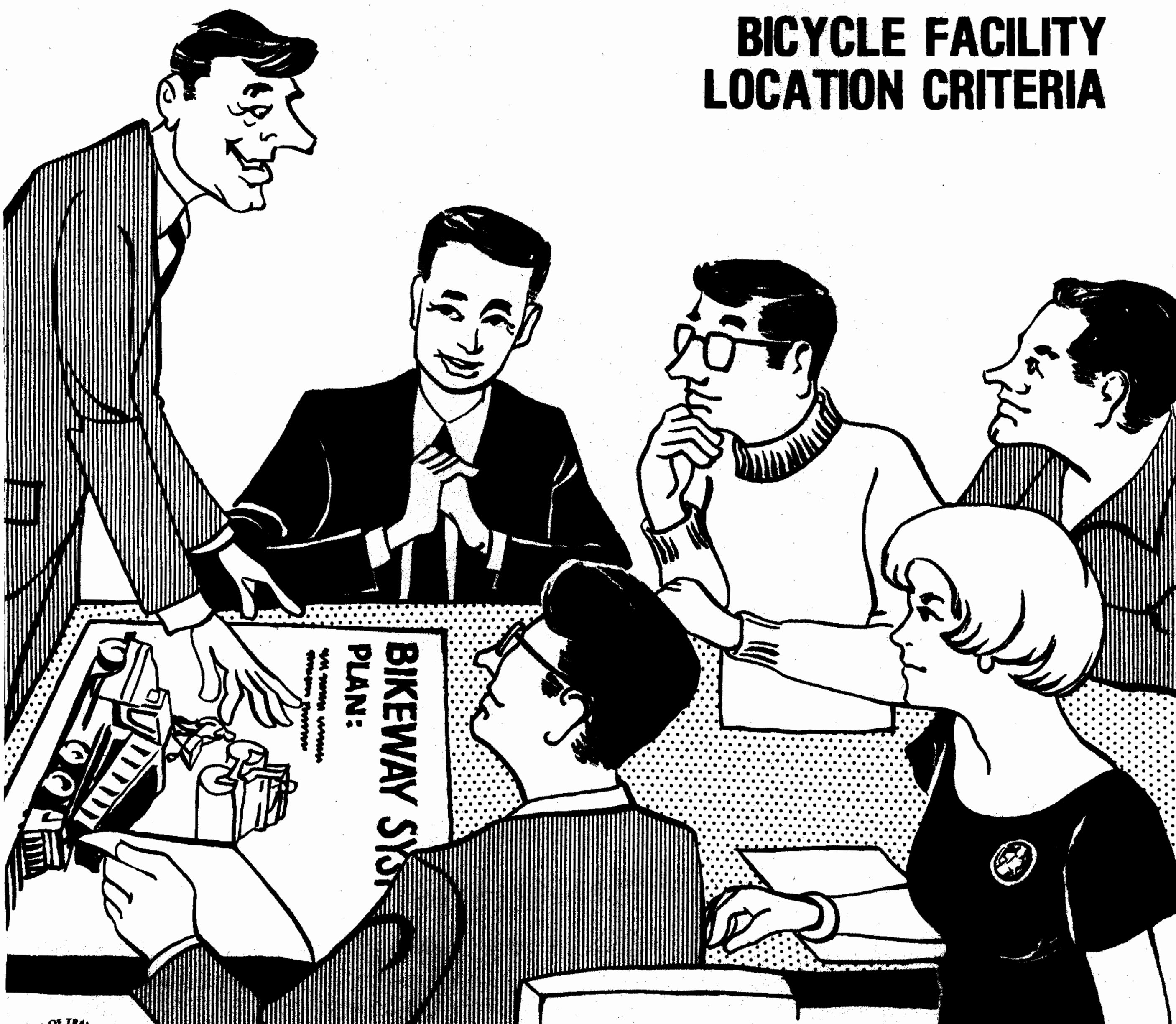
SAFETY & LOCATIONAL CRITERIA FOR BICYCLE FACILITIES

USER MANUAL VOLUME I: BICYCLE FACILITY LOCATION CRITERIA



DEPARTMENT OF TRANSPORTATION
Federal Highway Administration

FHWA-RD-75-113

NOTICE

FHWA DISTRIBUTION NOTICE

Sufficient copies of this report are being distributed by the FHWA Bulletin to provide a minimum of three copies to each regional office, three copies to each division office, and five copies to each State highway agency.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-RD-75-113		

4. Title and Subtitle	5. Report Date
SAFETY & LOCATIONAL CRITERIA FOR BICYCLE FACILITIES USER MANUAL VOL. I BICYCLE FACILITY LOCATIONAL CRITERIA	February, 1976
	6. Performing Organization Code
7. Author(s) D.T. Smith, Jr.	8. Performing Organization Report No.
9. Performing Organization Name and Address DeLeuw, Cather & Company 120 Howard Street San Francisco, Cal. 94120	10. Work Unit No. FCP 31E3022
	11. Contract or Grant No. DOT-FH-11-8132
	13. Type of Report and Period Covered Final Report
12. Sponsoring Agency Name and Address Offices of Research and Development Federal Highway Administration (HRS 41) U.S. Department of Transportation Washington D.C. 20590	14. Sponsoring Agency Code

15. Supplementary Notes

FHWA Contract Manager John C. Fegan (HRS-41)

16. Abstract

This manual is designed to enable users to make judgements on the need for and the location and form of bicycle facilities. The document offers an overview of the planning process and relevant locational criteria. In addition, a methodology for estimating potential bicycle activity is presented. An appendix which discusses the use of surveys in locational planning has also been included. Finally, a design solution for the provision of bikeway grades based upon a consideration of physiological work capability is described.

17. Key Words	18. Distribution Statement
Bicycle Planning Locational Criteria Survey	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	99	

Form DOT F 1700.7 (8-69)

CONTENTS

FIGURES

TABLES

ACKNOWLEDGMENTS

Grateful appreciation is extended to personnel of the Federal Highway Administration Office of Research who provided direction and assistance. John Fegan guided the overall research effort. Julie Fee and Walter Adams provided helpful comment over the course of the program.

Special recognition is due project staff through whose efforts this report was produced. Charles De Leuw Jr. assisted in overall conduct of the research. Dale and Donna Lott undertook case studies of ongoing bikeway planning programs. Sherrill Swan researched bicycle activity data and forecasting techniques. Dr. Melvin Ramey and Dr. William Adams developed grade evaluation methodology. Steve Lowens, Dr. Robert Knight and Michael Kennedy edited the first draft of this report. The laborious work of typing the manuscript was done by Brenda Walker and Alice Sgourakis. Merle Bessie and Inger Knox were responsible for graphic design.

CHAPTER 1

INTRODUCTION

In 1973 the Federal Highway Administration undertook a 2-1/2 year program of research in bicycle facility planning and design entitled "Safety and Location Criteria for Bicycle Facilities" (DOT-FH-11-8134). This effort has included both an extensive study of experience on existing bike facilities and new experimental research. Its objective has been to develop methods and guidelines for effective planning and design of bikeway facilities.

This manual is one of three produced as principal products of the FHWA program. It deals with planning, through a focus on the process of bicycle facility location. A companion volume presents recommended bikeway facility design practices and related operational considerations. These two volumes are intended as basic reference sources for jurisdictions at all levels engaged in the bikeway planning and design process. They expand upon an earlier interim product of the program, the FHWA report "Bikeways -- State-of-the-Art -- 1974" (FHWA-RD-/4-56, available* from NTIS). However, most of the information in that report remains relevant. The third product is a final report which provides an overview of the project together with documentation of research findings.

PRIMARY PURPOSE

The basic purpose of this volume is to enable users to make judgments on the need for and the location and form of bicycle facilities. However, the manual is not a "cookbook." Bicycle facility planning is in its infancy; there is only a limited body of hard technical data that can be used, and the variety of situations where bike facilities may be desired is too wide to lay down a series of axiomatic rules for the planner to follow. Rather than imposing the authors' judgment upon the user of this manual, the objective in this volume is to establish a framework of analytic procedures in which the user will have at hand the pertinent technical facts, an understanding of techniques which are appropriate for development of additional data, and a "shopping list" of factors to consider. The user can bring these together with his own sensitive insight to develop independent judgments regarding solutions.

NON-PHYSICAL ELEMENTS

It is necessary to set such locational decisions within the broader framework of what may be called "bicycle activity planning." The planning of physical facilities is but one aspect of a range of program and

*P.B. Number 236998/AS

policy decision-making related to providing for bike use. There are legitimate non-physical responses to many bike-related issues and problems which must be considered; examples are:

- bicyclist education or training;
- law enforcement; and
- vehicle code changes.

In many jurisdictions today there is a tendency to initiate physical planning processes too soon. Problems may be only dimly perceived and in many instances non-physical solutions may well be more appropriate. Thus, an important secondary objective in this manual is to provide guidance in truly considering the process from start to finish. This begins with the question "Does a physical facility solution respond directly to the specific need at hand?" Accordingly, the manual attempts to indicate points of departure in the bicycle planning process at which non-physical avenues of approach may be indicated.

NEW DEVELOPMENTS

In applying material from these manuals it is essential that the reader recognize that the field of planning and design of bicycle facilities is still a dynamically developing one; new findings on factors affecting bicyclist safety, amenity enhancement, and usage motivation as well as new techniques for planning and design continue to emerge. Although the content of these volumes is based upon evaluations of experience to date and the findings of most recent research, it is imperative that users keep abreast of developments subsequent to this date of publication.

DEFINITIONS

Locational Criteria Defined

Within this volume the term "locational criteria" refers to guidelines for assessing the various factors which influence a bikeway location's acceptability. Technically, "criteria" are defined as standards upon which a judgment or decision is based which define satisfaction of specific objectives. At present, most of the criteria involved in bike facility location are subjective, with quantitative definition not possible from present knowledge. This requires a less rigorous interpretation of the term.

Bicycle Facility Defined

The term "bicycle facility" is not limited to "bikeways." Support facilities such as a STOP sign, traffic signal, or special storm drainage grate installed to eliminate bicycling hazards and bicycle storage and parking provisions at work for convenience are as much "bicycle facilities" as is a paved bicycle path through a park or a bike lane along a city street. Many such support facilities are dealt with in detail in the companion volume on design practices. In this volume bicycle facilities primarily relate to choice of a travel path, including bike lanes, paths, intersection treatments and means of breaching barriers. The term can also denote a system of bike routes rather than an individual facility.

ORGANIZATION OF THIS MANUAL

The following chapter, Chapter 2, summarizes the planning process and locational criteria presented in this manual. Chapter 3 details the planning process, beginning with determining the need for facilities, identifying potential facility locations and impediments to travel, defining alternatives at an appropriate level of detail and deriving the final plan. Chapter 4 details the locational criteria to be used in developing a comprehensive bicycle plan. The chapter identifies state-of-the-art technical data which is useful in decision-making and details the many considerations which are involved in developing a plan. The appendicies present a number of techniques and determinants which will aid planning for bicycles.

This manual is written primarily as an aid to technical and administrative personnel, so it is for their perspective that the approach is developed. However, citizens with general interest in the subject will be particularly interested in the summary presented in Chapter 2 and may be attracted to particular sub-topics in Chapter 4. In addition, students with an interest in extending state-of-the-art research in this field are directed to the Appendices which summarize many of the technical skills and data currently available.

CHAPTER 2

PLANNING PROCESS AND LOCATIONAL CRITERIA OVERVIEW

This chapter summarizes the material presented in Chapters 3 and 4. Although all key concepts and conclusions are repeated in this chapter, the reader is directed to the later chapters for any details or support documentation.

THE PLANNING PROCESS

When a jurisdiction chooses to act upon a bicycle-related issue, often the tendency is to react along the lines of the initial vision of the problem, accepting or rejecting courses of action within that limited framework. This can easily result in leaping to a solution without really defining the true problem and the range of potential solutions.

The Question to Ask

"Where should this facility be placed?" is often the initial question asked. A better question might be "Do we need this facility?" The best question, however, is "What do we need?" The first question presumes both a problem and a solution and only addresses details of the solution. The second question recognizes the problem, but limits alternative solutions to one. Only the third question is broad enough to consider bicycle needs completely. Only this approach can lead to an appropriate understanding and resolution of community needs.

Steps in the Planning Process

A comprehensive, systematic bicycle planning process is required, and need not be difficult to apply. A suggested sequential process is shown in Figure 1, consisting of the following major steps:

1. Identify Problems and Objectives

   This step should answer the question "What do we need?", whether that be a physical bike facility or otherwise.

   It is necessary to clearly define the problem(s), without reference to any particular solution. This sets the proper tone for identification of the root causes of the problem.

   Once the problem is brought into clear focus, an objective should be defined which specifically describes the future condition to be reached in order to consider the problem solved.

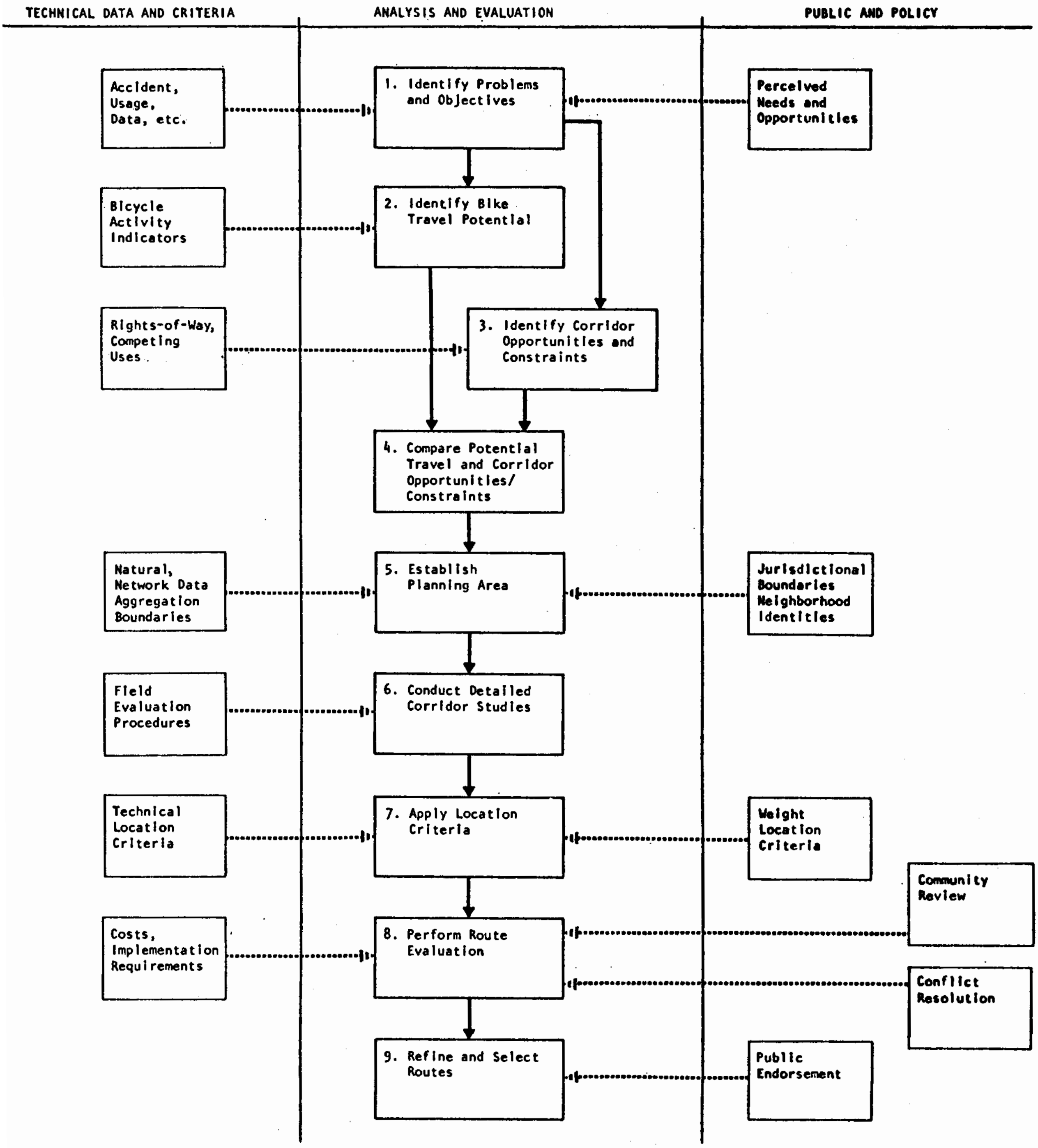


Figure 1
BICYCLE FACILITY PLANNING PROCESS

2. <u>Identify Bike Travel Potential</u>

If it is established that a bikeway facility is a plausible alternative, the demand for or potential use of such facility is assessed. Numerous methods may be used, including:

- Bicycle traffic counts,
- Bicycle accident records,
- Motor vehicle traffic counts,
- Existing regional travel data,
- Major travel generator identification,
- Community group participation, and
- Surveys.

Whatever the method(s) used, this step should result in estimates of potential bicyclist usage and major demand corridors.

3. <u>Identify Corridor Opportunities and Constraints</u>

This step consists of identifying physical corridors for bicycle travel as well as specific barriers to such travel, and includes:

- <u>Initial Corridor Identification</u>: Flagging on a map all streets and other rights-of-way which are reasonable candidates.
- <u>Identifying Obstacles to Bicycle Travel</u>: These should include but distinguish between absolute barriers and impediments, and key penetration points should be identified.

4. <u>Compare Travel Potential and Corridor Opportunities/Constraints</u>

This step brings together Steps 2 and 3, and should result in flagging of "high-potential" corridors and screening against identified bicycling obstacles. Where obstacles are present, searches can be made for alternate corridors, and studies of obstacle penetration schemes can be initiated.

5. <u>Establish Individual Planning Areas</u>

Factors to consider in subdividing the study area are:

- Size: A reasonable typical planning area size is on the order of two square miles, although this may vary depending on total study area size, intensity of activity and barrier conditions.

- Requirements and Constraints: There should be a relatively limited set of facilities linking any two adjacent planning areas, and use of physical barriers and data unit boundaries should be considered in defining boundaries.

- Local vs. Areawide Conflict: The planner must be continually conscious of the total study area cohesiveness while optimizing the bikeway system in individual planning areas. Conflicts should be identified and resolved on an individual basis.

6. Conduct Detailed Corridor Study

This step consists essentially of collecting detailed information on potential facility corridors. The following elements are involved:

- Specifying Locational Criteria: Locational criteria to be used in route evaluation must be identified prior to field studies.

- Field Reconnaissance: This is the primary input to route evaluation. It should be accomplished prior to preliminary design, and preferably done astride a bicycle.

- Use Conflicts: These should be identified during field reconnaissance, but might require further special studies. Examples of use conflicts are where auto parking must be removed to make room for bike facilities, and where social conflicts (e.g., security) are introduced.

- Costs: Preliminary costs should be prepared during this step, as well as identification of funding sources. These may vary with different bike route options.

7. Apply Locational Criteria

This step provides a systematic means of judging each alternative. Two elements are involved:

- The identification of major problems with the proposed facility.

- Combination of individual criteria rating to form indication of plan acceptability.

8. <u>Perform Route Evaluation</u>

In this step, potential routes are evaluated. Two elements are involved:

- Assessment of Each Route Alternative. This involves giving an alternative measures of acceptability for all selected locational criteria.

- Comparison of Alternatives. Measures of acceptability are combined into a composite measure for each alternative to allow a direct comparison. The combining process may be formal or informal, and may or may not involve weighting of individual criteria.

9. Refine and Select Routes

This process is inherent to several of the preceding steps, but merely formalizes the process prior to final route adoption. Two distinct elements may be involved:

- Cyclic Process: If route evaluation has necessitated major changes to original concepts, it may be advisable to repeat the sequential planning process.

- Final Check: The revised facility location should be checked against travel potential patterns to ensure that route revisions have not negated the original premise for the route: its potential for use.

Throughout the planning process, community inputs and review should be sought.

The planning process can be responsive to varying means of citizen participation and different levels of data availability. It is not intended as a rigid step-by-step process, but a flexible, systematic procedure through which locational criteria can be applied to a route or system of routes.

LOCATIONAL CRITERIA

Chapter 4 of this manual details the major considerations involved in bikeway facility planning and their related criteria. In summary, the most relevant topics of user specific criteria fall into three groupings:

- Primary User Related;

- Other User Related; and

- General.

Elements of each criteria group are identified in the following paragraphs.

Primary User-Related Criteria

- Potential Use: The major intent of any bicycle facility should be that it be used. Depending on the objective at stake, this could involve either the improved accommodation of existing traffic or the encouragement of new bicycle use.
- Basic Width: Separate operating areas of at least recommended minimum widths for motorized vehicles and bicycles should be created.
- Connectivity and Directness: Connectivity implies a clear and uninterrupted path between centers of activity for cyclists. Directness implies minimizing distance and/or energy exertion by the user.
- Safety: Safety is an obvious criterion topic. In location planning, the type of user will determine the degree to which safety is emphasized.
- Grades: The amount of work required to negotiate grades can be quantified, and a "minimum energy" path can be described for each alternative. Out of direction travel is often acceptable to cyclists to avoid steep grades. Grade criteria will vary depending on the age and/or condition of potential cyclists.
- Barriers: Physical barriers to cycle usage should not be avoided, but should be seen as prime opportunities, if breached, for increasing continuity and usage.

Other User-Related Criteria

- Attractiveness: An attractive environment is greatly desired by recreational cyclists, although less important to those with specific trip purposes.
- Image Projection: A bikeway, even on a local street, must clearly appear to provide continuity and destination service to the unfamiliar user.
- Air Quality: Air quality should be judged for its effect as a regional health factor and for the specific effect on cyclists closely exposed to pollution sources.
- Pavement Surface Quality: While poor surface quality is a negative factor in location planning, assessment of improvement costs can be included in the planning process.

- Truck and Bus Traffic: At high speeds, the aerodynamic effects of trucks generally rule out mixed or adjoining bike usage. At low speeds on city streets, high truck usage requires adequate width of vehicle lanes. Truck noise is an amenity factor which is especially undesirable for recreation trips.

General Criteria

- Cost/Funding: While a large number of low cost facilities might be constructed within available funds, over-emphasis on this criterion may produce non-optimal unused facilities. Consideration should be given to routes which qualify for special funding from sources external to the planning agency.

- Use Conflicts: These include competition for right-of-way between bicycles and motor vehicles (moving and parked); between bicycles and pedestrians; between government agencies with differing interests, and between social groups which bikeways may bring into contact.

- Security: Security must be provided for cyclists passing through high-crime areas, and for residential locations which might perceive cyclists as a security threat.

CHAPTER 3

THE PLANNING PROCESS

This chapter describes a comprehensive, systematic process for planning bicycle facilities. Although the description implies an areawide bike system, the suggested procedure is sufficiently general to be used for planning of individual bike facilities.

THE NEED FOR SYSTEMATIC PLANNING

The appropriate solution to an identified bicycle planning problem must arise out of a systematic planning process, rather than using "planning" only to implement a preconceived solution.

