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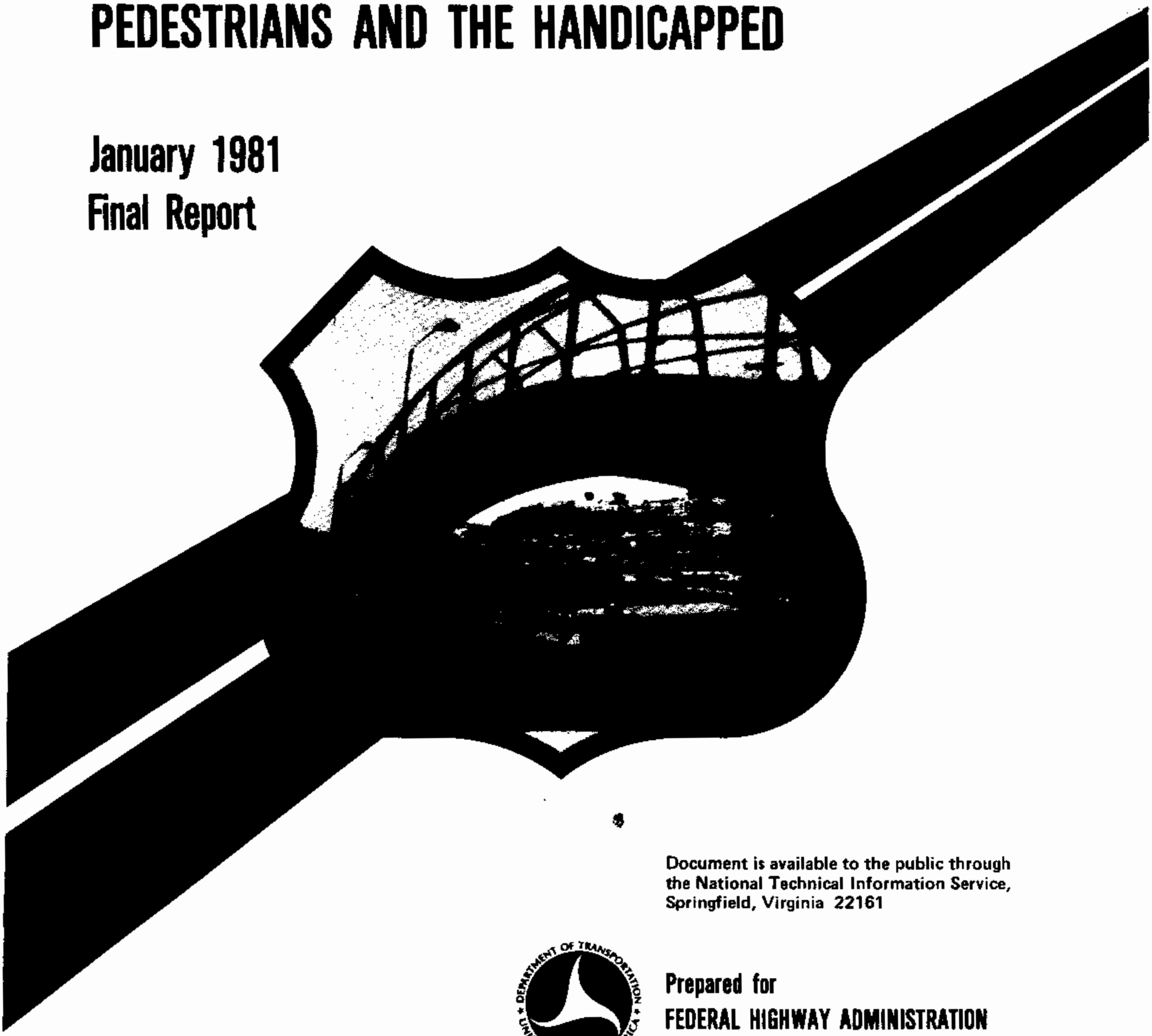
EFFECTIVE TREATMENTS OF OVER AND UNDERCROSSINGS FOR USE BY BICYCLISTS, PEDESTRIANS AND THE HANDICAPPED

January 1981

Final Report



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DEPARTMENT OF TRANSPORTATION • UNITED STATES OF AMERICA

Prepared for
FEDERAL HIGHWAY ADMINISTRATION
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Environmental Division
Washington, D.C. 20590

FOREWORD

This report provides information on the feasibility of retrofitting existing over- and undercrossing facilities to accommodate the non-motorized travelers.

Research in pedestrian and bicycle safety is included in the Federally Coordinated Program of Highway Research and Development as Task 3 of Project 1E, "Safety of Pedestrians and Abutting Property Occupants." Mr. John C. Fegan is the Project Manager.

One copy of this report is being distributed to each FHWA regional and division office.

D. Solomon
for Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

NOTICE

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16. Abstract

This study provides information about over and undercrossings directed toward planners, designers and decision makers who are trying to best serve the needs of bicyclists, pedestrians and the handicapped, whether by means of constructing new facilities or by retrofitting improvements to existing structures. The study was designed to accomplish three basic objectives:

1. Determine the feasibility of new and retrofit design modifications of over- and undercrossings for use by non-motorized travelers;
2. Develop warrants for new and retrofit design modifications of crossings for these three user groups; and
3. Develop design strategies for the accommodation of these three user groups on new and retrofit crossings.

This report includes a review of the state of the art; a discussion of facility needs assessment procedures, including warrants and design selection criteria; the results of field evaluations of various over- and undercrossing facilities conducted by a team of engineers and a panel made up of members with various types of physical disabilities; and recommeded design treatments. Also, features for non-structural solutions and innovative or less traditional treatments, as well as prototypical design strategies for both new and retrofit facilities, and examples of desirable and undesirable design practices are given.

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CHAPTER 1
INTRODUCTION AND SUMMARY

1.1 BACKGROUND

Communities are becoming increasingly concerned with the transportation needs of bicyclists, pedestrians and the handicapped. Of particular interest is the inclusion of facilities for such travelers when designing new over- and undercrossings, and in retrofitting improvements to existing structures. In some instances, the over- or undercrossing facilities constitute a barrier in themselves, which affect the ability of certain non-motorized travelers from using the facility. While some general guidance for the design of new crossing structures for cyclists is already available, a need for additional information has become evident. Consequently, in March 1977, the U.S. Department of Transportation, Federal Highway Administration (FHWA), contracted with De Leuw, Cather & Company to undertake this study.

1.2 STUDY PURPOSE

The study was designed to accomplish three basic objectives:

1. Determine the feasibility of new and retrofit design modifications of over- and undercrossings for use by non-motorized travelers; i.e., bicyclists, pedestrians and the handicapped.

2. Develop warrants for new and retrofit design modifications of crossings for these three user groups.

3. Develop design strategies for the accommodation of these three user groups on new and retrofit crossings.

The results of the study are intended for the use of federal, state and local officials and technical staffs engaged in both the planning and engineering design of such facilities, interested user groups and political decision-makers responsible for funding and implementation.

1.3 ORGANIZATION OF THIS REPORT

The report constitutes the principal documentation of all research activity undertaken in connection with the study and the major findings, conclusions and recommendations arising out of that activity. As such, the greater portion of the report is organized in parallel to the work tasks carried out in the course of the study. Chapter 2 describes the methodology used and the approach followed; Chapter 3 reviews the state of the art and evaluates current practice with respect to treatments of over- and undercrossings for use by bicyclists, pedestrians and the handicapped; Chapter 4 deals with the needs assessment activities, including the areas of warrants; Chapter 5 discusses design selection criteria and formulation of design concepts; Chapter 6 summarizes the findings of the field evaluations which were conducted as a part of this study; and Chapter 7 presents descriptions and graphic portrayal of design strategies and design treatments. References are listed at the end of the report, while glossary of terms and other material are contained in the Appendix.

A summary of key findings, results and recommendations is presented below in the remainder of this chapter.

1.4 SUMMARY OF KEY FINDINGS

Particularly noteworthy findings are outlined below, grouped as follows:

- State of the Art Review
- Facility Needs Assessment
- Design Strategies and Considerations
- Handicap Considerations

1.4.1 State of the Art Review

The state of the art phase of the study encompasses both a review of the published literature and a compilation of 72 over- and undercrossing case studies. These, supplemented by a variety of field evaluations and design reviews, provided the basis for establishing the feasibility of new and retrofit design modifications.

- In general, it was found that there is very little literature dealing directly with the subject matter of this study, and that for the most part over- and undercrossings have been treated as special situations in planning for non-motorized travel.

- From the work carried out to date on case history studies, it is clear that there exists a very large number of applications throughout the country, but very few of them are documented. This may be because over- and undercrossing treatments have formed an incidental part of some larger project, or because no need for documentation beyond that needed for applications for funding and construction has been perceived.

- As a general rule, each situation has, in the past, been evaluated individually. Where widely circulated sources have been used to aid evaluations, findings and recommendations have often been used without critical assessment.

- Many states have made provisions for customarily including facilities for non-motorized travel in plans for new or retrofitted under- and overpasses.

- When a decision is made by a state or local agency to construct facilities for bicyclists or pedestrians, usually at least one of the five following project "actuators" is present:

  - A strong lobby representing bicycle riders.

  - A developed state or local bikeway plan.

  - Particular adjacent land users:

    - schools
    - parks and other recreational facilities
    - residential development

  - Recent accident and injury to a bicyclist or pedestrian.

  - Sidewalks and/or a bikeway exist on approach roads to a planned structure.

- Cost is the most common reason why facilities for non-motorized travel are not provided.

- Until recently, it was rare to find provisions made with the handicapped in mind on over- and undercrossing facilities.

- Retrofitting of motor vehicle overpasses or underpasses to accommodate bicycle and pedestrian travel is not common. In instances where the retrofit involves structural modifications, general upgrading and repairs to the entire structure are usually undertaken concurrently. The most common retrofits are to bridges or other overcrossings, rather than undercrossings.

- Data was gathered for 47 new projects and 25 retrofit projects from 16 states around the United States. Of the 47 new projects case studies, 39 were overcrossings and 8 were undercrossings, while 24 of the retrofit projects were overcrossings and only one was an undercrossing.

- Field evaluations took the form of comprehensive evaluations at six selected sites. Visits to seven locations where the reactions of a panel made up of persons with a variety of physical disabilities were obtained. About 200 less formal investigations were conducted with respect to one or more design or operational features.

- The primary products of the field evaluations were tabulations of especially good design features and observed deficiencies. The latter were grouped as follows:

  - Signs, Signals and Markings - Maintenance - Design Features, and General Considerations

- Types of barriers (subdivided into absolute obstacles and disincentive obstacles) and a variety of hazards and impediments to use of over- and undercrossings applicable to each of the user groups were also identified in the course of the study.

1.4.2 Facility Needs Assessment

A variety of approaches are possible in deciding whether or not over- and undercrossings are needed. Based on the findings of this study, experience to date indicates that warranting procedures appear to facilitate decision-making and enhance reliability of results.

- There is little doubt that an organized review of available information and a structured, systematic approach to rational decision-making is to be preferred, since it is most likely to produce credible, unbiased assessments. A logical framework for project analysis is presented in the report which includes the use of both warrants and design selection criteria.

- The study found that a variety of different warrants are currently in use, either singly or in combination. These include: economic, system, threshold and point warrants. In addition, the roles of established policies and political prerogative (or community preference) should be explicitly recognized in the need assessment process.

- A procedure which combines all, or elements of all, of these areas appears to be the most reasonable method for establishing the relative need for bicycle and pedestrian facilities on over- and undercrossings.

- Design selection criteria help resolve such questions as: non-structural versus structual solutions; overcrossing versus undercrossing; exclusive use or structures shared with motor vehicles; new facility versus retrofitted structure; and need for special features.

- The needs assessment procedure should be uniformly applied without bias. It cannot, however, be followed blindly and must be combined with sound judgement based on experience. Similarly, it must be flexible enough to allow proper consideration of special circumstances and conditions at a given site.

- Establishing the degree to which warrants are satisfied should not be so cumbersome or require data so difficult to obtain that their use is discouraged. Similarly, the degree of precision of data and evaluation factors should not be in excess of their likely impact on the conclusions reached.

- Based upon the research, it is our conclusion that there is no single formula or warrant which aggregates the individual criteria to give a "Build-No-Build" decision.

- Adoption by a jurisdiction of specific policies addressing the needs of pedestrians, bicyclists and the handicapped, and the provisions for meeting those needs, can greatly simplify and expedite decision-making.

1.4.3 Design Strategies and Considerations

Major portions of this report deal with such areas as: general design considerations, standards and features; prototypical design strategies for five different types of new projects and three kinds of retrofit projects covering commonly encountered situations; discussions of non-structural as well as structural solutions and some potentially applicable innovative techniques.

- Many characteristics of non-motorized facilities are determined depending upon whether the primary purpose of the crossing is to serve motor vehicles, bicycles and pedestrians, or utilities.

- Planning, conceptual design and construction activities for such projects, therefore, should generally be predicated on concurrently meeting the combined requirements of bicyclists, pedestrian and the handicapped, as well as the needs of motor vehicle operators.

- Currently, maximum or minimum allowable design standards are often applied in practice, whereas use of desirable design standards would be preferrable. (There is almost no conflict in design standards for bicyclists, pedestrian and the handicapped if the most desirable standards are used instead of maxima or minima.) In fact, inclusion of desirable features for one group of non-motorized travellers usually enhances travel for the others as well.

- To function smoothly as a part of the transportation network, over- and undercrossing design must be continuous with the existing facilities, as well as compatible with future plans.

- Non-structural solutions to crossing problems should receive primary consideration and be thoroughly evaluated as an alternative or supplement to a structural solution. Non-structural solutions can be grouped under five headings; Traffic Control Strategies, Alternative Routes, Alternatives Travel Modes, New Technologies and Land Use Planning.

- The discussion of design elements includes: geometrics, details, special features and construction materials. Suggested design standards and treatments are described.

- Generic or prototypical design strategies in the form of detailed graphical illustrations and key design notes are presented for five of the most basic situations likely to be encountered:

  - Overcrossing Shared with Motor Vehicles
  - Underpass Shared with Motor Vehicles
  - Long Bicycle and Pedestrian Bridge
  - Short Bicycle and Pedestrian Bridge
  - Bicycle and Pedestrian Undercrossing

- Similarly, basic retrofit design strategies are presented, as follows:

  - Cantilever Addition of Non-Motorized Facilities to an Overcrossing
  - Expansion or Upgrading of Existing Non-Motorized Facilities
  - Conversion of an Existing Over- or Undercrossing to Exclusive Use by Bicyclists and Pedestrians.

- Since the three grade crossings components (ends, approaches and structures) function together as a crossing system, end conditions must also be considered in the design process. The report, therefore, contains a section describing potential problems applicable to five basic kinds of end conditions which can be combined with the treatments of approaches and structures discussed elsewhere in the report.

- The results of this research study indicate that there is no imminent technological breakthroughs that will drastically change the development of non-motorized facilities on over- and undercrossings. However, there are a number of modifications or enhancements of existing methodology and procedures which are innovative and which may have application to specific problems.

- Unintentional exclusion of some non-motorized users has occurred in certain situations because maximum and minimum standards were incorrectly utilized.

- The design deficiencies which were observed fell into three general areas: signs, signals and markings; maintenance; and design features. The major findings in each of these areas are summarized below.

  - By far the most common deficiency of the sites visited pertained to a general lack of guide and directional signing facilitating travel by bicyclists and pedestrians. The next most common deficiency related to signing was lack of proper horizontal and/or vertical clearance between the sign or sign post and the pathway edge.

  - Periodic maintenance is necessary to maintain the effectiveness and attractiveness of even the best design. Proper design can minimize the magnitude of maintenance effort and costs required. Most maintenance deficiencies observed at the site evaluation locations were related to debris or vegetation on the pathway.

  - Typical features identified as deficient during the site evaluations involved elements which were incomplete and fall into three categories: Alignment and Clearances; Sight Distance and Pavement Quality; and Appurtenances. Specific examples in each area are cited in the body of this report.

- The findings of this study indicate that the planning, design and operation of non-motorized facilities on over- and undercrossings can be considerably enhanced if technical personnel and facility users achieve a better understanding of the subject matter and several means of improved education and communications are suggested in the report.

- Examples of both adequate and inadequate crossing treatments and designs were identified as a part of this study. These are described and, for the deficient treatments, corrective measures are suggested. Material is grouped as follows: sidewalks; railings and fences; structure; traffic control; and maintenance.

1.4.4 Handicap Considerations

In view of the importance of this topic in terms of both social concern and potential impact on the limited funds available for maintaining, replacing and/or improving existing over- and undercrossings and statutory requirements under Title 23 of the Highway Act to ensure that certain federally assisted facilities are usable by handicapped persons, some key study results in this area are summarized below.

- The handicapped are a heterogeneous group with varied mobility limitations and needs. Persons with apparently similar medical conditions are likely to vary in their physical stamina and willingness to negotiate level changes.

- Many handicapped persons are able to use facilities designed for bicycles or pedestrians with little or no modification. Other handicapped persons would require special features such as ramps, rest areas or elevators. Finally, there are some persons who would not be able to use the over- or undercrossing regardless of the improvements provided.

- Considerable attention has been focused in the past on the costs associated with accommodating the handicapped, particularly on ramp grade restrictions which increase their length and consequently their cost. Designers should realize, however, that they can greatly improve access for the handicapped at little cost by modifying some design details. Sidewalk cross slopes, curb widths, handrail types and configurations and pavement textures are all examples of elements of an over- or undercrossing that could be made more amenable through virtually zero cost alternations.

- A general conclusion with regard to over- and undercrossing situations is that areas rather than just facilities should be made accessible so that continuous routes are available for non-motorized travelers.

- Priorities for implementation of improvements on existing facilities to enhance handicapped accessibility should be based upon extent of need and anticipated use by the handicapped.

- The method of using handicapped panelists to conduct on-site evaluations and/or be an advisory group was successful in this study, and can be a useful technique for local and state officials to use in the planning, design and decision-making process or retrofit construction of over- and undercrossings.

1.4.5 Cooperating Organizations

Numerous cooperating organizations and persons contributed their efforts, ideas, and data to this study.

Mr. Hale Zukas and Eric Dibner of the Center for Independent Living, Inc., Berkeley, California, were participants from the outset of the study. They and their associates provided extensive knowledge of, and direct experience with, the needs of the physically handicapped traveler. Contributions were also made by volunteers from a number of organizations in Florida who served on the facilities evaluation panel.

Many federal, state and local agency staff members, private practitioners, manufacturers, academics and other individuals supplied data, reports, drawings and other material and answered questions concerning individuals from agencies in the states of Alaska, California, Florida, Maryland, New Hampshire, North Dakota, Ohio, Texas, the Commonwealth of Virginia and the cities of Palo Alto and Sunnydale, California.

CHAPTER 2
STUDY METHODOLOGY AND APPROACH

2.1 INTRODUCTION

This study extended over approximately a two year period and included the following activities:

- State of the Art Review
- Research and Development
- Site Evaluations
- Final Documentation

Figure 1 on the following page illustrates the conceptual approach followed in conducting the study.

The site evaluation activity was carried out: a formal, structural in-depth study of facilities at six selected locations (including a pilot project designed to test and improve evaluation procedures); evaluations of facility treatments for the handicapped conducted with the aid of a panel made up of persons with various types of disabilities; and less formal, less exhaustive evaluations made by study team members at numerous sites throughout the life of the project to either check on a limited number of design or operational features or to generally add background material and photographs to the study's data base.

The remainder of this chapter contains an expanded description of the study methodology and approach utilized in carrying out the major activities in Figure 1.

2.2 STATE OF THE ART REVIEW

The state of the art review represents an analysis of the relevant literature in readily available published form, and recent experiences in the planning, design, and construction of crossing facilities and facility treatments to serve non-motorized travelers.

2.2.1 Literature Review

The literature review (1) was undertaken to not only provide basic resource data needed for this study, but also to develop an information source for practitioners in various aspects of the study topic.

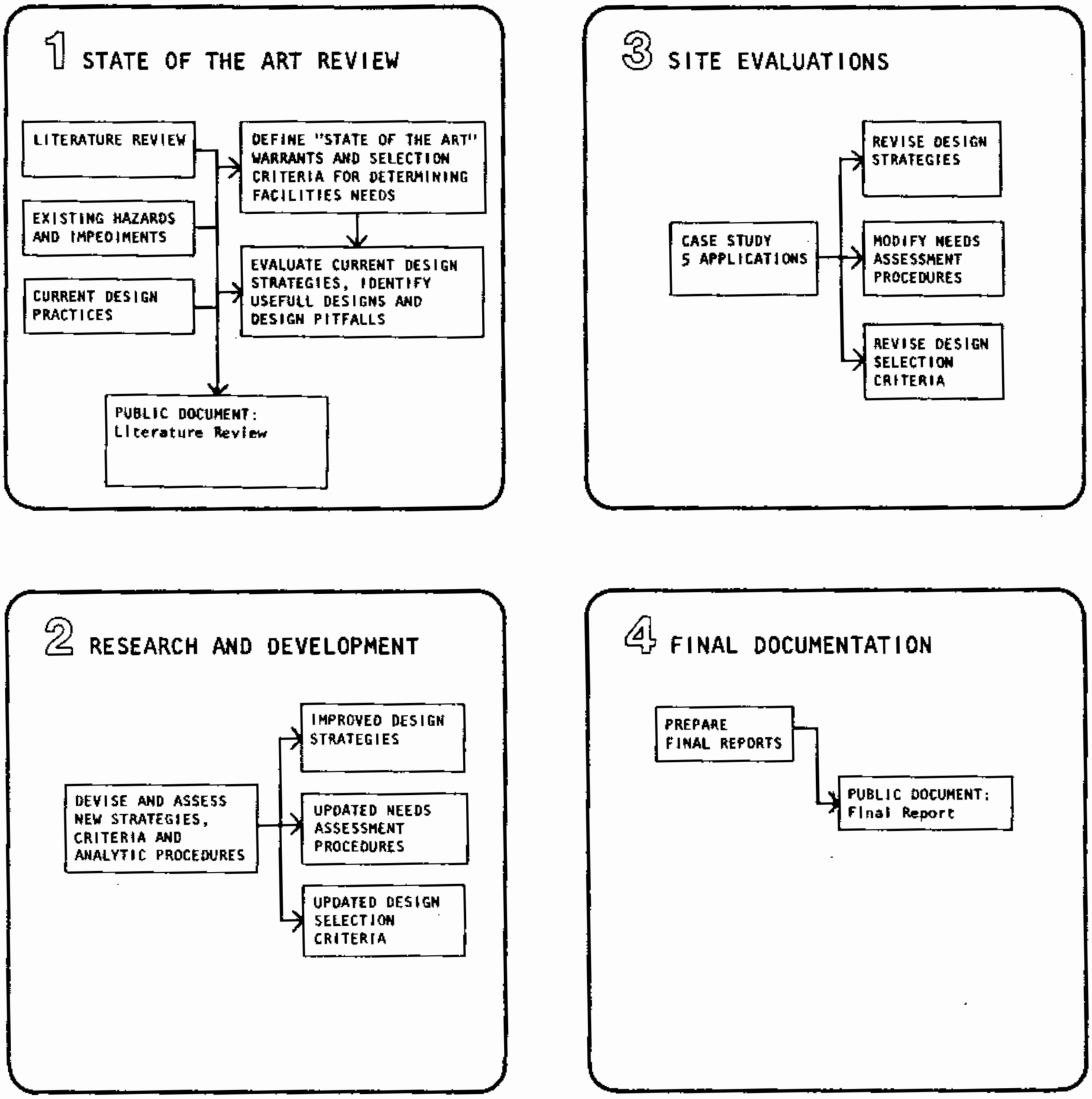

Figure 1. STUDY CONCEPTUAL APPROACH

Several different techniques were used to insure that the most pertinent materials would be collected and reviewed. First, a list of key topics and relevant issues was prepared. Then, bibliographies were gathered and scanned to find sources addressing the listed key topics and issues. Major libraries and reference services were also contacted and asked to provide lists of applicable references. Contacts included the Highway Research Information Services, the Transportation Research Information Service, the National Technical Information Service, Northwestern University, Harvard, and MIT libraries, the Institute for Transportation Studies, University of California, UMTA abstracts, the Engineering Index, and the De Leuw, Cather and Center for Independent Living libraries.

In addition, major contributors to research in the field in the United States and elsewhere and state and local practioners were contacted and asked to recommend literature sources addressing key aspects of the study problem. An initial review of gathered literature also provided a source for additional works. Finally, documentation of facility planning and design experience was collected from local and state agencies and De Leuw, Cather work files. This information was used to illustrate current practices in the field.