There is another need for a systematic planning process. Although the focus of this portion of the FHWA program is on recommendation of facility locational criteria, it is also necessary to show how these criteria can be applied. Other questions arise almost automatically: How should alternatives be selected? How can a choice be made using multiple criteria? To answer these requires the development of a systematic process in which the role and use of locational criteria can be made clear. Therefore, this manual describes the process before presentation of the criteria themselves in detail.

An Example

The need for systematic planning can best be illustrated with an example. Consider the following scenario:

> A single accident involving a child bicyclist on his way to school generates an emotional appeal for a school-oriented bike route system, an appeal of such force that local public officials feel they must respond. The local jurisdiction applies to the Traffic Safety Program and obtains funds to plan such a school route system. The local jurisdiction then signs another contract, this time with a consulting firm to do the planning work. After the consultants have digested all the police accident records involving bicyclists, they discover that safety of young cyclists commuting to school is not the problem at all. The single accident which led to the emotional appeal has in fact been the only one involving a child cyclist on the way to or from school. Virtually all other accidents involving young cyclists have occurred at times and places unrelated to school commutes.
>
> The proposed school commute bike routes would make no significant contribution to reduction of the real accident problem. But by the time this discovery is made, there are already two signed contracts

with specific end products to be delivered, the school bike route plan, and a citizens group mobilized around the issue and eager to go forward. The original approach has a momentum of its own. There is a high probability that the school route planning will grind on to conclusion rather than the effort being redirected toward schemes which respond to the real child bicyclist safety problem. Even if redirected, substantial effort, time, and cost will almost surely be required to halt the initial momentum of preconceived solutions, bureaucratic procedures and political postures established.

This scenario is hypothetical, but it is not an exaggeration of what can happen when a community attempts to implement solutions without careful, systematic, and comprehensive planning.

THE PROCESS IN BRIEF

As shown in Figure 1, the planning sequence is as follows:

1. Identify problems and objectives.
2. Identify bicycle travel potential.
3. Identify bicycle corridor opportunities and constraints (concurrent with step 2).
4. Compare potential travel and corridor opportunities/constraints.
5. Establish individual planning areas.
6. Conduct detailed corridor studies.
7. Apply locational criteria.
8. Perform route evaluation.
9. Refine and select routes.

Throughout the process, active community participation and review is recommended. With such community involvement and the use of a systematic process with clear objectives, the successful planning of bike facilities should be assured. The classic planning process requires continuing effort, and bikeway planning is no different. The minimum commitment should involve achieving yearly goals by modifying and expanding the bikeway plans and funding as required to meet community requirements and by being flexible enough to enable responding to unique situations and taking advantage of emerging opportunities.

The various elements of the planning process are discussed in detail in the following sections of this chapter.

STEP 1: IDENTIFY PROBLEMS AND OBJECTIVES

The intent of this section is to provide a brief discussion of how definitions of problems and objectives may be produced. This will not include a detailed procedure, however, for such information is widely used in planning and readily available from other sources.

In this initial step we are simply trying to prevent a too-quick assumption that what is "needed" is a specific facility such as a bikeway system. Ideally, we would like to answer a question such as "What do we need?" But this answer is the result of planning, not its beginning. More appropriate at this initial step is to identify the problem at the root of any desire for bikeway improvements.

The Problem

The problem to be solved may be a high rate of bicycle accidents or potential accidents; auto traffic congestion which might be eased through encouragement of bike use; a public demand for more outdoor recreation opportunities; or many others. It is likely that several problems will be identified. The key point is: The problem should be defined without reference to any particular solution. (For example, a high bike accident rate should not be interpreted immediately as a need for a bikeway, but rather explicitly as an accident problem.) This prevents a hasty narrowing of the scope of concern, which might result in overlooking far better solutions.

Once the problems are thus defined, the proper tone is set for identification of their causes. Who is involved? Where? When? This corresponds to the example of the school commute bikeway system cited at the beginning of this chapter. The purpose here is to understand the problem as well as possible. This can lead to redefinition of the problem itself, as in the school bikeway example.

The Objective

Simply put, the objective is to solve the problem. More specifically, the objective should define and describe the future condition which is to be reached. Sometimes the effort of identifying problems and their causes will show clearly that a physical facility (typically a bikeway system) is needed. In other instances, it may be necessary to conduct a brief study to answer this question: "Can anything other than a physical facility better solve the problem?" If other candidate solutions are generated, they can be carried through the planning process as alternatives.

The result of this step, then, is a statement of the objective to be reached, in as much detail as possible. At a minimum it should state what constitutes a solved problem, such as a particular reduction in accidents. This will allow a solution or alternative solutions to be developed to meet this need.

The remainder of this bicycle facility planning process assumes that a bikeway or similar facility is at least one of the plausible solutions to the problem at hand. If this is not the case, a more general planning process should continue. However, this situation is not within this manual's scope.

STEP 2: IDENTIFY BIKE TRAVEL POTENTIAL

Once the problems and objectives are defined and it is established that a bikeway facility is at least one of the plausible alternatives, the next step is to assess the demand for or potential use of such facilities. The product of this step should be estimates of major bike travel flows by general location and type. One example method of graphically presenting these results, referred to as "desire line" estimates, is shown in Figure 2.

Techniques for identifying potential bicycle travel demand and activity corridors include the following:

- Bicycle traffic counts;
- Bicycle accident records;
- Motor vehicle traffic counts and flow maps;
- Existing regional travel data;
- Major travel generator identification;
- Community group participation; and
- Special surveys.

Bicycle Traffic Counts

The simplest source for bicycle travel data is a bicycle traffic count program, which leads to a "flow map" of bicycle volumes.

Problems inherent to this approach are:

- It says little about where bicyclists are coming from or going to, or trip purposes.

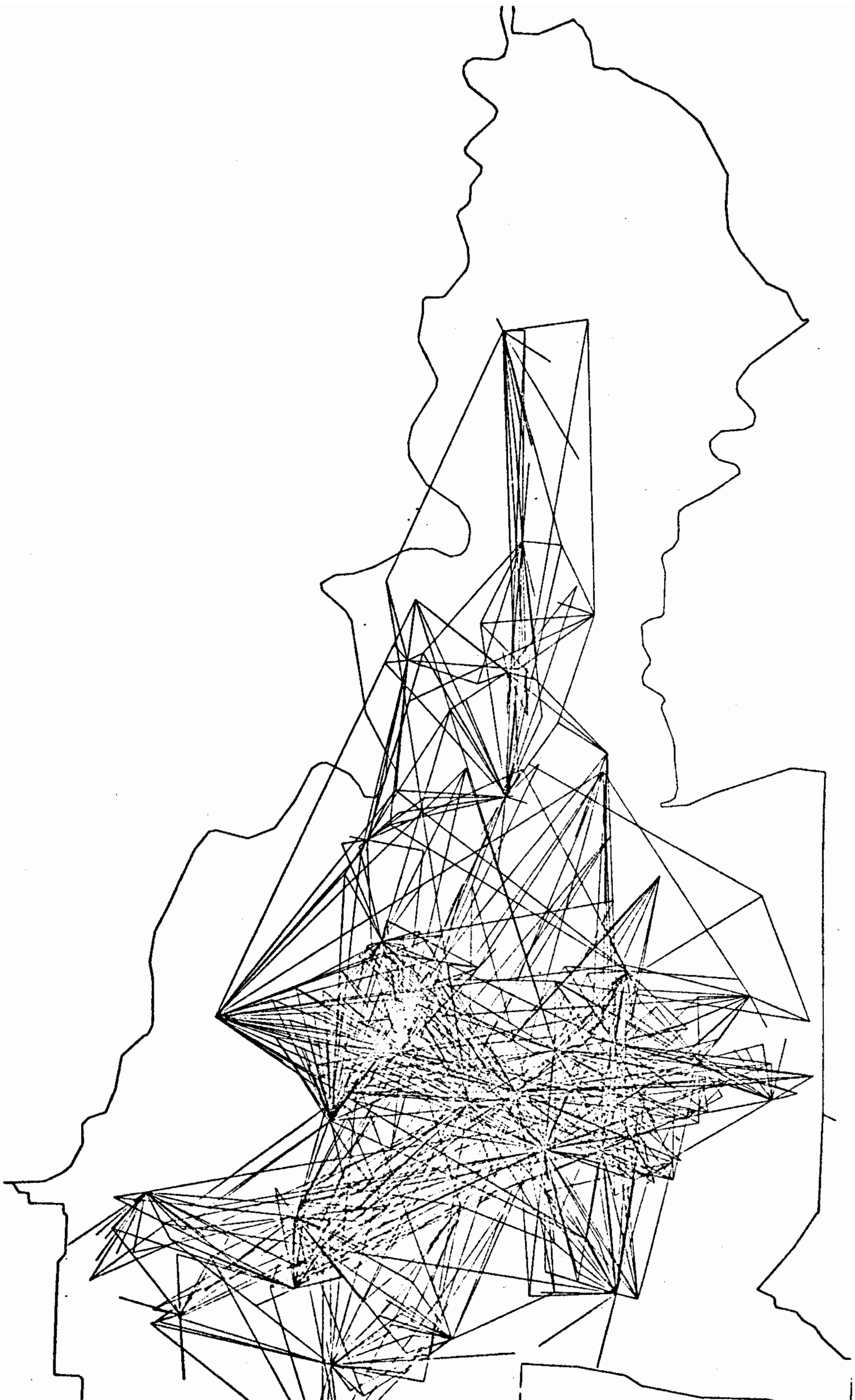


Figure 2
DESIRE LINE ESTIMATES

- It simply reflects the configuration and quality of the existing bike route/street system, rather than where riders would prefer to travel or what latent demand there might be for the bike facilities. Thus, bike counts indicate only the minimum potential demand.

- Costly manual counting is normally required since bicycles will not usually register on pneumatically actuated traffic counters.*

- Counts must be rather closely spaced to give a representative picture of bike travel activity since bike traffic may vary sharply within short street segments.

Despite these problems, this technique may be useful in some circumstances, such as:

- Where ridership is fairly static, and the analysis is responding to existing deficiencies; and

- In providing checks on other data, such as survey results.

Some communities have developed systematic counting procedures in which a very fine-grained set of bike counts on the entire network are initially taken and analyzed. It is contended that, on the basis of existing count relationships, it is possible to project bike volumes on the entire network by taking new bike counts at a very limited number of key indicator stations. This technique offers a reasonable chance of success in a community where the situation remains relatively static but if the system is perturbed by anything more than marginal change -- the opening of new major activity centers, the addition of new bicycle facilities or elimination of bike travel barriers which would significantly change the accessibility pattern in the community or the attractiveness and safety of bicycling -- the entire count model must be recalibrated.**

Accident Records

Accident records are useful in several ways:

- To indicate hazardous locations or circumstances for bike travel. This includes review of bicycle accidents as well as of motor vehicle accidents.

---

*Mechanical traffic counters actuated by magnetic conductors have been successfully employed for counting bicycle traffic on off-street facilities "Oregon DOT Bikeways Progress Report," February 1973. However, their applicability for counting mixed traffic is constrained by inability to distinguish between bicycles and motor vehicles.

**Lloyd N. Popish, Roger B. Lytel "A Study of Bicycle -- Motor Vehicle Accidents" Santa Barbara, California.

- To indicate whether the hazardous situations at these points will respond to physical treatments such as improving traffic control, geometrics or provision of a bikeway facility.

- In some cases, to provide an indirect measure of overall patterns of bicycle activity.

It must be recognized that this is an incomplete indicator. Personal decisions of whether or not to make a trip by bicycle and what route to travel are both influenced by the form and quality of existing bike facilities. Certain areas may be so hazardous -- literally unpassable -- that people simply avoid them when bicycling or don't bicycle at all. As a result, these areas are not indicated in the accident statistics. But accident records are a useful preliminary indication of the patterns of bicycle activity and identify important points or corridors of concern.

This type of information is usually readily available in local law enforcement records. However, in most communities with normal levels of bicycling activity it is necessary to analyze bike accident records for several prior years to obtain a sufficient number of incidents for patterns to emerge. Along with accident location analysis, it is important to determine whether the types of accidents found can be eliminated by provision of physical facilities.

Motor Vehicle Traffic Counts and Flow Maps

Another indirect indicator of bicycle activity is motor vehicle traffic counts and motor vehicle flow maps. This is because:

- Utility-oriented and some recreational bicycle traffic, like motor vehicle traffic, tends to concentrate on the fastest and most direct streets.

- Bicycle traffic tends to have as its destinations many of the same activity centers as motor vehicle traffic.

Motor vehicle traffic volume patterns are most suitable as indicators of potential bicycle activity in small and medium-sized communities, particularly when they are self-contained communities rather than part of a larger metropolitan area. Within a large metropolitan area, there is a tendency for long-distance regional traffic to be mixed with and mask local traffic. However, with the exception of freeway and expressway facilities, even in the larger urbanized areas motor vehicle flow maps remain a useful indicator of likely bicycle trip patterns.

Existing Regional Travel Data

Another indirect method of estimating potential bicycle activity involves use of existing regional travel data. Most jurisdictions over 50,000 population and many smaller communities have available a reasonably representative transportation data base. Typical data collected includes:

- Numbers, purposes and modes of person-trips on an average day;
- Trip length frequencies for each trip purpose;
- Origin-destination patterns; and
- Household socio-economic data.

There are several advantages to using such data:

- It is readily available;
- Because trip purpose breakdowns exist, the variation in bicycling propensity with trip type (see Chapter 4) can be explicitly considered in gauging potential for bicycle trip-making;
- Area-specific estimates of bicycle activity can be built since data includes trip origins and destinations; and
- Likely travel desire corridors can be identified from linked origin-destination data.

Possible applications of regional travel data include the following:

- <u>Development of short-trip travel matrix</u>

  Respondent trip length distributions can be compared by purpose to typical acceptable bicycling trip lengths. This is a useful exercise for indicating the bicycle's potential share of the total trip market.

  Using a bicycle trip action radius determined from local data if available; data from other jurisdictions (see Appendix A); or hypothetical values, one can modify a regional trip matrix or set of matrices (by trip purpose) to develop a travel matrix which contains short trips only. These are trips which are likely to be highly susceptible to diversion to bicycle.

- <u>Trip assignment</u>

  With a short-trip matrix and standard traffic assignment procedures, it is possible to develop a specific network loading of short trips. This even more closely defines prime corridors for study focus and gives a measure of anticipated relative bike traffic volume. Unfortunately, because of the short lengths of many bicycle trips and the large analysis zones in most travel data bases, a high percentage of the trips in the prime bicycling range appear as intrazonal trips or are not represented at all. Hence they are not assigned to the transportation network. The extent to which this occurs varies with sizes and analysis zones.

The fact that many biking-length trips are represented as intrazonal trips is not necessarily a serious drawback. In some situations, trips represented as intrazonals may in fact be so short that they would likely make limited use of any bicycle facility that would be provided. Trips susceptible to diversion to bicycle facilities (trips of more than several blocks) would be normally represented on the network.

In the typical coarse-grained travel models most of the potential benefit of assigning bicycle trips to a network is lost. More profitable analyses can be made simply by examining and plotting origin-destination matrix data. Typically, network assignments will remain useful for zones up to one mile square, although smaller zonal scale is obviously preferable. Usefulness of such data will vary according to the size of the bicycle planning area. Obviously assignments from a regional model with a one-square mile zonal structure will provide little input to bicycle planning for an isolated five-square mile community on the region's fringe.

- <u>Bike-Specific Model</u>

  It is theoretically possible to develop a bike-specific model using existing transportation planning software. Networks could be coded, typically with all lengths coded at the same speed. Travel speeds of about 10 to 12 miles an hour are reasonable except where grades or other speed constraints exist. European efforts have shown the applicability of conventional and advanced transportation planning trip distribution and mode split models for the bicycle mode.* However, for the United States insufficient data exist to develop specific household bike trip generation or mode split parameters at this time. Factors which are involved include:

  -- bicycle ownership;

  -- availability of facilities;

  -- changes in public attitudes towards utilitarian bicycling;

---

*"Disaggregate and Simultaneous Travel Demand Models -- A Dutch Case Study." Project Bureau Integrate Verkeer -- en Vervoerstudie, 1974. Richards, Martin G., "Some Aspects of Transportation Study Procedure in the Netherlands" Verkeerstechnick, 1970, No. 9.

-- changes in the economics of travel (sharp increases in energy cost);

-- other social incentives (e.g., concern for air quality); and

-- public policies (e.g., combat air pollution).

Although such information will probably emerge in the future, such bike-specific model applications appear impractical now.

For the present, it seems most advisable to utilize travel model data where available to examine existing total travel within bikeable range and to estimate bike potential from that rather than attempting to synthesize a bicycle trip matrix directly. There is current direct application for conventional travel model methods in the area of network accessibility analysis. This is described later in this chapter.

Major Travel Generator Identification

The identification and location of obvious major bike trip generators is an activity which might be substituted for the analysis of regional travel data. However, it is best done to supplement such work. While this information in a sense parallels that which can be gleaned from regional travel data, it is extremely valuable in that it can be plotted at the fine scale of detail at which bike travel decision-making is normally made. The area of influence of many types of activity centers can be readily defined, thereby giving information not only about the major destination centers but the trip patterns to those centers as well. Some of the types of bicycle travel activity generators which should be specifically located on street maps include these:

- Schools: Distinguish by type and indicate catchment areas based upon school districts or student and/or employee residence statistics;

- Community parks and recreation areas: Identify catchment areas on the basis of competing zones and influence and distinguish among facilities offering bike activities and those with only bike access;

- Community activity centers: (such as libraries, City Halls, social centers); Define tributary areas if appropriate;

- Employment concentrations: Identify white collar and blue collar employment separately since the propensity to ride bicycles may be significantly different between these groups and define origin-destination patterns or trip length distributions from employee zip code lists, journey-to-work statistics or other information sources;

- Transportation terminals: Focus on identification of express bus and rapid transit stops and stations (local bus and long distance inter-city transportation facilities normally have limited importance); and

- Shopping areas: Potential sites for light convenience shopping are most important; identify catchment area.

The identification of activity centers gives a general indication of the major points bicyclist destinations in a community, a general indication of bicyclists' trip purposes, and a general indication of bike trip patterns based upon the catchment areas of various sites.

Community Involvement

Travel patterns of bicyclists can be estimated simply by asking people. This may involve formal surveys (discussed in the next section) or public meetings, community workshops and the like.

Two potential problems should be kept in mind:

- Overstatement of Usage

  There is often a vast gap between what people say they would like to do (or would do) under certain conditions and what they actually do when those conditions are met. This is particularly true with popular subjects such as bicycling. As a result, people are quite likely to overstate their usage of specific facilities.

- Non-Representative Sampling

  Capabilities, attitudes and needs of highly skilled and experienced bicyclists (which is a relatively limited group) differ greatly from those of casual and potential bicyclists. Provisions which seem non-essential to experienced cyclists may be highly significant in motivating other cyclists, and vice-versa. Thus, extreme caution must be used in designing the citizen participation process and in interpreting their inputs to avoid biases.

Public participation can be quite time consuming and costly, and this needs to be considered in designing the citizen involvement process. However, the method is a powerful one, and has the additional benefits of enhancing study results credibility and soliciting early public support for recommendations.

Surveys

The use of surveys is an obvious means of developing projections of bicycle usage. A number of survey techniques could be used:

- Questionnaires (mail-back);
- Personal Interviews; and
- Telephone Interviews.

Surveys may be directed at existing and potential bicycle facility users or at the general public. The type of survey and its target group will determine the type of information which can be collected.

- Comprehensive Origin-Destination Surveys

  As discussed in a previous section, comprehensive origin-destination surveys have already been conducted in numerous urban areas. These are typically based on personal interviews at the household level, and utilize sophisticated sampling and analysis techniques. Use of the existing data base should be considered prior to conducting additional surveys.

- Special Surveys

  Special surveys directed toward existing and potential bicyclists or the general public can provide useful information for estimating bicycling potential. In particular, they can yield information on:

  -- Origins, destinations and purposes of travel;

  -- Attitudes, concerns and needs of bicyclist; and

  -- Attitudes, concerns and needs of non-users.

  These types of information cannot be discerned from bicycle traffic counts or the like.

- Survey Guidelines

  While a detailed discussion of survey methods is beyond the scope of this manual, since there are many existing publications dealing with the topic, Appendix B of this manual does give guidelines for avoiding some of the common pitfalls associated with past bike-related surveys. Some of these are:

  -- Objectives and Outputs: Spell out the survey's contribution in detail, including specific results to be obtained.

-- Survey Design: Clearly identify the target population and design the survey accordingly.

-- Sampling Techniques: Exercise extreme caution to avoid biases in results. Qualified statisticians should be consulted.

-- Questionnaire Design: Avoid unclear, biased or unnecessary questions. Pre-test the questionnaire.

-- Conducting the Survey: Train and closely supervise field staff.

-- Analysis/Reporting: Design analysis procedures prior to conducting the survey, and keep reports to a minimum. Assure respondents confidentiality.

- Interpretation of Results

  Caution must be used in interpreting survey results, particularly answers to "What if?" questions. There is often a gap between what people say they would do under certain conditions and what they actually do when conditions are met. This can result in overstatement of future usage. Also, results are only as good as the survey design. If biases are present in sample design or questions, results will be similarly biased.

- Conclusions

  Survey research, no matter what methods are utilized, can be costly and time-consuming. Where survey data already exists, or where other lower-cost data sources would suffice, maximum use should be made of these sources.

  In some instances surveys will be the only means of gathering data related to bicycle use potential. In addition, surveys can enhance plan credibility and public support, particularly when combined with community involvement. These benefits should not be overlooked.

STEP 3: IDENTIFY CORRIDOR OPPORTUNITIES AND CONSTRAINTS

The foregoing techniques related to identification of potential bicycle trip patterns and trip desires. Activity which can be undertaken concurrently with those tasks involves identification of potential physical corridors for bicycle travel and specific barriers to such travel.

Initial Corridor Identification

The initial screening of routes should be one which attempts to identify reasonable candidates for a bicycle facility. On a street map of the study area all streets having continuity and providing important linkages across the area should be identified or "flagged" together with notation of topography, barrier and other problems or benefits. A corridor can be a single street or a family of parallel adjacent streets. Where parallel minor streets are about as continuous as nearby major streets, such families of streets should generally be defined.

In addition to streets other opportunities for bike travel should be identified on the map. Some of these include the following:

- green belts;
- parks;
- utility rights-of-way;
- drainage rights-of-way;
- stream courses;
- railroad rights-of-way;
- freeway and parkway rights-of-way; and
- beach fronts.

In addition, corridors which would appear to have particular intrinsic merit for recreational bicycling could be specially flagged on the map.

Identification of Bicycling Obstacles

Any locations posing obstacles to bicycle travel should be identified on an overlay to the corridor map. Obstacles should be separated into two groups:

- Absolute barriers to bicycle travel, such as:
    - -- elevated rail embankments,
    - -- rivers, streams, canals, bays and other large bodies of water, and
    - -- freeways.
- Bicycle impediments which can be crossed by a bicyclist but only with difficulty, such as:

-- busy streets at locations without traffic signals,

-- steep grades (up and possibly down), and

-- freeway interchanges.