2.2.2 Review of Recent Experience

In order to ascertain the current design practices with respect to facilities for non-motorized travellers on over- and undercrossings, and to understand the rationale for developing facilities for the bicyclists, pedestrian and handicapped on particular structures, an extensive data gathering inquiry was undertaken. Building upon existing study team contacts at the federal, state and local levels and the leads developed in the course of preparing the literature review, requests for information were made of state transportation departments (or their equivalents) in each of the 50 states, Puerto Rico and the District of Columbia. They were asked to supply descriptions of over- and undercrossing structures they had designed, with particular emphasis on those incorporating new or retrofitted facilities for bicycles and pedestrians. In addition, they were asked for referrals to jurisdictions within their area (cities, counties or other agencies) that might have experience with such facilities.

The initial responses varied. Some agencies replied enthusiastically and sent fairly complete project descriptions, drawings and cost information; others stated that they had had little relevant experience. Follow-up inquiries were then made as appropriate to elicit specific additional information about the projects mentioned and to explore the experiences of the cities, counties and other jurisdictions to which reference had been made. The material and data obtained was then combined with similar information already available in De Leuw, Cather files and that received from other sources. The resulting compilation, which was updated as material continued to be received throughout the life of the study, was sufficient to draw appropriate conclusions about current design practices and standards and the decision-making process with respect to providing facilities for bicyclists and pedestrians and constituted a most valuable study resource.

2.3 RESEARCH AND DEVELOPMENT

The major activities undertaken in this phase of the study were the continuing work on facility needs assessment (or justification); assembly and analysis of design selection criteria; preparation of general design strategies and other potential solutions to meeting the needs of non-motorized travellers and review of promising design strategies with an expert panel.

2.3.1 Needs Assessment and Design Selection Criteria

The concept of warrants is widely used within the needs assessment process as one of the techniques to assess the justification for providing a facility or other form of improvement. Warrants are measures of need which serve as guidelines in the decision-making process used in determining whether or not to do something. Design selection criteria, on the other hand, are guidelines for the next step; once it is decided that an improvement is justified, design selection criteria are guidelines which can assist in determining what specific type of facility or improvement best satisfies the needs.

Development of a needs assessment procedure and design selection criteria involved gathering and analyzing material primarily drawn from the literature and state of the art reviews. A recommended needs assessment process was developed from this analysis and ultimately modified based upon experience gained from the site evaluations.

The design selection criteria investigation dealt with decision-making with respect to choices in such areas as:

- Non-structural versus structural solutions
- Over- or undercrossing
- Exclusive use or structure shared with motor vehicles
- New versus retrofitted structures
- Facilities on one or both sides of structures
- Need for special features

Work sheets were developed to assist in the documentation of the design selection analysis and are shown in the appendix. These were evaluated and refined by field testing at two locations in California.

2.3.2 Design Strategies

The primary emphasis of this portion of the Research and Development phase was on seeking to improve current design practices and techniques. It included: completion of the gathering of decision-making, design, construction and cost data initiated during the state of the art review; preparation of design classification systems; analysis of design types to determine various generic design strategies; conduct of a Design Innovation Workshop with an expert panel consisting of senior personnel from De Leuw, Cather's structural, civil engineering, traffic and transportation planning departments -- along with representatives from the Federal Highway Administration and the handicapped community.

A number of different sources were utilized in the carrying out of the design strategies task. Principal among these were:

- Published and unpublished literature, including design manuals, standards and guidelines for bicycle, pedestrian and handicapped facilities from the American Association of State Highway and Transportation Officials and various State transportation agencies, articles on construction and design techniques, and material use.

- Conversations with designers of bicycle and pedestrian facilities and over- and undercrossings in a number of cities and states, and within De Leuw, Cather & Company.

- The Design Innovation Workshop conducted on July 14, 1978, and the resulting notes and materials.

The product of this phase of the study included initial definitions of: general design consideration; desirable standards and features of over- and undercrossing design elements; project classification systems; eight prototypical new structure design strategies; six prototypical retrofit design strategies; end condition treatments; non-structural solutions; and design innovations and new techniques.

2.4 FIELD EVALUATIONS

The basic purpose of the site investigations carried out in the course of this study was to evaluate some of the promising new designs, design modifications and non-structural solutions previously identified among the recorded 72 case study examples of current practice cited earlier (5). As mentioned above, the field work took the form of comprehensive evaluations at six selected sites, as well as visits to three locations in California and four in Florida where the reactions of a panel made up of persons with different physical disabilities were obtained, and about 200 structures were visited and less formally inspected by team members throughout the duration of the study.

2.4.1 Site Selection

The initial step in selecting sites for field evaluation was to summarize the 72 case studies documented during the development of the State of the Art and Research and Development project phases. Information provided for each of the 72 sites included location, whether it was a new or retrofitted treatment; estimated order of magnitude of usage (high, medium, low) for motor vehicles, bikes, pedestrians and the handicapped; land use, whether urban or rural; an indication of whether the site was an especially innovative treatment and comments regarding basic design features. Criteria were established for site selection for comprehensive evaluations, as follows:

- Innovative design features preferred
- A mixture of new and retrofit designs required
- Examples of both over- and undercrossing projects required
- Sponsoring state and local agencies that had ongoing programs for meeting the needs of bicyclists, pedestrians, and the handicapped preferred
- A broad geographic distribution preferred

Review of the material gathered indicated a number of potential sites located in the eastern, central and western United States. The three locations were:

Palo Alto, California. An exclusive bicycle and pedestrian bridge with an approach cantilevered along a drainage canal was selected as the site of the pilot study carried out to test and refine the site evaluation procedures.

Sunnyvale, California. A new exclusive pedestrian and bicycle overcrossing of a busy freeway at this location was chosen as a representative example of a facility with the latest treatments intended to facilitate use by the handicapped.

Eugene, Oregon. Two structures were evaluated in detail in Eugene, Oregon. One location combines a bicycle and pedestrian undercrossing of the Southern Pacific Railroad with a nearby bicycle and pedestrian bridge over the Willamette River. The second facility is a retrofitted direct ramp connection for bicyclists and pedestrians only, leading from the sidewalk along one side of a four-lane highway bridge to a park and riverside trail system.

Designation of the remaining three sites chosen for in-depth evaluation took place after the conclusion of the July 1978 Design Innovation Workshop conducted as a part of the study.

Hampton, New Hampshire. A retrofitted bicycle and pedestrian facility cantilevered from a highway bridge over a railroad was analyzed at this location.

Route 183, Randolph Road, Maryland. This site was chosen for its modified box culvert featuring an elevated pathway capable of use during most of the year as an underpass, except when it becomes innundated during periods of high water.

Austin, Texas. Special off-street facilities have been constructed to accommodate bicycle and pedestrian travel through a complex interchange made up of one-way streets and ramps.

Handicapped User Evaluation Sites. The seven sites for the field evaluation of facilities for the handicapped were chosen after discussions with a panel of disabled persons with varied disabilities. Observation sites were selected in the San Francisco Bay and Miami, Florida areas to provide for a variety of recent designs of crossings with and without special provisions for the handicapped. Further, the sites were chosen so as to encompass a variety of situations likely to be commonly encountered by handicapped users (6, 7).

2.4.2 Field Procedures

Prior to conducting the site evaluations, various procedures were evaluated during the pilot study to assure that the field reviews would produce the maximum amount of usable data. Forms were developed to assist in data retrieval. The study and observation techniques used were as follows:

- General assessment of the facility was made independently by two engineers.
- Measurements were taken of various elements, such as grades, slopes, etc.
- Identification was made of features that might be critical to non-motorized travel.
- Volume of users, by type and age, was noted for selected periods.
- Observations were made of user travel behavior.
- User position on pathway and extent of handrail usage were noted.
- Photographs were taken and their location recorded.

Local designers and technical staff knowledgeable about the specific study site were also interviewed in person by the study team. The results of these conversations added depth to the knowledge of the site gained through the field evaluation. This was especially true in understanding the decision-making and planning process from the conception of the project through construction and operation.

The field team was made up of a civil engineer with a running background and a traffic engineer/transportation planner who is a daily bicycle rider, thus providing a variety of user and evaluator perspectives. Additional personnel were assigned to the field team to assist with volume counts.

Handicapped persons participated in the evaluation of seven sites. In each case they traversed the facility, its approaches and end conditions and thereby became familiar with the system as well as individual components. A set of choice responses and open-ended questions about the experience were then administered by study staff. This was followed by a more general discussion about the site among panelists and project staff. At each location, photographs were taken to illustrate major findings.

Informal site visits usually consisted of general observation and frequently included the taking of photographs. At times, some measurements of specific features of interest were recorded and follow-up discussions with local officials were held either in person or by telephone. This material was then included as part of the study's information resources.

CHAPTER 3
STATE OF THE ART REVIEW

3.1 INTRODUCTION

The previous chapter described how the review of readily available published literature and recent experiences in the planning, design and construction of crossing facilities to serve non-motorized travelers was carried out to provide insight into current practice. This chapter presents the highlights of the results of that activity. Some general aspects of the literature review and case study compilation are first discussed, followed by more specific details concerning the State of the Art in such area as:

- User Characteristics
- Crossing Conditions
- Hazards and Impediments
- Design Standards and Approaches

3.2 LITERATURE REVIEW

In general, it was found that there is very little literature dealing directly with the subject matter of this study, and that for the most part crossings have been treated as special situations in planning for non-motorized travel.

From the work carried out on case history studies, it is clear that there exists a very large number of applications throughout the country, but very few of them are documented. This may be because over- and undercrossing treatments have formed an incidental part of some larger project, or because no need for documentation beyond that needed for applications for funding and construction has been perceived.

In addition to this final report, the 341 documents listed in the Annotated Bibliography section of the Literature Review Report(1) constitute a logical starting point for those seeking information on the subject topic of this study. For ease of access, the bibliography is subdivided into the sections listed below, plus a listing of other bibliographies and general references.

- Travel Behavior and Needs of Non-Motorized Groups
- Typical Crossing Situations
- Crossing Hazards and Impediments
- Needs Assessment Practices
- Design Standards
- Structural Treatments

- Non-Structural Solutions
- Case Histories
- Annotated Bibliography

Each of these sections (except the Annotated Bibliography) presents and appraises the major findings of the literature review. For each topic, analysis of references related to pedestrians is presented first and then followed by a review of works pertaining to cyclists and the handicapped.

3.3 CASE STUDY COMPILATION

As stated in Chapter 2 earlier, the methodology used to gather the data for the 72 Case Studies included contacts with State Transportation Departments (or their equivalent) in the 50 states, Puerto Rico and the District of Columbia. A number of cities and counties and other agencies were also contacted. Data received from all sources, together with information already in De Leuw, Cather files, were utilized as a base from which to draw conclusions about current design practices and standards and the decision-making process with respect to bicycle and pedestrian facilities associated with grade separations. The following section focuses on the kinds of information gathered, and the general conclusions that were derived.

3.3.1 Case Study Information

The kinds of information requested from the various agencies that responded to the initial inquiries was multifaceted. Desired data included the following:

- A short account of what initiated the installation of the facilities -- a brief project history.

- The construction cost for the total project. (An engineer's estimate or unit bid sheet was desired.)

- An estimate of the construction cost associated with accommodating bicyclists, pedestrians, and the handicapped.

- The construction duration.

- Available basic engineering drawings, such as a plan view of the structure, including approach and end treatments, and a typical cross-section of the structure itself.

Ultimately, data was gathered for 47 new projects and 25 retrofit projects from 16 states around the United States. Of the 47 new projects case studies, 39 were overcrossings and 8 were undercrossings, while 24 of the retrofit projects were overcrossings and only one was an undercrossing. The case study information was supplied for the most part by those state or local agencies throughout the country who were most active in planning and construction of bicyclist, pedestrian and handicapped facilities. The actual case study information received, other written replies from various agencies, plus telephone conversations and face-to-face discussions with designers and planners, allowed the formulation of some conclusions about current decision-making procedures and design practices. It is noteworthy, however, that many of the state transportation agencies responded that they had had little experience with the design and construction of facilities for the non-motorized traveler.

3.3.2 Conclusions About Current Decision-Making Procedures and Design Practices

- Many states have made provisions for customarily including facilities for non-motorized travel in plans for new or retrofitted motor vehicle under- and overpasses. Usually, to assure consideration, requests for the accommodation of non-motorized travel must be made by an interested government agency or by a citizen's lobby. Thus, decision-making occurs discretely, structure by structure, rather than in a comprehensive and planned manner.

- A comparison of rural and urban policies with respect to non-motorized travel provides an interesting contrast. In rural areas, no special provisions generally are made for non-motorized travel. The common clearance or shoulder widths of 4-6 feet (1.2-1.8M) on highway bridges, for example, is considered sufficient for the use of the occasional bicyclist or pedestrian.

- Near Metropolitan areas, provisions for pedestrians and bicyclists are more common in projects undertaken by both state and local agencies.

- Smaller cities where a college or university exerts a significant influence in the community often are very committed to providing special facilities for pedestrians and bicyclists. Three notable examples are Davis, California; Eugene, Oregon and Austin, Texas.

- When a decision is made by a state or local agency to construct facilities for bicyclists or pedestrians, usually at least one of the five following project "actuators" is present"

- A strong lobby representing bicycle riders.
- A developed state or local bikeway plan.
- Particular adjacent land uses:
  - schools
  - parks and other recreational facilities
  - residential development
- Recent accident and injury to a bicyclist or pedestrian.
- Sidewalks and/or a bikeway exist on approach roads to a planned structure.

- Cost is the most common reason why facilities for non-motorized travel are not provided. A combination bicycle and pedestrian path on only one side of a structure whose main function is the movement of motor vehicles can increase construction costs from 5 to 20 percent. A bridge solely for bicycle and pedestrian use with a clear deck width of 8 feet (2.4 M) could cost $30,000-$300,000 for lengths of 50 to 500 feet (15.2-152 M). Since grade separated structures for bicycle and pedestrian facilities are considered luxury items by most government agencies, the costs associated with accommodating these activities tend to be heavily scrutinized.

- Until recently, it was rare to find provisions made with the handicapped in mind on over- and undercrossing facilities. Attention to such features has been focused on accommodating the handicapped only where receiving federal or state funds is contingent upon compliance with certain standards, or where a particularly effective organization of handicapped persons has been successful in alerting decision-makers and designers to the problem so that accessibility could be improved for all users.

- Attention has been focused on the cost associated with accommodating handicapped persons, particularly on the question of making grades and ramps less steep, thus increasing their length. However, some attention to design details such as approach sidewalk cross slopes, handrail types and configurations, and the texture of paved surfaces are all examples of elements that could be made more amenable to all users, including the handicapped, through essentially zero cost alterations.

3.4 USER CHARACTERISTICS

As noted earlier, research related to identifying travel behavior and needs of non-motorized groups has been limited. There is not yet a clear understanding of what characteristics are most influential in determining whether or not a non-motorized trip will be made. In addition, only a small number of research studies have been conducted to identify travel patterns, particularly characteristics influencing how non-motorized trips are made. Behavioral studies of crossing trips are virtually non-existent. Some modeling of pedestrian travel behavior in downtown areas has been conducted; however, this is still a very inexact science.

3.4.1 Pedestrian Characteristics

Pedestrian trip generation appears to be influenced in both rural and urban environments by one or more of the following:

- Perceived accessibility of major origins to destinations
- Land use at trip origins and destinations
- Number of total trips attracted by major generators and number of total trips generated by major sources.
- Car availability

Perceived accessibility has been considered to be related to one or more of the following: availability of time, distance between origins and destinations, trip purpose, the walking environment, and the traveler's ability to walk.

Again, few comprehensive empirical studies have been conducted to provide information about pedestrian walking patterns. In one study (8), an observational experiment was conducted to describe pedestrians' walking patterns. It was concluded that walking space or distance is perceived through the perception of time. Pedestrians tend to: follow the simplest path; are not deterrred by the number of motor vehicles; walk as directly as possible to the destination following a straight path; and anticipate a change in direction of travel a long time before it occurs. In addition, several sources stated that walking speed varies by age and sex of the pedestrian and walkway grades (9, 10, 11).

No general agreement was found as to usual walking distances. Estimates for the average distances of most trips ranged from 200-300 feet (61-91M) to over 1,000 feet (305M).

Major conclusions about behavior when crossing intersections were:

- many pedestrians do not look at oncoming traffic before crossing;

- people usually cross streets faster than they walk on sidewalks; and

- adults are more often deviant crossers than children.

Three comprehensive investigations (12, 13, 14) of pedestrians' use of grade separations were reviewed. All of these research efforts were conducted in urban areas in England. The major conclusions resulting from these studies were in general agreement. It was found that the following factors influence the use of crossing facilities:

- Travel time differences between crossing at-grade and using grade separated facilities.

- Facility ramp length: pedestrians perceive that long ramps impede travel.

- Visible locational convenience of the facility.

- Presence of signing to direct the user to the facility.

- Entrance design of subways.

Some of the most comprehensive studies of pedestrian behavior in downtown areas have been conducted by John Fruin, Boris Pushkarev and Jeffrey Zupan, and Scott and Kagan (15,16,17). Major factors affecting tripmaking were concluded to be the density, size, type and quality (attractiveness) of major origins and attractors within a given area, time of day, and quality of the walking environment. Other research which describe characteristics influencing trip generation have been conducted in Toronto and Sweden (18, 19). However, identification of causal relationships is not very far advanced.

Two major empirical studies (20, 21) presented the following conclusions about walking patterns:

- Walking distances are generally consistent among cities of similar size.

- Walking characteristics vary slightly by trip purpose (e.g., walking distances in Boston were found to be shorter for shopping trips than for work or social trips).

The Pushkarev, Zupan study (16) is the only research reviewed for which inferences can be made about use of crossing facilities in downtown areas. In the authors' view, pedestrians will use grade separations only if they are extensions of a major continuous level walkway on which pedestrians already find themselves. The authors also concluded that obvious horizontal or vertical detours will inhibit pedestrians from using crossing facilities.

3.4.2 Cyclist Characteristics

Still less information was found describing cyclist travel behavior and needs. The available material indicates that the following factors may influence whether or not bike trips are made:

- Trip distance: Smith (22) concludes that cut-off points of maximum trip distances vary from 3 to 6 miles (4.8-9.7 km), depending upon trip purpose.
- Route characteristics (traffic, terrain, perceived safety, etc.)
- Trip purpose
- Climate: extreme temperatures and rain are significant deterrents.
- Age
- Bike ownership
- Car availability

Several major conclusions related to travel behavior were found in the literature. The conclusions most relevant to the planning and design of grade separation treatments are described below (22):

- Bike facilities are perceived by most recreational and infrequent bicyclists as safer than no facilities.
- Generally the greater the separation from motor vehicles, the greater is the level of safety perceived by the users.
- Sidewalk bikeways are perceived by most users as less safe than on-street facilities.
- A distance as little as two blocks out of the direct travel way may be considered as a significant inconvenience.
- The average cycling speed is 12 mph (19 kmh).

- Where there are moderate headwinds, bikes will sway significantly.
- Young bicyclists are most prone to accidents.
- The majority of bike accidents occur at intersections.

3.4.3 Characteristics of the Handicapped Traveler

References describing travel characteristics and needs of the handicapped are also rare. Most of the recent transportation studies are related to the need for motorized systems rather than pedestrian facilities. Literature identifying trip generation characteristics and general walking behavior tends to be based on empirical research, while most of the reviewed information on specific needs of the handicapped is based on expression of opinions and hypothetical situations.

The Disabled Population: According to the 1972 National Health Survey, as cited by Crain and Associates (28), about 6,458,000 or 3.2 percent of the population have a chronic mobility limitation. Of this population, about 1,227,000 are severely impaired visually (i.e., have no useful vision in either eye), while 423,000 use wheelchairs. According to Abt Associates (24), an additional 567,000 have acute conditions such as fractures and sprains, which temporarily affect mobility, and about 1,671,000 of the institutional population have other mobility limitations.

Importance of Walking: Recent studies (23, 25, 26, 27) and interviews with disabled persons indicate that they are more reliant on the walk mode than are members of the non-disabled adult population. It can be concluded from these results that the majority of disabled persons depend on others for transportation unless the walk mode is used. It is expected that the importance of pedestrian travel will continue to remain high among handicapped persons. New laws (e.g., the recently enacted HEW 504 legislation) will mean that handicapped people will be able to travel further and more often as their environment becomes more accessible.

Current Travel Behavior: The character of pedestrian travel among the handicapped appears to vary with environmental setting, disability type and social role (e.g., employed, retired, student). The walking range of this study's disabled panel varied from a few blocks for a person using a walker to all over a small-sized city for a person in an electric wheelchair. With the increase in speed and range of wheelchairs, severely disabled persons will be able to achieve trips of several miles where the path is accessible. Robert's study (28) of persons who are visually and hearing impaired showed that they averaged 10 to 14 block walking trips. The study also concluded that surface textures, sidewalk construction, pathway directness and noise diffusion are influential factors in walking safety for the blind. Signing is particularly important to the deaf.

Data based on empirical research indicates that the most frequent goals of walking trips among the handicapped are shopping and social activities. One survey in a suburban area found that health care was a frequent trip purpose. Another indicates that walking is an important source of exercise and daily recreational activity. Knowledge regarding the residential location patterns of the handicapped can provide insight into the trip making characteristics of this group.

There is some evidence in the literature to indicate (a) that the transportation handicapped form a higher percentage of the urban population than of the suburban population; and (b) that many of the handicapped may locate their residences close to or within preferred social, religious and shopping activity centers. This seems to be particularly true among the elderly handicapped.

Mobility Needs: Evaluations of mobility needs by Roberts (28), Jones (29), and Crain (23) indicate that mobility needs vary according to both different disability types and the severity of disabilities. A summary of these mobility needs by disability type is presented in Table 1. Jones (29), Templer (30) and others (31, 32), have also suggested minimum and maximum space requirements for wheelchair persons, semi-ambulatory and the blind. Most of these suggested standards are not based on behavioral studies, but are based on commonly accepted guidelines.

3.5 CROSSING CONDITIONS

For purposes of this study, grade separations have been grouped into two categories -- overcrossings and undercrossings. Overcrossings are structures which provide passage over barriers for non-motorized travelers. Undercrossings are facilities which provide passage under barriers. All grade crossings have been defined as having three components, as shown in Figure 2.

Ends: That portion of the traveled way which is adjacent to the physical limits (on both ends) of an over- or undercrossing and which affects the ability of non-motorized travelers to use the crossing.

Approaches: The transition sections between the end conditions and the structure crossing the barrier.

Structure: That protion of the traveled way actually crossing over or under the barrier.

Table 1. Mobility Needs by Disability Type

Disability Type	Mobility Needs
Semi-Ambulatory	• Low level of toleration for abrupt changes in level or uneven walking surfaces. • May need support to rise when seated. • May require support where level change occurs. • (With Aids only) additional space to maneuver aids may be required.
Wheelchairbound	• Need for even surfaces to prevent erratic movement or sudden stops. • Need for space to allow passage and maneuvering of wheelchair. • May have difficulty twisting and turning. • Gradual changes in level are necessary. • Need for guards to prevent wheelchairs from rolling off sloped surfaces.
Lack of Maturity or Mental Development	• Simple environment with clear-warning signs.
Impairment of Postural Mobility or Upper Torso	• Need to minimize required twisting and turning. • Need for supports with level changes which are easily reached and grasped.
Physically Restricted - Agility, Stamina, Reaction Time (Heart Disease, hypertension, degenerative diseases, aging)	• Minimize need for sudden decisions. • Minimize need for quick or sustained movement.
Auditory Impairment	• Clear visual cues and signing to direct and caution.
Visual Impairment	• Unevenly distributed or unbalanced light sources can distort visual picture. • Limited if any ability to judge distances. • Limited if any ability to differentiate between color intensities. • Limited if any ability to see objects clearly or to focus on objects of different distances. • Need for tactile cues to hazards. • Difficult to compensate for sudden change in level or direction. • Sound diffusion likely to confuse blind persons. • Need for guards to prevent falling.