Key penetration points to barriers and obstacles should also be distinctly flagged on this overlay. This provides a basis for later determining the feasibility of breaching obstacles.

STEP 4: COMPARE TRAVEL POTENTIAL AND CORRIDOR OPPORTUNITIES/CONSTRAINTS

This step consists of three distinct elements:

- <u>Screen Travel Potential Against Corridor Opportunities</u>

  Patterns of travel potential can be very effectively screened against identified corridor opportunities using graphic overlay techniques. Additional corridors constituting special recreational opportunities should also be identified. Areas where bike trip potential is unserved by identified corridors would also be denoted. One result of this process is identification of "high-potential" corridors for which demand coincides with candidate routes.

- <u>Check Locations of Bicycling Obstacles</u>

  High-potential corridors flagged above are screened against barriers and impediments to bicycling identified in STEP 3. There are two objectives:

  -- identify key corridors which match travel desire lines but which are interrupted by barriers;

  -- find specific barriers/impedances which "explain" the unserved areas already identified.

- <u>Search for Alternate Corridors</u>

  Where high-potential corridors conflict with bicycling obstacles, and where areas are unserved because of obstacles, alternate corridors are sought. Studies of barriers/impediment penetration schemes are then initiated where these conflict with "flagged" corridors or explained unserved areas.

STEP 5: ESTABLISH INDIVIDUAL PLANNING AREAS

At this point, if the overall planning area is large, it is appropriate to subdivide it into smaller study areas (subareas). The rationale for such subdivision is multi-fold:

- Such subdivision facilitates planning at a scale of detail consistent with the subtleties of bicyclists' decision-making. This is necessary if the plan is to have any relevance to individual behavior.

- It enables the planner to understand all the factors which contribute to the success or failure of individual proposals and the system as a whole.

- Disaggregation into small planning areas increases the likelihood of consensus of goals and opinions within the area.

- It is possible to finish a subarea plan and get implementation started within a shorter time frame. This demonstrates positive intent and also opens up the possibility of test programs to measure plan effectiveness, public attitudes, and usage parameters. This allows the planner to approach the remaining subareas with a narrowed set of options, based on these "trial runs."

  Factors which should be considered in establishing and utilizing study subareas are:

  - Size

  - Boundary Requirements

  - Local vs. Areawide Conflicts

<u>Size</u>

A reasonable area for local planning is on the order of two miles square. Several factors influence this:

- the <u>size of total planning area</u>

- the <u>intensity of activity</u> within it; and

- the configuration of <u>barrier conditions</u> which constitute the ideal lines for subarea delineation.

<u>Boundary Conditions</u>

There are two key considerations in determining subarea boundary lines:

- Physical Barriers: There should be a relatively limited set of bike facilities which traverse subarea boundaries. Accordingly, barriers such as freeways and bodies of water are good dividers between study subareas.

- Planning Units: It is desirable to utilize established boundaries of planning units (e.g. census tracts, jurisdictional boundaries) since it is often necessary to supply plans and planning information according to defined planning units.

Where planning unit boundaries coincide with physical barriers to bicycling, these are natural boundaries for subareas. In other instances the planner must balance the need to carve out relatively independent subareas with limited linkages between them, and the desirability of employing established boundaries for data compilation and decision-making.

Local vs. Areawide Conflicts

In optimizing internal bikeway systems in individual study subareas, a danger exists that the areawide system might lack cohesiveness. This danger can be minimized by:

- Drawing subarea boundaries along physical barriers having limited points of penetration, so that subareas are relatively independent of each other.

- Identifying routes of areawide significance during establishment of study subareas.

- By being continually conscious of the total planning area concept while dealing with localized issues.

In some situations, a clear conflict is posed between local and areawide system optimizations. In such instances, each case must be judged individually in accordance with overall planning objectives. For example, if an overriding objective is safety of young cyclists, an option which caters to local area riders might well be favorable; if the overall program objective is to encourage bicycling as an alternative to automobile use, an option which optimizes the areawide system might be favorable.

Potential conflicts between localized and areawide objectives are inherent whether the planning is done on an areawide basis or by use of study subareas. Subarea planning merely brings these conflicts into the open.

STEP 6: CONDUCT DETAILED CORRIDOR STUDY

The next stage in the planning process involves detailed site exploration of potential facility corridors. Each of the initial corridors including those matching travel desire lines, those created to serve areas unserved, and those defined in response to barrier and obstacle conditions are reviewed for physical design possibilities and constraints. The design procedures detailed in Volume II are appropriate tools for this task.

Specifying Locational Criteria

It is at this point that locational criteria enter the process. Essentially the detailed corridor study is the site reconnaissance and initial route refinement step, built around the collection of locational criteria data. This brief discussion avoids redundant enumeration of the criteria, and instead places emphasis on two key factors in the process:

- The importance of field reconnaissance, and
- Resolution of competing use conflicts.

Field Reconnaissance

The field inventory/assessment procedure presented in Volume II is employed to evaluate both on-street and off-street corridor potentials. In addition, contact is initiated with agencies and jurisdictions controlling off-street corridor rights-of-way to determine their feasibility of use. Based upon field assessment results, the physical treatments possible in each corridor are then defined preliminarily, rated qualitatively and roughly costed. The field reviews also provide a more refined identification of barriers and obstacles, and provide insights into their possible design solutions.

There are two key points with respect to field reconnaissance:

- It should be done prior to preliminary route design; and
- It would preferably be done on bicycle.

Field review at this stage is a critical step. Prior to this step all planning activities have involved working from data, maps and the planner's personal insight and familiarity with the study area. Successful bicycle facility design requires a close-working knowledge of the subtle details which affect bicyclists' behavior. Such a knowledge can come only through field observation, preferably done astride a bicycle.

In a number of programs reviewed in this study, field inspection was done only after a route and its preliminary design had been selected. The problem with this approach is that although it saves the cost of a more extensive field inventory, it seeks only to identify and correct defective conditions in the preliminary proposed plan. It fails to seek out opportunities either on the given route or a parallel one which might be superior to the preliminary defined plan. Moreover, it is conceivable that the added field inspection cost for several route alternatives may well be offset by the cost of wasted design effort in cases where designs are detailed and then scrapped in light of field evidence gathered later.

Use Conflicts

The field inspections also identify and evaluate competing use conflicts. These are situations in which existing uses would necessarily be eliminated or curtailed in order to provide a bicycle facility within the given route corridor. Need for elimination of parking or a travel lane in order to provide a bike lane are examples of competing use conflicts. The field inventory identifies the fact that such a conflict exists. If possible, it also gathers relevant data.

Field inventory resources may not be sufficient to determine whether a particular use conflict is an irresolvable obstacle to use of a particular type of treatment in the corridor. In such cases, the planner must determine whether the conflict merits additional studies, or should simply be presumed to be irresolvable and the alternative discarded. This determination will depend on a number of factors including the importance of the facility to the system; the inherent attractiveness and quality of the alternative itself assuming the conflict did not exist, and the quality of other alternatives which could fulfill the same function as the proposal at conflict. This determination might be reserved until the initial formal evaluation of the alternatives (Step 7). Two examples of use conflicts are:

- Parking Removal

  An example of the type of study which might be undertaken to resolve a competing use conflict is a parking study. At times the field inspector can undertake a limited parking occupancy study as part of the field evaluation procedure. However, this would normally be done only in cases in which parking removal is not an anticipated problem, such as removal on one side only in a single family residential neighborhood. The data gathering in such a case is done mainly to provide an element of reassurance that such a proposal is reasonable. Use conflicts are likely to be more significant in cases such as parking removal in a commercial district or in a multi-family residential area where street parking is needed for storage of vehicles. In such instances a formal parking study is likely to be necessary.

- <u>Social Conflicts</u>

  Another kind of potential conflict which should be identified in a field inventory is that of social conflict. This involves a broad range of conflicts such as home security versus mobility, invasion of privacy, resistance to change, racial conflict, class/life style conflicts, and other problems of social interaction. This general type of conflict is often overlooked. However, it can be as serious an obstruction to the implementation or use of a bicycle facility as is a physical barrier. (Examples of social conflicts are specifically discussed in Chapter 4.) The significant point here is that they must be recognized in the planning process and explicitly dealt with. While such recognition may come through mapping of factors such as high street crime locations or identifying elements from survey results, many of the social conflicts which are most significant can only be identified by a trained observer on the site.

The intent in anticipating these conflicts is to allow development of possible counter-measures such as adjustments to physical form as well as to identify alternatives which should be discarded due to irresolvable conflicts.

<u>Costs</u>

Costs for each candidate route and design option should be preliminarily estimated. Funding sources for the various types of facilities should be identified at this stage.

STEP 7: APPLY LOCATIONAL CRITERIA

As Figure 1 shows, Application of Locational Criteria enters into the detailed study of route/facility alternatives. This step is devoted to collecting the information needed to evaluate the alternatives on each criterion. This information is then applied in the next step, the actual evaluation of routes.

The role of the Locational Criteria, then, is to provide a systematic means of judging the relative merits of each alternative. This is the heart of the planning process, for it controls the selection of a plan. In the evaluation, the facility (or alternative) is rated against each criterion such as use, safety, and barriers. This permits two analyses:

- First, it allows the identification of major problems with the proposed facility, such as an inherently high risk of accidents.

- Second, this process leads to the combining of individual criteria ratings to form an overall indication of the acceptability of the plan.

STEP 8: POTENTIAL ROUTE EVALUATION

In this step locational criteria are utilized to evaluate alternative routes. Two parallel lines of approach are involved:

- Assessment of each alternative

- Comparison of Alternatives

Assessment of each Alternative

The planned (or alternative) route is assessed for its performance on each of the locational criteria. At least a level of minimum acceptability should be reached on each criterion. Where failures are identified, revision or rejection of the plan is required.

This process consists of two elements:

- Defining criteria to be used; and

- Measuring acceptability of the alternative against each criterion.

In Chapter 4 a number of locational criteria are described, as well as measures of acceptability. It is intended that the criteria constitute a comprehensive "shopping list" rather than standards for evaluating bicycle facilities. It should be noted that each community and each situation may require modifications to the list of criteria and to their measures of acceptability.

Comparison of Alternatives

Where more than one alternative is under consideration, they should be ranked against one another as an aid in selecting a preferred alternative.

In order to compare alternatives, each one must be ranked against selected criteria, and a procedure for combining ranks is needed.

The differing needs and priorities of communities make it impossible to provide a standard ranking procedure. This again must be done locally. It should be consistent and as objective as possible, and should reflect local needs and values. But it need not be complex.

In some cases, it may be convenient to assign numerical ratings (e.g., from one to five) to each alternative's performance on each criterion. This may be refined further through identification of the relative importance of each criterion under the circumstances, with weights applied to the ratings to reflect this. Ratings can then be summed across all criteria to yield a weighted average ranking of each alternative.

It should be noted that a formal composite ranking may not be required. In many cases the alternative facility locations will quickly reduce to one simply by elimination of all which fail on one or more important criteria.

The central point in this evaluation process is not its elegance or rigor, but in its appeal to common sense and judgment. Its essential inputs are not explicit rating schemes, but local needs and values. The suggestions of this manual are intended to enhance local knowledge and permit its application; not to replace it.

STEP 9: REFINE AND SELECT ROUTES

To this point either one or several alternatives may have been considered, with many informal revisions and refinements to the original concepts as the process was followed. This step merely formalizes and continues that effort of revision and refinement.

Cyclic Process

Completion of the route evaluation step as just described may well have highlighted some specific weaknesses of the initial plan or alternatives. These may require only minor adjustment, or they might necessitate a major revision of a candidate route. When major changes are indicated, it is often advisable to consider the entire planning process a cyclic one and repeat the sequence of steps with the new information gained in the initial evaluation. This aids in keeping the process logical and defensible.

Final Check

In addition to revisions based on application of locational criteria, one final test should be performed. This is a recheck of the revised facility's location against trip potential/desire lines initially identified. The objective in this step is to insure that the system which has emerged after screening against cost, functional safety, physical design feasibility and other criteria still bears a reasonable relationship to indicated bicycle travel desires. If a system does not respond to travel desires, it simply will not be well used -- no matter how satisfactorily it meets other criteria. In any areas where correspondence is lacking between system service and travel desire, either a feedback process in which corridor searches are reinitiated must be undertaken or a specific rationalization for accepting this situation must be prepared.

COMMUNITY REVIEW

An extremely significant element of the bikeway planning process is to review the "selected" system with the community. Ideally, community inputs and reactions should be received at all stages of the process, and at a minimum the final plan must be reviewed and endorsed by the citizenry. It is extremely important that the plan as a whole has public endorsement. If the public does not endorse and actively support a bikeway plan, that plan is unlikely to be implemented. While more and more state and federal monies are becoming available to local jurisdictions for planning and implementation of bicycle facilities, the total "external" funding available to local communities in relation to total implementation funding requirements for a bikeway plan is often relatively small.

Thus, funds for a bikeway implementation must in large measure be allocated from local sources. Bikeways must compete for funds with other local facilities and services needs such as schools, fire and police protection, parks, street maintenance, transit services, social services and the like. Without public endorsement of the plan and an active group of citizenry supporting it, meaningful allocations will never be made. To gain such endorsement, public participation throughout the planning process is essential. However, aside from ongoing citizen review and input, at the conclusion of the process there must be a significant event of public affirmation which lends a mandate and momentum to carry the plan through the final stage of funding and implementation, a process which may be more political than technical. Appointment of an official bicycle committee composed of citizens and staff is a useful method of creating a knowledgeable group of varied backgrounds and aliances to serve as the catalytic nucleus of action.

CHAPTER 4
LOCATIONAL CRITERIA

INTRODUCTION

In order to successfully apply the criteria, the planner must have a basic understanding of the users and the types of trips they make. The following section will detail those user characteristics. A second section will discuss key points in the proper use of the locational criteria. Finally, the criteria themselves will be presented in three sections.

- Suggested primary user-related criteria are potential use; basic width; continuity, directness and destination service; safety; grades; and barriers.

- Secondary user-related criteria include imageability; attractiveness; pavement surface quality; trucks, and air quality.

- Non-user criteria include cost and funding, competing use, social status and privacy, and security.

The discussion of each criterion will include a definition of basic characteristics, a description where possible of unacceptable conditions, and general guidance for positive and negative rating definition.

While a complete data base does not currently exist to support bicycle planning, much is known about characteristics of users and bicycle facilities that together can be used to plan a successful bikeway system. This chapter defines 15 distinct criteria, each of which should be examined to ensure successful planning. In some cases, criteria for completely unacceptable locations can be defined based upon planning goals. For most of the sets, however, only positive and negative qualities can be defined. The chapter will point out these qualities in sufficient detail to enable the planner to use the criteria in evaluation.

TRIP AND USER CHARACTERISTICS

There are two functional types of bikeway users, and their differing characteristics will influence the use and emphasis of the location criteria. The principal division of user types is between utilitarian and recreational bicyclists. Utilitarian bicyclists use the bicycle for transportation on some purposeful trip which they are making -- to school, to work, to shop, etc. For recreational bicyclists, the act of riding and the enjoyment of it is the primary purpose of the trip. Utilitarian bicyclists tend to be sensitive to the functional service qualities of the bikeway. They are willing to trade off amenity and, to some extent, safety in order to get where they wish to go and to maximize the efficiency of their effort in propelling themselves there. By contrast, recreational bicyclists tend to place higher value on amenity and safety qualities. The differences between these two types of bicycling activity have been well documented in the literature and are generally well understood by facilities planners, but there are a number of factors which have been generally overlooked.

Activity Differences

Differences between utilitarian and recreational bicyclists are not necessarily differences of personal traits but rather a function of differences in the type of activity. While there are numbers of persons who use a bicycle solely for recreation or solely for utility purposes, there are equally large numbers of persons who ride a bicycle for both types of activities. Thus, except in unusual circumstances, it is not the specific traits of the population which dictate whether utilitarian-oriented or recreationally-oriented locational and design variables should be emphasized in considering bikeway alternatives within a corridor. Rather, it is the inherent character and siting of the corridor which dictate whether it will be most predominantly used by individuals on utilitarian, recreational or both types of trips and, therefore, what kind of values to emphasize in tradeoffs among locational criteria.

Predominant Type of Use

A second major point is that whether a facility serves predominantly utilitarian, recreational or both types of bicycle trips, there is a tremendous individual variation in the types of persons engaged in these bicycling pursuits. For instance, there is a tremendous range of bicyclist skill and experience. At one end of the spectrum are extremely young bicyclists having limited experience in traffic judgment, incomplete knowledge of or respect for the rules of the road, and incompletely developed motor skills relevant to controlling a bicycle, who may well be riding a bicycle too big for them. At the other end of the spectrum are highly sophisticated bicyclists often riding bicycles specially designed for their physical needs and uses, highly developed physical and judgmental skills essential to effective riding in traffic, and a strong confidence in these skills and willingness to use them. Falling in between are large numbers of cyclists with varying degrees of skill and experience and varying degrees of willingness to rely upon that skill and experience in traffic situations.

Work Capabilities

Another type of variance among cyclists, irrespective of their trip purpose, is in their physiological work capabilities. The typical sophisticated bicyclist is capable of aerobic work efforts some 50 percent higher than the casual cycling population and nearly 100 percent greater than post-coronary patients who are also members of the potential cycling population. The inference of this is two-fold.

- First, no single "design cyclist" can be defined as the uniform basis for design; there is too great a variance in bicycling skill and physical performance capability.

- Secondly, site-specific characteristics rather than area population traits generally dictate whether a bicycle facility will be used for utilitarian or recreational purposes or for both.

The trip purpose identification is as important as the characteristics of any specific segment of the population to be served in deciding which of the criteria to emphasize.

The locational criteria which follow must be used in the context of the probable user population. Any extreme compromises to competing financial and social constraints will render a bicycle facility useless.

USE OF LOCATIONAL CRITERIA

As in all types of planning, a set of criteria cannot stand alone as independent measures of satisfaction. They must be considered in the context of the situation of concern and the parties involved. The following paragraphs are intended to set that context as defined by previous experience in the field.

The criteria listed below are not absolutes; they will vary according to the particular problem to be solved, the population group to be served, the type of trip, and the agency involved. They are in many cases contradictory (directness of service vs. attractiveness, cost vs. safety, etc.), so that their relative importance will again vary with the situation. The criteria should thus best be thought of as tradeoff variables; if the planner understands the trading involved in evaluating alternatives, he will arrive at more logical planning results.

There are two major groups of objectives for a bicycle facility, one of which predominates in any situation:

- to influence more people to use bicycles; and

- to serve existing cyclists more safely and efficiently.

Planners should be aware that they will inevitably use the criteria differently in these situations. The former will generally tend to emphasize attractiveness and amenities; the latter will tend to emphasize safety and service. The important point is that while some criteria are emphasized, all should be evaluated.

Since the criteria are primarily subjective in nature, the approach in this manual is to suggest a rating system as an evaluation tool. The rating system should be of two parts, as described in Chapter 2. With some criteria such as safety, grades and width, conditions which cannot be made "completely acceptable" can be defined and applied as direct tests of a locational alternative. In these cases, failure to be able to satisfy the "acceptable" standard should eliminate the candidate location. A second part of the suggested procedure deals with a composite "score" across all criteria for each locational alternative. In this technique, the varying situations will induce a need to weight some of the criteria differently to reflect community priorities. A weighted total rating is suggested as the basic composite criterion for locational planning. The character of the criteria will be discussed with enough detail to enable the local planner to develop the scales and weights for his situation.

The fact that locational criteria are not absolutes poses the potential for controversy in any community embarking upon a bikeway planning process. Explicit assertion of priority of one goal over another and one user group over another inherently involves conflicts among competing interests. Since little precise information is presently available to allow quantitative prediction of the results of a proposal, criteria and their weightings are subject to dispute even among those who have reached consensus upon the overall objectives in providing facilities. Therefore, bikeway planners should be careful to document the criteria values and weights so that others can review the procedure. The primary benefit in using distinct criteria for evaluation and establishing a rating system is that the system can provide a focus for logical discussion of the process and its results. It can identify points of conflict and can demonstrate the effect of changing the relative importance of any particular factor. Providing this framework will insure logic and communication in the process.

The criteria presented below are concerned with locational factors. Any locational analysis requires an acceptable physical solution. As locations are selected and evaluated, it is important that the design factors described in Volume II be kept in mind. The planning process in Chapter 2 includes a recycling step, and this should include review of the design standards to insure that a suitable physical solution is available for an otherwise ideal location.

Finally, a word of caution in use of the criteria. Fourteen have been listed in the following pages, allowing much latitude for compromise among both the criteria and the affected population groups. An obvious point, but one often forgotten, is that a bikeway must in the end provide a useful service to its target group. Too much emphasis on non-users or on cost and interagency complications will produce a facility which is little used, thus defeating the entire intent. Concentration on the study objectives and on the potential users of the system should be continually maintained.

Principal User Criteria

1. Potential Use

   Potential use is the basic reason for planning and creating a bicycle facility. As noted in Chapter 3, it should be evaluated at least twice during the planning process:

   - Initially, corridors should be identified on the basis of need or potential use.

   - At the completion of the planning process, the resultant plan should be re-evaluated to ensure that it still serves the originally identified needs.

     Several planning guides have proposed a specific value, in number of bicycles per day, as a minimum criterion (warrant) for creation of a bikeway. Such a proposal usurps the community's right to define its own needs. The correct minimum level of usage should be whatever the community believes is appropriate given both its needs and constraints. It should only be noted that potential rather than observed need is the criterion. If a location has little existing usage, the conclusion should not be that demand is lacking, but that possibly some impedance exists that discourages usage.

     Most existing methods of estimating usage are rudimentary and imprecise. They are better used for comparison of alternatives than close prediction of future use. However, it is possible to generate useful estimates of facility use, so long as inherent accuracy limitations are understood.

2. Basic Width

   Basic width is the fundamental physical requirement of a bikeway. If a location cannot provide four feet of operating width, it should not be considered as a potential location for bicycle travel unless it can be improved. If a location requires street widening, removal of parking, or reduction in motor vehicle lanes, these should be appropriately reflected in the rating for this category and in cost and competing use categories.

3. Connectivity and Directness

   Connectivity consists of three basic factors, as follows:

   - Continuity

     Continuity refers to continuous service and guidance where bicyclists travel or wish to travel. It means logical connection to other bikeway facilities and routes upon which bicyclists can reasonably be expected to travel. It requires that bicyclists not be led into and then abandoned in hazardous situations.

For all cyclists, the ability to maintain momentum uninterrupted or with as few interruptions as possible -- is important. Observations have shown that cyclists tend to have a very strong desire to maintain the forward momentum their efforts have created. They also naturally desire to minimize their own delay and usually are more comfortable on the move. Hence a facility with numerous full stops or abrupt turns is likely to be unacceptable. However, in most locations design treatments can be used to maximize the cyclists ability to maintain momentum so it is only important for route choice where such treatments are infeasible.