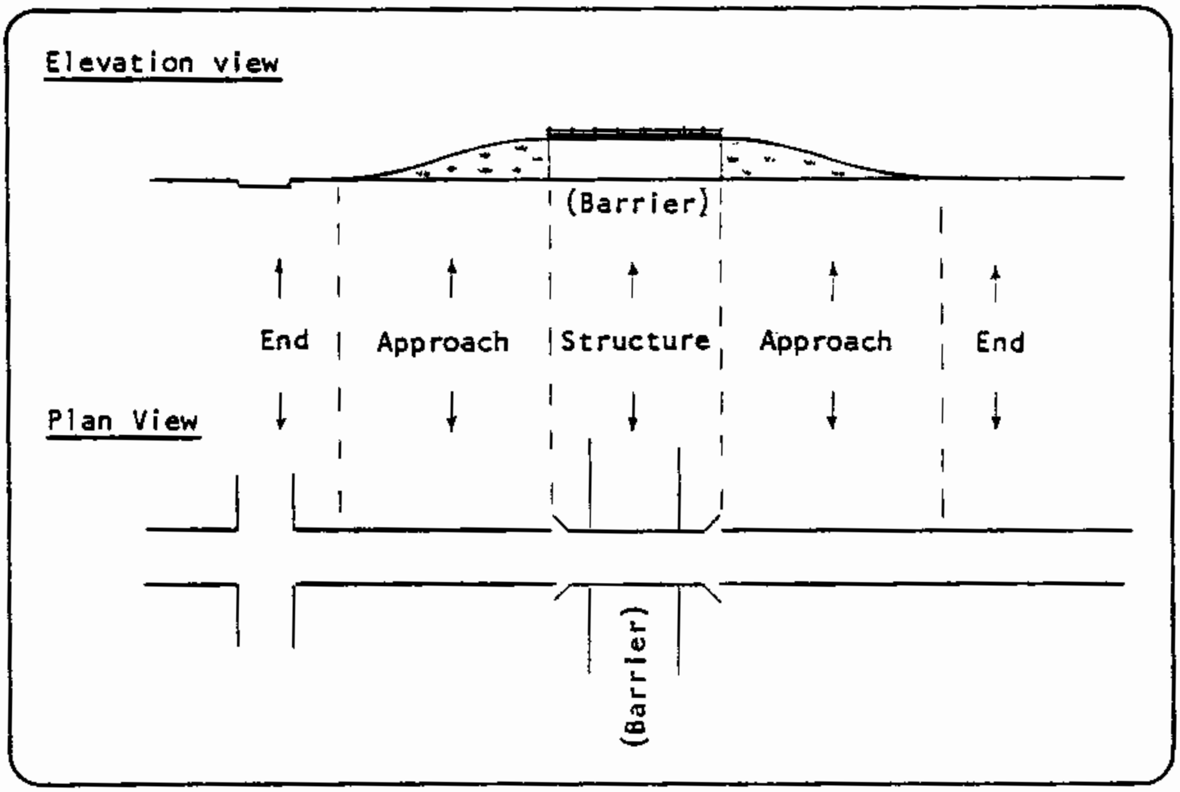

Figure 2. GRADE CROSSING ELEMENTS

Review of current practice indicated that certain factors influence the type of planning for and implementation of crossing facilities. These factors or considerations have been grouped into (a) locational characteristics, (b) structural characteristics, (c) approach characteristics, and (d) end conditions. These considerations are listed below:

3.5.1 Location Characteristics

- School Crossings: The development of treatments to provide safe access to schools has traditionally received high priority in both the development of refined designs and in funding.
- Central Business Districts: In areas where there is urban renewal, grade separated systems for pedestrians are often part of downtown renewal plans.

- High Activity Residential Urban Areas Outside Central Business Districts: Some sources indicate that these areas have the greatest need for grade separated facilities for non-motorized travel.

- New Towns: Some of the most extensive grade separated systems have been built in these areas at the time the new towns were created.

- Suburban and Rural Areas: Single facilities have been built where a clear need has been established, such as construction of a freeway which cuts off travel between major activity centers.

- Long Bridges Over Waterways: Many of these bridges were constructed without pedestrian or bike facilities. Bus transit has been one technique used to accommodate bicyclists and pedestrians.

3.5.2 Structure

- Over- or Undercrossings: The benefits and costs of these alternative treatments are sensitive to a variety of influences such as site condition, construction method and social setting.

- Types of Overcrossings: According to one source (33), the cost and construction feasibility of downtown overcrossings varies by the degree to which they are integrated into buildings.

- Construction Materials: Construction and maintenance costs, and life span vary according to whether constructed with concrete, steel, wood, aluminum, or plastic fiberglass.

From on-site examination of crossing facilities, a typology of non-motorized treatments on structures was developed. The typology is presented below:

- Absence of treatments on the structure for non-motorized travel.

- One-sided treatments on the structure (e.g., shoulder and/or a walkway on one side of structure).

- Two-sided treatments (an exclusive structure serving non-motorized travel is a special case of a two-sided facility).

3.5.3 Approach

- Ramps or Stairs: These are primary characteristics together with grade which determines how accessible structures are to bikes and the disabled.

3.5.4 End Conditions

- Intersection or Midblock: Midblock end conditions have been rated as preferred from the viewpoint of safety, but they often result in out-of-the-way travel.

- Type of Freeway Interchange: Different configurations of interchanges result in varying types of solution for connectivity to structures.

- Presence of Non-Motorized Travel Facilities: According to sources reviewed (e.g., 33, 34), treatments on ends are often not designed to be integrated with existing approach facilities. In cases where there are barriers to travel at ends, pedestrians and cyclists are prevented from taking advantage of structural treatments.

3.6 HAZARDS AND IMPEDIMENTS

Information collected about crossing hazards and impediments mainly consisted of opinions based on casual observation or intuitive judgment from planning experiences. Hazards are defined as the presence or absence of facility treatments which affect crossing safety. Impediments are defined as the presence or absence of facility treatments which affect crossing convenience. Few rigorous research efforts have been conducted to identify and compare the perceived hazards and impediments to non-motorized travel. There have been some studies (35, 36, 37), particularly related to pedestrian facilities, where variables related to hazards and impedences have been identified and quantified. However, results have not been consistent.

3.6.1 Pedestrian Facilities

Most of the reviewed studies point out that the main reason for non-use or avoidance of pedestrian facilities is inconvenience. According to one source (38), most people do not perceive that grade separations significantly reduce accident risk. Another author (39) stated that some people look at structures as further evidence of the domination of autos. Several authors (38, 40, 41, 42) claim that where people have alternate routes available, a grade separation needs to reduce the time of crossing to be competitive.

The following types of crossing hazards were identified in one or more of the reviewed studies:

- No sidewalks on crossings where there is motor vehicular traffic
- Grades too steep for safe travel
- Inadequate separation from motor vehicle traffic
- Facility approaches which require crossing of high speed freeway interchange ramps
- On some facilities where there is a high level of structural sway due to low live load standards, users tend to perceive that the structures are unsafe.

In addition, reviewed sources (36, 43) identified a hazard associated with overcrossings over roadways which affect motorists. Low railings on overcrossings allow facility users to throw objects onto the roadway below.

It was pointed out that often safety is the reason cited for construction of grade separations. From study of national accident statistics, some authors (35, 44, 45) concluded that high risk areas for pedestrian accidents are crowded, older residential areas outside central business districts and freeways where pedestrians are not prevented from crossing traffic streams.

The reviewed literature identified several impediments associated with pedestrian use of grade separations:

- Level Change: amount of climbing and descending required.
- Lack of Continuity: awkward transition to continuing facilities on either side of structures; signs, and street furniture obstructing pathways.
- Lack of Directness: sight distance restrictions; facilities not in direct line with major attractors and generators or crosswalks on either side of the facility.
- Insufficient Capacity: pedestrian congestion, particularly in downtown areas.
- Lack of Protection from the surrounding atmospheric environment: exposure to motor vehicle pollution, traffic noise, and adverse weather conditions, such as rain, wind and snow.
- Lack of Coherence and Interest: winding or monotonous pathways.

Impediments associated with subways -- i.e., underpasses for pedestrians -- are poor lighting and security resulting from poor sight distance. One author (46) stated that subways represent "lifelessness." Another (39) perceived subway impediment as unsanitary or unaesthetic environmental conditions and encouragement of vandalism attributable at least in part to limited sight distance. If well-designed, however, there is evidence that pedestrians prefer subways to overcrossings (12).

3.6.2 Bicycle Facilities

Reviewed sources (47, 48, 49) indicate that bicyclists and pedestrians generally experience the same crossing hazards and impediments. However, authors generally agree that underpasses rather than overpasses are preferred among cyclists, due to the less steep slopes and because momentum gained going down helps bicyclists overcome the up slope. Hazards of particular importance for bicyclists which were mentioned are:

- Traffic lanes too narrow for sharing by motor vehicles and bikes.
- Steep grades which significantly reduce cyclist control.
- Storm sewer grates with bars parallel to the curb.
- Too low railings.
- Snow, ice, or debris obstructing the pathway.
- Overhead or lateral obstructions.
- Signs and street furniture obstructing the pathway.
- Shared bike and pedestrian facilities where there is a large differential in travel speeds.
- Intersection Conditions: A frequently cited example is where bike facilities on a crossing structure are provided on one side only, while cyclists on the approach are expected to ride directionally (i.e., on the right). Such designs place cyclists in the predicament of either riding in a traffic lane or having to make two crossings of the street at each end of the facility.

Impediments of particular importance to cyclists, other than those mentioned for pedestrians, included:

- Stairs - a barrier to riding.

- Squared Curbs - an obstruction to travel if a sidewalk-to-street transition has to be made.

3.6.3 Handicapped Facilities

Documents summarizing design criteria for handicapped facilities were found to be the primary source for identifying hazards and impediments (23, 61, 63). Relatively few documents were found which discussed the problems of the handicapped pedestrian. One of the main findings of the literature review was that hazards and impediments vary for persons with different types of handicaps. Hazards and impediments of particular importance to the handicapped are listed below:

Hazards

- Excessively steep grades on approach ramps.

- Slick surfaces due to poor drainage or use of improper construction materials.

- Abrupt (squared) nosing on stair treads.

- Obstructions on the sidewalk or walk area.

- Overhanging obstructions.

- Drain inlets and storm drainage channels located in intersections.

- No handrails or handrails which do not allow a firm grasp.

- Loose debris on sloping surfaces.

Impediments

Sources reviewed (24, 30, 31) indicate that major impediments to the disabled are long distances (over 100 feet or 30.5 meters) where there are no areas to rest which do not obstruct other travelers. In addition, the lack of curb cuts in approach areas and stairs are repeatedly mentioned as barriers to the wheelchairbound. However, one author (50) points out that ramps are an impediment to travel by persons with leg braces or crutches; ramps are more difficult for this group to negotiate than stairs.

3.7 DESIGN STANDARDS AND APPROACHES

3.7.1 Design Standards

The most common reference for design standards for bicycle and pedestrian facilities are the American Association of State Highway and Transportation Officials (AASHTO) publications -- Guide for Bicycle Routes, 1974, and A Policy of Urban Highways and Arterial Streets, 1973 (51, 52). (FHWA is in the process of developing their own design standards for bicycle facilities.) The recommended widths of bike trails and sidewalks, overhead clearances, grades, barrier rail types, and the characteristics of bicyclists and pedestrians, may be found in these publications. The heavy reliance on these sources by many agencies means that design standards often used are only as current as the most recent editions of these references. Some cities and states have developed their own manuals (43, 53, 54, 55); often incorporating AASHTO standards as well as local criteria.

Standards for handicapped design are currently undergoing major upgrading and revisions. At present, there is some confusion and trepidation among designers about accommodating the handicapped. There is no widely used standard reference, equivalent to the AASHTO publications, for handicapped facilities on grade separations.

3.7.2 Accommodating the Non-Motorized

Facilities for bicyclists, pedestrians and the handicapped on over- and undercrossings are provided in two ways; either as part of newly constructed projects, or modification (retrofitting) of existing over- or undercrossings. Both types are briefly reviewed in this section.

Facilities for the Non-Motorized in New Projects: Bicycles and pedestrians often travel on sections of over- and undercrossings whose main purpose is the movement of automobiles. Where facilities for non-motorized travel are shared by bicycles and pedestrians, an eight foot (2.4 M) wide sidewalk physically separated from automobile traffic is sometimes provided, usually on one side of the structure. Another common treatment is to provide a shoulder or wide curb lane to accommodate bicycle travel. The extent of separation between motor vehicles, bicyclists and pedestrians is dependent on the speed and volume of automobile traffic, and ranges from widened curb lane to a full barrier separation.

In many instances, sidewalks for pedestrians with a four to six foot width (1.2-1.8 M) are installed on one or both sides of an overpass or underpass. Bicyclists have the option to ride or walk their bikes on the sidewalk or continue across the structure in the roadway or on the shoulder or clearance area between the edge of the traveled way and the curb or barrier.

A fairly common method of retrofitting a bridge structure for pedestrian use is to cantilever a walkway from the outer edge. This construction is easiest if the bridge is composed of steel beams, since the walkway can be fastened to the edge with a combination of welded and bolted connections. Fastening cantilevers to reinforced concrete structures is also fairly simple. Railings are provided on the outside of the walkway.

Due to structural limitations, both types of retrofits cited above tend to have narrow, three to four foot wide, (0.9-1.2 M) walkway areas, Bicyclists have the option of walking their bikes on the pedestrian walkway or riding on the roadway.

Additional discussion concerning current practice can be found in Chapter 6 of this report, which describes the results of the field evaluations carried out at a number of existing over- and undercrossings.

Where conditions warrant, separate overpass and underpass structures are constructed exclusively for bicyclists and pedestrians. These structures are usually built as part of recreational bike or pedestrian trail systems (for example, through parks); for access to special facilities expected to have a high volume of non-motorized travel, such as stadiums; or where residential areas are separated from community facilities (shopping centers, schools, recreation areas) by highways or other barriers. Grade separations are also becoming more commonplace in central business districts as part of new construction or redevelopment where aerial walkways connect buildings and elevated plazas.

These overcrossings generally have a clear width of 8 to 12 feet (1.8-3.7 M) between railings or curbs. The width of the structure and the actual design loads are determined more by the need for maintenance vehicle access than for bicycle and pedestrian use. Depending on desired structure length, site conditions, and most economical material use, the construction can consist of prestressed concrete girders, single span welded plate girders with reinforced concrete deck, wood beams with wood decking, or steel through trusses.

Underpasses built solely for pedestrian and bicycle travel exist in much fewer numbers than do overcrossings. This is largely due to maintenance and social problems, and vandalism. Where these features are most critical, underpass utilization is low or the structure has been removed from service. Minimum heights for pedestrian and bicycle underpasses are usually eight to nine feet (2.4-3.1 M), while minimum widths vary from 8 to 14 feet (2.4-4.3 M). Some jurisdictions have attempted to adjust the proportions of pedestrian underpasses in an attempt to overcome the psychological barrier associated with a long, narrow tunnel. The City of Chicago has a standard tunnel width ratio of one-quarter of the length, with a maximum width of 24 feet (7.3 M). Pedestrian underpasses are commonly arch shaped and constructed of reinforced concrete or steel plate.

CHAPTER 4
NEEDS ASSESSMENT

4.1 INTRODUCTION

A variety of methods to deciding whether or not to incorporate non-motorized facilities into over- and undercrossings are possible. These can vary from basic application of judgment or direct compliance to an adopted policy to consideration of a full range of implications and impacts, together with multiple iterations of public participation and reviews. Even though there may be many similarities between sites, individualized characteristics oftentimes produce marked differences, thereby influencing both need assessment and design requirements.

This chapter provides background on the current warranting practice, as well as presents a recommended generalized approach or needs assessment procedure within which most situations can be evaluated.

4.2 WARRANTS

A basic cornerstone of good design and traffic engineering practice is that similar circumstances or situations should be given similar treatments, and where certain combinations or conditions are present, a "need" or warrant exists for a specific type of control or facility. Warrants can be defined as criteria or measures of need which serve as guidelines in the process of deciding whether a particular form of physical improvement or traffic control should be implemented. Since warrants describe general conditions, they should be viewed as guidelines only, and not as hard and fast rules for the installation or rejection of facilities or devices at a specific site without considering its individual conditions and circumstances.

4.2.1 Purposes of a Warrant

Warrants have been established for the following purposes:

- To utilize criteria reflecting actual experience
- To provide a rational basis for decision-making
- To promote a more effective application of funds
- To avoid the installation of facilities or devices where they are not needed or could be detrimental.

The application of warrants is most effective when coupled with qualified engineering judgment and consideration of all pertinent facts, whether quantifiable or not. As applied in current practice, ascertaining the degree to which various warrants are satisfied is but one step in the decision-making process, which justifies and ultimately authorizes construction of facilities or implementation of devices.

4.2.2 The Need for Warrants

It might well be asked, however, whether correct and defensible decisions regarding non-motorized facilities can be made without following a warrant process. The answer is both yes and no.

- The answer may be YES if the evaluation is conducted by a team of skilled designers, planners and advisory groups thoroughly knowledgeable about both grade separations and local conditions. Such an evaluation process would typically contain many of the elements considered as warrant criteria. The degree of success of this process is directly proportional to the skill and level of knowledge possessed by the participants.

- The answer is probably NO if less experienced or less knowledgeable persons analyze the criteria and/or where political prerogative is excessively applied to satisfy vocal but inadequately informed demands. In these situations, the chances for effectively analyzing the problem markedly decrease and it becomes more likely that facilities approved in this fashion will ultimately prove to be deficient in some way.

Frequently when warranting procedures are not used it is because of lack of knowledge about available procedures, rather than a knowing rejection of the concept.

There is little doubt that an organized review of available information is a more valuable tool for decision-making than a haphazard approach. A logical, structured and consistent approach is also more likely to be understood and accepted by both technicians and lay people concerned with the crossing. However, warranting procedures with complex or excessive input needs may discourage warrant use and/or acceptance of results. In essence, this may force users to avoid the process entirely.

4.2.3 Warrant Types

• Economic Warrants	- are based upon a comparison of construction and maintenance cost to monetary benefits anticipated from providing the facility or device.
• System Warrants	- consider to what degree the proposed facility is an essential component of an entire system.

- Threshold Warrants - state that a certain combination of factors must exist to justify implementation.
- Point Warrants - employ selection or assignment of numerical values to quantify various factors. Facilities can then be compared to a base level figure and be ranked relative to other candidate sites.

To these four systematic warrant procedures should be added two other related and important criteria of the decision-making process, namely: established policy and political prerogative.

- Established policy - can define predetermined guidelines affecting various aspects of non-motorized travel, thereby eliminating or reducing the need for action justified by the warrant process. A decision to make all facilities accessible to handicapped travelers as a matter of public policy, for instance, is one example of such a guideline.
- Political Prerogative - can complement or bypass the warranting evaluation process. Design responsiveness to public preference (expressed through a community involvement process or through elected political representatives) is a valid consideration which should be explicitly recognized. However, problems can occur when decisions are largely based on emotion and political pressure, rather than on rational review of advantages and disadvantages.

4.2.4 Use of Warrants

It appears on the basis of available information that justification of non-motorized facilities on new grade separations shared with motorized vehicles is seldom rigorously analyzed, unless the structures are long or unusual in some way. Many design decisions for ordinary highway bridges are resolved by applying a given policy. This may mandate inclusion of non-motorized facilities where such facilities exist on the approach, or it may specify that space, such as a shoulder, be included to serve as shy distance or as a safety zone for stopped vehicles. Such space can also be used by non-motorized travellers.

Recommendations for retrofitting structures for non-motorized facilities are typically based on responses to experience with existing use and observed deficiencies or are designed to provide continuity along a travel corridor.

In summary, the most rigorous justification techniques for non-motorized facilities appear to be directed toward new, exclusive pedestrian (bicycle) grade separations or for long structures shared with motor vehicles, where the total cost of such non-motorized facilities may amount to large sums of money. Established policies and political prerogative are other important factors in determining whether, and to what degree, non-motorized facilities will be included in over- and undercrossing designs.

4.2.5 Current Warrant Systems

Most of the warranting systems devised to date for non-motorized facilities have been directed toward determining the need for exclusive pedestrian facilities. Assessment of the need to develop bicycle facilities has been treated to a lesser degree, although the recent resurgence of bicycling has resulted in increased effort to establish better means of facility justification. Justification for making facilities accessible to handicapped pedestrians is another area which has been almost entirely neglected in the past, but which is now receiving considerable attention.

Economic Warrants. These can be useful, especially where facility costs can be compared directly to the cost of alternative strategies such as installing a traffic signal, busing, or providing an adult crossing guard. Scott and Kagan (17) list various aspects of costs and benefits of facilities for pedestrian crossings of highways.

Cost factors can be grouped as follows:

- base facility construction costs
- site specific facility construction costs
- annual cost of facility operation and maintenance
- facility economic investment cost

They found the most often overlooked items with regard to costs to be:

- Annual maintenance cost
- Vehicle delay during facility construction
- Right-of-way costs at the end conditions
- Effects of span lengths and total facility length

Benefit factors of grade separated pedestrian crossings included improved linkage between land uses, as well as reduced costs related to:

- Vehicle Delay Time
- Vehicle Operation
- Pedestrian Injury and Fatality
- Alternative Crossing Controls
- Pedestrian Roadside Delay
- Pedestrian Trip Delay

According to Scott and Kagan (17), potential utilization of the facility must be determined and if less than 100 percent then the gross benefits are reduced accordingly to net benefits.

System Warrants. Use of this process is facilitated by adoption of a master plan specifying pedestrian and pedestrian and bikeway elements. Master planning typically explores a variety of alternatives and identifies linkages important to the creation of a comprehensive and coordinated network of pedestrian and bicycle facilities. The ultimate plan involves technical as well as public participation to assure satisfaction of community needs. Subsequent proposals for non-motorized facilities are then simply checked for consistency with the adopted plan (56).

Threshold Warrants. These state that if a certain combination of factors exist, then a structure is justified. Certain fundamental criteria must also be met before a grade separation structure is considered to be justified. Basic to all situations are:

- Existence of permanent conditions requiring the crossing (i.e., not just a temporary condition or need).

- Engineering feasibility of the proposed facility.

In addition, other factors come into play depending upon the degree of access control on the highway to be crossed by an exclusive pedestrian/bicycle facility. For instance, the State of Washington (57) specifies that one of the following items must be satisfied when crossing fully controlled access highways:

- At least 200 pedestrians crossing per hour for two hours each day; if there were no structure, the additional average walking distance required for 85 percent of the pedestrians having the shortest walking distance exceeds one-half mile.

- The severance damages for the taking of property shall be more than the cost of the structure or structures necessary to cure the severance.

Structures proposed to cross partially controlled and non-controlled access highways must satisfy any one of the following, plus the fundamental criteria listed above:

- An economic analysis indicates that the yearly cost of the separation structure is less than the yearly cost of installing and maintaining the required signal(s) and appurtenances (signs, crosswalk painting, fencing, etc.). Before making this comparison, additional average walk distance required for 85 percent of the pedestrians having the shortest walking distance must exceed one-half mile, if there were no structures.
- The vehicular and pedestrian traffic is so great that a traffic signal could not handle both without being overloaded during peak hour traffic.

Point Warrants. This method is based upon the realization that there are a number of factors which influence the need for a grade separation. Efforts are then directed toward identifying these factors and assigning appropriate point values. Summation of all values produces a score which can then be utilized as a comparison or ranking tool. By applying the same methodology to other sites being evaluated, it is possible to draw conclusions about the relative need of each.

The City of Seattle, Washington (58) and the Institute of Traffic Engineers (56) (now Institute of Transportation Engineers), were early advocates of the point method of warranting pedestrian separation facilities. While both recognized the difficulties in assigning weights or values to intangible items, they found the method generally satisfactory in providing a working tool for those persons responsible for placement of pedestrian separations. However, both groups caution users that the system was not an automatic and infallible selector of locations. They stressed that it was intended to provide the skeleton upon which enlightened judgment of engineers and planners could be placed and that the system was empirical in nature, which makes any and all parts subject to challenge.

The Seattle point ranging system (58) was calibrated by rating 27 existing and 36 proposed overpasses and was found to provide a reasonable measure of reliability. The factors utilized for the priority ranking system were measurable characteristics, considered common to all crossing situations. The weighted values for these factors, as refined from the Seattle experience, are as follows:

Factor	Value
Vehicle and pedestrian volume	40 percent maximum
Accident experience	15 percent maximum
Miscellaneous and vision factors	45 percent maximum
	100

A nomograph was developed to derive vehicle and pedestrian volume percentages. In Seattle it was found that there was a maximum number of correctable pedestrian accidents occurring at any intersection during the previous five-year period. Therefore, the ranking system assigned five points for each correctable pedestrian accident, without regard to severity.