- Directness

Directness is a quality which indicates the degree to which out-of-direction travel is minimized. It is relatively unimportant to the recreational bicyclist, but of great importance to the utilitarian user. For the utilitarian cyclist, connectivity is desired along the lines which define the minimum distance or "minimum energy" path from origin to destination; little deviation is tolerated. The recreational cyclist is more willing to accept deviations from the minimum distance/minimum energy path to avoid unpleasant environmental conditions or hazardous situations so long as the deviations are not out of scale with trip length and perceived severity of the condition avoided. Thus, "direct connectivity" may be said to be the criterion applicable to utilitarian cyclists while a less demanding "linkage continuity" may be acceptable on facilities intended primarily for recreational cyclists.

Observations from research performed for this manual show that for both short and long utilitarian trips, little out-of-direction travel is tolerated. For trips of up to one-half mile, cyclists may object to diversions as short as one block; however for trips in the one to two mile range this much diversion will generally be acceptable. Cyclists on longer utilitarian trips will generally not perceive a nearby diversionary route to be beneficial if its extra length is significant.

- <u>Destination Service</u>

Closely related to continuity is destination service. The ability to get from one human activity point to another is essential to the fulfillment of the purpose of a utilitarian bicycle trip. If bicycle facilities are to serve such trips, they cannot simply be placed where it is easy to provide bicycle facilities or where planning decision-makers would like bicyclists to go. They must be located to provide convenient, direct access to centers of activity.

In rating a route for connectivity, emphasis will differ for the two trip types. For utilitarian trips, destination service and directness are the more important categories. For recreational trips, continuity should be emphasized. While there is no quantifiable lower bound for this criterion, particularly for a specific route, the total incidence of connectivity problems for the entire system is a reasonable indicator of its probable success or failure.

4. <u>Safety</u>

Safety is an obvious criterion in bicycle facility location planning. However, beyond basic minimum levels it should be viewed as a tradeoff variable just as with all other locational criteria. The emphasis safety receives will depend both on the specific situation and the importance placed on other criteria in that situation.

Bicycle safety research is a neglected topic. Unlike traffic signals and school route safety programs, definitive criteria have not been developed for bicycle safety. The primary emphasis in analysis, if a bicycle safety program is the stimulus for facility planning, should be on an area-wide bicycle accident survey. Only such a survey can place in perspective the severity of any specific incident and identify specific accident patterns which can be corrected. Again it is the community's responsibility to define an "acceptable" safety level for an existing or proposed facility: no single safety measure can be given.

- <u>User Characteristics</u>

No discussion of bicycle facility safety can be complete without consideration of user characteristics. Potential users range from small children who may have incomplete knowledge of or concern for the rules of the road, limited experience in judgment of traffic situations, and incompletely developed motor skills in riding a bike -- to sophisticated bicyclists having expert physical skills in riding a bicycle and a finely honed sense of judgment in the art of surviving on a bicycle in traffic.

The various types of cyclists, their riding capabilities and their behavior patterns interact with design and site conditions in affecting the inherent safety quality of any facility alternative. A young child cyclist who travels on a sidewalk facility, stopping at each intersection to carefully check traffic before crossing might be significantly safer on that sidewalk than on an on-street facility. A sophisticated cyclist who tends to travel at a higher speed, attempts to maintain momentum and assert right-of-way through intersections and has better overall traffic judgment than the child cyclist who would likely be safer on a street than on a sidewalk.

- Evaluation Procedures

Since no single measure of safety can be defined, two evaluation procedures are suggested for safety in the locational planning process:

- An areawide accident survey should be undertaken to identify existing problem locations. Any bicycle facility that can solve an existing problem should be rated positively.

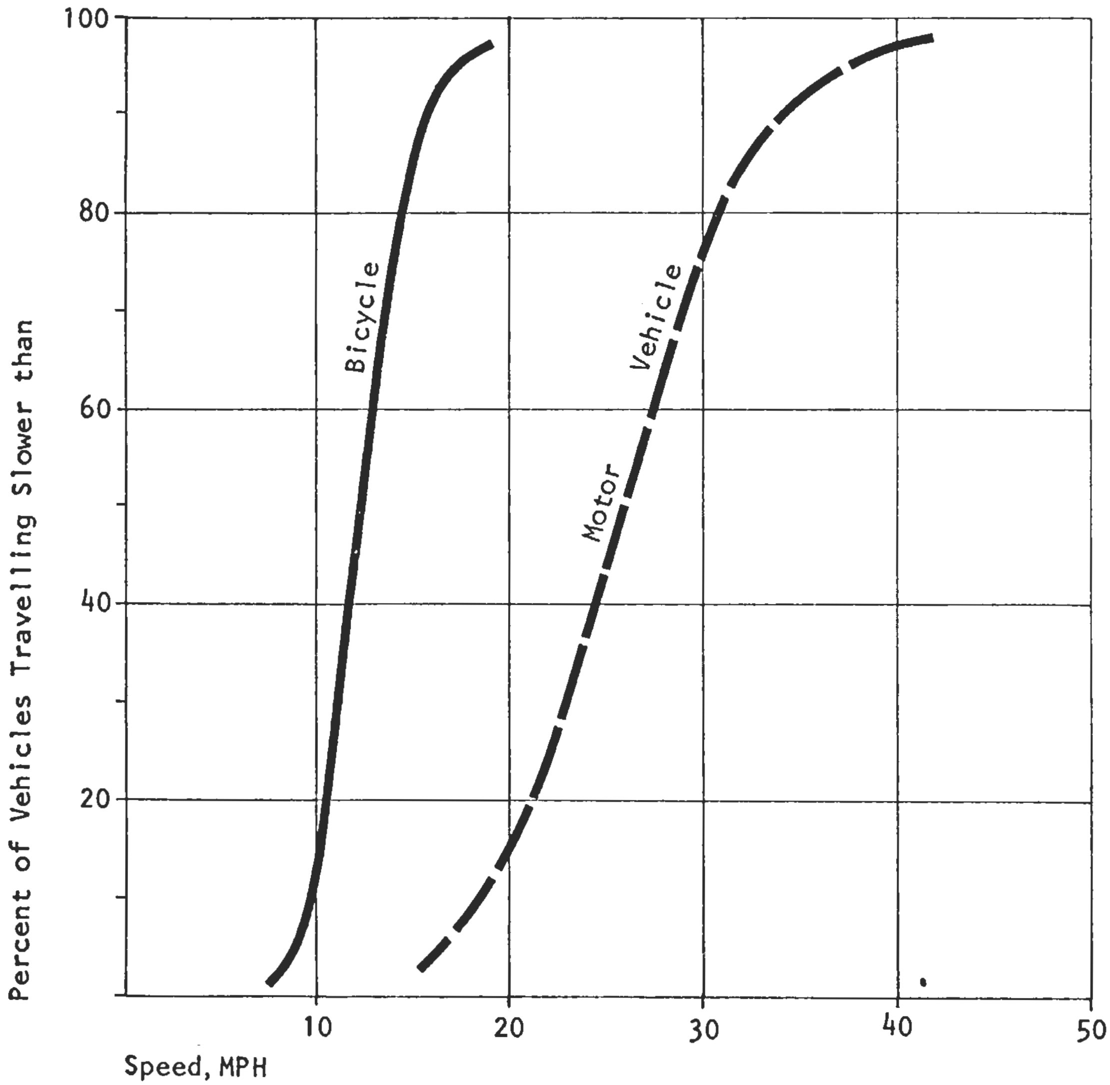
- Each route should be evaluated on the basis of potential motor vehicle-bicycle conflict.

The fact that a safety evaluation is really an evaluation of existing or potential conflicts is not always realized. Often the existence of a large volume of cars adjacent to a bicycle facility is taken to be an inherently unsafe situation. This is generally not true. High traffic volume is a hazard only if there is close and continual conflict between vehicles and bicycles.

Potential conflicts can best be categorized into four categories: parallel, right-turning, left turning, and crossing conflicts. Each of these conflicts should be evaluated separately and combined for a final safety ranking. Following is a discussion of these conflict types:

-- Parallel Conflicts

Parallel conflicts are caused by two conditions: close proximity of auto and bike travel, and speed differential between the two. Bicycles and motor vehicles can successfully mix in the traffic stream if speeds of the two types of vehicles are compatible. Although racing cyclists on downgrades can reach speeds approaching 50 MPH, the distribution of cyclist speeds on level terrain and in negligible wind conditions is typified by Figure 3.



<u>Midblock Speeds</u>

Bike Speeds on Level Ground

Motor Vehicle Speeds Typical of 25 mph Speed Zone

Figure 3
COMPARATIVE SPEED PROFILES
Bicycles and Motor Vehicles

Source: De Leuw, Cather & Company

Motor vehicles are capable of a far higher speed range, but normally this capability is constrained by traffic and road conditions or a speed limit. A typical distribution of motor vehicle speeds on free-flowing facilities having a 25 MPH speed limit is also shown on Figure 3. The figure indicates that, under free-flow conditions, even at the lowest speed limit normally encountered:

- About 90 percent of the bicyclists travel slower than nearly all motor vehicles.
- The average bicyclist travels only about half as fast as the average motorist.

Hence mixed flows are generally undesirable. Areas where mixed flows may be acceptable include:

- On surface streets in urban centers where traffic conditions constrain motor vehicle speeds resulting in considerable overlap of bicyclist and motor vehicle speed distributions.
- On long downgrades where bicyclist speeds are significantly above those on the level.
- At and on the approaches to intersections where motor vehicle speed is depressed preparatory to stops, turning movements and intersection-related decisions.
- On lightly traveled streets on which encounters between bicyclists and motor vehicles are infrequent and on which motorists can be expected to tolerate brief delays until bicyclists can be safely passed.

-- <u>Right-Turning Conflicts</u>

The hazards inherent in the conflict between bicyclists and right-turning traffic are primarily a function of the geometric design of the intersection or driveway involved. An unchannelized intersection presents relatively minor problems for cyclists; a double-right turn lane presents unacceptable hazards. Table 1 is a tabulation of the possible design conditions, the severity of the hazard, and recommended solutions to improve safety. In rating alternatives for this condition, it is not necessary to evaluate all right turning possibilities along a route; only major volume locations and any intuitive problem areas should be investigated. Ratings should consider costs of corrective measures for reducing potential conflicts.

Table 1
SAFETY EVALUATION OF RIGHT-TURNING CONFLICTS

Design Condition	Conflict Potential	Specific User Problems		Proposed Forms of Solution
		Inexperienced Cyclist	Sophisticated Cyclist	
Unchannelized intersection				
Controlled	Minimal			
Uncontrolled	Minimal +			
Exclusive right-turn lane				
Controlled	Mild	Weave across turn lane or hug curb lane and wait	Weave across turn lane	
Free right-turn lane				
Uncontrolled at signalized intersection	Moderate	Weave thru moving traffic or hug curb	Weave thru moving traffic	Specific design solutions
Exclusive double right-turn lane	Severe - must be corrected or alternative location picked	Weaving across two lanes of traffic		Elimination of double right-turn lane; Separate bicycle signal phasing; Grade separation of bicycles and motor vehicles; Physical restraint to force bicycle to act as pedestrian (last resort -- bicyclist acceptance is unlikely).
Exclusive free double right-turn lane				
Uncontrolled at signalized intersection	Severe - must be corrected or alternative location picked	Weaving across two moving lanes of traffic		Elimination of double right-turn lane; Grade separation

-- <u>Left-Turning Conflicts</u>

Accidents involving left-turning vehicles and bicycles are generally about half as common as those involving right-turning vehicles. The critical feature of left-turning conflicts is that a bicycle has low visibility and is often observed only after initiation of the vehicle's turning movement. This is particularly true at high-volume intersections where bicycle visibility is further masked by vehicles. Thus left-turn conflicts are a function of the turning volume, its opposing through volume, and the type of intersection control. Intersections with left-turn phase signalization present no hazards and should be highly rated. Signalized intersections without separate phasing should be rated on the basis of turning volume and opposing traffic, as should major unsignalized intersections and driveways on major streets. Other locations present minimal left-turn hazards.

<u>Crossing Conflicts</u>

Conflicts between bicycles and crossing traffic are a function of both the crossing volume and intersection control. Parallel routes along a corridor usually are crossed by roughly equal vehicle volumes; thus rating can best concentrate on the nature of the controls at the cross streets.

Signalized intersections are the most positive means of dealing with crossing traffic and should therefore be highly rated for safety. Any location which controls cross traffic by STOP or YIELD signs is also relatively safe. Locations where STOP or YIELD control confronts the cyclist's path are more hazardous, since this situation implies a higher level of motor-vehicle cross traffic. The hazard at these locations is a function of volume and the width of the cross street. They can best be evaluated by on-site observation of the spacing of crossing traffic at the times when bicycling is expected. Locations with insufficient spacing for safe crossing (five seconds plus crossing time at 7.35 feet per second) more than 75 percent of the peak two hours of cycling usage should be considered either as unacceptable or should be improved by grade separation or signalization.

The preceding paragraphs have detailed specific areas for investigation in evaluating route safety. While each of the types of conflicts must be evaluated, it is necessary to combine the evaluations to determine overall safety. The basic criterion should be minimization of total probable conflicts. Weighting of the individual categories must be done in a way that ensures a logical sum of the components.

5. Grades

Grades not only influence bicyclists' route choices, but affect the operational safety and feasibility of bicyclists' maneuvering in the traffic stream as well. Bicyclists may accept substantial out-of-direction travel as well as reduced safety and amenity conditions in order to avoid significant energy expenditure on an upgrade. Some cyclists do not have a choice; they are simply physically incapable of riding uphill at an acceptable riding speed. Bicycle speed reductions caused by grades affect bicyclists' safety in maneuvering with motor vehicles at intersections. Downhill grades which increase bicyclists' speeds also are significant because they affect bicyclist behavior in mixing with traffic and bicycle stopping distance requirements.

The subject of human work effort in riding a bicycle on the level and upgrades is complex. Adequate discussion cannot be presented within the context of this section on locational criteria. For that reason, Appendix C provides a primer on human work physiology related to bicycling, with explanations of the relationship of work effort, speed, and grade along with intervening parameters such as wind speed, gear ratio, pedal frequency, and the like. The relationships presented therein can be utilized to evaluate the work requirements which would be imposed by alternative route proposals -- identifying the minimum energy route and the differential between it and other alternatives. The "work" equations and the related physiological data can also be used to indicate which user subgroups would be limited or incapable of using an alternative.

Another application of this methodology relates to planning for recreational cyclists -- the concept of defining and marking "high energy" and "low energy" recreational routes so as to provide recreational bicycling opportunity within the physical capabilities of the full range of potential bicyclists. This is a significant concept. For the "fit" recreational bicyclist, grades are not necessarily something to be avoided; they can add interest and challenge to a ride. But if a recreational route includes such challenges for the fitter individuals, it may preclude individuals at the other end of the fitness scale from using the facility at all. The work effort relationships and physiological data presented in Appendix C provide the planner with tools for defining bicycling opportunities for particular subgroups of the bicycling public.

An evaluation of grades should be done at least whenever candidate routes have markedly differing grades. Work effort calculations should be conducted for each route to determine ranking. The ranking should also consider the trip type, so that routes for recreational trips can be classified by energy requirements where required by a particular program's objectives.

6. <u>Barriers</u>

Barriers are the antithesis of bikeway continuity: places where it is extremely difficult or hazardous, if not impossible, for bicyclists to travel. Barriers include natural features such as bodies of water, steep ridge lines and the like, and manmade objects such as elevated rail lines and freeways with limited points of street crossing. Existence of a facility which permits motor vehicles to penetrate a barrier does not necessarily imply that bicyclists will be able to do so. For example, bicyclists are often barred from bridges carrying motor vehicle traffic across major water barriers. Similarly, though not specifically barred, it can be extremely difficult for bicyclists to negotiate their way through a busy interchange at a major freeway crossing.

As a locational criterion, barriers are not necessarily to be avoided. In fact, the breaching of barriers may be one of the most important factors in providing continuity and increasing bike usage. As such, barriers should be evaluated for feasibility of breaching. Breaching with a bikeway may be infeasible in some obvious cases, such as long bridges with no sidewalks and low potential usage. In many cases it would seem more reasonable to carry the occasional bicyclist on a bridge maintenance or patrol vehicle, graduating to a more formalized bicycle transit service if this clientele developed. Such a scheme is now in successful use on the Coronado Bridge in San Diego, California, employing bike-carrying trailers which are attached to the rear of regularly routed transit vehicles as they reach the ends of the bridge structure.

While barriers could be included under the category of connectivity, their specific nature and potential for service when breached suggest a separate evaluation. Each barrier should be evaluated for potential for increased service, difficulty of breaching, cost of breaching and possibility for solutions other than physical solutions. Those barriers for which cost of improvements is clearly excessive will eliminate a candidate route from consideration. All others should be carried forth in the evaluation process.

Secondary User Criteria

7 Attractiveness of the Bicycling Environment

Given the close interaction between the bicyclist and his environment, it is natural that the attractiveness of the environment be evaluated. This is a quality which has different importance for the two basic purposes: utilitarian and recreational travel. The utilitarian rider generally considers attractiveness as a nice thing to have if it coincides with the directness of his path. For the recreational cyclist, the attractiveness may be the primary motivation for his trip, and he will seek out attractive locations. Weighting of this category will thus vary depending on the purpose.

Attractiveness is the most subjective criterion in this set, being a highly personal factor: some people do like to ride along a junkyard to see what's new. Thus any rating system will be greatly influenced by the values of the rater. The important point is that attractiveness consider many factors including view, sound, and (in the case of parks, trucks, and buses) smell.

A few elements related to attractiveness, such as air quality, noise level, and presence of trucks can be quantified and are presented in following sections. Other less quantifiable elements may include:

- Natural settings
- Points of scenic, architectural or historical interest
- Points where interesting human activities may be briefly observed
- Points where interesting diversions from the ride may be briefly engaged in
- Geometric interest; routes with horizontal and vertical undulations to break monotony but not so severe as to require significant extra effort or sharply constrain speed.
- Convenient rest points with shade, water, and possibly restroom facilities.

8. Imageability

Whereas continuity, directness, and destination service may be skillfully designed into a bikeway system, to the stranger or occasional user these characteristics may not be readily apparent. Imageability is the characteristic concerned with how the facility appears to the user, rather than how it actually is. While two routes may be rated equal in connectivity, a route that uses clearly defined paths such as major streets will appear to be more effective, especially to the new user.

While imageability is an inherent characteristic of some routes, it can be designed into others. Effective use of bikeway trail markers and destination signs can be used to improve the imageability of bikeways on local streets. Route maps and descriptions can improve imageability in recreation areas. Thus imageability should be rated in terms of the final treatment proposed for the facility rather than the inherent characteristics.

Like attractiveness, imageability is largely a subjective criterion. No minimum standards can be defined to rule out a route; such a standard does not exist. Imageability should be thought of as a factor that enhances a route, in varying degrees, rather than an absolute standard.

9. Air Quality

Air quality is a potentially important locational criterion since air pollution has more serious implications for persons involved in physical exercise such as bike riding. Exercise increases lung uptake of a pollutant by minimizing air flow through the nose and maximizing air flow to the mouth (the nose tends to eliminate a significantly higher portion of reactive gases than does the mouth), ventilating the lung more uniformly and hence exposing more reactive lung tissue and increasing the replacement of a gas which reacts at a given point within the lung.

There are two critical aspects of air pollution as a locational criterion for bicycle facilities. These are:

- concentrations of various types of pollutants which could cause long or short term health effects as a result of exercise, and
- length of exposure at which concentrations of pollutants would produce such health effects.

Air pollution rarely if ever consists of only one toxicant. Complex mixtures of pollutants are prevalent in the air over most urban centers. In assessing these diverse pollutants as locational criteria for bicycle facilities, it is important to consider how each type exists as a concentration in the atmosphere. For instance, photochemical oxidant or smog exists as a dispersed-area phenomenon. Hence, its presence in concentration sufficient to pose short or long term health concerns to bicyclists is not meaningful as a criterion for selection of one route over another at a location within an established corridor. On the other hand, since gross concentrations of photochemical oxidant do vary between major subareas of a region, this variance of a concentration might be used as a locational guideline for regional recreational bicycle facilities.

Other types of pollutants are typically found in limited site or line concentrations; carbon monoxide (CO) is a typical example. If such concentrations are at levels which could pose potential health effect problems for cyclists, their existence would constitute a reasonable criterion for selection of one route alternative over another. However, examination of available technical data indicates that in all but the most extradordinary conditions, the likely length of exposure of bicyclists to site concentrations of pollutants such as CO at typical ambient worst-case concentrations would not be a concern.

10. Pavement Surface Quality

The fact that bicycles do not have the shock-absorbing capability of motor vehicles means that the quality of the surface will have a significant impact on usage of a facility particularly if there is a more satisfactory alternative. Ride quality as well as tire damage can be involved. High surface quality should be considered as an essential part of the bikeway design. However, if the desire of the community is to use only existing facilities with a minimum of capital improvement, surface quality of candidate routes should be rated.

11. Truck Traffic

Truck and bus traffic is a significant factor affecting the acceptability of a candidate route. Because trucks and buses are larger than automobiles, the level of their presence may influence cyclist perception of a street's safety. At high speeds they create aerodynamic disturbances which could cause a cyclist to lose balance and fall. The ambient noise levels along the street also significantly increases, thereby decreasing amenity for bicyclists.

A review of technical literature provided little support for defining a specific level of truck traffic as a maximum along parallel bikeways. A standard maximum percentage of trucks should definitely not be used as a criterion, since the type and absolute number of trucks are the real issues.

Physical encroachment by trucks is generally not of concern on bike lanes, since traffic engineering standards for lane design account for truck size. Truck widths of 96 inches for general use and 102 inches for non-interstate use will fit within the standard 12 foot lane, though they may be a problem where substandard lanes exist.

-- Recreational Vehicles

One specific concern is a facility used heavily by recreational motor vehicles. Interviews with experienced cyclists indicate that drivers of these vehicles are often unfamiliar with their equipment -- of its length, projecting mirrors, or handling characteristics. In locations where these vehicles and bicycles must share a right-of-way, good locational planning should provide extra separation between cyclists and vehicles.

-- Aerodymanic Disturbances

The potential for aerodynamic disturbances which might overturn a bicyclist is primarily a function of truck speed and available lane width. Aerodynamic forces generated by large moving vehicles at various speeds and separation distances have been estimated from prior research. Figure 4 indicates lateral force which a bicyclist might experience while being passed by large vehicles (buses and heavy trucks) at various speeds and separation distances. Research suggests that aerodynamic forces upon bicycles are not a problem when truck speeds are below 50 MPH. Above this speed, lane width provisions should permit bike/truck separation distances which will yield lateral force levels less than or equal to those experienced at four feet separation and 50 MPH as determined from Figure 4 (approximately 3.5 pounds side force). If this separation cannnot be provided, the facility should not be considered for use as a bikeway regardless of the level of trucking activity.