Miscellaneous factors were weighted, as follows:

Factor	Points
Marked School Crossing	10
Elementary School Crossing	10
Presence of Adult Crossing Guard	10
Vision, Growth, Street Width, Speed, Capacities	15
	45

A salient thought expressed in the Seattle study (58) was that the priority system will at best be a guide to administrative decision since it is based upon many estimates and judgments. The writers cautioned that the system should not become so burdensome as to demand more time and measurement than the level of accuracy it can produce on the end product.

In a recent study, researchers from the New Jersey Department of Transportation (59) expanded upon the concepts developed in Seattle and adopted by the Institute of Transportation Engineers (ITE) for exclusive pedestrian grade separations. Refinements included separating the evaluation into two categories and selecting appropriate factors for each. These are as follows:

- Where pedestrian activity exists:

    1. Pedestrian and vehicle volume with peak hour delay factor. (40 points max)

    2. Actual versus desirable sight distance at unsignalized locations, or pedestrian crossing time versus maximum green/yellow time at signalized locations. (50 points max)

3. Number of school children and type of crossing protection. (30 points max)

4. Distance to nearest alternative crossing, considering protection there. (30 points max)

5. A judgment value.

- Where pedestrian activity is not currently possible:

1. Pedestrian trip generation. (70 points max)

2. Distance to nearest alternative crossing, considering protection there -- flashing signal/signs only/no signs (70 points max); traffic signal (60 points max) and Grade Separation (50 points max)

3. A judgment value. (60 points max) This includes Safety of Alternate Crossing (5 points max); Surplus Trip Generation (1 point for each 15 trips in excess of 700 per day) and Origin of Location (35 points max)

Calibration of pedestrian trip generators was segregated into five categories:

1. Bus Stops
2. Commercial
3. Schools
4. Institutional
5. Recreational

It was decided to select the single most dominant trip generation category where more than one land use was present. If the same land use type existed in each zone, then the corresponding trip generations would cancel one another (i.e., travel was assumed to be local and not cross the barriers).

Ten charts and graphs were prepared from which various point scores could be determined. A series of three computer programs were developed to facilitate data processing and to compute the following information:

1. Peak hour pedestrian delay at intersections.

2. Priority ranking score for each location based on delay data and data collected in the field.

3. Formated priority ranking designed to accept additional scores and rerank previous listings accordingly.

Another team of researchers from Stanford Research Institute (SRI) independently assessed the benefits of separating pedestrians and vehicles (60). The objective of this research was to identify and develop techniques for quantifying all of the significant direct and indirect benefits associated with the separation of pedestrians from vehicles and to develop a methodology for relating these benefits to the evaluation of proposals for separation.

Four major categories (Transportation; Safety Environmental/Health; Residential/Business; and Governmental and Institutions) were identified which are comprised of a total of 11 impacted groups. Each group is characterized by two to four variables identified during the project.* Some of the variables were further stratified where there were more detailed measures. A unitless scoring scale was developed for each of the 36 variables identified during the project. A +10 unit is the maximum positive value and a -10 unit is the maximum negative value. A zero denotes neutral or not applicable. The various measurement techniques can be summarized as follows:

1. Selection of Score from Table

   Use a table to find the score corresponding to an actual measurement or observation.

2. Simple Formula

   Insert observed and/or appropriate unitless value into preset formula to calculate total score.

3. Summed Table Values

   Select applicable components from a table and then sum values to find the total score.

4. Separately Scored Components

   Select the appropriate value from the scoring range for each component, then sum values to produce a total score.

5. Weighted Formula

   Insert measurements or values into a formula that can be adjusted or weighted to produce a score which maintains its comparability to scores of other facilities.

6. Qualitative Scoring

   Assign a score to a subjective variable based upon judgment and the guidelines given.

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* These are listed in the Appendix.

The SRI authors (60) believe that their defined methodology is a flexible and responsive tool which is both comprehensive and consistent, and which makes the decision-making process easier. They state that the techniques can be used even if specific values for individual variables or components change over time.

4.2.6 Warrant Data Availability

Some insight into the kind and amount of data used in justifying over- and undercrossing facilities for non-motorized travel can be obtained by reviewing relevant experience elsewhere.

On-going warrant systems in the states of Alaska, California, Kentucky, New Jersey, Texas and Washington were reviewed to determine data requirements. Items commonly considered of primary importance include accident experience and vehicular and pedestrian volumes. Accident data is city wide, whereas volume counts and other planning data are most often taken in high activity areas. Other primary evaluation factors are sight distance, location and type of traffic control devices, location of adjacent crossings, permanence of the factors requiring the crossing, and basic engineering feasibility.

It should not be surprising that readily obtainable data is often featured in evaluating the need for a structure. Data most often used in the needs assessment process can be grouped into the following categories:

- Traffic Characteristics
- User Characteristics
- Land Use and Zoning
- Crossing Location
- Cost
- Miscellaneous Factors

The list of possible evaluation factors is a long one. To "precisely" derive values for each of these items would be a major task for most agencies. In addition, the accuracy and degree of precision that can be obtained for some items is questionable.

Pedestrian and bicycle facility needs analysis requires accumulation and review of data resources to gain a thorough understanding. Some data can be found in existing files, while other data must be collected in the field. In addition, there are a number of subjective features which have some degree of influence in determining the need for pedestrian and bicycle facilities. For these, there are no readily acceptable numerical values. Therefore, ranking systems must be devised to facilitate comparative analysis. Wherever possible, such ranking systems should involve a variety of analysts with different viewpoints and value systems so as to minimize the possibility of bias.

4.3 RESEARCH EXPERIENCE

Based upon our research experience with the 72 case studies and detailed site evaluation, we believe that there should be a great deal of flexibility in a needs assessment process of evaluating over- and undercrossings, since in most situations individualistic site characteristics are dominant or decisive considerations. Examples of this individuality can be found in the six site evaluations studied in this project.

4.3.1 Palo Alto, California

Palo Alto established justification for a facility on the basis of a combination of high bicycle usage along bordering arterials and identification of a special site opportunity to supply a missing linkage in their bikeway network by connecting two cul-de-sac streets. Current usage exceeding 500/day is indicative of the appropriateness of this justification process.

4.3.2 Sunnyvale, California

The City of Sunnyvale and the California Department of Transportation responded to continuing community concern about the need for school children to travel through one of two busy freeway interchanges to reach school or a regional park. While estimates of usage were available for some time, action did not occur until it was decided by the State that the previously planned improvements to the interchanges would not occur. There then began a long period of evaluation of the proposed exclusive pedestrian overcrossing. This included recommendations with regard to facility design and location by engineers, based on technical knowledge. These concepts were ultimately modified by citizen input based upon a blend of desire to have the facility but concern about the impact the facility would have upon the adjacent homes. (Current usage is estimated as being 150-250/day.)

4.3.3 Eugene, Oregon

In Eugene, Oregon, improvements were based on the fact that a bikeway system had been planned and development was geared to completing the important links. Construction of the SPRR underpass came about because users were crossing the tracks at-grade to gain access to the existing Autzen bicycle/pedestrian bridge across the Willamette River. This well-used unofficial crossing of the railroad was then identified as a link in the bikeway system and the undercrossing was built to assure safety. (Estimated usage 500-1,500/day.) The Ferry Street Bridge improvements responded to existing usage and travel patterns documented by field studies. This facility was also a vital link in a bikeway master plan and reduced bicyclists and pedestrian exposure to heavy volumes of fast moving traffic. Current usage is estimated as being 500-1,500/day.)

4.3.4 Hampton, New Hampshire

The retrofit of the highway bridge carrying Route 1 over the B&M RR in Hampton, New Hampshire, responded to a perceived safety problem along a route used by bicyclist and pedestrians. The existing highway overcrossing facility ascended a grade in order to go over the railroad and the width of roadway was felt to be too narrow to facilitate heavy vehicular traffic and bicycles. Route 1 was also identified on the State Master Plan for bikeways. The facility serves local demand year around as well as recreational bicycling in the summer tourist season. (Current usage is estimated as being 50-150/day.)

4.3.5 Maryland

The undercrossing of Route 183 in Maryland resulted from coordination between government agencies. A previously planned overcrossing of a creek was evaluated by staff to identify opportunities to create a trail undercrossing. The discussions centered upon location of such an undercrossing, with the final judgment being to slightly modify the four-cell culvert to accommodate a walkway. Provision of some sort of hiker-biker facility maintained accessibility along a green belt corridor which was planned to serve future recreational and local circulation needs. (Current usage is 0-10 per day prior to completion of trail system. After trail completion, estimated usage would grow to 50-200.)

4.3.6 Austin, Texas

Experience with bicycling and walking through a complex highway interchange led planners and engineers in Austin, Texas, to conceive an off-street pathway system. The interchange area was a focal point for several intersecting planned and existing trails, so implementation was based upon system as well as perceived safety concerns. (Current usage is estimated as being 100-200/day.)

4.3.7 Summary and Conclusions

In summary, the six sites studied, all relatively successful treatments, were justified (or warranted) on radically different bases. Case (a) involved high usage and a special site opportunity to supply or improve the quality of a network linkage. Case (b) involved relatively light usage but a reasonable perception of hazard to a particularly sensitive group -- school children. Case (c) involved elimination of hazards or barriers on an extremely heavily used route. Case (d) involved relatively light usage, but the nature of the route and the site were felt to justify the action taken. Case (e) involved moderate usage projection and justification was driven by system considerations -- the desire to provide a continuity linkage on a regional trails system -- and the ease of incorporating the facility in a new construction project. Case (f) involves a moderate usage where the project was undertaken to improve and formalize a linkage already being used informally. A similar pattern of diverse justifications was found for the sites reviewed in less detail during the study.

Based on the research conducted, it is our clear finding that facilities must be justified by considering a range of criteria including known or expected use, cost, safety considerations, system linkage factors and sensitivity of users or sensitivity of the public to user needs. Quantitative or qualitative value can be estimated or measured within each of these criteria sets and our report extensively cites or presents methodology for determining valuations on each criterion. However, there is no single formula or warrant which aggregates the individual criteria to give a "Build-No Build" decision, nor should one be formulated. Flexibility is needed once intelligent valuations have been made within each criterion to allow local decision-makers to weigh the relative importance of the various criteria in light of their own particular situation. The flow chart on Figure 3 rationalizes the fundamental evaluation steps to be taken in the needs assessment process. But it is our conclusion, based on the research conducted, that it would be wrong to impose a rigid formula or warrant for reaching final decisions regarding justification of over- and undercrossing facilities for use by bicyclists, pedestrians and the handicapped.

4.4 NEEDS ASSESSMENT PROCESS

Current experience with the planning for bikeways and pedestrian grade separations provides a good basis for understanding the factors to be considered and the data needed to assess the desirability of providing new or retrofit over- and undercrossings for use by bicyclists, pedestrians and the handicapped. The need for including intangible factors and items that cannot be quantified but only ranked qualitatively, in addition to numerical data, should be particularly noted.

The needs assessment procedure must be flexible enough to allow proper consideration of special circumstances and differences among jurisdictions and among sites within the same jurisdiction. Once a needs assessment procedure is set up which is responsive to local needs, it should be applied consistently and uniformly without bias if its results are to be credible.

Described below is a recommended generalized approach which is believed to be applicable to the majority of situations likely to be encountered. The process is depicted graphically in Figure 3. As can be seen in the figure, the process has been divided into seven categories of activity. These include identifying problems and potential sites; data gathering; examining alternatives; determining if mandatory preconditions exist; reviewing warrants and criteria, establishing priorities; and implementation action. Each of these categories is briefly discussed in the following text, approximately following the logic flow and decision branches indicated in Figure 3.

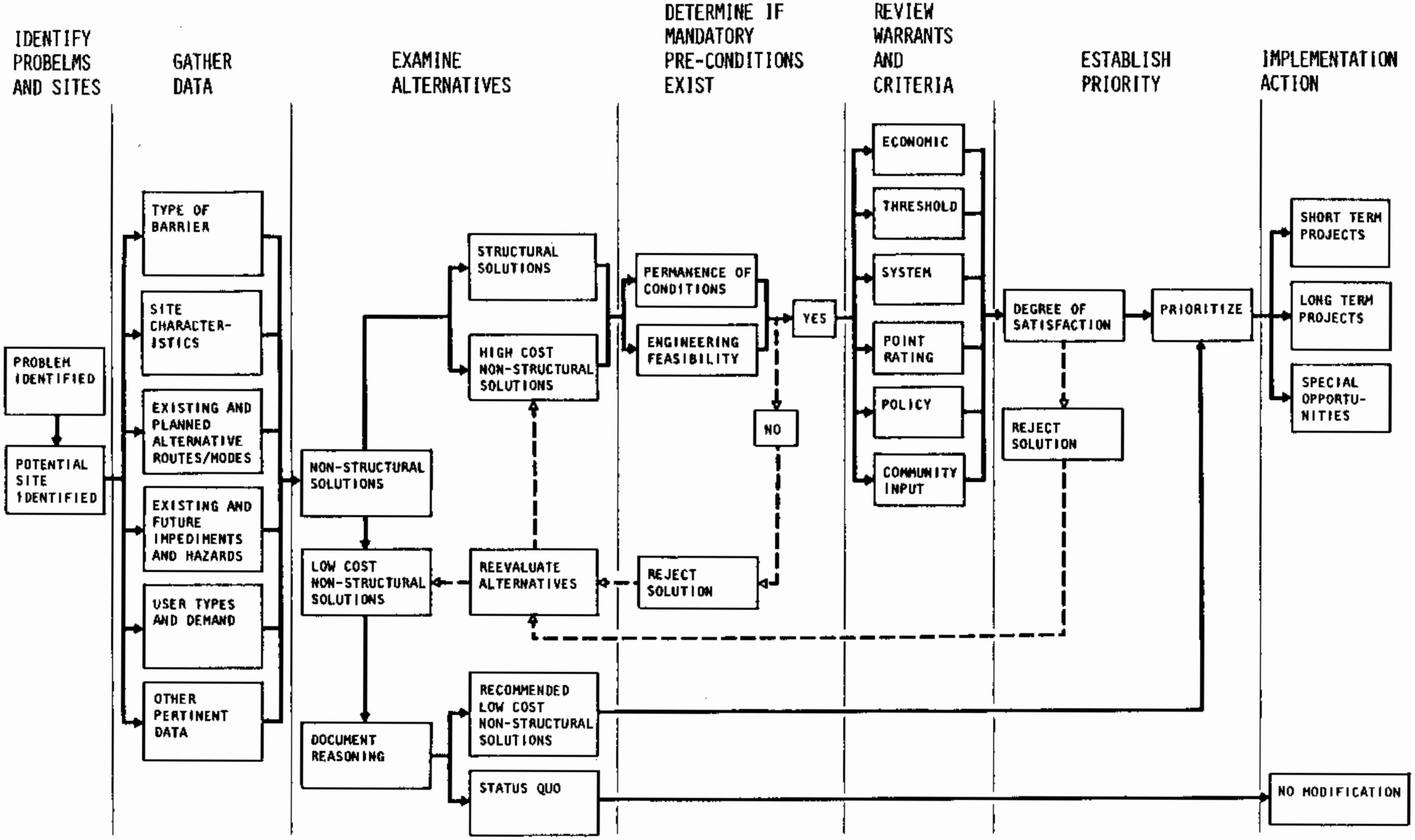


Figure 3. FACILITY NEED ASSESSMENT PROCESS

4.4.1 Identify Problems and Sites

The initial step in the needs assessment process is to identify the problem. This can occur as a result of staff, citizens organizations or community leaders who become aware of a deficiency or an opportunity with regard to bicycle and pedestrian facilities and who initiate steps to begin the process of analysis. One common example of a problem would be where accident experience is frequent or particularly severe, or where potential for hazardous conflicts is high. Another illustration is where a highway facility is to be constructed or modified, thereby creating an opportunity to upgrade bicycle and pedestrian facilities. Preliminary identification of potential alternative sites to evaluate is directly related to problem identification.

4.4.2 Data Gathering

Once a site is identified as a candidate for new or improved bicycle and pedestrian facility on an over- or undercrossing, basic data needs to be assembled about its physical and potential or actual user characteristics. Where possible, data should be gathered or derived from existing files, although some new field work may be necessary. The data provides background information to be used when evaluating alternatives and determining need, and includes material such as:

Type of Barrier. Barriers to non-motorized travel generally fall into two categories -- absolute and disincentive.

> Absolute Obstacles. Features which physically or legally prevent all crossings are considered to be absolute obstacles. Therefore, potential trip makers must either circumvent the barrier or not make that particular trip at all. Examples of absolute obstacles include natural features, such as mountains, canyons, and water, as well as man-made barriers, such as freeways, railroad embankments, canals and fences. Absolute obstacles may be extensive or relatively site specific.
>
> Disincentive Obstacles. These discourage or inhibit non-motorized travel by providing a quality of travel which is marginal or less than acceptable. Therefore, some users will tend to totally avoid or decrease their frequency of use along routes which include, for example, long or steep grades, insufficient space allocations, poor maintenance, heavy traffic volume, and traffic control deficiencies. Disincentive obstacles may be psychological, as well as physical. For instance, routes that are perceived as dangerous, even though the facilities are technically adequate. Excessive noise, heavy traffic, isolation, and the threat of crime are some of the elements which influence user acceptance or rejection.

Site Characteristics. Descriptions of physical attributes of the site which may influence the operation or desirability of the site should be assembled. Data would include such features as topography, existing land uses, traffic control devices, dimensions, alignment and quality of adjacent highway, bikeway and pedestrian facilities, traffic volumes and accident experience.

Existing and Planned Alternative Routes and Modes. The presence and characteristics of existing alternative routes/transportation modes should be determined. Distances from the candidate site and the degree of accessibility to bicycle and pedestrian travel should be identified. Existing transit routes and schedules and any future plans to expand or to implement transit service should be noted. Future plans to construct or modify routes or structures which could be an alternative route should also be identified, along with the approximate timetable for implementation.

Existing and Future Impediments or Hazards to Non-Motorized Travel. Impediments and hazards to non-motorized travel within the tributary area for the candidate site should be identified and evaluated to determine their distribution and order of magnitude. (See Section 3.6 and Tables 13 and 14.) Potential projects affecting the ability of non-motorized users to gain access to the site should also be identified. Similarly, projects which may be abandoned, thereby adversely affecting non-motorized accessibility, should also be noted.

User Types and Demand. Information on pedestrian and bicycle mix and age distributions, together with a knowledge of primary trip purposes, is important to the needs assessment and design process for over- and undercrossing sites. In some cases, existing travel patterns and behavioral characteristics will indicate existing and even future use potential. Other situations will require estimates to be made to determine patronage because sites have either restricted or nonexistent usage before the improvement is made. The technique reported by Templer (61) for measuring pedestrian activity provides useful guidance for estimating over- and undercrossing patronage. The technique recognizes differences in data availability and staff availability and expertise required to produce the estimates. Essentially, the process is comprised of three methods. Utilization of data available from already completed origin destination studies is one method. A second approach involves gathering data about residential population distribution; concentrations of trip destinations, primarily in non-residential areas (shopping, office, service-institutional recreational, etc.); locations of special attractors of bicycle, pedestrian and handicapped travel; and trip making patterns and preferences. The third method is intuitive, relying upon detailed and accurate personal knowledge of members of an advisory panel. The second method is seen as being one which would be followed in most instances.

Other Pertinant Data. Information which is relevant to analyzing a crossing situation or evaluation alternatives, but which is not included in the above descriptive categories, should be recorded here.

4.4.3 Examining Alternatives

The next step in the need assessment process should be to explore various non-structural and structural alternatives to meeting the requirements of the crossing situation.

Non-Structural Solutions. First consideration should be given to non-structural solutions. These can be grouped into six categories: (1) Status Quo; (2) Traffic Control Strategies; (3) Alternative Routes; (4) Alternative Travel Modes; (5) New Technology; and (6) Land Use Planning. They are described in further detail subsequently in Chapter 7. Non-structural solutions can be selected from one or more of these categories and may be used as the only recommended improvements or in combination with structural improvements, in order to reduce the cost of the latter. Non-structural solutions can be low cost or high cost improvements.

Low Cost Non-Structural Solutions. Each of the six non-structural categories have low cost solutions within them and these should be considered first. Status quo is essentially a decision to do nothing, which may be the final approach adopted, depending upon the results of the analysis of other strategies. Relatively minor traffic control modifications are a common example of low cost, non-structural solutions. Utilization of alternative routes to circumvent a barrier may also be a satisfactory low cost solution where little or no improvements are necessary to the existing street network. Alternative travel modes, if requiring only rerouting or rescheduling of existing services, may be an inexpensive solution to some crossing problems.

Document Reasoning. If a low cost, non-structural solution is selected, the reasons for its selection should be documented, together with the reasons for rejecting other solutions considered.

Recommended Low Cost, Non-Structural Solutions. Recommended low cost non-structural improvements should be described in detail, along with preliminary cost estimates. This information is then entered into the ranking process so that the priority of the proposed improvements can be established.

Status Quo. The decision to make no improvements at all based upon a thorough assessment of alternative methods of solving the problem at the potential site is a definite option for short-term as well as long-term planning. If this conclusion is reached, the reasoning should be documented and the recommendation made that no modifications be implemented.

If neither a low cost, non-structural solution nor maintaining the status quo appears desirable at this point, higher cost, non-structural alternatives, such as signalization or transit, and structural alternatives should be evaluated.

High Cost, Non-Structural Solutions. Each of the six non-structural solution categories have high cost versions. Continuance of the status quo may have high cost consequences for impacted travelers, for instance, while alternative route utilization may require extensive upgrading to make it accessable and safe, as another example. Each of the six categories should be reviewed and any promising possibilities identified.

Structural Solutions. Construction of a new or retrofitting an existing grade separation may prove to be the most effective method of providing access across the barrier. Representative examples of such strategies are described in detail later in this chapter. Preliminary decisions should be made to determine the basic type of structure required (whether over- or undercrossing, new or retrofit, and so on), using design selection criteria described elsewhere in this report.

At this stage in the process, one or more high cost, non-structural alternatives and one or more potential structural solutions will have been selected for further analysis. The process can then be continued so as to establish the relative attraction for various alternatives at the same site, or to establish the relative priorities of improvements at a number of different sites.

4.4.4 Mandatory Pre-Conditions

For high cost improvements to be justified, whether structural or non-structural, there are two pre-conditions which must be satisfied before these strategies merit further consideration. These are permanence of conditions and engineering feasibility.

Permanence of Conditions. The site conditions requiring a high cost alternative and the anticipated service life of the improvement must be sufficiently long lasting to justify the expenditure of funds involved.

Engineering Feasibility. The proposed improvement must be feasible with regard to satisfying accessibility and engineering design criteria.

Reject Solution. If one or both mandatory pre-conditions cannot be satisfied, then the high cost solutions should be rejected.

Re-evaluate Alternatives. If the original high cost solutions have been rejected, alternatives must be re-evaluated to determine if there are any other promising low cost or high cost strategies that may be acceptable before concluding that the only acceptable course of action is to maintain the status quo.

4.4.5 Reviewing Warrants and Criteria

If both mandatory pre-conditions are found to exist, for either structural and/or high cost non-structural alternatives, the next step is to evaluate the degree to which each solution satisfies adopted warrants. The warrants and criteria fall into six categories: economic, threshold, system, point rating, policy and political prerogative (community input). A procedure which combines all, or elements of all of these areas, appears to be the most reasonable method of determining relative need for bicycle and pedestrian facilities. Each of the warrant and criteria categories should be reviewed and procedures exercised where found to be applicable.

In order to estimate how well each warrant is satisfied, the alternative strategy will need to be detailed to the point where various input data (such as cost, for example) can be estimated. The process is essentially an iterative one which should be repeated as required until the alternative is sufficiently refined or is rejected as not being applicable.

Established Policy. Established policies or pre-determined guidelines affecting various aspects of non-motorized travel are useful tools when assessing facility need. Increased use of policy-based decisions will simplify the warrant process. The following list are examples of general policies affecting non-motorized travel which might be considered:

- Pedestrian patterns should be maintained across limited access roadways and major arterial routes where such patterns have been established prior to construction of the roadway.

- Where pedestrian and/or bicycle facilities exist on the approach roadway, they should be continued across the vehicular structure.

- Consideration should be given to a pedestrian/bicycle grade separation only when the conditions that require the structure are likely to continue indefinitely.

- Every effort should be made to provide an overcrossing rather than an undercrossing, unless special circumstances particularly favorable to an undercrossing exist.

- Bicyclists should be allowed to utilize shoulders of limited access roadways wherever the safety and convenience thereon is greater than alternative routes available to bicycle travel.

- All pedestrian facilities should be accessible to the handicapped.

- Space for pedestrians and bicycles should normally be included in the design of all new highway grade separations.

- Pedestrian and bicycle facilities should generally be provided on both sides of grade separations shared with motor vehicles.

- Space for pedestrians and bicycles should be available on all grade separations along designated emergency evacuation routes in urban areas.

Policies are not meant to be followed indiscriminately. When specific situations appear not to justify following the directive set forth in a policy, then a rationale should be developed for a variance to the established policy. The burden of proof, however, would then rest on those who believe non-motorized facilities should not be provided as stated in the policy. Typically, this procedure would involve technical staff presenting professional opinions as to why, in that particular instance, the policy should not be applied and what alternatives should be considered instead.

Political Prerogative. Citizen and community representatives can provide valuable assistance to planners and designers during the planning and design stages of over- and undercrossing projects. Public participation is typically solicited and generally takes the form of public hearings and advisory committees as means by which local preferences can be expressed. Therefore, many of the basic questions have already been studied in detail and resolved prior to the public hearing. This process allows decision-makers to focus their attention on the remaining questions and thereby maximize the opportunity to further improve the proposed facility. Community input is most effective when provided throughout the planning process, rather than after many of the important decisions have been made.

A specialized form of community input involving the handicapped should also be considered. For instance, panels made up of persons with varying disabilities were used successfully in this study to provide insight into special travel problems. This type of input would be very useful in the planning and site evaluation stages of future over- and undercrossing projects and make it possible for planners and designers to develop facilities more responsive to the site specific needs of the handicapped. Wherever possible, local handicapped persons should be involved in the process.

Similarly, bicyclist organizations and jogging clubs can also contribute their users perspectives on needs and relative attractiveness of design approaches and details.

4.4.6 Establishing Priorities

Structural and high cost, non-structural solutions assessed in the previous step now can be either rejected or relatively ranked, depending upon the degree to which they satisfy the warrants and criteria.

Identify the Degree of Satisfaction. Each alternative evaluated satisfies a warrant or criteria to a certain degree, The cumulative result may range from being very positive to very negative. The more absolute negative factors, such as those contrary to an adopted policy or strongly opposed by the community, may be sufficient reason to completely reject the alternative. Those alternatives which do not have a clear reason for rejection are carried forward and prioritized.

Reject Alternative. If an alternative is rejected, the next step is to re-evaluate other non-structural and structural solutions to determine if there are other strategies which hold promise. This re-evaluation may lead to other solutions which are not rejected and become eligible to be prioritized or the result may be that no solution is acceptable and the status quo is retained.

Prioritize. This process can be used to help select a preferred alternative from among the various possible improvements at one given site or to help establish the relative priorities of improving a number of sites competing for limited funds, depending upon how well the criteria are satisfied. At this stage in the planning process, priority is probably best indicated by broad groups (high-medium-low), rather than by giving a numeric point score implying a more rigid sequential priority. Grouping allows flexibility and facilitates the project selection and budgeting process. Community participation is very useful in establishing priorities. The panel of handicapped persons mentioned earlier could provide insight as to locations particularly important to handicapped accessibility, while other user groups can help in identifying those projects which would be particularly beneficial to them.

4.4.7 Implementation Action

Proposed improvements should then be categorized with respect to type of action anticipated for implementation. This includes establishing short-term and long-term priorities, as well as noting the existance of special opportunities for implementation.

Short-Term Project. There are generally improvements which can be completed within a two-year period. Low cost, non-structural solutions, as well as very urgent structural or high cost non-structural solutions would often be in this category. The design of a future project could also qualify as a short-term priority.

Long-Term Project. Projects to be implemented within the two to five-year range, as well as those in the more distant future, can be classified as long-term projects. Expensive projects most often will require more time to implement because of funding limitations and the longer lead time to fulfill approval, coordination design and other requirements. There are some instances where desired improvements logically hinge upon completion of other projects. Therefore, even a relatively inexpensive solution may have to be deferred and should therefor be classified as a long-term project.

Special Opportunities. Special opportunities for implementation may arise and thereby accelerate the implementation of a project, regardless of its relative priority. Some examples of circumstances which may create special opportunities include sudden positive changes in funding availability; land developement or redevelopment; construction or rehabilitation of a grade separation; construction of any kind which creates a barrier to non-motorized travel or catastrophies which damage or collapse existing grade separations and which require immediate attention. Special opportunities can best be taken advantage of where the planning process has already identified the preferred alternative movement, thereby enabling timely decisions to be made to include the appropriate type of non-motorized facilities.

CHAPTER 5
DESIGN SELECTION CRITERIA AND DESIGN CONCEPTS

5.1 INTRODUCTION

This chapter describes a series of basic questions on design selection criteria for which the answers provide guidance in determining whether structural or non-structural alternatives are most appropriate. In addition, various elements of the system developed to classify new and retrofitted structures is presented and explained. Both design selection criteria and design concepts lead directly into the Design Approaches and Strategies documented in Chapter 7.

5.2 DESIGN SELECTION CRITERIA

Once the decision has been made to provide some sort of crossing facility, the next question to be resolved is identification of the most appropriate solution. Design selection criteria are defined as those measures which help select the preferred basic design type or types from among a variety of possible alternatives available at a crossing site. It should be kept in mind, however, that over- and undercrossings should be considered as parts of existing and future transportation systems, and their elements -- end conditions, approaches, structure -- must also be designed as a system.

Early answers to fundamental questions regarding selection criteria are very useful, since they focus design efforts on the most productive areas. Fundamental questions to resolve include:

- Non-Structural versus Structural Solutions
- Over- and Undercrossing
- Exclusive or Shared Structure
- New versus Retrofit Structure
- One-Sided versus Two-Sided Facilities
- Need for Special Features

Approaches which help answer each of these questions are discussed in the following paragraphs:

5.2.1 Non-Structural versus Structural Solutions

The first decision which should be made is whether the problem is solved best by a non-structural solution or a structural solution. Since non-structural solutions can usually be implemented faster and/or at less cost than structural solutions, they should always be considered first. Non-structural solutions for non-motorized travelers are defined as those solutions which:

- Utilize existing structures without requiring modifications of structural features; or
- Provide alternative travel routes; or
- Reduce the need to cross barriers; or
- Provide alternative travel modes.

The various types of non-structural solutions are described in detail in Chapter 7 of this report, where Design Approaches and Strategies are presented.

5.2.2 Over- or Undercrossing

If it has been decided that a structural solution is appropriate to meet the needs of non-motorized travelers, the next decision is whether the grade separation should be an overcrossing or an undercrossing. In most instances, this is a relatively straightforward decision based on such fundamental questions as ...

- Do site conditions favor an overcrossing or do they favor an undercrossing? (See Table 2.)

- Is there an existing over- or undercrossing which can be shared or retrofited?

- Are there adopted policies favoring over- or undercrossings in similar situations?

Answers to these questions should readily resolve the appropriateness of an overcrossing or undercrossing.

5.2.3 Exclusive or Shared Structure

Another early decision to be made is whether the grade separation should exclusively serve non-motorized travel or whether it should serve both motorized and non-motorized travel. Again, the answers to the following provide guidance:

- Is an existing or planned vehicular structure available?

- Is there space available on the structure to accommodate non-motorized travel?

- If not, is it feasible to retrofit the structure to create the space necessary for non-motorized travel?

- Are there reasonable alternative routes available for non-motorized travelers to cross the barriers?

YES answers favor a shared facility, while if all answers are NO, an exclusive bicycle/pedestrian grade separation should be explored.

TABLE 2
Typical Ramp Lengths For Overpasses and Underpasses*

Description of Structure	Elevation Change	Approximate Length of One Approach Ramp**	
		8% Grade	10% Grade
UNDERPASSES:			
Pedestrian Undercrossing beneath public highway	10-12' descent	140'	110'
Pedestrian Underpass beneath railroad	10-14' descent	150'	125'
Vehicular Undercrossing, where sidewalk follows same grade as vehicular roadway rather than elevated independent grade (15 ft. vehicular clearance)	18-20' descent	240'	190'
Vehicular Underpass under railroad, where sidewalk follows same grade as vehicular roadway rather than independent grade (15 ft. vertical clearance)	19-24' descent	270'	215'
OVERPASSES:			
Overpass spanning Interstate highway with a 17' vertical clearance	19-21' ascent	250'	200'
Overpass spanning public street with a 15' vertical clearance	17-19' ascent	225'	180'
Overpass spanning railroad, non-electrified, with 23' vertical clearance	27-30' ascent	360'	285'
Overpass spanning railroad, electrified or requiring provisions for future electrification, 26' vertical clearance	30-33' ascent	400'	315'

To convert to metric, multiply Feet x 0.3048.

Source: De Leuw, Cather & Company.

* In some marginal cases the choice between an overcrossing or undercrossing may depend on the ramp lengths required and the impact of such ramps. This table displays the lengths required for a variety of elevation changes.

** Landings not considered, but if used will lengthen the approach ramp.

5.2.4 New versus Retrofit Structure

Several questions should be asked to confirm the need for a new or retrofited structure. They are as follows:

- Is there an existing structure?
- If yes, is it structurally feasible to modify the existing crossing to accommodate non-motorized users?
- Is the remaining life of the existing structure sufficiently long to amortize the expense of modification?

If any of the answers to the above questions are NO, then a retrofit solution is either not possible or not practical. If all answers are YES, then a retrofit solution should be considered along with new structures which appear to be feasible. Ultimately, cost estimates may be the single most important deciding factor between new and retrofited facilities.

5.2.5 One-Side versus Two-Side Non-Motorized Facilities

There are often pressures to reduce costs by providing pedestrian/ bicycle facilities on only one side of a structure, regardless of the consequences. Two-sided facilities are the preferred design for most shared grade separations because of safety reasons. It is very important that pedestrians and bicyclists should not needlessly have to cross a travelway to use a one-sided facility. However, there are certain special circumstances where non-motorized facilities on one side may be acceptable. To ascertain such acceptability, the following questions should be asked:

- Does the structure serve one-way traffic?
- Is a central pathway position feasible?
- Do all non-motorized travelers use a single, separate pathway on both ends of the structure?
- Is a culvert or tunnel used?

YES answers indicate a situation where a one-side facility may be acceptable. There may also be situations where one-sided non-motorized facilities can be tolerated as a temporary solution prior to completion of two-sided facilities.

5.2.6 Special Design Features

Special design features may be required to facilitate access and enhance use by non-motorized travelers in the presence of certain site characteristics. These features are described in the following paragraphs, together with the applicable site conditions.

Rest Areas. These are places where non-motorized users can stop and rest. Typically, a rest area is flat or has a flatter grade than the adjacent segment. Hand rails and sitting places may also be provided. A rest area may be created as a by-product of a specific design. For instance, a switch back ramp design has landings each place that the ramp changes directions. Other rest areas are especially created. Site conditions indicating that a rest area should be considered are:

- Regular use by the handicapped.

- Long ramp (greater than 100 feet)

- Steep ramp (exceeding the 5 percent desirable maximum)

- Limited approach space which may result in steep ramps.

- Connection to a transportation terminal or other high usage area where significant numbers of handicapped, elderly or travelers carrying bundles can be expected.

- Scenic view opportunities where persons stop for sightseeing.

Special Signing. These can be very helpful in regulating, warning or guiding users along and through a transportation system. Signing serves to increase the users' degree of confidence, allows persons to decide early whether or not to use the route, and serves to avoid surprises along the way. Site conditions indicating that special signing may be needed are as follows:

- Complex crossing situations.
- A large number of infrequent users.
- Regular use by the handicapped.
- A connection to a transportation terminal or other high usage area.
- Scenic view opportunities.

Elevators/Escalators. Specialized equipment can serve a very useful purpose in certain situations. Some fundamental access site characteristics indicating potential use of elevators include:

- Frequent use by the handicapped.
- Connection to transportation terminal or other high usage area.
- Regular access is via stairs or long and/or steep ramps.

View Screens. These are provided to preserve the privacy of adjacent land uses; such as where residential privacy is infringed upon by users of grade separations, for example.

Sound Screens. These are used in areas where high noise levels impact adjacent land uses. Sometimes view screens can also serve to decrease noise levels. At other times, a grade separation itself may functionally serve as a partial sound barrier. A sound barrier is typically placed to protect adjacent land uses and they are rarely used to reduce sound impact on the users of a grade separation, although this is sometimes an additional benefit.

Wind Screen. This special design feature is sometimes installed in extremely windy areas where grade crossing users would be adversely affected. View screens and sound screens may also provide some protection from the wind.

Surface Treatments. These are important to assure user stability and usability during a variety of weather conditions. Textured pavement could include brushed surfaces or surfaces with imbedded grit. Pavement grooving is another technique used to provide improved traction. Open grating has been used successfully to lessen the impact of snow accumulation. Site conditions indicating potential use of special surface treatments include.

- Regular use by handicapped.
- Steep grades.
- Connection to transportation terminal or other high usage area.
- Snow accumulation.

5.3 DESIGN CONCEPTS

As part of the Research and Development phase of this study, methods were explored to categorize and classify types of design strategies. A classification system was developed for each of the two major categories, new projects and retrofit projects. Classifying the project types and analysis of the 72 case studies led to the development of initial generic prototypical solutions applicable to the majority of crossing situations. Further treatment and refinement were directed toward concepts of non-structural, as well as structural solutions; innovative and unusual treatments were also analyzed. A summary of these results is presented in this section.

5.3.1 Crossing Classification Systems

A classification system was developed to facilitate organization and analysis of the case studies assembled early in the study and as a base from which to refine prototypical solutions. The 72 case studies were first divided into new and retrofit projects. The projects were further separated, as follows, in Figure 4.

NEW PROJECTS

- <u>Main crossing purpose</u>.
    - movement of motor vehicles
    - serve bicyclist and pedestrian travel
    - other purposes (carry utilities, etc.)

- <u>Crossing type</u>.
    - overcrossings (overpass or bridge)
    - undercrossing (underpass or tunnel)

- <u>Motor Vehicle Traffic Characteristics or Length of Structure</u>.

RETROFIT PROJECTS

- <u>Situation</u>.
    - addition of bicycle and pedestrian facilities where they did not previously exist.

    - expanding or upgrading existing bicycle and pedestrian facilities.

    - widening, expansion, or repair to accommodate additional motor vehicles and simultaneously adding bicycle and pedestrian facilities.

    - conversion of an existing structure to the exclusive use of bicyclists and pedestrian.

- <u>Crossing type</u>.
    - overcrossing
    - undercrossing

- <u>Solution characteristics</u>.
    - type of alteration: cantilever, traffic barrier addition, etc.

    - type of structure modified: highway bridge, culvert, railroad trestle, etc.

Figure 4. CROSSING CLASSIFICATION SYSTEM

In developing the classification systems for new and retrofit projects, it was found that the kind of barrier crossed -- water, roadway, railroad, or other -- can greatly affect parts of the overall structural design and the total cost of a project, but has virtually no influence on design strategies for bicycle and pedestrian facilities and their categorization. For instance, the operational characteristics of non-motorized travel on a bridge over a river or on an overpass over a roadway are usually indistinguishable.

The classification systems developed for new and retrofit projects are illustrated in Figures 5 and 6, respectively.

5.3.2 Derivation of the Prototypical Design Strategy

Using both classification systems, it is possible to identify 14 categories of design types for new projects and 23 for retrofit projects. Fortunately, all of these design types need not be considered as different design strategies. From the perspective of providing facilities for the bicyclist and pedestrian, many structural and crossing types can be considered to be the same. Further, the design strategies for retrofit and new projects act in a complementary manner to each other. Particular features, such as placement of traffic barriers, shown in one strategy are often applicable in another as well.

Consideration of these factors, plus the desirability of reducing the number of design strategies to a more manageable number, resulted in the selection of generic prototypical new projects and retrofit projects. These solutions are representative of the majority of crossing situations encountered and contain both structural and non-structural elements. They constitute a sufficiently comprehensive display from which an appropriate design for a specific site condition can reasily be extracted. Selected examples of these prototypical design strategies are included in Chapter 7, Design Approaches and Strategies, of this report.

It should be generally noted that a policy of providing access for the handicapped is a principal design consideration responding to federal and many state standards, and has been followed in this report.

Currently, maximum or minimum allowable design standards are often applied in practice, whereas use of desirable design standards would be preferable. There is almost no conflict in design standards for bicyclists, pedestrians and the handicapped if the most desirable standards for each group are used, rather than maxima or minima. In fact, inclusion of desirable features for one group of non-motorized users usually enhances travel for the others as well. In view of current operating practices, it must be assumed that bicyclists, pedestrians and the handicapped will all use the same facility.

MOTOR VEHICLES GRADE SEPARATION

Overpass or Bridge		Underpass		Tunnel	
TRAFFIC CHARACTERISTICS		TRAFFIC CHARACTERISTICS		TRAFFIC CHARACTERISTICS	
$\boxed{1}$	$\boxed{2}$	$\boxed{3}$	$\boxed{4}$	$\boxed{5}$	$\boxed{6}$
4 or more Traffic Lanes & Speeds over 35 MPH & Medium to Heavy Traffic *	2 Lanes or 4 Lanes Speeds 35 MPH or less Light to Medium Traffic	4 or more Traffic Lanes Speeds over 35 MPH Medium to Heavy Traffic *	2 Lanes or 4 Lanes Speeds 35 MPH or less Light to Medium Traffic	Medium or Heavy Traffic	Light Traffic

BICYCLE/PEDESTRIAN GRADE SEPARATION

Overpass or Bridge		Underpass or Tunnel	
LENGTH		LENGTH	
$\boxed{7}$	$\boxed{8}$	$\boxed{9}$	$\boxed{10}$
Over 100' *	100' or less*	Over 100' *	100' or less*

OTHER TYPE (UTILITIES ETC.) GRADE SEPARATION

Overpass or Bridge		Underpass or Tunnel	
LENGTH		LENGTH	
$\boxed{11}$	$\boxed{12}$	$\boxed{13}$	$\boxed{14}$
Over 150'	150' or less	Over 100'	100' or less

To convert to Metric Multiply Feet x 0.3048 and MPH x 1.609

* Solution illustrated in Chapter 7

Figure 5. NEW PROJECT-GRADE SEPARATION CLASSIFICATION

<table>
<tr><th colspan="8">SITUATION CATEGORY</th></tr>
<tr><td colspan="2">Addition of bicycle and pedestrian facilities where they did not previously exist.</td><td colspan="2">Expansion or upgrading of existing bicycle and pedestrian facilities.</td><td colspan="2">Widening, expansion, or repair to accommodate additional motor vehicles and simultaneously add bicycle and pedestrian facilities.</td><td colspan="2">Convert an existing over or undercrossing to exclusive use of bicyclists and pedestrians.</td></tr>
<tr><th colspan="8">SOLUTION CHARACTERISTICS</th></tr>
<tr><td><u>Overcrossing</u></td><td><u>Undercrossing</u></td><td><u>Overcrossing</u></td><td><u>Undercrossing</u></td><td><u>Overcrossing</u></td><td><u>Undercrossing</u></td><td><u>Overcrossing</u></td><td><u>Undercrossing</u></td></tr>
<tr><td>1 Cantilever*
2 Traffic Barrier Addition
3 Railing Alteration
4 Adjacent Structure</td><td>5 Traffic Barrier Addition
6 Slope Cut/ Retaining Wall</td><td>7 Railing Alteration
8 Cantilever
9 Adjacent Structure</td><td>10 Traffic Barrier Addition*
11 Slope Cut/* Retaining Wall
12 Horizontal Separation At-Grade</td><td>13 Widen Deck
14 Adjacent Structure</td><td>15 Traffic Barrier Addition
16 Retaining Wall</td><td>17 Railroad Trestle*
18 Highway Bridge*
19 Utility Bridge</td><td>20 Railroad Tunnel
21 Highway Tunnel
22 Utility Tunnel
23 Culvert*</td></tr>
</table>

* Solution Illustrated in Chapter 7

Figure 6. RETROFIT PROJECT CLASSIFICATION

5.3.3 Non-Structural Solutions

Non-structural solutions provide a crossing service to non-motorized users without construction or modification of structural features. They may include operational changes to existing structures, providing alternative travel routes, removal or reduction of the need to cross the barrier, and provision of alternative travel modes. The use of non-structural strategies can sometimes provide crossings for bicyclists, pedestrians, and the handicapped with minimal investments of time and money. They should be given priority consideration involving crossing problems. Non-structural solutions can be grouped under five headings; these are listed below and discussed in detail in Chapter 6.

- Traffic control strategies
- Alternative routes
- Alternative travel modes
- New technologies
- Land use planning

5.3.4 Structural Solutions

Structural solutions involve construction or removal of physical facilities to accommodate bicyclists, pedestrians and the handicapped. As already mentioned, there are two major classes of projects, new and retrofit. The non-motorized travel way on new projects can be part of a bridge, overpass, underpass, or tunnel, whose major purpose is the conveyance of motor vehicles, or it can be a separate structure intended solely for the use of bicyclists and pedestrians. Bicycle and pedestrian crossings will continue to be primarily built as part of motor vehicle crossings because of the cost savings inherent in combined facilities and the difficulty of justifying the cost of facilities for the exclusive use of non-motorized travelers. Most of the facilities, whether on combined or exclusive structures, will be overpasses or bridges rather than undercrossings or tunnels.

Retrofitting involves the addition of facilities to existing structures, or the conversion of existing structures to non-motorized use. Retrofitting existing structures to create or modify facilities for non-motorized users is still relatively rare and is usually undertaken in conjunction with other repairs or reconstruction. Designing quality of retrofit facilities is usually more difficult than design of new projects, since existing conditions sometimes restrict opportunities to implement desirable designs.

New Project Structural Solutions. A major determinant of the characteristics of non-motorized facilities is the primary purpose of the crossing. While all bicycle and pedestrian facilities should adhere to design standards, the construction materials and the physical layout of approach and end conditions will vary depending upon whether the crossing primarily carries motor vehicles, bicycles and pedestrians, or utilities.

- Structures Shared with Motor Vehicles. In some instances, space must be allocated on the structure and approach roadway cross-sections to enhance safety and ease of operations for bicycle and pedestrian travel. This could involve a wider deck on a bridge or overpass, or additional shoulder area in an underpass. For an underpass, a separated path or sidewalk is also an alternative.

  Physical barriers, such as New Jersey barriers or vehicle guardrail, should be considered where traffic is heavy or operates at high speed and the bicycle and pedestrian travel way is adjacent to that for motor vehicles. Vertical or horizontal separation of non-motorized and vehicular ways is also a possibility, particularly on approaches. Where motor vehicle traffic volumes are relatively light and slower, signing and striping may provide adequate protection for the non-motorized user.

  Difficulties for the bicyclist and pedestrian can occur at the ends of the crossing where the existing sidewalk, bikeway and street system begin, and where vehicular traffic may have to be crossed in order to proceed in a desired direction. Special attention must be paid to signing, striping and signalization to insure safe operating conditions; especially where end conditions require complicated movements to be made by the non-motorized traveler.

- Structures for Bicyclists and Pedestrians Only or Shared with Utilities. Opportunities for providing a good crossing for the non-motorized traveler are greatly enhanced when motor vehicles are eliminated from design considerations. In such instances, the length of the structure then exerts the most significant influence on the design by generally eliminating use of some materials, such as wood, for longer span overcrossings. However, bridges, underpasses, and tunnels for bicyclists and pedestrians are usually constructed using the same materials and construction techniques as for motor vehicle structures.

  Advantages in both aesthetics and cost can be achieved by combining utility crossings with those for bicycles and pedestrians. The utilities can often be fastened below or alongside the bridge deck. The disadvantage may be that the optimum crossing point for the utility and for bicycle and pedestrian travel may not be coincident.

  End conditions for the solely non-motorized facility can often be complex when users rejoin the existing street and pedestrian travel system. In addition, posts, gates, or other barriers, may be required to prohibit use of the facility by motor vehicles. Some of these barriers present operations hazards to bicyclists and the handicapped as well, however.

Retrofit Structural Solutions. Where a retrofit solution adds bicycle and pedestrian facilities to a structure shared with motor vehicles, there are three basic methods of providing space. These are: reallocation of existing space to the non-motorized traveler; construction of additional space; or some combination of these.

As was the case with new construction, a degree of separation must be provided between motor vehicles and bicyclists and pedestrians. Separation can be accomplished by addition of a physical barrier if traffic is heavy or high speed, or by striping and signing if motor vehicles constitute less of a hazard. There are some instances where an unmarked shoulder of adequate width is satisfactory.