-- Noise

The concern for traffic noise, particularly that caused by trucks, is predominantly an amenity factor rather than a safety criterion. There is some difference in the noise levels which would be experienced by the bicyclist under typical street dimensional relationships over a wide range of traffic volumes, truck percentages, and surface street operating speeds. But the street is an extremely noisy and unpleasant place for the bicyclist to be as long as there is any measurable percent of trucks. There is no clear breaking point at which noise generated by trucks or traffic in general would become an absolute concern. This assessment is based upon analytic procedures presented in FHWA's "Manual for Highway Noise Prediction" (Report No. DOT-TSC-FHWA 72-2). Procedures presented in that manual could be utilized to make comparative

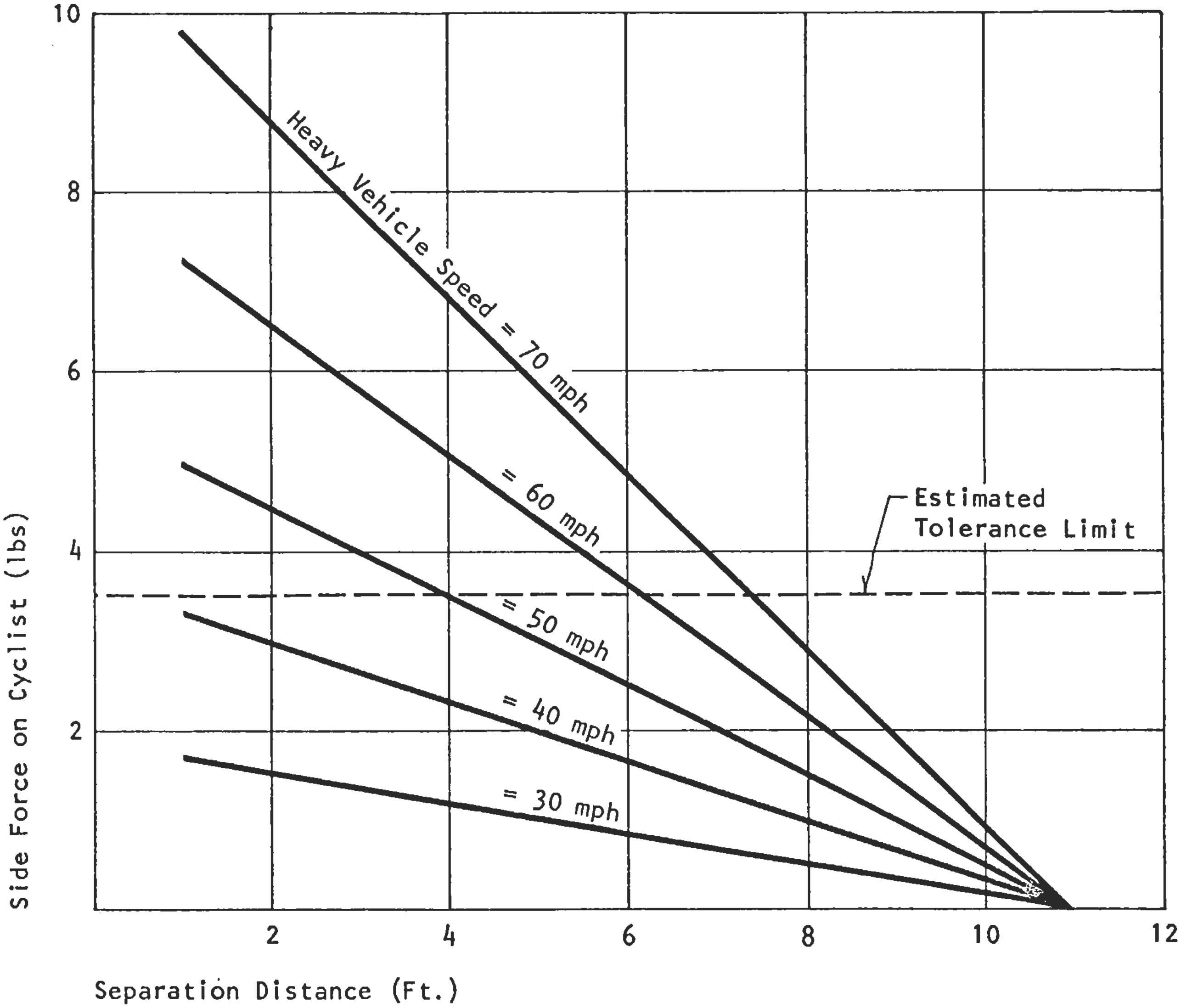


Figure 4
HEAVY VEHICLE INDUCED AERODYNAMIC DISTURBANCES:
Lateral Force on Bicyclists

noise evaluations of alternative routes under study. However, carrying out such an analysis is worthwhile only when comparing alternative routes having gross differences in travel speeds, percentage of trucks and total traffic volume.

To summarize, presence of heavy trucks is definitely a negative factor in the acceptability of a street as a bicycle facility candidate. However, no specific volume of trucks should be regarded as an absolute negative criterion.

Non-User and General Criteria

The foregoing 11 locational criteria were associated with the effect of locational choice on the quality of service to the bicyclist. However, certain aspects of choices related to bicycle facility location affect the public as a whole or certain segments of the non-user public. Hence, they too constitute relevant locational criteria. The remaining three criteria are non-user or general criteria which may be relevant in a locational choice situation.

12. Cost and Funding

Facility cost is a criterion in two senses:

- In determining whether a facility is built, and
- In determining what facility is built.

While locational planning is primarily concerned with the second condition, the overall quality of planning combined with political conditions will determine whether the facility once planned and designed is built.

As a location planning criterion, cost is an extremely powerful influence -- so powerful that special care must be taken to assure that it does not overwhelm the user-desired elements. Given a limited budget, the planner may have the option of creating a limited number of costly routes or a larger number of economical routes. In choosing between high cost and low cost alternatives, it is necessary to insure that the options selected fulfill the bicyclists' needs since an unused facility is costly regardless of the expense.

Source of funds is also a factor in cost. Although most facilities will be funded by local sources, some routes may qualify for state or federal funding. The temptation to distort a network to qualify for these sources must again be tempered by the need mentioned above for satisfaction of users.

Creating a rating system for the cost criterion involves the relatively straightforward process of estimating both capital and operating costs for each alternative route, and identifying external funding sources where they are different for contending alternatives. The cost data should be scaled to be comparable to the user-related criteria to avoid over-emphasis.

13. Competing Uses

Competing use in this manual represents basic conflicts between populations affected by the bicycle planning process. Three major conflicts have been identified: bicycle vs. motor vehicles, bicycle vs. the penetrated neighborhood, and governmental agency vs. agency.

Other kinds of conflict are certainly conceivable as, for instance, the potential interaction between bicyclists and pedestrians on a sidewalk bikeway. However, that type conflict is taken into account in design criteria. The type of conflict described as competing uses herein is one which involves denial of a use because of a real or supposed incompatibility -- not decreased quality of service or satisfaction due to introduction of an additional use.

- Bicycle vs. Motor Vehicle

  The conflict between bicycle and motor vehicle referred to here is not that defined in the section on safety. Rather, it is the conflict in use of available facilities. An existing right-of-way can support a varying combination of motor vehicle and bicycle facilities; the relative demands of each mode will determine the feasibility of creating a bikeway on a specific right-of-way. The possibility of resolving this type of conflict frequently can be subject to analysis and technical policy decision. For instance, on a street of single family residential character, street parking space available on one side of the street may be sufficient to serve all on-street parking needs. Parking could be eliminated on one side to provide sufficient space for lane redefinition and inclusion of bicycle facilities. But in a high density residential area, analysis of parking conditions might indicate residents' strong dependence on all existing on-street space for storage of vehicles and parking removal would be technically infeasible. Similar types of analysis might be made of traffic conditions to determine feasibility of eliminating a motor vehicle travel lane on a multi-lane street.

  In other cases, decisions regarding resolution of competing use conflicts cannot be made on the basis of technical feasibility; social value judgments and political considerations enter the picture. A common example is the situation in which parking removal on one side of the street along the length of a candidate route is technically feasible for the entire length in question and socially feasible except at a few limited points at which roadside business has a vested interest in parking immediately adjacent to the individual establishments. In these kinds of situations, decision-making may be lifted from the technical planner's hands and is often postponed until complete plans are forwarded to elected officials for approval and funding. In the light of this decision-making uncertainty, or the fear that disapproval of this specific alternative will cause disapproval of a more comprehensive system plan, there is a tendency for planners to anticipate and preempt public officials' decision-making. Some planners tend to assume that invariably elected officials will decide against the bikeway plan and in favor of the local property interests. This presumption of automatic plan rejection should never be made by a technical planner. Elected officials should be permitted to exercise their prerogatives and responsibilities in these sorts of situations. The value judgments they make may well run contrary to planners' conditioned expectations. Preferably the planning process would be structured to obtain early resolution of this type of conflict situation so that the process could continue on the basis of certainties rather than assumptions.

- <u>Bicyclist vs. Penetrated Neighborhood</u>

  A second type of conflict that may occur in locational planning is that between the bicyclist and the penetrated neighborhood. This conflict may occur whenever there is a clear difference in apparent lifestyle between the cyclists and the residents whose homes they pass. The conflict may be racial, it may be socio-economic, or it may be one of lifestyle. If the planner is aware of this type of conflict, he can attempt to deal with it in the planning process rather than struggling with adverse reaction when his plans are made public.

- <u>Governmental Agency vs. Agency</u>

  A final type of competing use occurs when one agency has responsibility for bicycle planning and another (such as a water or utility district) has responsibility and control over a right-of-way ideal for biking but used for other purposes. Often these other agencies may have no interest in aiding bikeway development and may in fact have sound reasons, such as added maintenance and insurance costs, for opposing bicycle usage of the right-of-way. Situations of this type should not be rejected out of hand. The objective should be to maximize the public's benefit rather than that of the specific agency.

In those cases, solutions should be investigated as with any other alternative, and any special costs associated with bicycle facilities on the competing right-of-way should be accounted for.

14. Security

Security is a locational factor which relates to both users and non-users.

- Residence Security

  Bikeways are sometimes perceived as facilities which bring with them bicyclist users who are thought to be a threat to the security and safety of the neighborhood. In other cases, it is not the bicyclist users who are perceived as the threat, but other persons who might be able to use a secluded bikeway to gain surreptitious entry to homes and property.

- Bicyclist Security

  Bicyclists' concerns for security of their persons and property are much more genuine and well-founded. An obvious response to concern for property is provision of effective bicycle parking facilities at bicycle trip activity generators. Unfortunately, all but the most elaborate and costly bicycle parking facilities are little more than theft-retardant and only minimally effective unless open to relatively continuous public view.

  Personal security of bicyclists is of greater concern. A number of locational and design considerations can help minimize this concern. Areas of high street crime can be readily identified from police records or may be identified from survey results. Where these areas interdict potential bike routes, routes should either be modified to skirt the area of concern or the facility should be located where it will be open to relatively continuous public view and ready scrutiny of enforcement officers. For instance, a bicycle path passing through a park area would preferably be located in an open meadow rather than a secluded wooded area. An overpass treatment open to view is preferable to an underpass treatment in shadow. When an underpass is necessary, its sight distance properties should allow cyclists to see prior to entering if anyone is loitering there. The possibility of street crime should not preclude building a bicycle facility, particularly when there appears to be real potential for use. But it is good reason to use prudent judgment in locating and designing the bicycle facility so as to minimize crime potential.

APPENDIX A
ESTIMATING POTENTIAL BICYCLE ACTIVITY

PURPOSE

In order that a bicycle facility be designed to provide adequate service, and to justify public investments in facilities, it is necessary to derive an estimate of potential activity. Following are some of the factors known to be determinants of the level of bicycle use.

- Trip Length
- Trip Purpose
- Climate
- Age
- Bike Ownership
- Cost
- Occupation
- Status

The pages which follow discuss how these factors influence bicycle use and how they can be used to gain some sense of the potential for bicycle activity in a community. Some planners have expressed the need for sophisticated techniques paralleling conventional transportation models for estimating bike mode split potential and trip patterns within an urban area. Such techniques do not appear feasible for near term application in the United States. Reasons for this are discussed at the conclusion of this section.

DETERMINANTS OF BIKE USE

Trip Length

Trip length is a factor in the likelihood of making trips by any mode. Its importance in the choice to make a trip by bicycle is heightened by several factors:

- The bicyclist must do physical work to propel himself over the distance to be covered. Very naturally there is a decreasing willingness to undertake the greater physical efforts imposed by increasing distance.

- A bicycle is inferior in terms of travel time to motor vehicles for all but the shortest trips, and the time difference expands with increasing distance.

- Even if the potential bicyclist is not swayed by the travel time savings achievable by motor vehicle, at typical bike speed the distance which can be covered within a realistic travel time budget is sharply limited.

Typical bicycle trip length distributions are illustrated on Figure 5. The figure shows the variation of trip length-frequency by trip purpose category. For each purpose there is a relatively clear "cut-off" distance beyond which only small numbers of trips are observed. Cutoff values range from three to six miles. These values may be used to define in general the potential bike service area of an activity center. They can also be used to operate on regional transportation planning data to define a "short trip matrix," an origin-destination table of trips within reasonable bicycling range.

Trip Purpose

Trip purpose is a significant determinant of the likelihood to use the bicycle as a transportation mode. Each trip type has a set of characteristics associated with it which may make the bicycle absolutely or relatively unsatisfactory for fulfilling the purpose of the trip. For instance, bicycles are not very useful for carrying large packages. As noted previously, the probability of selection of a bicycle as the travel mode is considerably affected by trip length. Differing trip purposes have different characteristic trip length-frequency distributions.

Table 2 shows distribution of bicyclist trips by purpose categories as indicated in surveys taken in several urban areas. Trip purpose mentioned most often among respondents in each of the surveys reported was recreation. Where percentages could be determined, over half the respondents in each study area claimed that they either made recreational trips or ranked recreation as their most important bike activity. (This exaggerates the probable level of recreational use, since some surveys included trips to recreational sites in this category.) A similar problem arises when exercise is specified as a trip purpose . In many cases the bicycle is used for transportation on a purposeful trip with the underlying motivation for choice of the bike as the mode travel being the exercise value. Again there is a tendency to underestimate utilitarian, destination-oriented trips. Data summarized in Table 2 is drawn from what are judged to be generally typical urban areas. Usage patterns differ in communities having unusual population characteristics as in university campus towns. In such situations substantially higher utilitarian use than indicated in the cited surveys can be anticipated.

Another problem with data of the type presented in Table 2 is that it simply notes individual incidence of trip purpose; it gives no indication of frequency with which various trip types are made. Reliable data describing trip frequency by purpose has been developed in only a limited number of surveys. Table 3 presents findings of two such surveys taken in Santa Clara County, California and the state of Arizona. The surveys show that although recreation trips are made by more cyclists than are any other trip type, utilitarian trips are made far more frequently. The inference here is that utilitarian trips are of much greater importance than surveys which focused on trip type incidence rather than frequency might indicate.

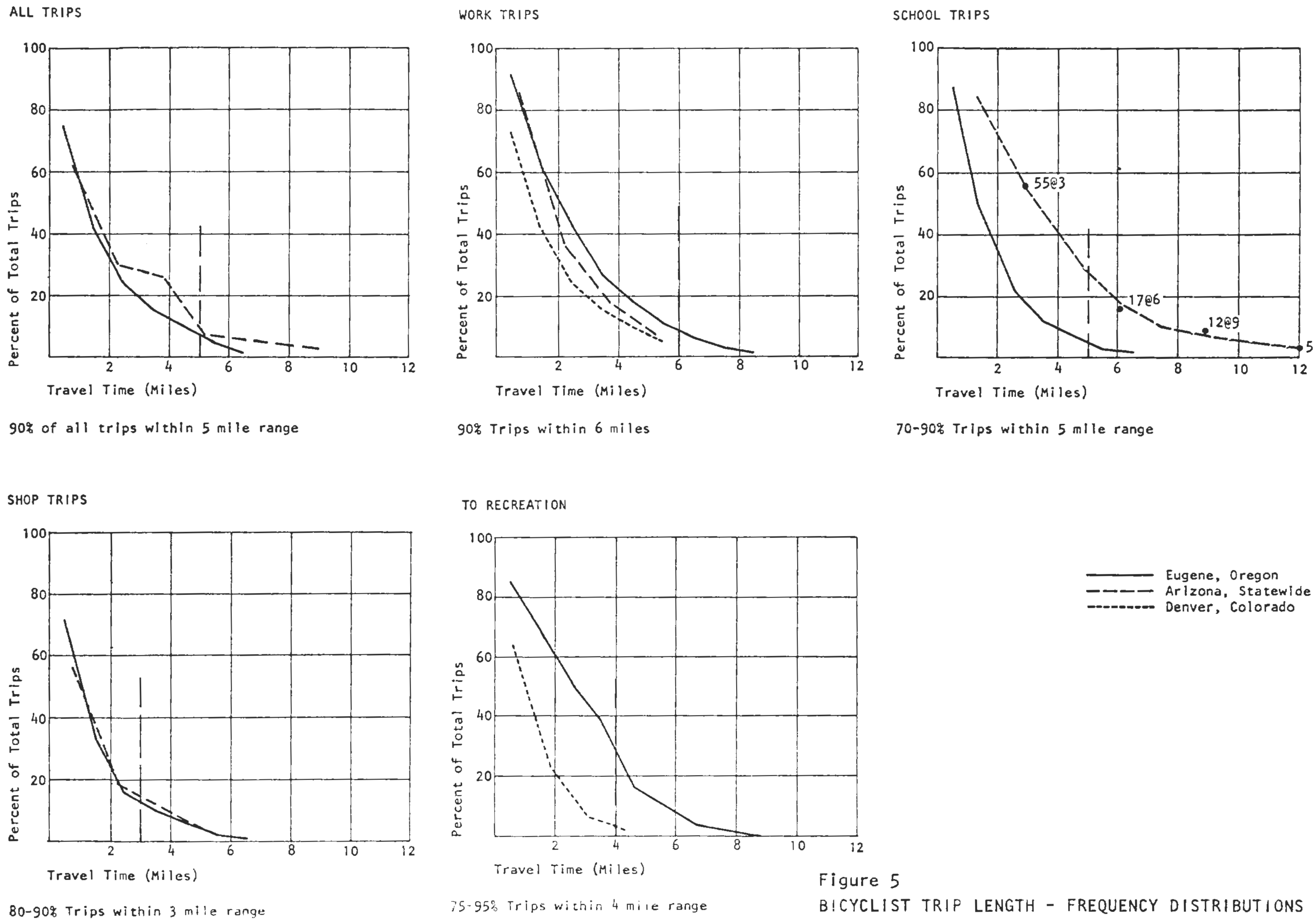


Figure 5
BICYCLIST TRIP LENGTH - FREQUENCY DISTRIBUTIONS

Table 2
TRIP PURPOSE SUMMARY

Trip Purpose	Arizona, Statewide %	Arizona, Statewide Rank	Santa Clara Co., Ca. %	Santa Clara Co., Ca. Rank	Fresno, Ca. %	Fresno, Ca. Rank	Santa Barbara Ca. %	Santa Barbara Ca. Rank	Tempe, Arizona %	Tempe, Arizona Rank	Washington, D.C. %	Washington, D.C. Rank	Boise, Idaho Rank	Berkeley, Ca. Rank	Lexington, Kentucky Rank
Recreation	55	1	70	1	63	1	88.3	1	77	1	47	2	1	1	1
Shopping	11	3	38	3	16	2	36.0	2	43	5	--	-	4	3	3
School	21	2	20	4	10	3	30.0	3	58	4	7	7	2	2	2
Work	3	5	8	5	6	4	23.7	4	16	6	11	6	3	4	4
Social (visiting)	6	4	68	2	--	-	--	-	65	3	39	3	-	-	-
Exercise	11	3	--	-	--	-	--	-	--	-	--	-	-	-	-
Personal business	--	-	--	-	--	-	--	-	--	-	32	5	-	-	-
Touring	--	-	--	-	--	-	--	-	--	-	35	4	-	-	-
Around the neighbor-hood	--	-	--	-	--	-	--	-	75	2	67	1	-	-	-
Other	--	-	--	-	5	5	--	-	7	7	--	-	-	-	-

Table 3
TRIP FREQUENCY BY PURPOSE

Frequency	Social %	Recreational %	Shop %	Work %	School %
At least once a day	34	14	11	33	52
At least once a week, not once a day	48	46	63	44	38
At least once a month, not once a week	13	27	21	11	5
Less than once a month	4	13	5	11	5
% riders who make trips (all riders = 3,122)	68	70	38	8	20

Source: Santa Clara County Bicycle Study

Frequency - round trips/week/household	Recreation	School	Shop	Exercise	Social	Work	Paper Route	Tour
1-2	31	9	34	47	28	25	21	100
3-4	18	14	26	12	24	25	7	0
5	15	42	14	17	9	21	0	0
6-9	24	7	14	16	16	11	61	0
10 +	12	28	12	8	23	18	11	0

Source: State of Arizona

Following is a discussion of factors particular to individual trip purposes which affect the probability of utilitarian bicycle use for that trip purpose:

- Work Trips

  Work trips are highly sensitive to travel time. Consideration of trip length and relative travel times is a best first approximation method of identifying work trips which could be served by bicycles.

  Bicycle work trips of five to six miles to intense urban activity centers are competitive with motor vehicles in travel time as indicated on Figure 6. Work trips to suburban employment centers within three to four miles are also potential candidates for cycling. It should be noted that in large urban areas, many work trips will be longer than these limits allow.

  Factors which affect the choice of an individual whose work trip falls within reasonable time/distance range of bike travel include:

  -- climate,

  -- topography,

  -- cost differential with alternate modes,

  -- employment-related status concerns,

  -- employment-related attire requirements,

  -- ability to change clothes or shower at place of employment before work,

  -- personal motor vehicle needed/not needed during course of day,

  -- tiring physical labor involved/not involved in employment activity, and

  -- personal safety (crime harassment, theft -- etc., as well as safety from automobile traffic)

- School Trips

  School trips are the utilitarian trip type having most probability of being served by bike. Nearly all school trips except those made to commuter (non-resident) colleges are within easy bicycling range. In addition, students below mid-high school grades generally do not have the option to travel by motor vehicle. On college campuses the bicycle is a particularly attractive mode, not only because it eliminates the need to compete for scarce and expensive

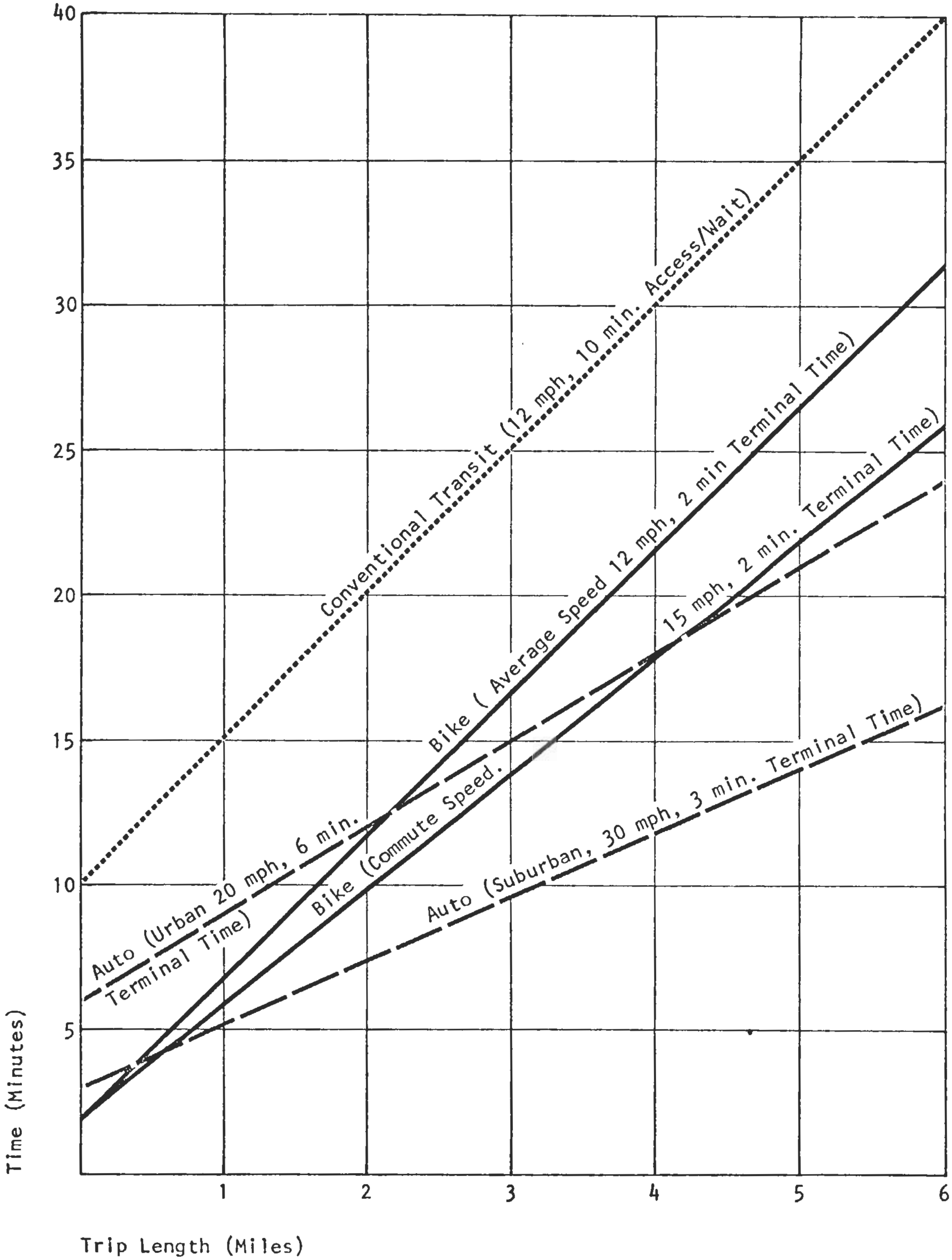


Figure 6
MODAL TRAVEL TIME COMPARISON

parking spaces, but also because it is particularly useful for getting from one place to another on campus. For elementary school children, riding a bicycle to school is a positive status symbol. For college students it is at least neutral. Only among junior high and high school age groups is riding a bicycle for transportation perceived as a negative status symbol. But for all youth below driving age, the bicycle is a primary means of independent personal mobility.

For these reasons virtually all school trips can be regarded as potential candidates for bicycle travel. Although heavy traffic, busing, school policy and parental judgment may serve to reduce the bicycle riding potential somewhat, particularly for younger elementary school students; and since schools at all levels have available information on enrollment districts and student residence locations, tasks of specific route planning and estimating route usage potential are straightforward.

- Shopping Trips

Shopping trips pose mixed potential for bicycle activity. Only a relatively few "convenience" type trips involving the purchase of a few small items are likely to be made by bicycle. Planning exercises related to shopping trips should be limited to simply identifying locations of convenience shopping centers and attempting to assure service to these locations on routes planned primarily to serve other trip purposes.

- Recreation

In planning for bicycle transportation to recreation activity sites, neighborhood and regional recreation centers must be considered separately. In the case of neighborhood centers, "tributary areas" to competing activity centers are defined. Normally all trips within a center's tributary area will be within reasonable bicycling range. For each activity center, logical routes from subsegments of the tributary area are defined. Usage potential of any route is proportional to the number of households served, total activity at the recreation center and character of the activities taking place at the center.

For bicycle transportation to regional activity centers, trip length once again becomes a factor. Methods similar to those used for work trips should be used to estimate bike trip potential and corridor demands.

- Other Trip Types

  A motor vehicle trip type in which there is high potential for diversion to bicycle activity is the trip to "serve passenger." Some of these involve "kiss-n-ride" trips to transit stations. Numerous others are relatively short trips involving parents driving children to such activities as music or dancing lessons, extra-curricular school functions, the dentist and others. The pattern of this trip type is random and difficult to quantify in any meaningful way for planning purposes. But it is possible to deal with "passenger" trips to specific activity centers such as transit stations in much the same way as trips to recreation activity centers.

  The potential for use of bicycles on personal business trips is generally limited as is the potential for adult bike trip-making for purposes of social visits. Generally, the unusually high response in the social or "visit friends" category on bicyclist surveys does not reflect true utilitarian trips. The response is attributable to young bicyclists and their tendency to answer in this way rather than give the probably more correct response of aimless play riding (which cannot be served with physical facilities).

  Non-home-based trips are extremely unlikely to be made by bicycle since they involve the joint probability that the prior home based trip was made by bicycle and that the bicycle will be an acceptable form of transportation for the current trip. No attempt should be made to quantify these trip types for route planning purposes.

Climate

Four types of climatological factors and their various combinations affect the potential for bicycle activity:

- Extremely cold temperatures,
- Precipitation,
- Extreme heat, and
- Significant prevalent wind.

In areas experiencing significant cold with snow covered and icy pavements in winter, bicycle activity will drop to nearly zero during these periods. This is not just because it is rather unpleasant to ride a bicycle while exposed to these elements; the presence of snow or icy pavements makes control and balance on a bicycle extremely difficult. Clearly this has an implication for usage justifying the cost of facilities. An important factor often overlooked is that if bicycle activity is impossible or extremely unattractive for a significant portion of the year, this may affect the likelihood of bicycling on certain utilitarian trips at other times of the year when bicycling is possible and attractive. Even if the principal employed person in a household could conveniently bicycle to work for nine months out of the year, if a household must own a second family car primarily for work commute purposes during the season when bicycling is not a viable transportation means, then that car will likely be used for commute purposes year round.

Precipitation has been assumed to be as absolute a deterent to bicycle activity as cold weather, particularly in cases where there is a seasonal expectation of a high probability of rain on almost any given day. But actual effect of this climatological factor is somewhat contrary to expectation. In areas where in certain seasons precipitation falls very often such as in the Pacific Northwest, there is evidence that rain has a less detrimental effect on bicycle activity than in areas where far less precipitation might fall but where its likelihood of occurrence is far less <u>predictable</u>. This seems to reflect a greater capability for physical and psychological adaption to adverse weather conditions which are both predictable and relatively continuous over a period of time as opposed to intermittent and relatively unpredictable adverse conditions.

<u>Age</u>

Figure 7 presents a typical distribution of bicyclist age as measured in an area of typical non-homogeneous distribution of total population age. The distribution of bicyclists' age is in contrast to the age distribution of the total population and illustrates the disproportionality of bicyclist age concentration in the youth and young adult groups in relation to the total population age distribution. Age distribution of bicyclists is in a state of flux, with significant growth of the bicycling population among adult categories.

Since there is a tendency to clustering by age among residence areas, at times it may be possible to utilize census data on resident age distribution to identify high potential and low potential bicycle trip generation areas. However, two words of caution are advised. The level of detail at which resident age clustering becomes significant may be too fine-grained to be relevant to estimation of bicycle activity for purposes of facility location. Secondly, in relatively large areas having unique population age distributions, age may no longer be a reliable indicator of the potential for bicycle activity. Factors which induce age clustering on an unusually large scale may also induce other changes in expected behavior. For instance, in an adult retirement community or enclave, site conditions and peer reinforcement may induce far more active bicycling by senior citizens than would be the case if the same individuals were dispersed in a normal residential mix. An illustration of this is Hemet, California where nearly 60 percent of the population is above 60 years of age and where persons over 60 years of age are estimated to account for 50 percent of the active cycling population. Thus age distribution must be tempered by knowledge of special area characteristics when determining its influence on bicycle potential.

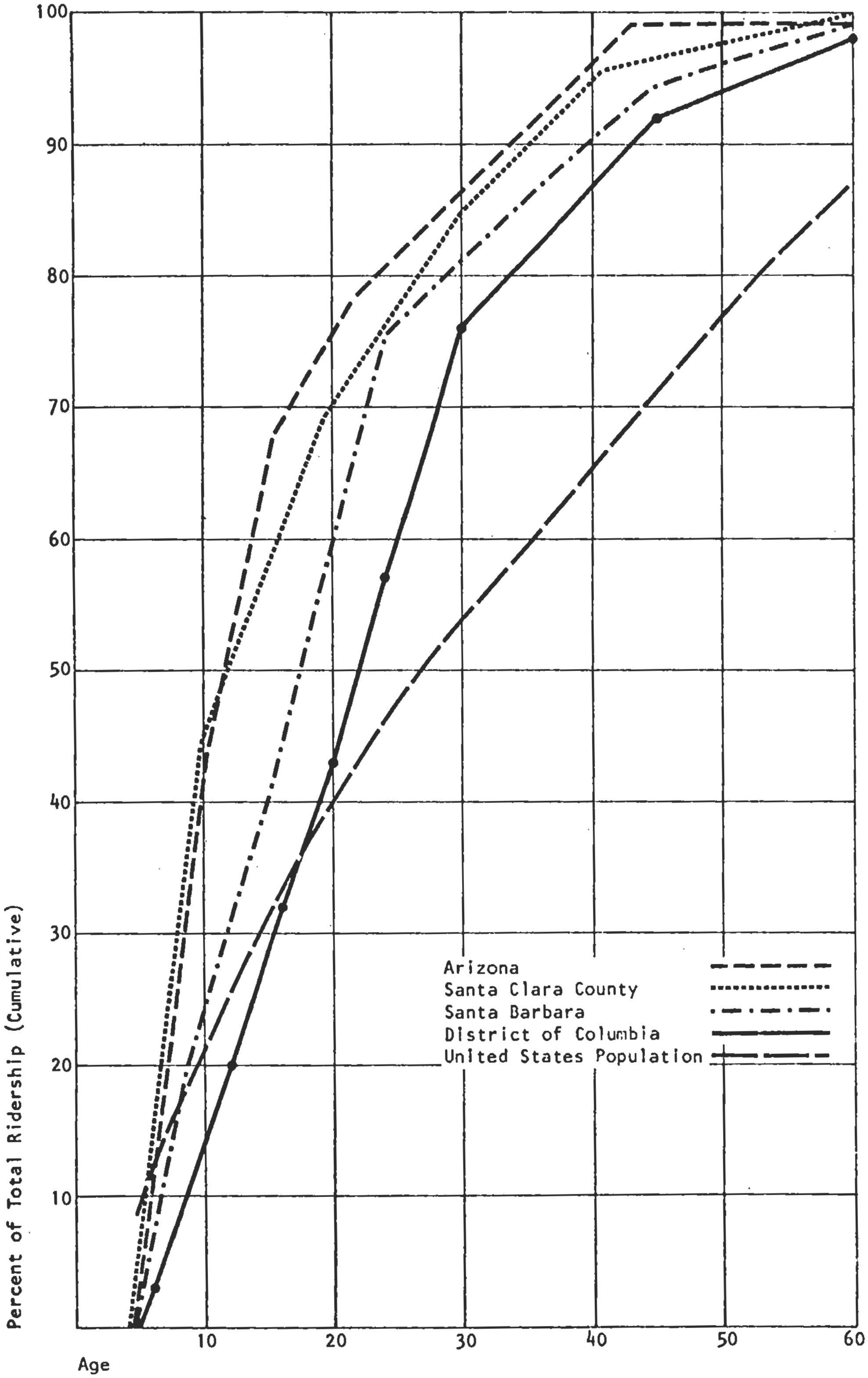


Figure 7
BICYCLIST AGE TYPICAL DISTRIBUTIONS

Bike Ownership

In order to ride a bike, a person must have one available. And ignoring the opportunities to rent a bicycle or borrow from friends, bike availability can be presumed to be equivalent to personal ownership of a bicycle or ownership in the household. In 1973, an estimated 37 percent of the United States population owned bicycles. Considering sales in the intervening period, perhaps as much as 45 percent of the United States population owns bicycles (Bicycle Institute of America, "Booming Bikeways," Volume 8, No. 1, New York, N.Y., March 1973). Since many of these bicycles are available to other household members than their owners, a greater percentage of the population may be potential bicyclists.

Table 4 presents bicycle ownership and ridership in a number of communities for which data was available. Although there are few sites in which data permits direct comparison of ridership to ownership levels, the table inferentially indicates a fairly parallel relationship between ownership and ridership. Thus, it might be theorized that a reasonable growth method of estimating and planning for bicycle activity would be to determine bicycle ownership in various sub-areas of the community, thereafter focusing facilities planning efforts in sub-areas having high or average ownership levels and placing less emphasis on areas of low bicycle ownership.

Table 4
BIKE OWNERSHIP VS. RIDERSHIP

	% Bike Owners	% Bike Riders
U.S.	37	
Santa Clara County, Ca.		49
Arizona	46	41
Santa Barbara, Ca.	41	47
Fresno, Ca.	41	
Eugene-Springfield, Ore.		39
Ann Arbor, Mich.		29

However, there are drawbacks to this planning strategy. Current bicycle ownership (and usage rates) may very closely reflect the existing conditions for bicycling in a community or sub-area thereof. Such conditions can sharply change if measures are undertaken to change the safety, attractiveness and public attitude toward bicycling. There may be a latent ridership potential far divergent from the existing ownership pattern. A low ownership pattern may, in fact, be indicative of tremendous opportunities to bring about increased bicycle activity through bicycle facility provision or other measures rather than an indication that no facilities should be provided. This latter hypothesis is reinforced by the fact that unlike the case of a motor vehicle, there is a relatively minor economic barrier to ownership and operation of a bicycle. A sturdy, functional three- or ten-speed bicycle can be bought new for as little as $50 or $100, respectively. Once acquired, it costs virtually nothing to operate. Thus, bicycle ownership statistics may be useful for little more than indication of immediate use potential and may be a misleading indicator of longer term opportunities and needs.

Cost

Estimated operating cost differentials between the bicycle, automobile and transit are presented on Figure 8. Sheer cost, and comparison of cost and travel time differentials to accepted estimates of the value of time, indicate that cost saving potential is not a dominant consideration for most persons who are in reasonable bicycling distance of their destinations. While cost is a motivating factor to some who now use bicycles, it appears clear that other factors are much more important than cost to those who choose other modes.

Occupation & Status

A number of relationships between bicycle use and social station have been identified in surveys of bicyclists. However, specific social status variables which are useful as predictors of bicycle activity have not been determined. Available data show conflicting and inconclusive evidence of the effects of status-related factors.

Table 5 presents indicators of bicycle use among adults in various occupation categories.

Although these data compare ownership in one case and bicycle use for work trips in the other, some useful inferences can be drawn.

- Probability of bicycle ownership varies among employment categories. The pattern tends to conform to expectations based upon information on bike ownership in relation to income and educational attainment.

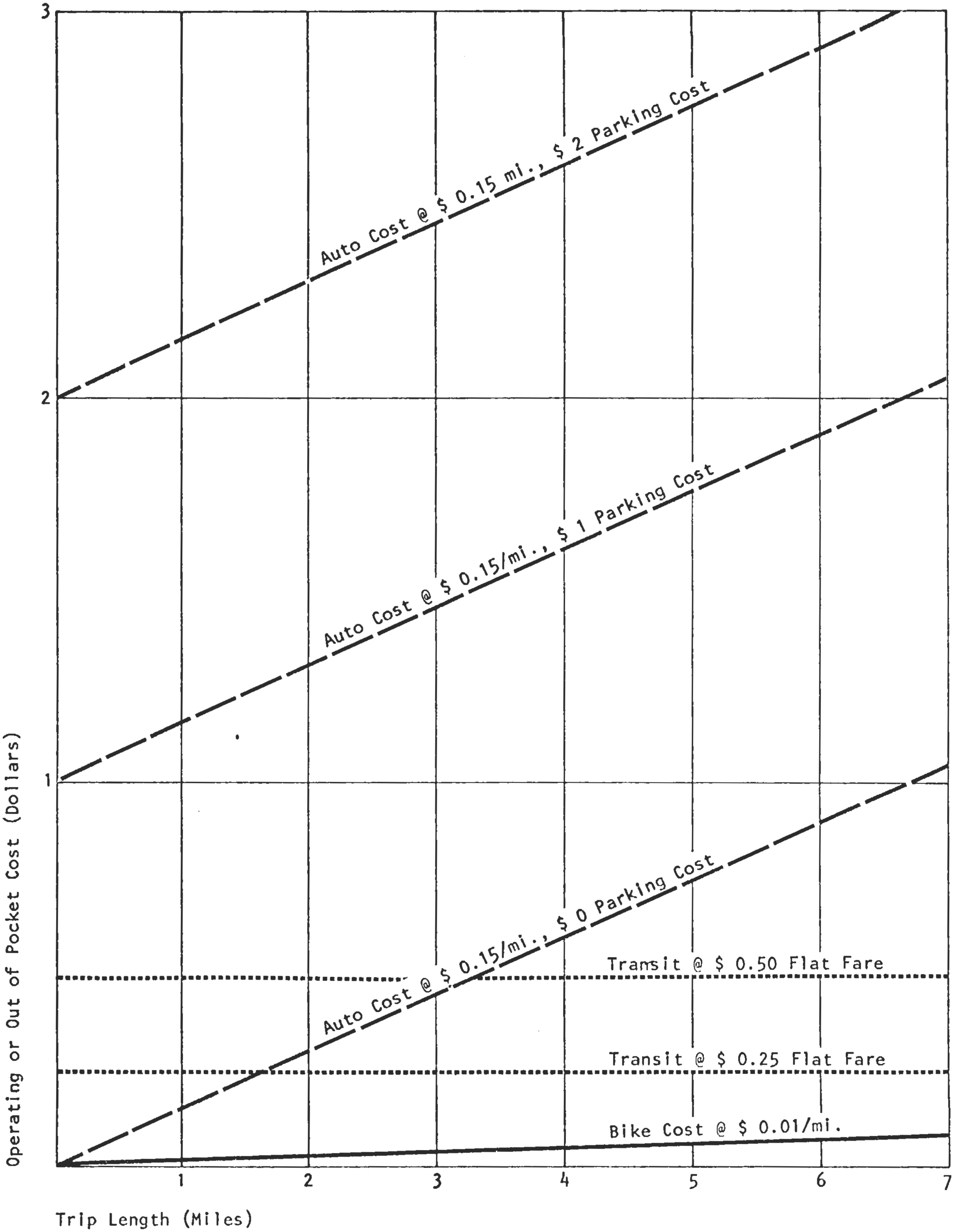


Figure 8
MODAL COST COMPARISON

Table 5
INDICATORS OF BICYCLE USE AMONG ADULTS BY OCCUPATIONAL CATEGORY

Occupation	Arizona		Davis	
	Bike Owners %	Non-Owners %	Make Bike Work Trips %	Never Bike Work Trips %
Professional-Technical	68	32	29	71
Managerial-Business	66	34	11	89
Sales	50	50	32	68
Clerical	50	50	26	74
Skilled/Semi-Skilled	52	48	-	-
Service	54	46	25	75
Unskilled	50	50	22	78

- Differences in usage rates for work trips among occupational categories does not significantly reflect differences in ownership rates.

- The lower work-trip usage rate among the managerial-business category conforms to intuitive expectation that usage by this group would be discouraged by employment-related image or status concerns. However, analysis of the Davis data showed that this apparent difference was not a direct function of occupation. Age and residence distance from place of employment tended to explain differences in bike usage rates for work trips among occupational categories.

- The Davis data give some notion of a reasonable upper limit of bike mode split for work trips within reasonable bicycling distance range which might be achieved under conditions approaching ideal. (Note that persons included in the "user" category are full time employees but may make as few as one trip per week by bicycle.) From these studies, a reasonable <u>maximum</u> work mode split assumption for travel on a daily basis under <u>ideal</u> conditions for trips within previously noted "cutoff" range appears to be about 20 percent.

TRAVEL MODELING PROCEDURES

The foregoing indicates some rational methods for estimating bicycle activity potential and suggests the difficulty of developing more sophisticated techniques for analyzing bike travel demand and trip patterns. Despite this, at present there appears to be an over-emphasized interest in attempts to develop sophisticated techniques for forecasting bicycle activity. Interest in forecasting is a healthy indication that the bicycle is recognized as a viable element of the transportation system to which meaningful planning effort should be devoted. But sophisticated forecasting techniques are not on the immediate horizon, nor are they needed to achieve satisfactory bikeway planning and design.

In the early years of the automotive age, perhaps through the immediate post-World War II period, transportation planning involved relatively simple decision-making. Needs were obvious and virtually any "obvious" facility commitment would have significant payoff in benefit. Hence, there was little need for elaborate forecasting as a basis for justifying facilities. Since justification seemed obvious, as did priorities, the primary purpose of forecasting was to scale the physical design of the facility. For purposes of physical design scaling, rather gross forecasting methods were satisfactory. However as the transportation system developed to the point where basic requirements of accessibility were reasonably met, individual projects offered only marginal benefit increments. It became important to develop means of evaluating justification and relative priority of facilities since intrinsic worth and worth relative to other potential actions could no longer be perceived intuitively. The need for reasonably precise decision-making instruments gave rise to the "science" of transportation planning with its feasibility and benefit analyses which in turn demanded sophisticated forecasts of travel activity.

It can be asserted with some truth that the status of bicycle facilities today closely parallels the status of highways in the 1920's and 1930's, that most needs and justifications seem obvious and that sophisticated techniques of forecasting bicycle activity are not required. It appears that simple forecasting techniques are relevant to current bikeway planning and that more sophisticated techniques will evolve in time as they become truly needed.

The studies and surveys of bicyclist trip-making characteristics, some of which have been cited above, would appear to provide information paralleling that utilized in trip generation or modal choice relationships for motor vehicle and transit travel. These could presumably be reutilized to develop predictive equations for bicycle activities. However, the relatively simple variables utilized to explain total person travel and other modal choice forms are at this time inadequate to explain decision-making relative to bicycle use.