To gain additional space on overpasses or bridges, it may be possible to cantilever additional decking from the existing structure or to construct an adjacent fully or partially self-supported structure. Either method could provide all of the required space, or could be combined with some deck space from the existing overcrossing.

Underpass roadway sections may have to be modified by excavation of adjacent cross slopes and possibly construction of retaining walls in order to gain additional space.

Another form of retrofiting is the total conversion of an existing structure to bicycle and pedestrian use. Abandoned or greatly underutilized railroad trestles, highway bridges, and large culverts are prime candidates for this type of changeover.

5.3.5 Innovative and Unusual Treatments

Innovation is defined as something new or different or changes in anything established. Innovation ranges from minor modifications to direction-setting technological breakthroughs. In regard to over- and undercrossings, innovation is applicable to design strategies, design review, project implementation, maintenance, and user education.

At present, there appears to be no anticipated major technological breakthrough that will drastically change development of structures for non-motorized facilities. However, there are a number of modifications or enhancements of existing methodology and procedures which can be considered innovative. While unusual crossing treatments and applications of new technologies may represent satisfactory design solutions in only very limited instances, they still should be kept in mind in view of their potential benefits and/or lower cost. These are discussed further in Chapter 6 under the following four headings:

- Unusual locations and facility configurations
- Recycled materials
- Construction techniques
- Alternative methods of conveyance

CHAPTER 6
FIELD EVALUATIONS

6.1 INTRODUCTION

A number of site investigations were carried out in the course of this study, as described earlier in Chapter 2. The basic purpose of this activity was to evaluate some of the promising new designs, design modifications and non-structural solutions previously identified among the 72 case study examples of current practice cited earlier. The results of these evaluations are summarized in this chapter. These evaluations, together with the design strategies discussed in Chapter 7, provide the reader with descriptions of a number of good treatments and suggested design features, both conventional and innovative, for accommodating non-motorized travellers on over- and undercrossings. The discussion below also includes perceived deficiencies, as well as the favorable aspects of the various crossings studied.

The field work involved comprehensive evaluations at six selected sites; visits to three locations in California and four in Florida, where the reactions of a panel made up of persons with a variety of physical disabilities were obtained. In addition, team members visited, photographed and informally observed almost 200 other grade separations throughout the duration of the study.

6.2 COMPREHENSIVE EVALUATION SITES

The locations and types of facilities selected by the study team in consultation with FHWA staff for comprehensive evaluation were:

Palo Alto, California. An exclusive bicycle and pedestrian bridge with an approach cantilevered along a drainage canal was selected as the site of the pilot study carried out to test and refine the site evaluation procedures.

Sunnyvale, California. A new exclusive pedestrian and bicycle overcrossing of a busy freeway at this location was chosen as a representative example of a facility with the latest treatments intended to facilitate use by the handicapped.

Eugene, Oregon. Two structures were evaluated in detail in Eugene. One location combines a bicycle and pedestrian undercrossing of the Southern Pacific Railroad with a nearby bicycle and pedestrian bridge over the Willamette River. The second facility is a retrofitted direct ramp connection for bicyclists and pedestrians only, leading from the sidewalk along one side of a four-lane highway bridge to a park and riverside trail system.

Hampton, New Hampshire. A retrofitted bicycle and pedestrian facility cantilevered from a highway bridge over a railroad was analyzed at this location.

Route 183, Randolph Road, Maryland. This site was chosen for its modified box culvert featuring an elevated pathway capable of use during most of the year as an underpass, except when it becomes innundated during periods of high water.

Austin, Texas. Special off-street facilities have been constructed to accommodate bicycle and pedestrian travel through a complex interchange made up of one-way streets and ramps.

Following a discussion of general observations and findings drawn from composite results of the six studies, individual design characteristics and construction costs of each of the six sites are described below. More detailed descriptions of each site is contained in the Appendix.

6.3 GENERAL OBSERVATIONS

A number of especially good design features were noted during the evaluation visits and these are indicated in Table 3.

The deficiencies which were observed fell into three general areas: signs, signals and markings; maintenance; and design features. The major findings in each of these areas are summarized below.

6.3.1 Deficiency in Signs, Signals and Markings

By far the most common deficiency of the sites visited pertained to a general lack of guide and directional signing facilitating travel by bicyclists and pedestrians. The next most common deficiency related to signing was lack of proper horizontal and/or vertical clearance between the sign or sign post and the pathway edge. Deficiencies and problems identified at one or more of the six evaluation sites can be summarized as follows:

- Lack of guide and directional signs causes confusion.
- Lack of regulatory signing at beginning of pathway to inform bicyclists and pedestrians where usage is mandatory.
- Improper signing which is either unclear or inappropriate.
- Lack of additional advance warning signs where needed, such as at sharp curves, overhead clearance restrictions and flooding conditions.
- Raised pavement markers utilized to separate vehicular traffic from bike lane users, whether regular or oversized, create a potential hazard to bicyclists who may need to cross or travel where markers are placed.

Table 3. Site Evaluation
Especially Good Features

Feature	Palo Alto	Sunny-vale	Eugene	Hampton	Mary-land	Austin
Early and/or continuing planning	X	X	X	X	X	X
Rest areas		X	X			X
Uniform treatment on several structures						X
Path widening at curves			X			X
Pathway takes advantage of topo and surroundings	X		X		X	X
Added lighting						X
Took advantage of existing street lighting	X					
Aesthetic use of wood	X					X
High quality, sturdy, graspable handrail		X		X	X	
Bolt treatment to cover exposed ends				X		
Treated decking solidly attached to structure				X		
Heavy broom finish on walk surface			X			
New Jersey barrier separation from traffic			X			
Selective placement of guide and directional signs	X		X			
Bike lane transition weaving section			X			
Rest areas off pathway		X	X			X
Edge stripe			X			
Centerline stripe helps night-time visibility			X			
Continuous graspable handrail		X				
Recessed lighting		X				
Rubberized joint connection		X				
View screen	X	X				

- Lack of reflectorization or other delineation of bridge columns or utility poles close to the pathway.
- Signs placed too close to pathway edge thus restricting either horizontal and/or vertical clearance.
- Edge striping or centerline striping which is lacking where the pathway curves, or is subject to congestion. Striping has also been found helpful to guide bicyclists riding at night through remote and unlit areas.
- Lack of crosswalk delineation at ramps and end conditions is sometimes a disadvantage to a non-motorized traveler.
- Lack or improper placement of pedestrian signals at signalized intersections creates crossing problems for bicyclists and pedestrians.
- Lack of PED or BIKE XING advance warning signs at pathway crossings.
- Lack of signing or marking to identify the location of special rest areas.
- Lack of striping to delineate the approach to a barrier post intentionally placed in the pathway to prohibit motor vehicle access.

6.3.2 Deficiency in Maintenance

Maintenance is a continuing necessity which, if not properly performed, can decrease the effectiveness and attractiveness of even the best design. While some degree of maintenance must always be performed, proper design can minimize the magnitude of maintenance effort and costs required. Most of the maintenance deficiencies observed at the site evaluation locations were related to debris or vegetation on the pathway. Most of these were impediments rather than hazards. However, left unattended, an impediment can become a hazard or a barrier to travel. Some major maintenance deficiencies observed during the field evaluations are listed below.

- Glass, sand and miscellaneous debris deposited in bike lanes or shoulder areas utilized by bicyclists and pedestrians.
- Grass clippings on pathway creating the potential for slippery spots on the pavement.
- Weeds and grass overgrowing the pathway; varying from localized intrusion to long stretches of overgrowth.
- Tree branches overhanging pathway.
- A hazardous intrusion penetrated pathway space. (For example, at one location a metal anchor for a utility pole guy wire was bent into the pathway.)
- Debris on pathway from construction or maintenance operations.
- Sediment deposited on the pathway as a result of flooding. In some cases this is a seasonal event (as with pathways sharing culverts) and in other cases it occurs only during major flooding.
- Creek erosion of the pathway.
- Pathway shared with horses thereby requiring more frequent maintenance to remove droppings.
- Lighting which has burned out or which has been vandalized.

6.3.3 Deficiency in Design Features

Design features identified as deficiencies during the site evaluations typically involved features which were incomplete and can be subdivided into three categories: Alignment and Clearances; Sight Distance and Pavement Quality; and Appurtenances. The incidence of notable design error was low. Identified deficiencies and some desirable practices include the following:

Alignment and Clearances

- Pathway alignment which passes too close to a horizontal obstruction, especially where an alternative alignment is available.
- Locations where there are deficient or low and variable vertical clearances.
- Inadequate maneuvering space at the intersection of a new pathway and existing sidewalk. This may require that the existing facility be widened at least for a transition distance in the vicinity of the intersection.
- Alignments which promote the development of major or minor short cut usage. A typical example would be a looping alignment where a straighter, more direct route is available.
- Pathway alignments passing areas or localized points where existing features significantly contribute to the maintenance requirements. An example would be fruit trees or shrubs which seasonally deposit heavy concentrations of fruits and berries onto the pathway surface.
- Termination of construction at the exact limit of one agency's jurisdiction without regard for site characteristics can result in problems. One case observed left unsolved the erosion of a creek bank which, over time, would encroach upon the pathway extension. As a consequence, future construction may be more difficult and costly than if the extension was completed at least past the critical creek area, as part of the original project.
- Additional bridge widening was needed to conform with the approaches and to facilitate shared bicycle and pedestrian usage, but was not provided.
- Steep grades at localized points which occur where the new project transitions to the existing condition. While these probably do not show on the plans and may be a solution of opportunity taken during construction, the effect can detract from the usability of an otherwise satisfactory over- or undercrossing.

Sight Distance and Pavement Quality

- Landscaping is often the source of sight distance restrictions and extraordinary maintenance requirements. Care should be taken to select plantings which do not require frequent maintenance and to keep lines of sight free of obstructions. A quick review of the plans with regard to sight distance should identify potential problem areas.

- Wooden planking is susceptible to warping and this may detract from an otherwise acceptable facility. Designs should consider fastening each plank securely at each end, as well as at one or more places in between. A distance of two to three feet (0.6-0.9M) between fastening points on the plank appeared to be effective at those sites evaluated in the field.
- Pavement subsidence due to erosion or insufficient subbase strength significantly decreases the pathway quality and creates a hazardous condition.
- Pathways are susceptible to flooding such as those sharing culverts with creeks, did not have designated alternative routes to serve users during periods of high water.
- Drainage problems which result in water flowing across the pathway surface.
- Reverse super-elevation is a design error with respect to bicycle usage. The case observed was apparently used to facilitate surface drainage.

Appurtenances

- Transition from an off-street pathway to a parallel street requires relatively long curb cuts which, if underestimated, tend to pinch the entrance angle.
- Existing sidewalks serving as major access to an over- or undercrossing often do not have curb cuts. If they do, placement is typically random so as not to provide an effective, continuous access route for persons using wheelchairs.
- Lack of fencing along a pathway where a steep embankment slope exists close to the edge of the travel surface.
- Lack of fencing or barriers where needed to separate the sidewalk users from vehicular traffic. This serves the dual purpose of being a safety feature to prevent sidewalk users from falling into the street, as well as a splash guard to prevent road wash from being sprayed over the sidewalk.
- The New Jersey type concrete barrier to protect sidewalk users terminated just before the point where other pathways intersect.
- Handrails had unnecessary gaps in them, such as may occur between the approach and the structure or at locations where a future light pole is planned but has not been installed. Many such problems can be avoided during design, while others may require a retrofit treatment to close a gap permanently or temporarily until all facilities are completed.
- Lack of view screens to a crossing facility to protect the privacy of adjacent properties. However, care must be taken that such screening does not restrict sight distance along the pathway.
- Difficult nighttime pathway travel because of darkness or glare from approaching traffic where lighting, delineation and new screen were not used.

- Lack of lighting on many overcrossings, as well as in undercrossings. Lighting is often installed only on the structure, while there are locations on the approach or along other portions of the bikeway/pedestrianway system where lighting deficiencies significantly reduce the attractiveness and safety of the facility.
- Restrictive devices at entrances to pathway facilities which disadvantaged legitimate pathway users. Problems include devices which were not clearly visible to both day and nightime users; lack of advance warning signs; lack of signing designations; restricted and prohibited users; and "negotiation zone" through the restrictive device, were on a slope rather than level. That is, uphill and downhill travel characteristics should not complicate the users ability to safely and efficiently pass through the restrictive device. Common devices include closely spaced posts or fencing which requires users to travel in a "Z" pattern through a narrowed space.

6.4 GENERAL FINDINGS

6.4.1 User Counts

Counts were made of persons using each of the facilities observed during the site evaluations. Counts varied in duration from one-half hour long segments to continuous recording throughout the day, and are summarized in Table 4.

Table 4. Site Evaluation
User Count Summary

User Type	Palo Alto	Sunnyvale	Eugene		Hampton	Austin	Maryland
			Ferry	SPRR			
Pedestrian	10	67	150	362	2	55	0
Bicyclist	53	66	201	180	3	56	0
Total Persons	63	133	351	542	5	111	0
Child (0-12)	-	30%	-	-	-	1%	0
Teen (13-18)	30%	49%	10%	2%	60%	40%	0
Young Adult (19-25)	41%	11%	66%	72%	20%	49%	0
Adult (26-59)	27%	12%	17%	26%	20%	10%	0
Senior (over 59)	2%	1%	7%	0%	0%	0%	0
Total Percent	100%	100%	100%	100%	100%	100%	0
Hours of Observation	1.5	8	9.5	9.5	4	5.5	3

A total of 1,205 over- and undercrossing users were observed during the site evaluation studies. Of these, 559 rode bicycles and 646 were pedestrians (persons walking or jogging). Only one handicapped user was observed at the six field sites. However, supplemental evaluation studies, which featured site visits by individuals with a variety of physical handicaps were also conducted in California and Florida as a part of this study and results are also summarized later in this report.

6.4.2 Direction of Travel

The direction of travel is only meaningful on a site-by-site basis. Typically, directional splits ranged from 45/55 to 50/50.

With regard to wrong way travel, two sites had restrictions. One was signed as one-way for bicyclists and the other was implied since the end condition was a one-way street. There was some wrong way riding observed at both locations, probably because the alternative route required a significant detour in terms of both time and distance.

6.4.3 User Position

There was a strong tendency for pathway users to travel in the central portion of a straight path. This was evident on 4 foot (1.2M) wide pathways, as well as for 12 foot (3.7M) wide paths.

On curves, the travel zone shifted toward the inside of the curve. The shift became more pronounced as the curve became sharper. For example, the distance from the edge of pavement for an 8 foot (2.4M) wide path to the edge of the travel zone was 2 feet 6 inches (0.8M) on the straight away; 1 foot 6 inches (0.5,) on the inside edge of a slight curve, and 6 inches (0.2M) on a sharp curve. These relationships are portrayed in Figure 7.

With the exception of several persons on the narrow sidewalk of the Ferry Street Bridge in Eugene, Oregon, no one was seen using a handrail. The persons seen grasping the handrail were using it to steady themselves while they were being passed by someone in the opposite direction.

6.4.4 Handicapped Features

Three sites had special rest areas on or along the pathway or on the structure. No one was seen stopping at the rest areas located on a grade. The only observed rest area usage in Eugene, Oregon, where non-handicapped persons stopped to enjoy the view from the Autzen, and Greenway bicycle and pedestrian bridges crossing the Willamette River.

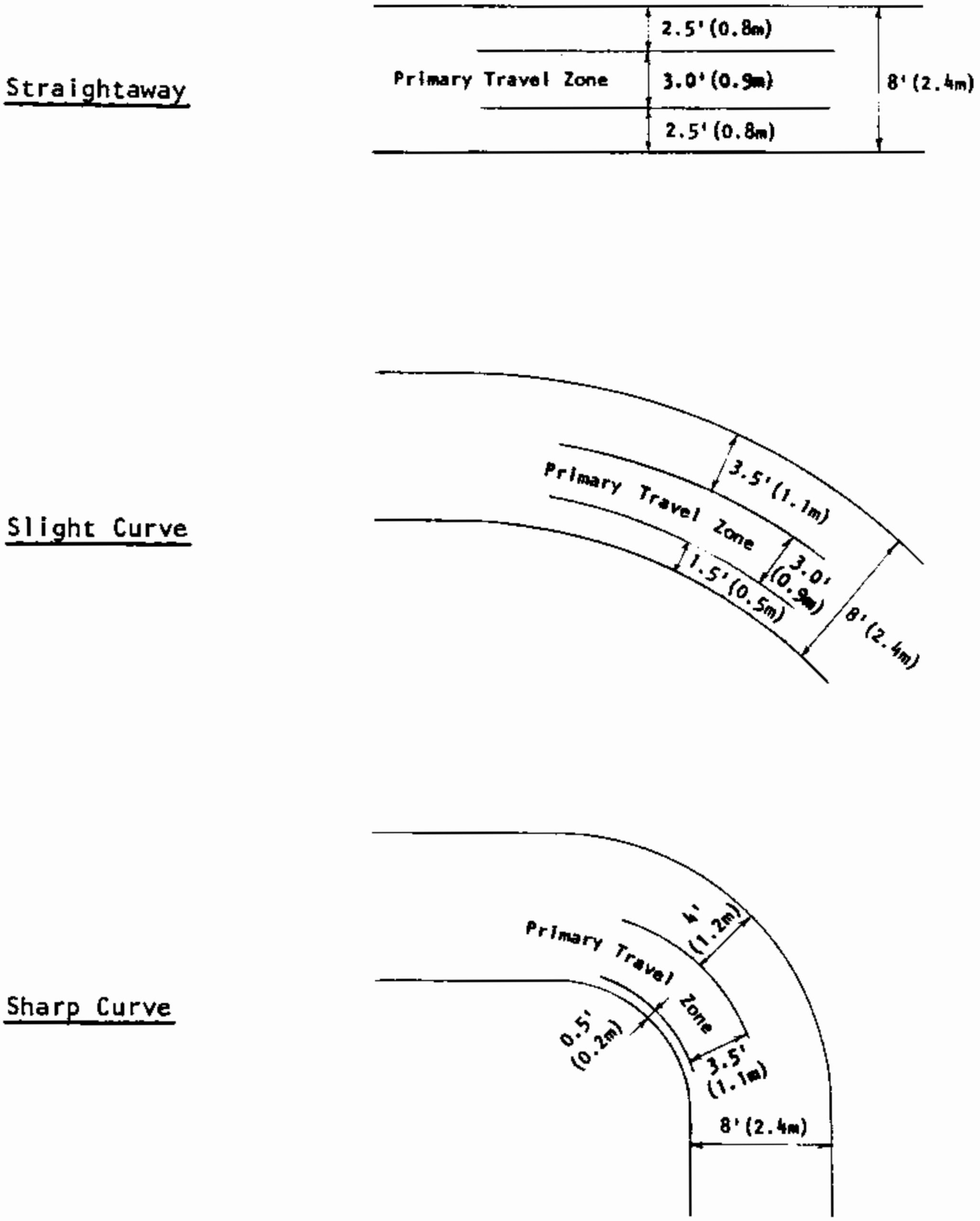


Figure 7. USER POSITION ON PATHWAY

6.4.5 Travel Behavior

As near as could be determined, nearly all of the 1,205 over- and undercrossing users observed during the site evaluation studies appeared to be regular users. However, at least two sites served other users at different periods of the year. For instance, football spectators in Eugene, Oregon, use the SPRR underpass and Autzen Bridge on their way to Autzen Stadium. In Hampton, New Hampshire, summer months bring a flood of tourist activity, with an associated increase in bicycle and pedestrian travel.

6.5.6 Short Cut Routes

Short cut routes were observed at four of the six site evaluation locations. Typically, short cuts truncated looping approach alignments where the user could clearly see a time and distance savings. Most of the alternate routes were relatively short and served the approach to the structure. None of the routes seemed to be illogical. Time savings ranged from several seconds by cutting a corner between intersecting sidewalks to several minutes through an interchange area.

6.4.7 Noise Qualities

With the exception of where loose or warped wooden planking existed, observed user noise levels were low. However, this observation may be different for the Ahwanee Overpass in Sunnyvale, California, during school arrival and dismissal time when high concentrations of students are using the facility. The site evaluation was conducted in July when school was not in session.

The ambient noise levels ranged from low to high depending upon the volumes of traffic or, in the case of the underpass in Eugene, the presence of a moving train. The noise appeared to be most noticeable at the Ahwanee overcrossing as a result of traffic on Freeway 101. Here, it was interesting to note that during the peak period traffic congestion of the freeway resulted in slow moving or stop and go travel. During these periods the ambient sound level, even though still high, was considerably diminished.

There were no sites where high noise level appeared to discourage bicycle and pedestrian travel. The Autzen and the Greenway bicycle and pedestrian bridges in Eugene, Oregon, were facilities where persons actually come to listen to "noise" -- the noise of the Willamette River flowing beneath the structure.

6.4.8 Structural Stability

All of the structures reviewed during the site evaluation studies were basically well-constructed and gave bicyclists and pedestrians the feeling of stability. The only exception to this was where wooden deck planks were loose or warped and one location where the fencing on the approach did not appear to be as strong as fencing used elsewhere on the facility. A jump test produced, at most, a slight vibration. However, joggers in cadence created rhythmic vibrations which could be felt but not to the point where the bridge appeared less stable.

6.4.9 Design Elements

The field study focused attention on specific elements and in so doing helped the evaluators become more aware of deficiencies which may not have been identified by a less detailed inspection. Comments applicable to some of the more important design elements are presented below.

1. Grades

   Grades along the pathway facilities typically did not exceed 8.33 percent. However, significantly higher grades were measured at localized points. At one facility the short ramps transitioning to the existing conditions had grades of 12 to 27 percent. Similar problems occurred at other sites where transitions to existing conditions or rest areas resulted in higher grades than specified on the design plans.

   This shows that more care needs to be taken in plan review to identify areas of potential problems and to specifically detail design criteria. In addition, construction engineers must be made aware of the problem so field alterations do not result in facilities which impede or prevent certain persons from using the route.

2. Cross Slopes

   Cross slopes ranged from 0-5.2 percent with most being about two percent. In one instance, a reverse super-elevation was built around a curve which facilitated drainage but which created a hazard for pathway users, particularly bicyclists. A two percent cross slope is commonly used to facilitate drainage.

3. Handrail

   Handrails varied from 2 feet 8 inches to 4 feet 1 inch (0.8-1.2M) high with 3 feet to 3 feet 6 inches (0.9-1.1M) being most frequent. Handrail heights of 33-36 inches (0.3M) is considered as being compatible with the needs of the handicapped (61).

4. Fencing

Fencing varied in height between 3 feet 5 inches and 8 feet 9 inches (1.1M and 2.7M). Some of the fencing was associated with a separate handrail and at other times there was only fencing without handrailing. Several locations along the approach pathway were identified as being in need of fencing to protect users from steep slopes. Fencing compatible with bicycle travel is a minimum of 4.5 feet high (1.4M).

5. Pathway Width

Pathway widths ranged from 4 feet to 12 feet 6 inches (1.2 to 3.8M) with 7 feet 4 inches to 8 feet 5 inches (2.2 to 2.6M) being the most common. The narrower widths did not readily accommodate two-way travel, while the 8 foot (2.4M) widths appeared to be quite usable. Four feet (4.3M) is commonly considered the minimum width for a one-way path, with 8 feet (2.4M) being the minimum for a two-way path (48, 51). The 12 foot (3.7M) widths were noticeably spacious at the volume levels observed and allowed much more flexibility for traveling in groups or passing other users.

6. Overhead Clearance

Two sites had places where the overhead clearance was 8 feet (2.4M) or less. Overhead clearances of 8 feet (2.4M) or more are preferred. In one place it was created by a bridge support and the restriction was signed. The other location was in a culvert where the vertical clearance was further reduced by silt deposit on the pathway surface during high water. Here the vertical clearance was variable and unpredictable.

6.4.10 Trip Generation

Elementary and high schools reasonably close to the facility increased its potential usage. This was particularly true if the location was such that students could conveniently use the structure. The proximity of a university is a significant source of users, particularly where the structure provides access to a bikeway or pedestrian pathway system which facilitates jogging and recreation trips as well as utilitarian travel. Linkage to a greenway trail system with varied destinations (such as exists along the Willamette River in Eugene, Oregon, or along Town Lake in Austin, Texas) is a definite attraction. This allows users to select the length of travel as well as the scenery that fits their mood.