In order to develop relationships of bicycle activity to objective quantifiables such as bike ownership, measurements of the relationships of activity to the objective quantifiables must be done relative to a fixed attitudinal framework. And not only is it extremely difficult to define such an attitudinal framework, attitudes relative to bikes and bicycling are shifting rapidly with time so that the relationships between bicycle and relevant objective factors which hold now are unlikely to hold in the future.

For example, as late as 1965, the adult bicyclist was a relatively rare individual. The adult who did own a bicycle and at least occasionally used it for recreation or exercise would not think of using it for a purposeful trip, such as a work trip, unless willing to be thought of as being highly eccentric. By contrast, by 1975 adult bicyclists are relatively common and while a professional person who rides a bike to work might be thought of as "a bit of an enthusiast," the whole perspective in which a utility cyclist is viewed is far less negative and may perhaps be even positive. As a result, adults who own bikes are likely to ride them far more frequently than they might have ten years ago. Thus, dramatic changes in trip generation rates in relation to ownership would be expected and additional changes in such rates can be anticipated as social acceptability of bicycling continues to change.

Another complicating condition is the fact that the likelihood of choosing to use the bicycle for trips currently made or to make new trips by bicycle is highly system-sensitive. System-sensitivity implies far more than the ability to get from trip origin to trip destination by traveling for a certain distance or time. In the case of bicycling choices, or a large number of factors including such things as the level of effort requried (which must take into account such things as adverse grades) and the perceived safety and amenity of the routes traveled upon.

The implication of system-sensitivity for estimation of the relationship of bicycle trip generation to objective factors such as bicycle ownership, trip length, or trip purpose is that some sort of index of system quality must be associated with each data point relating bike use probability to those objective factors. Complicating this is the fact that such a system quality measurement is itself an individual perceptual one rather than an objective measurement. It's important to note that when we speak of system variables in this context, we are speaking of qualities quite distinct from the kinds of system performance utility measurements employed in conventional transportation analyses -- things like cost and travel time.

To summarize the problem, the set of determinants of bicycle use comprise a multi-dimensional array and include not only a set of objective and relatively easily quantified variables, but a number of other variables which are extremely difficult to measure and more difficult to project. These can loosely be described as attitudinal variables and variables related to subjective perception of system quality in relation to service of specific trips. As a result, it is extremely difficult to estimate a model which explains bicycle usage behavior on the basis of existing data. Moreover, even if such a model were estimated, it would generally not be transferrable to areas other than the one for which it was estimated. Even in this area it would likely remain representative only for a short period of time. Estimation of a model having time and locational transferability does not appear to be a viable exercise for the near term future.

APPENDIX B

THE USE OF SURVEYS

PURPOSE

This brief Appendix is included in response to the many errors and misunderstandings identified in this program's review of surveys used in recent bikeway planning efforts. Its intent is to alert the planner to the most common pitfalls in survey use.

This is not a guide to how to do a survey. A proper treatment of survey methods is not difficult, but is beyond the intended scope of this manual. Moreover, there are many existing publications dealing with survey methods, including material for the layperson as well as the survey specialist.

A series of appropriate references are included at the conclusion of this appendix.

ORGANIZATION

A convenient way to organize these comments is in accordance with the major elements of a survey:

- Definition of objectives and outputs
- Selecting a survey design
- Sampling
- Instrument design
- Conduct
- Analysis and reportage

Within each of these general elements, the remainder of this appendix is devoted to enumeration of some major pitfalls and problems in survey work.

PITFALLS AND PROBLEMS

Definition of Objectives and Outputs

- The most important point at this early stage is simply to be sure that this step is in fact carried out. Too often a survey is launched without a clear understanding of exactly what it can or will produce.

- Specificity is essential. First, general objectives in data collection should be agreed upon; then the intended contribution of a survey should be spelled out <u>in detail</u>. This is best done by writing out mock-ups of the tabulation outputs (whether to be done by hand or computer), maps, and tables needed, to be sure that "what you get is what you want".

- This implies that the analysis should be designed first. This is correct; it should be, and with the survey objectives firmly in mind. Only in this way is the great danger of collecting the wrong data avoided. This cannot be stressed too highly; yet it is amazing how rarely it is done.

- If objectives are clearly identified, it may become evident that a survey is not really needed or adequately cost-effective. To further insure against the possibility of doing an unneeded survey, this entire step should be undertaken with this question foremost: "Could we satisfy our study objectives <u>any other way</u>?"

- There may be reasons for a survey quite unrelated to data needs. These often have to do with a desire to justify or give publicity to a plan. These may or may not be valid; in any case, they should be explicitly recognized and not masked.

<u>Selecting a Survey Design</u>

- The essential need here is to reach the desired target population group. Thus it is mandatory to define who is in this group -- it may be only bicyclists or bike owners or it may be the entire community.

- The design or strategy should involve selecting an approach which will reach the target group as effectively as possible within budget. This means, for example, that a random telephone survey would be an unlikely choice for reaching experienced bikers, since most calls would be to unqualified households.

- This step cannot be done independently of the two discussed next (sampling and instrument design). There are important tradeoffs among the choices within each step; for example, if the required data needs dictate a long interview, the number of interviews and alternative collection methods will be limited. As a rule of thumb, the following guide is helpful:

Survey Type	Length
-- Self-administered (e.g., mailback)	1-2 pages maximum
-- Telephone interview	15 minutes
-- Home interview	45-60 minutes
-- Travel stop	1-5 minutes

- Response rates vary widely according to type of survey. Generally, mail surveys achieve a lower response than others; the telephone survey is somewhat more effective; and the home interview and traveler surveys obtain highest percentages of response. However, many other factors such as wording, format, length, subject and population surveyed are also important, and no simple rule of thumb should be applied.

- Survey work can be very expensive. Great care must be taken to recognize all costs before beginning.

- Often surveys take far more time to produce results than expected. This is because of questionnaire approvals, weather, slow (mailback) or low rates (in other methods) of response, and delays in processing and analyzing data (particularly if computer analyses are used). Avoid study designs which leave too little slack in the time schedule for delays; an extra 50 percent is not too much.

<u>Sampling</u>

- In general, full enumerations (100 percent samples) are very seldom used. They are extremely expensive and usually add little if anything to the useful accuracy of the results. The major exception is in the case of a very small population (i.e., up to perhaps 200) in which samples would be too small for reliable inferences to be drawn.

- The major concern in survey sampling is to avoid bias, or non-representative results. Much of this requires only thoughtful common sense; for example, to learn about the desires of the bike-riding population one should not survey just the members of a bicycle touring club, for their needs, desires, skills and bike use are likely to be quite different from those of casual bikers.

- There are many clever statistical designs for sampling, including simple random, stratified, cluster, systematic, and various composite sampling techniques. The application of these principles in any reasonably large survey should be guided or at least advised by a competent statistical technician, to avoid embarassing (or worse) errors. Properly used, statistical survey principles can save much effort and money.

- Statistical inference, the power to draw from a sample reliable conclusions about the whole population, is mainly controlled by absolute sample size -- not the proportion of the population sampled. Ignore any advice to use "a straight ten percent" or other proportion. Get a statistician if in doubt.

Instrument Design

- The instrument must be clear and of interest to the respondent. Otherwise unsuspected and even undetected response biases as well as refusals will occur.

- The instrument should always be pretested, along with the procedure for administering it. Pretesting invariably uncovers points of misunderstanding, difficulty, or delay.

- Questions can all too easily be poorly worded, resulting in useless or no responses. This is especially true of items concerning future behavior of the respondent or his/her household "if a bikeway were provided". Great care must be taken in design of such items, and their results should be used with skepticism in any case. (No matter what the responses show, 40 percent of a community's population is not going to suddenly start riding bikes regularly!)

- Bias is as important a consideration in instrument design as in sampling. Even if the sample is perfectly representative and the response rate very high, ambiguities in the questions themselves may render the responses useless or unreliable.

- The temptation to include extra "interesting" questions should be resisted. They make the survey more expensive and less reliable, annoy the respondent, and usually never get analyzed anyway. This is a vice of many inexperienced survey designers.

Survey Conduct

- The field staff must be well trained and rehearsed, particularly for face-to-face or telephone interviews. The most common problem is in inconsistency of approach among different interviewers, possibly resulting in different interpretations of the same question by different respondents.

- Close supervision is essential with a staff of any appreciable size (over one). Problems arise virtually hourly and must be resolved quickly.

- Close track must be kept of nonresponse. Every attempt should be made to obtain responses from the initial sample, in order to avoid under-representation of the kind of people who may not be easily found or convinced to participate.

Analysis and Reportage

- Confidentiality of response is usually essential. There should be no possibility that a particular response could be traced to an identifiable person unless expressly permitted by that person. Otherwise credibility of the surveying agency will be damaged and the whole process of survey research tainted as well.

- As already noted, the analysis should be designed along with the instrument and sampling plan.

- Reportage should be organized by the initial objectives, and aimed at a specific audience. Generally, voluminous reports with many tabulations are needless, costly, and even counterproductive because they are invariably hard to follow. Nonetheless, they are far too common. Emphasize and illustrate main points, and stop.

REFERENCES

Urban Transportation Systems Associates, Inc., Urban Mass Transportation Travel Surveys, for U. S. Department of Transportation, August, 1972.

Raj, Des, The Design of Sample Surveys, McGraw-Hill Book Company, Inc., 1972.

Cochran, William G., Sampling Techniques, John Wiley and Sons, Inc., 1963.

APPENDIX C

PHYSIOLOGICAL CONSIDERATIONS IN BICYCLE FACILITY LOCATION

Both the total amount and peak rate of physical work in riding are major considerations in bicyclist choice of route. Consequently, the bikeway planner must determine:

- That the energy required at all points of a candidate route does not exceed acceptable human performance limits; and
- If reasonable alternative routes pose significantly lower work requirements than the candidate route.

Considerable amounts of research have been conducted in preparation of this report; the subject is quite complex. This appendix summarizes only those portions of the research readily applicable by planners.

Human work is accomplished through the burning of chemical fuels. There are two such bodily processes. Aerobic metabolism refers to the burning of fuels in the presence of oxygen. This is the method of energy conversion in a sustained manner for long periods of time. Anaerobic metabolism is a process in which high energy phosphates are burned to achieve very high levels of muscular effort possible only over short periods of time (usually less than two minutes). In bikeway planning, both of these characteristics must be considered; long range steady-state activities and the occasional peak efforts.

This section will explain the two computations necessary to analyze aerobic and anaerobic work efforts. A number of factors influence human work capacity, including body size, age, sex, and physical condition. The following sections will provide design data for a number of typical individuals representative of the range of persons who may bicycle. The planner must choose the design cyclist for the particular problem at hand, always keeping in mind that he must represent the minimum physiological ability of the total (majority) cycling population likely to use the facility.

It is impossible to use any one design cyclist for all situations. Table 6 presents characteristics of several person types used as test cyclists in the examples which follow.

The effects of bicycle rolling resistance, grades, bike speeds and wind speeds relative to the cyclists' physiological abilities can be approximated by the following equation:

$$K = \frac{1}{MAXVO_2}\{0.31415 + 8.6109 \quad \nu(F_G + F_D + F_R) \quad C_1\} \text{. . . . . .1}$$

where

K = fraction of aerobic work capacity

$MAXVO_2$ = maximal aerobic rate of oxygen consumption

ν = bicycle speed (MPH)

F_G = force due to gravity during hill riding (lbs)

F_D = force due to aerodynamic drag (lbs)

F_R = force due to rolling resistance (lbs)

C_1 = a constant required to convert the square bracketed term into horsepower

For the assumptions of grades less than 20 percent and sea level conditions of temperature and pressure:

$$F_G = (W_R + W_B)\phi \quad \ldots\ldots\ldots\ldots 2$$

$$F_D = 0.00256(\nu + q)^2 A_D \quad \ldots\ldots\ldots\ldots 3$$

$$F_R = (0.005 + \frac{0.15}{T}) \quad (W_R + W_B) \quad \ldots\ldots 4$$

where

W_R = weight of the rider (lbs)

W_B = weight of the bicycle (lbs)

ϕ = grade defined as the slope of the hill with the horizontal (+ slope is uphill)

g = wind speed; positive if opposite direction of travel (MPH)

A_D = drag area of the bicycle and cyclist (ft^2) (use 4.0 ft^2 for adult males in touring position; 3.5 ft^2 for adult females in touring position)

T = tire inflation presure (p.s.i.)

Equation 1 is based upon a cyclist riding at the most efficient pedalling rate. Generally this applies for typical bicycles operating at or in excess of about 6 MPH uphill.

Upon substitution of Equations 2, 3, 4 into Equation 1 and using various values of ϕ , one may obtain representative graphs of cyclist grade riding abilities as a function of v and k. Figures 9 through 14 present such

Table 6
REPRESENTATIVE CYCLIST TYPES

Subject	Age yrs	Sex -	Wheel Dia. D ft.	Tire Infl.prss. T psi	Bike Wt. W_B lb.	Rider Wt. W_R lb.	Max.aerobic work rate	Drag Area A_D ft^2	Comments
1	12	M	2.25	60	35	90	41	3.0	
2	22	M	2.25	60	35	160	41	4.0	
3	30	F	2.25	60	35	130	33	3.5	
4	40	M	2.25	60	35	175	25	4.0	Post coronary subject
5	55	M	2.25	60	35	185	30	4.0	
6	55	F	2.25	60	35	145	25	3.5	

plots for the representative cyclists described in Table 6. Figure 15 is utilized to assess riding abilities for periods of more than one hour where the aerobic work capacity is determined to be less than 100 percent.

The basic criterion upon which grade acceptability is judged is the amount of work of which a cyclist is capable. For short grades, this criterion is measured by the anaerobic work capability for various design cyclists. Work durations of one-third exhaustion level durations are estimated as reasonable periods bicyclists might be expected to work in the anaerobic range. The basic calculations which follow attempt to determine the length of time over which a calculated quantity of work is performed. Comparisons between calculated and observed limits of working time are made to determine grade acceptability.

Table 6 presents a range of typical bicyclists for analysis purposes. All are presumed to be riding the same three-speed bicycle with gear ratios of 1.9, 2.5 and 3.4 in the closest to optimal gear.

Three speed bicycles were selected as a reasonable "design bicycle" to simplify the analysis procedure. While standard five and ten speed bicycles offer more gears, their maximum range is similar to that of three speed bicycles. In addition most cyclists riding the five and ten speed bicycles do not come any closer to selection of optimal gear ratios than it is possible being in the optimal three speed gear. And further, one speed bicycles are typically most often ridden by younger cyclists who generally are not the critical design cyclists in terms of grade climbing. Precise procedure for accounting for specific gears on each type of bicycle are detailed in the final report.

Analysis procedures for design involve a trial and error solution:

1. Select a grade profile to suit the change in elevation required.

2. Calculate deceleration distance from the base of the grade to the point at which speed drops to a steady-state climbing speed.

3. Subtract deceleration distance from total grade distance -- determine time to climb this distance based on steady-state speed. If grade length is greater than 400 feet, STEP 2 can be omitted and climb time determined for the full grade.

4. Determine aerobic work requirement for various anticipated design cyclists for the chosen grade from Figures 9 through 14.

5. Determine maximum time that each cyclist can work at the above work rate.

6. Compare calculated time for climbing to maximum allowable time each cyclist can work and evaluate for acceptability. If unacceptable, repeat the process under new grade profile assumptions.

The following example details the steps in the calculation.

Sample Design Problem

A grade separation will necessitate an elevation change of 20 feet for bicyclists. No site constraints are present but reasonably short approaches are desired to limit costs.

Solution

STEP 1 The designer assumes an approach grade of eight percent. Grade Length (L) = 20 feet/8 percent = 250 feet.

STEP 2 The distance cyclists' initial momentum will carry then up the hill (L') until a steady-state speed of six miles per hour is reached is approximately by:

$$L' = (V_i^2 - V^2)\frac{1}{2gG}$$

V = Steady state climb velocity (assumes 6 MPH)

V_i = Initial approach velocity

g = Acceleration due to gravity (32.2 ft/sec^2)

G = Grade (ft/ft)

STEP 3 Assuming an initial approach speed of 15 MPH, L' = 36 feet. The distance cyclists must pedal upgrade at six miles per hour (l) is given by L-L' = 214 feet. Critical travel time (t) = distance/speed = 214 feet/6 MPH = 24.3 seconds.

STEP 4 Next, cyclist work rate on the six miles per hour steady-state segment is computed. Figures 9-14 present work-grade relationships for test cyclists identified in Table 6, each traveling at six miles per hour.

STEP 5 Figure 16 presents duration of time bicyclists can work at various percentages of maximum aerobic work capacity before reaching exhaustion. Work durations of one-third exhaustion level durations are estimated as reasonable periods bicyclists might be expected to work in the anaerobic range. These exhaustion level and reasonable work durations are summarized for each test cyclist on Table 7.

STEP 6 Assessing the results on Table 7 it can be seen that both the 12 and 22 year old males can ride the grade working in the aerobic range; it is well within the limits of their capabilities. The 30 year old female and the 50 year old male would be forced to work in their anaerobic range but the 24.3 seconds required to ride the grade would fall within their duration tolerances. Only the 40 year old post-coronary patient and the 55 year old female would be unable to ride the grade within reasonable limits of effort and duration.

Table 7
SUMMARY OF AEROBIC WORK CAPACITY

Subject	Percent Maximum Aerobic Work Capability (k)	Time to Exhaustion	One-third Time to Exhaustion
12-year-old male	114	155 seconds	51 seconds
22-year-old male	95	440 seconds	146 seconds
30-year-old male	134	90 seconds	30 seconds
40-year-old male*	166	42 seconds	14 seconds
55-year-old male	138	84 seconds	27 seconds
55-year-old female	166	42 seconds	14 seconds

* Post-coronary patient.

Here the designer must exercise judgment: The conclusion may be that the grade profile is generally acceptable and that the post-coronary patient will simply have to walk part way up the grade, or more moderate grade profiles will be tested until the post-coronary patient can ride is identified.

That judgment will depend upon site and economic constraints and characteristics of the expected users. For instance, 60 year old male and female cyclists might also be included among the cyclist types tested above. If the site of the proposed facility was in an adult retirement community, these persons might be identified as the critical design types and desirable standards identified for them according to procedures outlined above.

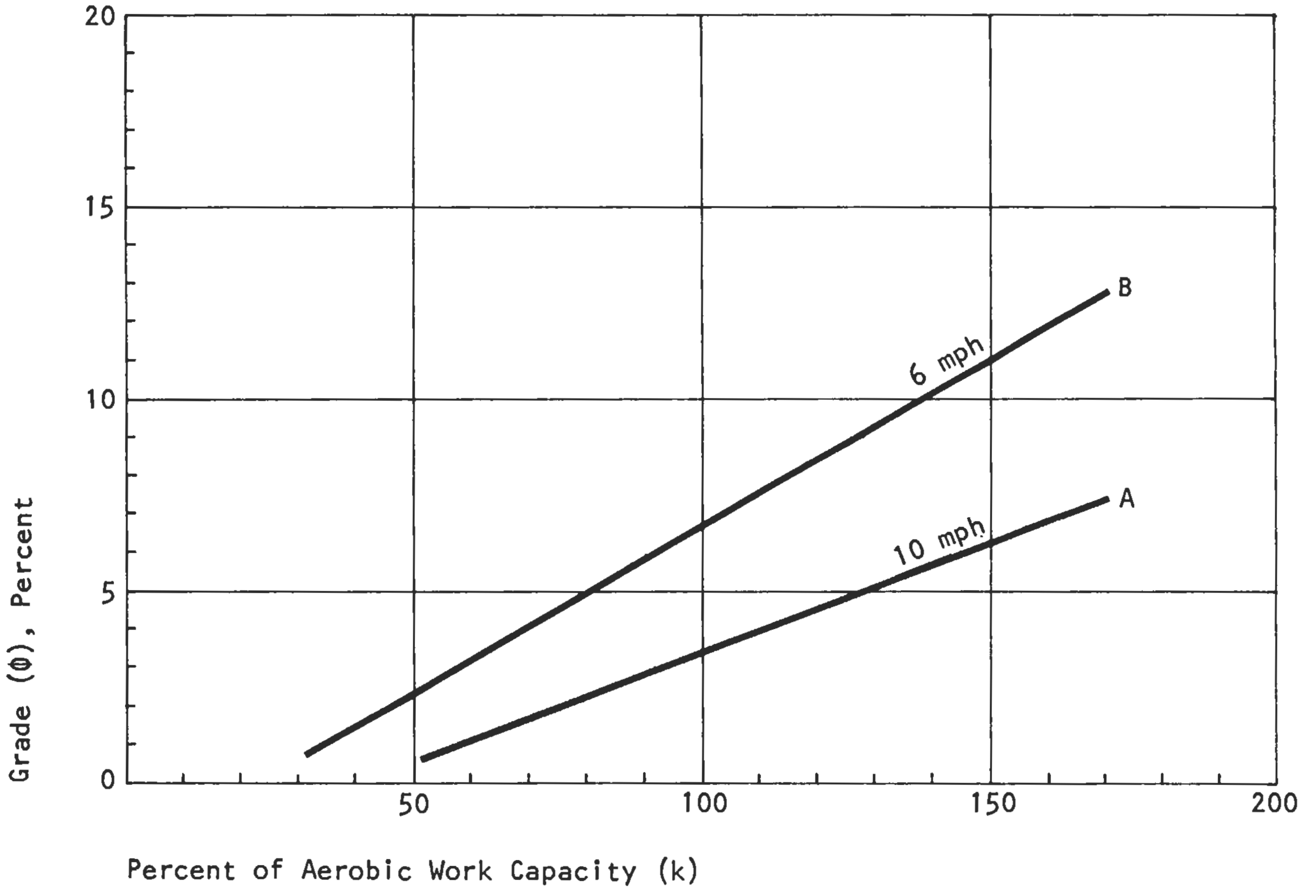


Figure 9
GRADE VS AEROBIC WORK CAPACITY -
12 YEAR OLD MALE DESIGN CYCLIST

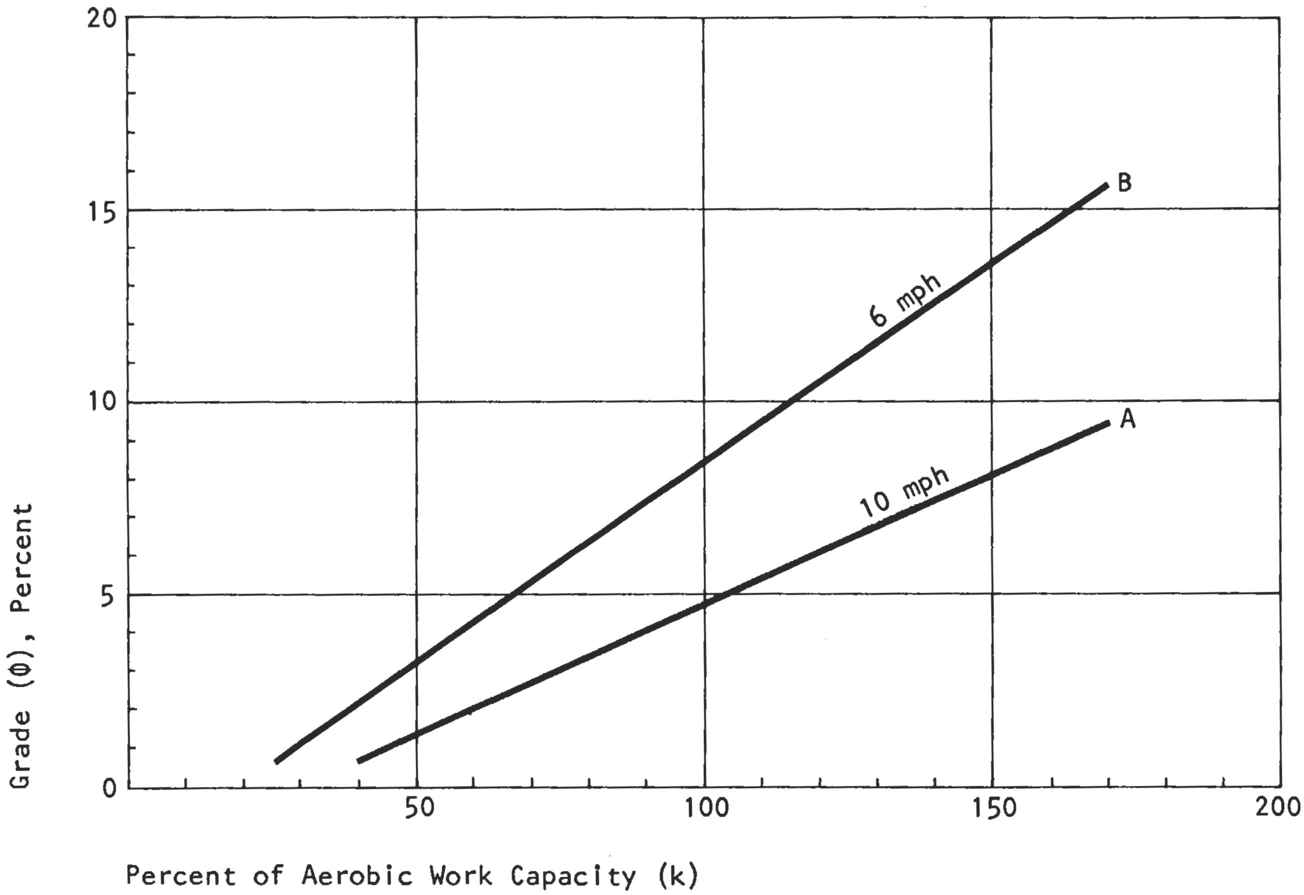


Figure 10
GRADE VS AEROBIC WORK CAPACITY -
22 YEAR OLD DESIGN CYCLIST

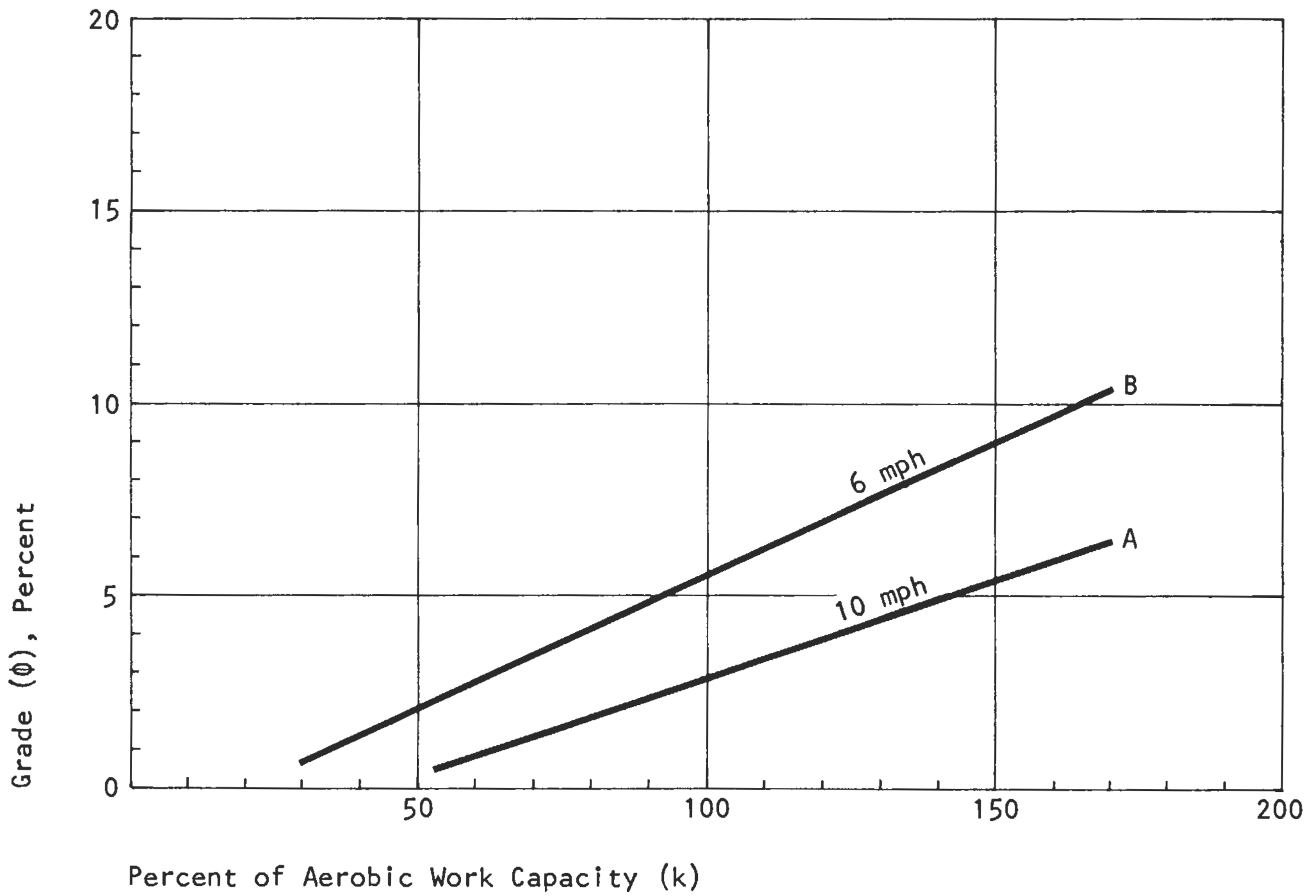


Figure 11

GRADE VS AEROBIC WORK CAPACITY - 30 YEAR OLD FEMALE DESIGN CYCLIST

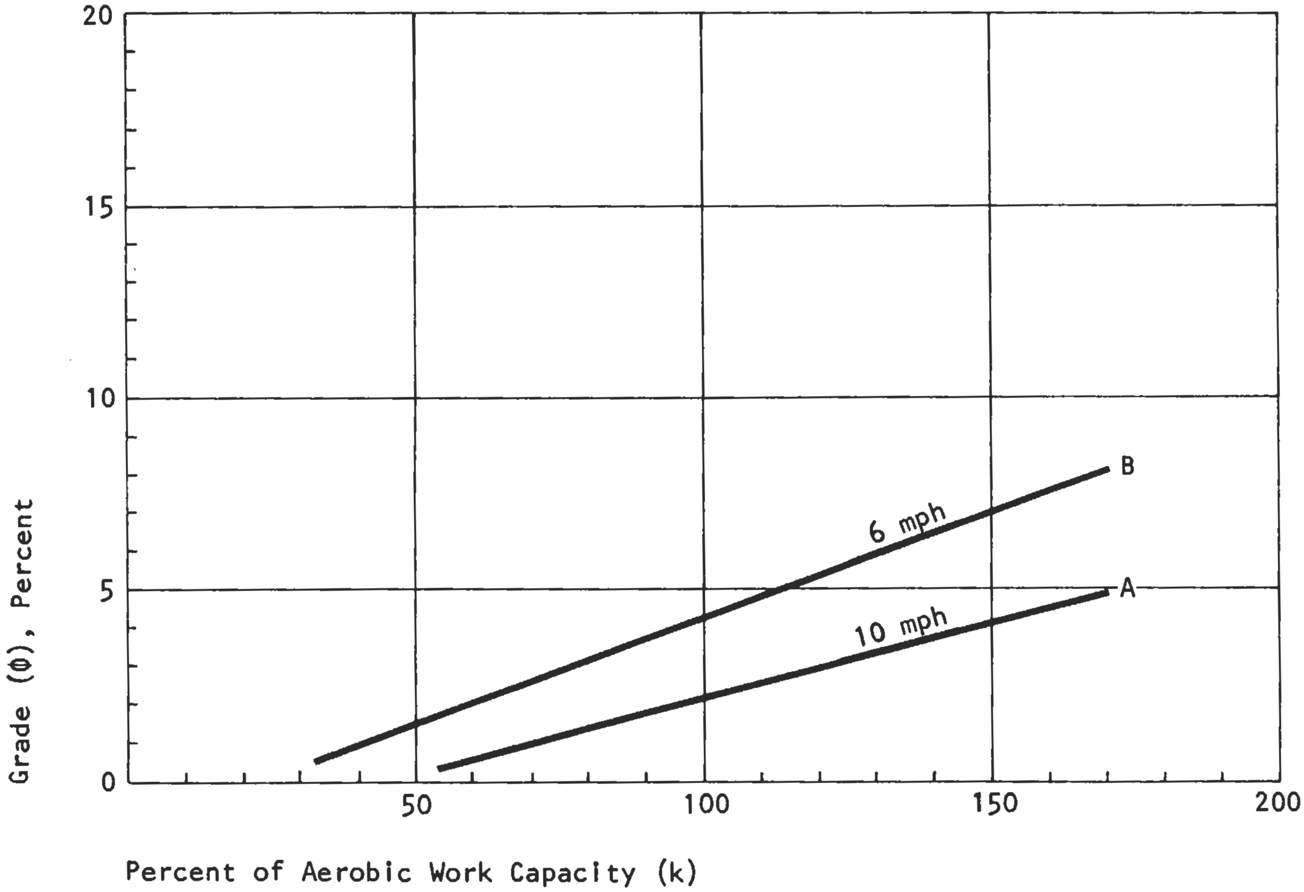


Figure 12
GRADE VS AEROBIC WORK CAPACITY -
40 YEAR OLD MALE (POST CORONARY) DESIGN CYCLIST

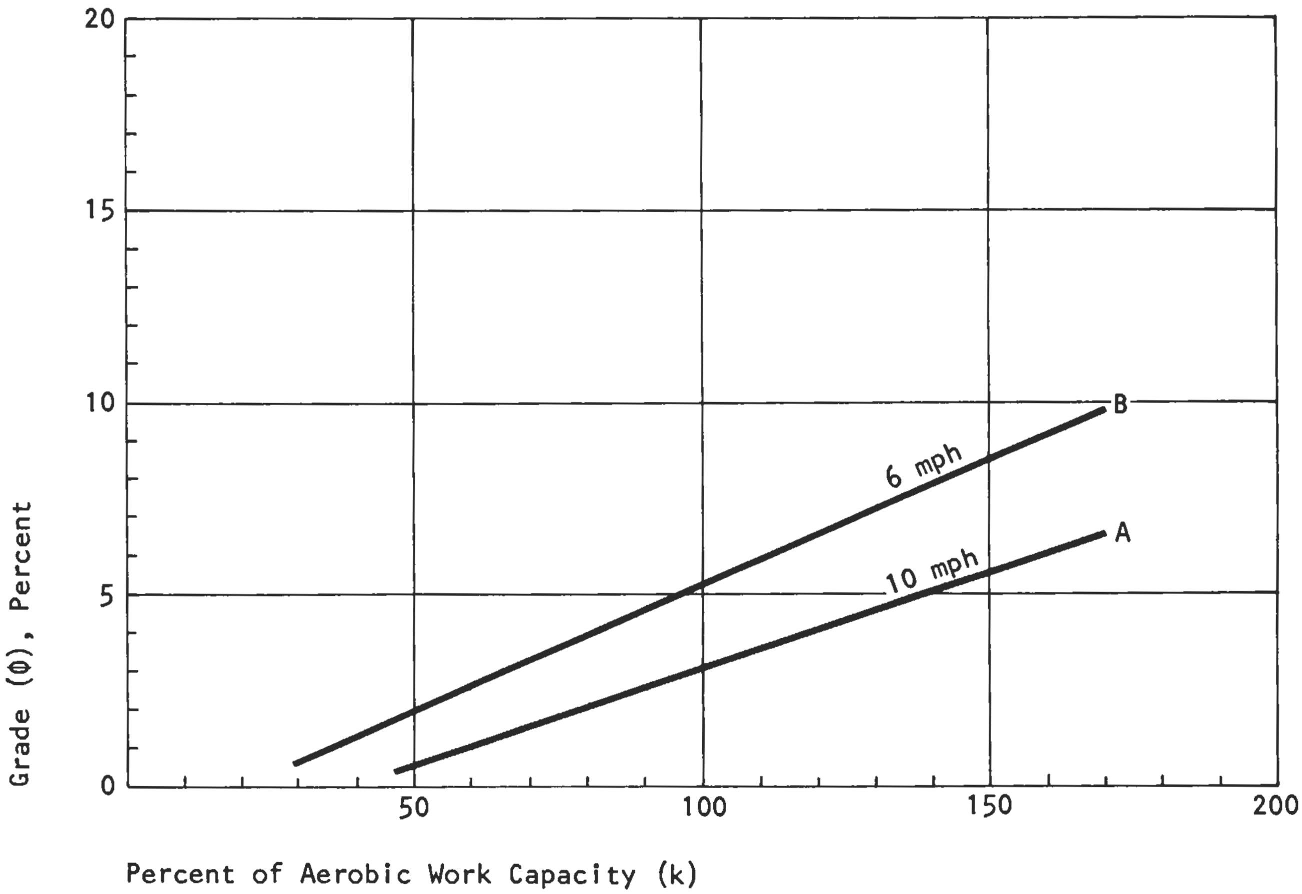


Figure 13
GRADE VS AEROBIC WORK CAPACITY - 55 YEAR OLD MALE DESIGN CYCLIST

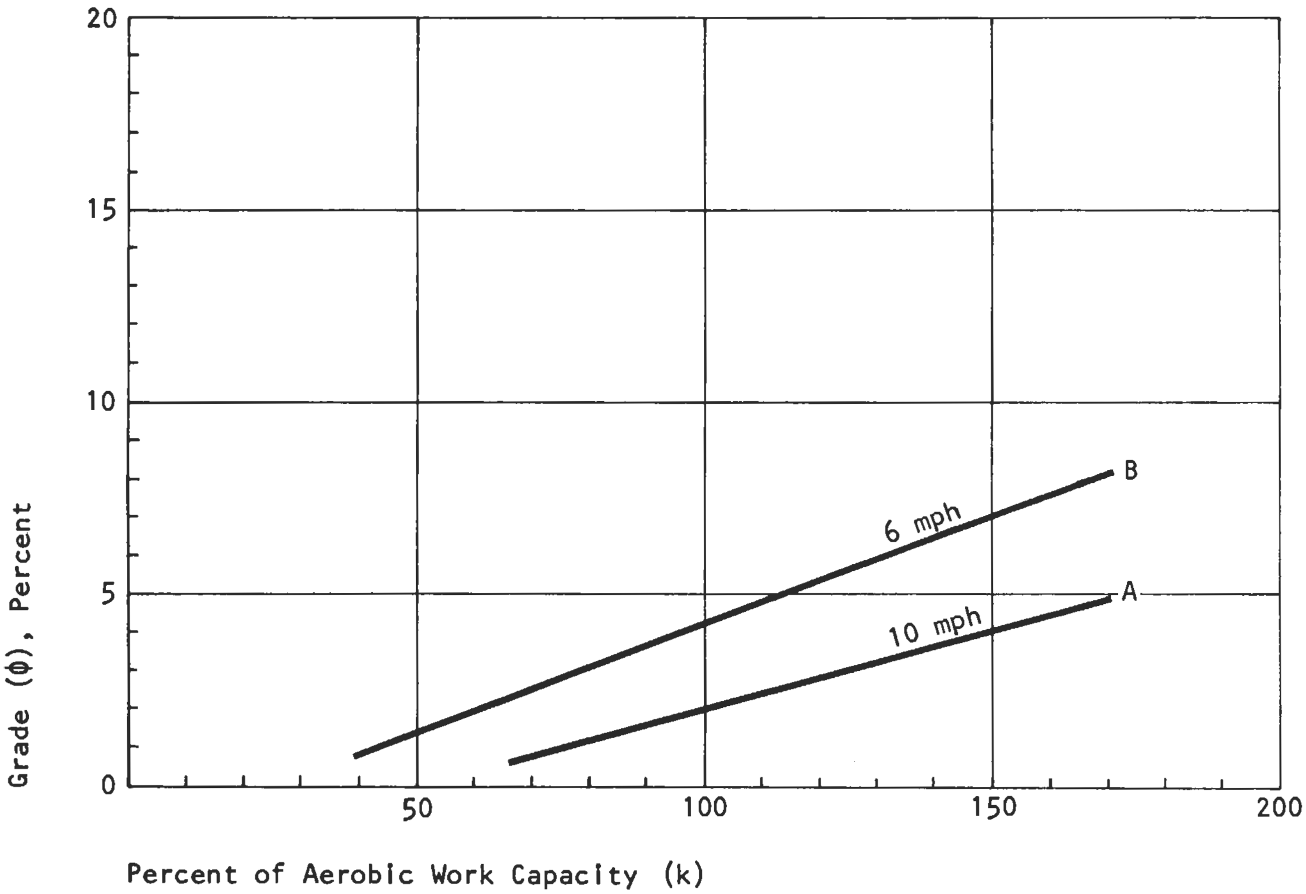


Figure 14
GRADE VS AEROBIC WORK CAPACITY -
55 YEAR OLD FEMALE DESIGN CYCLIST

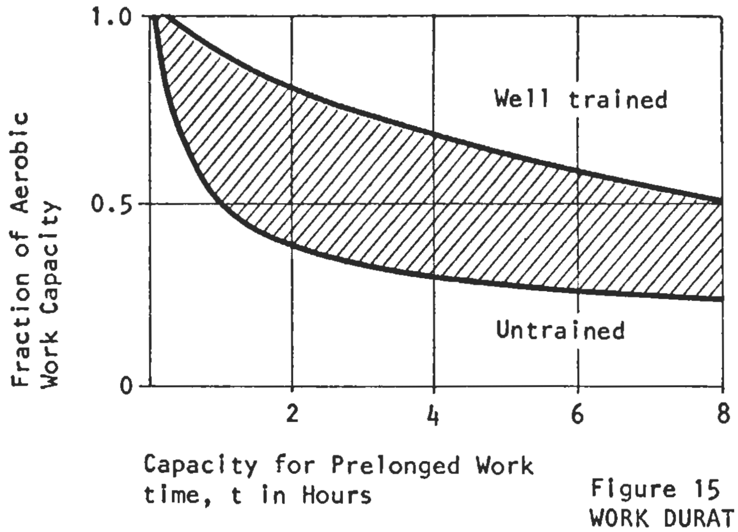


Figure 15
WORK DURATION CAPABILITY AEROBIC RANGE

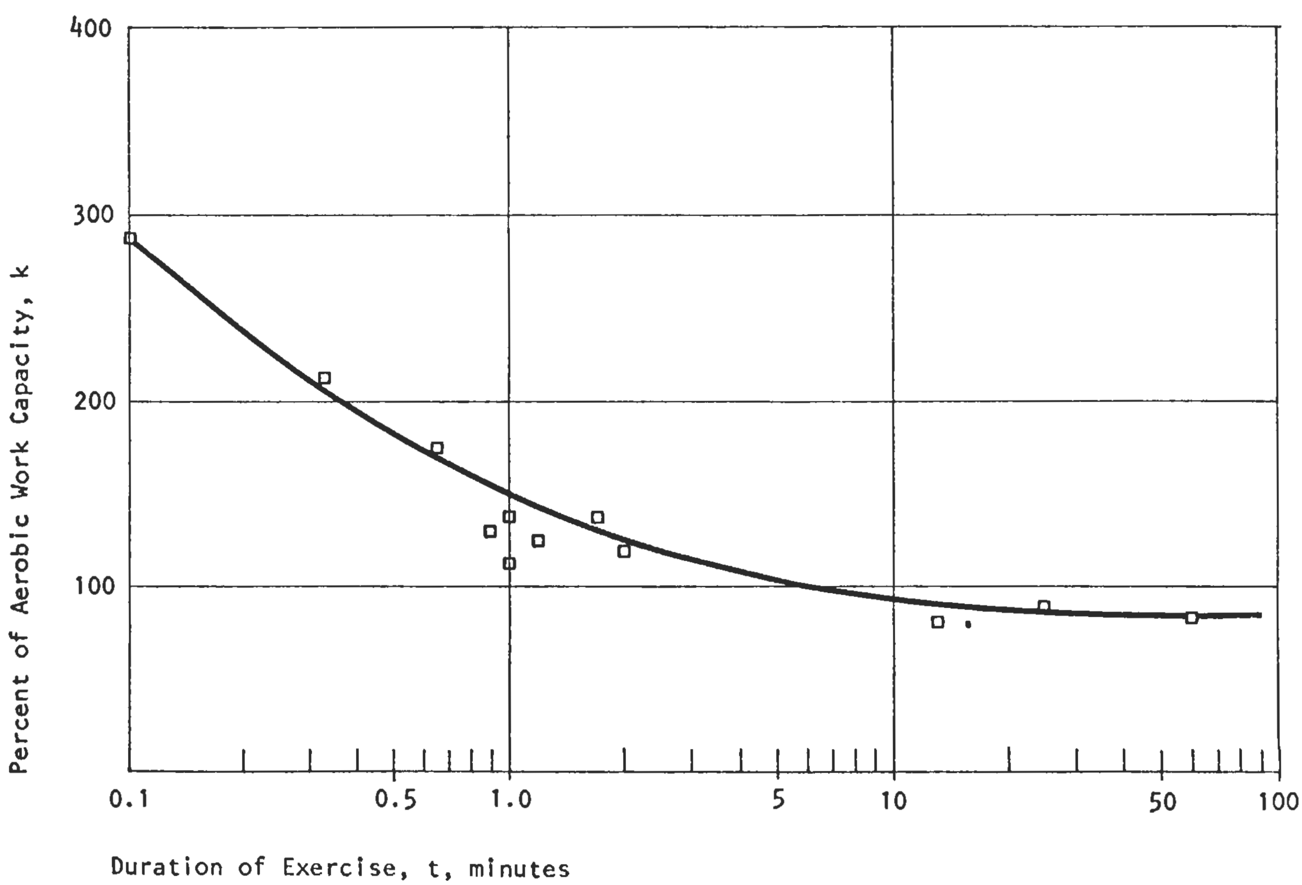


Figure 16
WORK DURATION CAPABILITY ANAEROBIC RANGE

FHWA

R&D