Proximity of residential housing and shopping were other factors which were noticeable factors in trip generations. Employment centers, particularly where the structure offered a significant time savings for bicycle and pedestrian travel, was another factor influencing the demand.

Special events, such as the football games near the Autzen Bridge in Eugene, Oregon, or seasonable influxes of tourists as experienced in Hampton, New Hampshire, created significant demand for non-motorized facilities during specific time periods.

Each site was evaluated with regard to the presence of various trip generation characteristics (see Figure 8). The relative potential, high or low, for future non-motorized travel was also estimated by identifying the possible changes in land use that could significantly increase or decrease non-motorized travel compared to the existing situation. Land use categories that were explored included residential development; new, enlarging or closing of schools; employment centers; recreational opportunities, or a combination of uses.

The trip generation factors which were most evident at the site evaluation locations are summarized in Table 5.

Table 5. Site Evaluation
Bicycle and Pedestrian Trip Generators

	LOCATIONS					
Significant Trip Generators	Palo Alto	Sunny-vale	Eugene	Hampton	Mary-land	Austin
High School		X				X
College Students and Faculty	X		X			
University Housing						X
Regional Park		X				X
Neighborhood Park		X				X
Regional Greenway Corridor			X		X	X
Work	X		X	X		
Residential	X	X		X		
Tourist				X		
Football Stadium			X			
Community Center		X				
Regional Shopping Center	X					
Local Shopping	X					

Type of Barrier

Water
Highway
Mountains
Canyon
Land Use
Railroad

Crossing Opportunities

Point Only
No restrictions
Closely spaced alternative

Distance to Alternate Route

< 1000 feet (305 metres)
1000 feet (305 metres)
2000 feet (610 metres)
3000 feet (914 metres)
4000 feet (1219 metres)
5000 feet (1524 metres)
> 5000 feet (1524 metres)

Anticipated Use

Local (Neighborhood)
Regional

Link in Bikeway/Ped Plan

Yes
No

User Volume

High > 200/day
Med 50-200/day
Low < 50/day

Permanency of Demand

Stable
Likely Increase
Likely Decrease

Desire Line Fit

Along It
Slightly Removed
Remote

Topography

Flat
Rolling
Hilly

Land Use

Residential
Commercial
Industrial
Institutional
Recreational (Park)
Open
Other

Schools

Elementary School
JHS
HS
College
None

Shopping Center

Local
Neighborhood
Regional
None

Special Considerations

Bus Stop
Parking Lot
Sports Complex
Other
None

Figure 8. TRIP GENERATION CHARACTERISTICS - FIELD EVALUATION FORM

6.5 HANDICAPPED USER EVALUATION

Facilities at each of the six site evaluation locations just described were reviewed with regard to their ability to accommodate all non-motorized users, including the handicapped. However, the study team also conducted special studies where handicapped travellers actually helped to evaluate grade separations in the field. Persons from the Center for Independent Living in Berkeley, California, formed the handicapped panel which reviewed structures in California while volunteers from various active handicapped groups in the Miami area participated in the Florida evaluations.

Selection of the handicapped panel was based on the desire to have persons of varied disabilities conduct the evaluations. The range of participant disabilities included:

- Wheelchairbound (electric and manual wheelchairs)
- Leg braces, canes, crutches
- Walker with wheels
- Limited stamina
- Blind

The general study approach of evaluating crossing treatments involved the use of a team leader and a panel of disabled persons participating in the discussions and on-site evaluations. Much of the literature and standards reviewed were found to be based on judgements of the non-disabled or perceptions of persons with only one type of disability. Guidelines for treatments have generally not been based on empirical evaluation of behavior on facilities. The technique used in this study provided for a greater variety of viewpoints which, it is felt, better reflects the heterogeneous composition of the handicapped community with its diverse characteristics and needs.

The sites for the field evaluation of facilities for the handicapped were chosen after discussions with state highway officials and the panelists and after preliminary visits by study team members. Observation sites were selected in the San Francisco Bay, and Miami, Florida areas to provide for a variety of recent designs of crossings with and without special provisions for the handicapped. Further, the sites were chosen so as to encompass a variety of situations likely to be commonly encountered by handicapped users (6, 7).

Each on-site investigation involved traversing a facility and its approaches by the panel, then on-site administration of a set of choice response and open-ended questions about experience using the facility, followed by later more general discussion among panelists and project staff about the site. At each of the sites, photographs were taken to illustrate user behavior and major findings. Analysis of results by project staff followed.

6.5.1 San Francisco Bay Area Sites

The three sites selected in the Bay Area included two exclusive pedestrian overpasses and one overpass shared with motor vehicles. All three structures provide access across a freeway. Various site details are listed in Table 6. Also see photographs, Figure 9.

The Milbrae Avenue overcrossing, a highway bridge with sidewalks within a freeway interchange, was regarded by the handicapped panelists as being a hostile environment for pedestrians and particularly the handicapped. While curb cuts provided accessibility according to early 1977 standards, crossing interchange ramps serving high speed traffic at unmarked locations was considered a major disincentive to non-motorized travel. Other findings from this evaluation are included in Section 6.5.3 below.

The pedestrian overcrossing at Mount Diablo Avenue is about half the length of the Milbrae Avenue structure and connects two residential neighborhoods. The structure is not new and is accessed by two solid core concrete spiral ramps. In general, the panel concluded from on-site evaluation that spiral approaches are acceptible if designed properly. Most problems for handicapped travelers at this site pertained to walkway cross slope and sight distance restrictions created by the solid core supporting the spiral ramps. Again, see Section 6.5.3 for additional findings.

The Ahwanee Avenue pedestrian overcrossing includes some of the latest design elements intended to facilitate travel by handicapped persons. These included continuous handrail on approaches as well as the structure and level rest areas on and off the pathway. Maximum ramp slope was designed to not exceed 8.33 percent. In general, handicapped panel members were favorably impressed with this facility and concluded that it came close to meeting the needs of the handicapped. The only major problem encountered was where a maze-like barrier had been installed near the bottom of each ramp to discourage speeding bicyclists and skate boarders. Problems for handicapped persons passing through the maze related to narrow clearances, location on a slope thereby making wheelchair manuevers more difficult, and a confusing route for blind persons to negotiate.

6.5.2 Miami, Florida Area Sites

The four sites selected in the Miami, Florida area were all exclusive pedestrian/bicycle facilities. Two of the structures spanned a freeway; one bridge crossed a major arterial and canal and the fourth bridge simply provided access across a canal. The site characteristics are summarized in Table 7 and photographs can be seen in Figures 10 and 11.

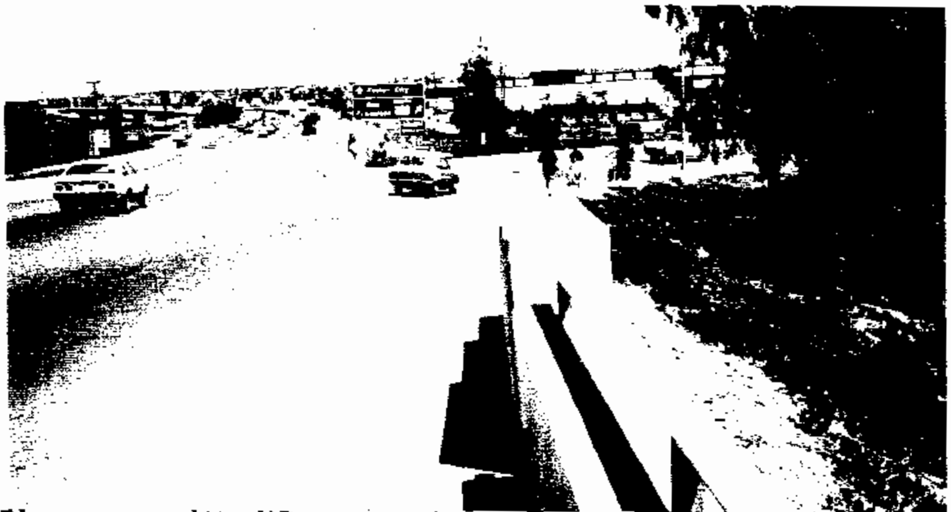
The pedestrian bridge north of Sample Road in Pompano Beach connected a residential area to an elementary school on the other side of Interstate Route 95. The structure had spiral ramps leading to level structure.

Table 6. California Overcrossings Evaluated by Handicapped User Panel

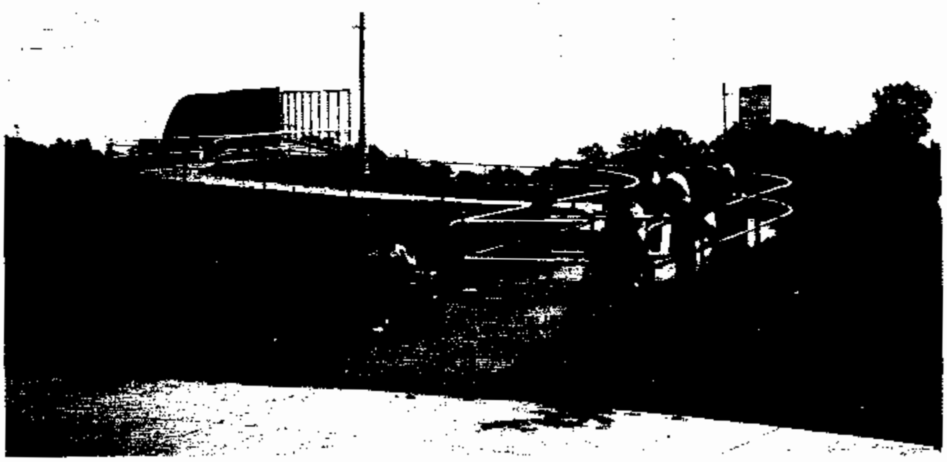
Site Specifics	Overcrossing Locations		
	Millbrae Avenue Millbrae	Mt. Diablo Avenue San Mateo	Awanhee Avenue Sunnyvale
Accessibility			
Pedestrians	Yes	Yes	Yes
Bicycles	Yes	Yes	Yes
Motor Vehicles	Yes	No	No
Surrounding Land Uses			
Multi-unit residential	Yes	Yes	No
Single-unit residential	No	Yes	Yes
Commercial	Yes	No	No
Industrial	No	No	No
Open Space	Yes	No	No
Adjacent Major Activity Centers	None	None	School, Park
Date of Facility Construction	1964 (curb cuts 1976)	1953	1977
End Conditions	4-lane signalized streets with sidewalks on one side	2-lane residential streets	2-lane residential streets
Approach Conditions	Sidewalks on one side with abrupt dropoffs over 10'; pathway crosses high speed freeway ramps	Spiral ramps	Switchback ramps
Structural Conditions	Sidewalks on one side with abrupt dropoffs over 10'; low railings, no fence	Fenced pathway	Fenced pathway
Reasons for Treatment for Disabled	Followed accessibility standards when widening facility; local request for widening	Not applicable	Local request for construction of facility; followed draft state standards

NOTE: To convert to metric: Feet x 0.3048 = Metres

Pedestrian crossing of Greeway on-ramp Millbrae Avenue



Spiral approach ramp to Mt. Diablo Avenue overcrossing



Approach to Ahwanee pedestrian overcrossing. Note Z gate on slope

Figure 9. HANDICAPPED USER PANEL EVALUATION SITES California

Table 7. Florida Overcrossings - Evaluated by Handicapped User Panel

Site Specifics	Overcrossing Locations			
	Sample Road Pompano Beach	Palmetto Expressway Miami	Route 27 Hialeah	Seminole Park Plantation
Surrounding Land Uses				
Multi-Unit Residential	No	No	No	No
Single-Unit Residential	Yes	Yes	Yes	Yes
Commercial/Public	Yes	Yes	Yes	Yes
Industrial	No	No	No	No
Open Space	No	No	Yes	Yes
Adjacent Major Activity Centers	School	School	Park, Stores	High School Auditorium, Ball Fields
Obstacle Crossed	Freeway	Freeway	Arterial, Water	Water
Date of Facility Construction	1972	1976	Unknown	1977
End Conditions	Narrow pedestrian pathways; pathway on one side leads to residential street	2-lane residential streets with sidewalks on one side	Two intersecting 4-lane signalized streets with sidewalks, both sides	Parking lots
Approach Conditions	2 spiral ramps, 16 feet high from ground	2 straight ramps, each 297 feet long	3 switchback ramps	2 short paved ramps
Structural Conditions	222 feet long; 8 feet of clear width between curbs on span	188 feet long span; 8 feet of clear width between curbs on span	2 spans at right angles; 5'8" of clear width walkway	128 feet long span; 8 feet of clear width between chained link fence on span
Accessibility				
Pedestrians	Yes	Yes	Yes	Yes
Bicyclist	Yes	Yes	Yes	Yes
Motor Vehicles	No	No	No	No

NOTE: To convert to metric: Feet x 0.3048 = Metres

Blind pedestrian crossing
bridge over canal
Plantation, Florida

Passing on narrow bridge
over Route 27
Hialeah, Florida

Long ramp serving pedestrian
overcrossing of Palmento Exprway.
Miami, Florida

Figure 10. HANDICAPPED USER PANEL EVALUATION SITES
Florida

Ascending steep inside
edge of spiral ramp
Pompano Beach, Florida

Handicapped panel discussion
and debriefing

Narrow variable width path
leading ot overcrossing
Pompano Beach, Florida

Figure 11. HANDICAPPED USER PANEL EVALUATION SITES
Florida

The major problems experienced by the handicapped panel included steep and variable grades on the spiral ramps and lack of handrails; other findings are listed in the following section.

The pedestrian overcrossing of the Palmento Expressway north of 36th Street in Miami has straight ramps approximately 300 feet (91.4M) long providing access to the structure crossing the expressway. Although the ramp grade was 8.33 percent, there was no intermediate rest areas. The length of the single long ramp appeared to be a psychological as well as a physical barrier to handicapped panel members except the blind person. Lack of handrail was also considered a significant deficiency.

The pedestrian overcrossing of Route 27 in Hialeah has three switchback approach ramps on each side to gain the elevation necessary to cross the highway and canal. Ramps were about 80 feet (24.4M) long between landings. This design was perceived by wheelchair-bound panel members to be more accessible than the long continuous ramp at the Palmento Expressway structure. The psychological problem of a long ramp was also relieved with the switchback configuration. The 5 feet 8 inches (1.7M) clear width walkway caused some persons to slow or stop when passing other persons. While this was noted as being an inconvenience, more concern was directed toward end conditions where drop-offs adjacent to the sidewalk were considered a hazard; particularly to a blind person.

The prestressed bridge in Plantation, Florida spanned a canal between two parking lots adjacent to a school ball field and auditorium. This overcrossing had very short ramps since the structure had to only have minimum clearance over the canal. Crossing this structure was relatively easy for all handicapped panel members.

6.5.3 Summary of Findings

The following summary of findings relating to handicapped accessibility on over and undercrossings identified during the handicapped user field evaluations and reviews by project team members is presented under four categories: (1) signs, signals and markings, (2)maintenance, (3) design features and (4) general conclusions.

Sign, Signals and Markings

- Advanced warning signs for motorists at striped crosswalks were lacking where pedestrians must cross high speed roadways and ramps.

- Directional and guide signing were often lacking. Where present, they were considered helpful in providing potential users with information regarding crossing location, destination points, length and special features or conditions.

- Signs reinforcing information to reassure users that they are on the proper route were lacking. These were viewed as particularly important if there are many first time users or infrequent users as could be expected in the vicinity of transportation terminals or recreation areas.

Maintenance

- Dirt or sand on the pavement can reduce traction and make traveling difficult for certain handicapped persons.

- Glass can become imbedded in wheelchair tires and cut a person's hands as they turn the wheels.

- Trash cans or other moveable objects placed randomly in a pathway create special problems for blind persons.

- Vandalism of signs and fencing that result in objects protruding into the pathway space is a hazard to all users.

- Fence patches are often left with jagged fasteners exposed to the touch.

- Differential settlement of sidewalks at the structure interface should be patched to provide a smooth transition.

Design Features

Sidewalk Characteristics

- Lack of curb cuts or inconsistent use of curb cuts prevents wheelchair-bound persons from travelling freely along certain corridors.

- Excessive cross slopes adversely affects handicapped persons guiding wheelchairs or wheeled walkers by making it more difficult for them to travel without veering toward the low edge of the pavement.

- Super elevated roadway ramps create a similar problem by requiring extra effort and more time to cross in the uphill direction.

- Level rest areas should also be placed at points of pedestrian crossings of roadway ramps so persons about to cross do not have to cope with sidewalk slope as well as roadway slope.

- Level resting areas are needed at reasonable intervals along long or steep ramps.

- Narrow sidewalks (i.e. less than 6 feet or 1.8M for two-way travel) were viewed as a hazard by wheelchair users and the blind and as an impediment to travel by all disabled panelists.

- Drop-offs close to sidewalks pose a hazard and should be fenced or transitioned to minimize the problem.

- Right angle sidewalks can be difficult for wheeled handicapped persons to negotiate, especially if they are narrow. Widening the pavement at the angle facilitates turning movements.

- Steep ramp slopes were a major problem for all panel members except the blind. The steepness was found in several forms. It could be uniform along the entire ramp or at localized points. Also, it could be variable such as occurs between the outside and inside edge of a spiral ramp.

- Unless the inside edge of a spiral ramp is specified to not exceed the maximum acceptable grade, grades along the inside edge will exceed acceptible standards because the grade on the inside edge is always greater than in the middle or on the outside edge of a spiral ramp. This is important because the inside edge provides the shortest travel distance and is thereby favored by most users.

- Switchback ramp designs create intermediate landings or rest areas as well as lessen the psychological impact of long straight ramps. However, persons with coordination loss may have problems with the switchback configuration.

- Smooth or slick pavement surfaces were viewed as a deficiency especially where ramps became steep. Rough pavement finish, built new or applied later, was considered a benefit.

- Structural joints, unless relatively narrow or smooth, caused uncomfortable jolting as wheelchair users passed over them. Differential sidewalk settlement frequently occurs at the interface with the structure, thereby creating a bump. At a minimum this results in discomfort to wheelchair users or bicyclists and at worse can represent a safety hazard.

- Sidewalk approaches should be at least as wide as sidewalks on the facility. If they are not, then a reasonable transition should be constructed.

- A single curb cut on diagonal at a corner creates orientation problems for blind persons trying to select their walking direction across the street.

- Landings at the bottom of ramps adjacent to traffic should provide sufficient space for a number of users to pause before continuing their journey.

Appurtenances

- Graspable handrails are viewed by many handicapped persons as being an essential element of design on approach ramps or stairs. Another area where handrails are important is where there are drop-offs close to the pathway which present a potential hazard to blind persons and wheelchair users.

- Inadequate sight distance is considered a major deficiency, whether occurring on the facility or at a roadway crossing.

- Indirect routes or pathway junctions on the structure can be confusing to the blind.

- Fences were considered helpful. However, problems may occur where bracing or fencing intrudes into the pathway as a result of vandalism.

- Curbs constructed on both sides of exclusive pedestrian overcrossings were found to have four positive features, they: 1) help to channelize drainage; 2) provide support to fence posts; 3) can be used as resting places for tired travelers; and 4) provide ideal boundaries for blind cane users.

- Barrier posts should only be used if they serve to block access of motor vehicles to non-motorized facilities and should be reflectorized to enhance nighttime visibility. They should be removed at locations where they are not effective.

- Well traveled short cut routes serving the facility should be formalized if deemed safe.

General Conclusions

- The disabled are a heterogeneous group with varied mobility limitations and needs. Persons with the same medical condition are likely to vary in their physical stamina and perceived fears about making level changes. It is important to note that this project's evaluators are active disabled people who are likely to be less fearful of new experiences than are many of the disabled population.

- A combination of treatments is needed to make a facility barrier free. Even then, a facility may not be used by some disabled groups who anticipate that the crossing trip will take too much effort.

- The method of using handicapped panelists to conduct on-site evaluations was successful in this study and can be a useful technique for local and state officials to use in planning new or retrofit construction.

6.6 SUPPLEMENTAL FIELD INVESTIGATIONS

In addition to the pilot study and the five sites selected for detailed evaluation, approximately 200 other structures were visited in 17 states and in Washington, D.C. Of the 72 case studies documented during the study, 41 were visited and inspected in the field. Over 1,000 photographs were taken to document site and user characteristics during the study.

Locations visited to examine one or more design and/or operational features or to generally add to the study team's background knowledge and data base were chosen based on personal knowledge, or at the suggestions of others. Visits were made whenever the opportunity presented itself. These sites tended to be located in the vicinity of the study team's offices and at sites at or adjacent to areas which were visited primarily for other purposes throughout the study.

The supplemental field investigations have produced an important reservoir of information which has been used to broaden the insight gained from those sites receiving more detailed evaluations. The additional information has been included in the findings and results presented throughout this report and particularly in the formulation of the design strategies described in Chapter 7. Figures 12 through 14 contain a sample selection of photographs taken during the supplemental site visits, illustrating both deficiencies and examples of good practice.

Photographic views presented in Figure 12 show a variety of different structural treatments. The exclusive bicycle and pedestrian undercrossing of a local roadway is in a planned unit development. An older railroad underpass shows where metal railing and splash boards protect pedestrians using narrow sidewalks. The bicycle and pedestrian overcrossing with lighting connects to a parking lot on a university campus. The overcrossing ramp gains access from a median between a freeway and a frontage road. A sidewalk on one side of the roadway crosses a small bridge on the outskirts of a small town. Finally, a wooden bridge with wooden piling built through a marsh is designed so the deck can be jacked up to compensate for differential settlement.

Several signs indicating various unique traffic control strategies are shown on Figure 13. Additional photos illustrate an underpass from a canal levee underneath the approach to a highway bridge. This provides levee protection from high water. The other undercrossing is constructed of corregated metal pipe and connects a residential area to a major street on the other side of an elevated railroad

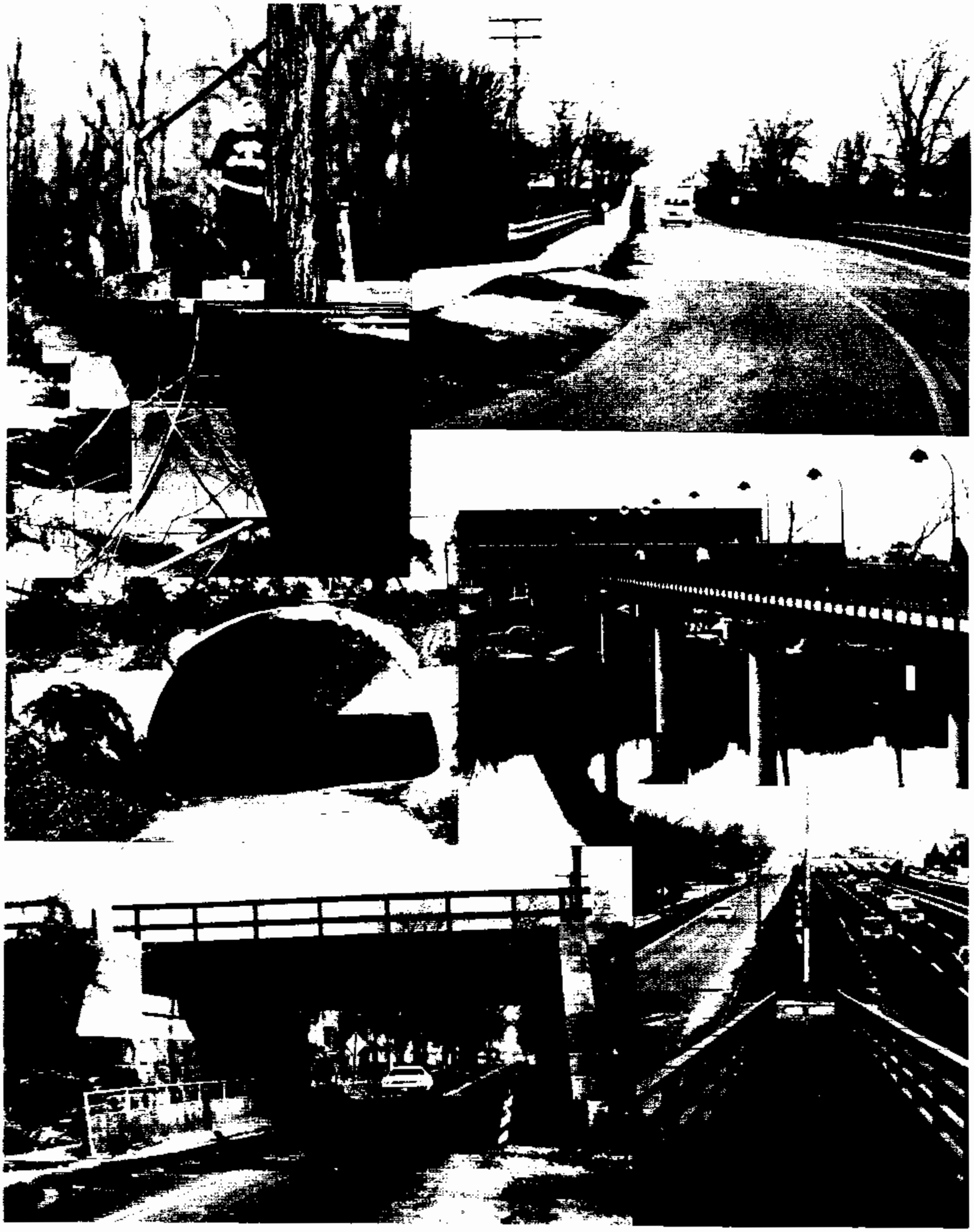


Figure 12. SELECTED SITE VIEWS

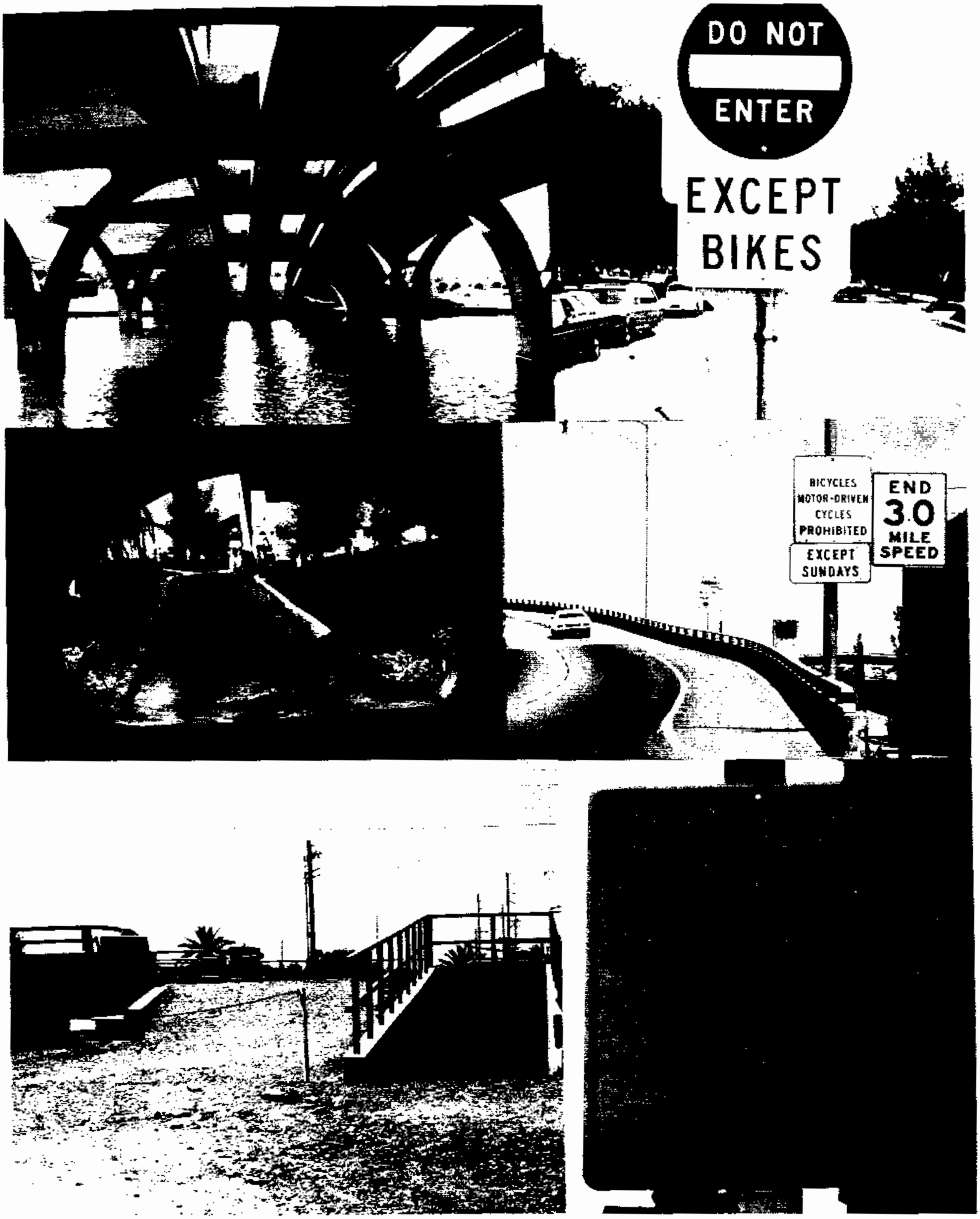


Figure 13. SELECTED SITE VIEWS

track. The final photo displays the underside of a dual highway bridge where a centrally located pedestrian and bikeway is incorporated in the structure. Access returns to each side of the roadway from a pathway under the bridge abutments.

The effectiveness of grating to reduce the effects of snow on a ramp to overcrossing is one feature shown Figure 14. Another view of the same ramp displays a unique treatment for driveway access. The keyhole like undercrossing is an old corregated pipe tunnel with ramp access to one approach and stair access on the other. Curvilinear wing walls serving a railroad overpass are set back from the roadway to allow a future shoulder or bikeway to be added. The continuous shoulder along a divided highway provides ample space for occasional non-motorized usage in this rural location. The protruding platforms over each pier along this major highway bridge connect to a wide one-sided bicycle and pedestrian path and serve as observation or resting areas for recreationally oriented bicyclists and pedestrians.

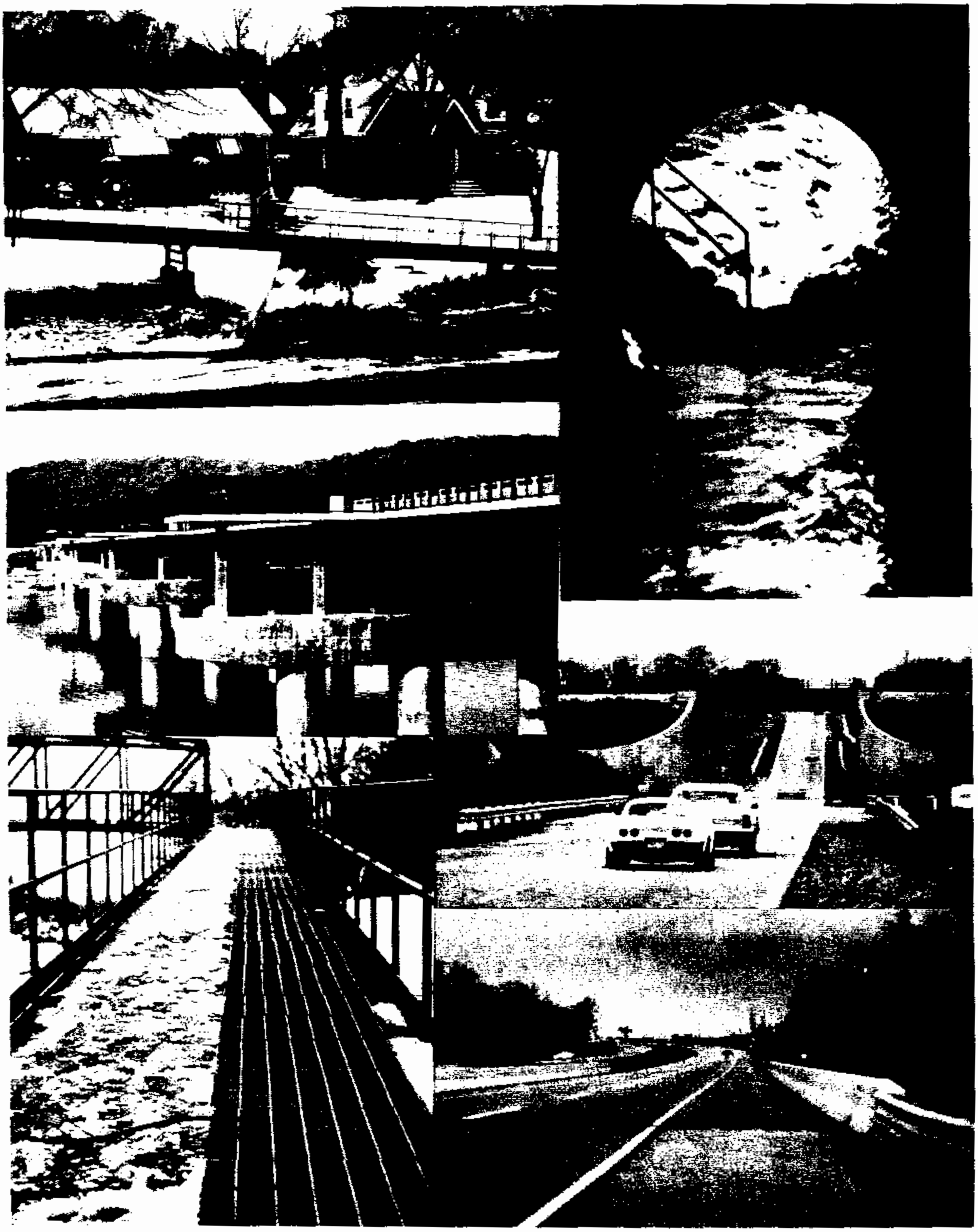


Figure 14. SELECTED SITE VIEWS

CHAPTER 7
DESIGN APPROACHES AND STRATEGIES

7.1 INTRODUCTION

This chapter presents a distillation of findings, conclusions and recommendations concerning facilities for non-motorized travelers on over- and undercrossings. Major sections describe a presentation of general design considerations, standards and features; a discussion of design strategies and effective treatments which includes generic, prototypical designs for five different types of new projects and three kinds of retrofit projects, as well as discussions of non-structural solutions and some potentially applicable innovative techniques; an approach to improving the awareness and understanding of both system designers and users through education, and a discussion of handicapped user considerations. The chapter concludes with a summary, drawn from current practice, of the examples of good and deficient design features. Accompanying the latter are suggested ways of overcoming, or at least ameliorating, unsatisfactory characteristics or conditions.

7.2 DESIGN CONSIDERATIONS, STANDARDS AND FEATURES

There are a number of common design elements which apply to all non-motorized facilities on over- and undercrossings. These are discussed below prior to presentation of prototypical design strategies for new and retrofit facilities in the following section (7.3).

7.2.1 Over- and Undercrossings as Systems

Over- and undercrossings are part of an existing transportation system. Whether they are jointly shared by motor vehicles and bicyclists and pedestrians, or intended solely for use of the non-motorized traveler, they interface with existing highways, bikeways and pedestrian ways. To function smoothly as part of the transportation network, their design must be continuous with the existing facilities, as well as compatible with future plans. By definition, grade separations have three components, namely end conditions, approaches and the structure (see Figure 2). To be properly designed, each component should be considered as part of a system rather than being an independent feature.

7.2.2 Design Elements

The design of non-motorized facilities can be divided into two areas:

- Geometrics
- Details, Special Features and Construction Materials

These subdivisions apply equally to grade separations shared with motor vehicles, those exclusively serving non-motorized travelers, and to new and retrofit situations. Application of specific design standards and solutions of special features are largely a function of the types of users anticipated and local design policies and circumstances.

Geometrics. Geometrics encompasses the determination and relationship of the physical dimensions of facilities. For the non-motorized traveler, the following items are of importance, defined as follows, and values are listed in Table 8.

- Clear width -- unobstructed travel width on the structure and approaches.

- Grades -- maximum slope and average slope.

- Cross slope -- slope across the facility surface perpendicular to the normal direction of travel.

- Design speed (bicycle) -- the speed at which a bicyclist can travel in safety and comfort.

- Design curvature (bicycle) -- radius of curvature consistent with the design speed of the bicyclists.

- Sight distance -- distance required to see an object or other non-motorized traveler on the facility and stop or avoid collision.

- Overhead and lateral clearance -- space required above and on each side of travel way for safety and comfort of moving, non-motorized travelers.

Design decisions made regarding the geometric elements determine the basic quality of travel on the facility.

Standard geometric elements are outlined in several publications. Usually the standards set forth are pertinent to one user group, that is, either for bicyclists or pedestrians or the handicapped. Table 8 shows relevant design guidelines and notes of explanation in a comparative manner for all three users. These have been derived from a number of sources, as noted on the table. Maximum or minimum criteria and desirable criteria are shown where possible.

While standards are useful guides for good design practice, indiscriminate adherence should be avoided. Their use must be tempered by engineering judgment based on prudent assessment of individual and

Table 8. Design Guidelines for Geometric Elements

Geometric Element	Bicycle (22,51,62)		Pedestrian (15,52)		Handicapped (61,63)	
	Max. or Min.	Desirable	Max. or Min.	Desirable	Max. or Min.	Desirable
CLEAR WIDTH						
One Lane	3.5 Ft. (Min)	4.0 Ft. (or more)	3.0 Ft. (Min)	4.0 Ft. (or more)	3.0 Ft. Min	4.0 Ft. (or more)
Two Lanes	7.0 Ft. (Min)	8.0 Ft. (or more)	6.0 Ft. (Min)	7.0 Ft. (or more)	4.0 Ft. Min	5.5 Ft. (or more) (Pass Two Wheelchairs)
More than Two Lanes	Where volumes of any or all of the user groups are heavy, calculate widths required using level of service concepts.					
CLEARANCE						
Vertical Unobstructed Height	3.33 Ft. Min	9.5 Ft.	7.0 Ft. (Min)	8.0 Ft.	(Same as pedestrian)	
Lateral Clearance to obstructions	1.0 Ft. Min	2.0 Ft.	1.0 Ft. (Min)	1.5 Ft. (or more)	(Assume same as pedestrian)	
GRADES	10.0% (For dist. of 50 Ft. or less) Max	5.0% (For Dist. of 300 ft. or less)	15.0% (Max)	5.0%	8.33% Max (Length of single run is 30 feet run)	5.0% (or less)
CROSS SLOPE	2.0% (Min on curves)	Calculated from super-elevation formulas	6.0% (Max)	5.0% (or less)	2.0% (Max)	1.0% (or less)
DESIGN SPEED (Bicycles)	10 MPH (Min)	15 MPH (20 MPH on long down grades)	Not Applicable		Not Applicable	
RADIUS OF CURVATURE (Bicycles)	15.0 Ft. (Min)	Calculate from appropriate formulas (See Table 10)	Not Applicable		Not Applicable	
SIGHT DISTANCE	Varies with grade and speed. Calculate from appropriate formulas (See Table 11)		Sight at curves and turns must not be obscured. Sufficient distance to avoid collision.		Sight at curves and turns must not be obscured. Sufficient distance to avoid collision.	

Source: Compiled by De Leuw, Cather & Company from references Nos.: 15,22,51,61 and 62

NOTE: To convert feet to metres multiply feet by 0.3048.

collective needs of the non-motorized traveler, and features peculiar to a particular crossing situation.

Details, Special Features and Construction Material. The special features and details listed are items that provide increased protection for users or enhance the travel characteristics of the over- or under-crossing. Their absence or lack of attention to their design may create an unacceptable situation for any of the three user groups. Judicious choice of construction materials can also result in an improved crossing experience. Particular consideration should be given to design or inclusion of the features listed below.

- Motor Vehicle Barriers: Barriers should be erected to protect the non-motorized traveler on both the approaches and structure where vertical or horizontal separation from motor vehicles is otherwise unachievable, and where motor vehicle traffic is heavy or operates at high speed. Concrete barriers with a sloping face on the traffic side (New Jersey type) have proven very effective. Solid barriers also offer non-motorized users protection from being splashed by roadway wash. Railings may have to be affixed to the top of the barrier to reach the minimum vertical height desirable for protection of bicyclists and pedestrians.

- Pedestrian Railings/Protective Barriers: What are commonly called "pedestrian railings" are really protective barriers to keep bicyclists, pedestrians or the handicapped from unintentionally leaving the facility. Pedestrian railings are commonly constructed of steel or aluminum pipe or tubing, wood, concrete, or some combination of these. Railings should have smooth surfaces and be free from protruding parts or discontinuities which can snag passers by. Where bicyclists are expected to use the facility, railings should have a minimum vertical height of 4.5 feet (1.4M). If only pedestrians and the handicapped have access to the facility, a 3.5 foot (1.1M) height is sufficient. (22, 65)

- Graspable Handrails: Handrails are placed on stairs and ramps to provide continuous support to aid pedestrians or the handicapped in ascending or descending. Handrails should be a part of all over- and undercrossings, preferably continuously across the approaches and the structure. If this is not feasible, at least those portions of the project with pronounced grades or slopes should have them. In addition to providing support for the handicapped and elderly, handrails serve for emergency grasping by pedestrians to maintain their balance, and act as a rub rail for bicyclists, separating them from metal barricades or fencing.

  Handrails should be graspable, with a shape that allows natural opposing grip. Their height should be 33-36 inches (0.8-0.9M) above the surface vertically below, and if mounted next to or on a wall or other barricade, there should be a space between the wall and the handrail of approximately 1-1/2 inches (38mm). (61)

- Curb Cuts and Ramps: Curb cuts and ramps are required features wherever curb barriers exist. They are essential for access by many types of handicapped persons, and are useful for both bicyclists and pedestrians. The minimum width of a curb ramp/cut should be 3 feet (0.9M) for one directional flow, 4 feet (1.2M) for two directional flows, and 5.5 feet (1.7M) to enable two wheelchair users to pass. The ramp slope should be a maximum of 1:12 (8.33 percent). Whenever possible, lesser slopes should be employed. (52, 61, 63)

- Landings and Platforms: Level landings or platforms should be provided at the top and bottom of ramp runs, and intermediate landings should be provided on long ramps. Where the ramp grade exceeds 1:16 (6.25 percent), level landings should occur approximately 40 feet apart. Provision of rest areas may satisy the handicapped user equally as well and, therefore, intermediate level landings may not be necessary. The landing should have a clear width at least equal to the width of the largest ramp run leading to it. The minimum landing depth should be 5 feet (1.5M). (61)

- Rest Areas: A very desirable feature is strategically placed rest areas. Rest areas may be located within the traveled portion or off to the side. A flat grade and a place to sit or to rest against are typical features included at rest areas. They are particularly beneficial on very long over- and undercrossings, and they can function as viewing areas along approaches and the structure in scenic areas. Care should be taken that rest area appurtenances do not intrude upon the travel space. A number of promising strategies are illustrated which could serve as rest areas without requiring a level landing. These appear to be applicable to retrofit as well as new construction. See Section 7.3.6, Figure 29.

- Surface Finishes, Materials and Construction Joints: Unsealed gravel, cobblestone and corrugated surfaces should be avoided. Smooth, jointless construction (such as that afforded by asphalt concrete) is preferred by all user groups. Smooth concrete surfaces are also good. Concrete surfaces should be made non-slip by use of broom finishes or an abrasive grain floated into them when they are laid. Wood plank decking is acceptable if joints are a maximum of one-half inch (preferably less) and warped planks are regularly refinished or replaced. Checker plate and walkway grating on structures functions well, if the surfaces are adequately roughened for slip-resistance. Grating appears to have a special advantage where snow fall is a regular occurrence, since it minimizes snow accumulation.

Expansion and construction joints should be the minimum allowable by structural and construction considerations. If the joint is greater than one-half inch (13mm) wide, a cover should be provided. A flush joint is desirable. Joint filler should not expand above or shrink below the surface excessively.

- Gratings: Drainage or other gratings that must protrude into the travel way of the non-motorized facility should have smaller openings than those commonly used. Large openings are a hazard to bicyclists, as they may "catch" wheels. If the grating bars are parallel, turning the grating so the bars are perpendicular to the direction of non-motorized travel may be an acceptable alternative.

  Handicapped persons in wheelchairs or using crutches and canes are even more affected by grating openings. To prevent the catching of wheelchair wheels or crutch and cane tips, gratings within the travel way for these users have been suggested to have openings no greater than 3/4 inch by 3/4 inch (19 mm by 19 mm). In retrofit situations where gratings have been installed with larger openings, straps or bars welded to the gratings have been used to reduce the maximum opening.

  Placing drainage gratings so the bars are perpendicular to the direction of non-motorized travel, or reducing the openings will have adverse affects on their hydraulic characteristics. Welding straps or bars to drainage gratings has in some instances proven unsatisfactory, as motor vehicle traffic has dislodged the welds. Analysis of drainage requirements and careful detailing of bar or strap position, type and welding procedures should precede grating installation. (64)

7.2.3 Designing for Multiple Users

Almost all facilities on over- and undercrossings for non-motorized travelers will be utilized by some bicyclists, pedestrians and handicapped persons. This is true for both new construction and retrofit situations. Planning, conceptual design, and construction activities for such projects, therefore, should generally be predicted on concurrently meeting the combined requirements of bicyclists, pedestrians and the handicapped, not merely one user group.

Design and the Application of Standards: Accommodating bicyclists, pedestrians, and the handicapped simultaneously may not be as formidable or as costly as might initially be supposed. Close examination of desirable design standards and treatments for each user group reveals a great deal of overlap. Further, specific features that appear to be related to enhancing the travel of only one user type often improve it for the others as well. An example would be curb cuts and ramps installed for the handicappped, being beneficial to bicyclists and some pedestrians.

Unintentional exclusion of some users has occurred in certain situations because maximum and minimum standards were incorrectly utilized. This can occur because of the tendancy to use maximum and minimum standards to produce the least-cost project without the designer taking the time to assess the actual needs of the non-motorized traveler who is expected to use the facility. This awareness of needs is particularly important because recent research has identified features and criteria which are not accounted for in historic design standards which themselves may be five or ten years or more old.

Based on the above and observations made during the course of this study, the following conclusions can be drawn:

1. The design standard for a geometric element acceptable to all user groups should be used; i.e., the lowest common denominator, or "most desirable" design standard, should be selected.

2. Details, special features, and construction techniques must be analyzed for potential effects on travel conditions for each of the three user groups.

Selection of the "most desirable" design features appears to either enhance travel for the remaining users, or at least have a neutral effect. This fact is demonstrated in Table 9, where accepted "desirable" design guidelines from Table 8 are summarized. When user groups associated with the "desirable" guidelines for these geometric elements are reviewed, it is found that the bicycle, not the pedestrian or the handicapped, is the group determining the design. One conflict in designing for bicyclists, pedestrians and the handicapped as a group is that superelevations on curves considered desirable for bicyclists would often exceed the two percent cross-slope considered as a maximum for handicapped use. Unless it is possible to increase radii of curvature on approaches or structure, lower design speeds for bicycles will result.

Another important consideration is that for long ramps or those with grades over 6.25 percent, intermediate landings or rest areas are needed for the handicapped. (61)

7.2.4 Designing for the Handicapped

Good design is based upon sound principles of engineering and planning, and is responsive to adopted policies determined by political process. Policies can directly affect the design of over- and undercrossings by requiring adherence to certain standards, or by specifying inclusion of special features. The federal policy mandating that over- and undercrossings be accessible to the handicapped overlies other design considerations and, thus, requires use of certain standards and inclusion of special features as listed below. (52, 61, 63)

Table 9. Most Desirable Design Guideline

Geometric Element	Most Desirable Design Guideline	Critical User Group		
		Bike	Ped	Handicapped
CLEAR WIDTH				
One Lane Two Lanes	4 feet 1 lane min. (1.2M) 8 feet 1 lane min. (2.4M)	X	X	X
More Than Two Lanes	Where volumes of any or all of the user groups are heavy, calculate widths required using level of service concepts.	X		
CLEARANCE				
Vertical Unobstructed Height	9.5 feet (2.9M)	X		
Lateral Clearance to obstructions	2.0 feet (0.6M)	X		
GRADES	5 percent maximum	X	X	X
CROSS SLOPE	1 percent or less			X
DESIGN SPEED (Bicycles)	15-20 MPH (24-32KM)	X		
RADIUS OF CURVATURE (Bicycles)	See Table 10	X		
SIGHT DISTANCE	See Table 11	X		

Source: Derived from Table 8.

- Stairs: Stairways are unacceptable as the sole means of access to the structure. However, stairs may be used if these are in addition to ramped approaches, elevators or other conveyances.
- Ramps: Ramped approaches by themselves are acceptable.

Table 10. Radius of Curvature - Bicycles (51)

Design speed, mph	Design radius, feet
10	15
15	35
20	70
25	90
30	125

Table 11. Stopping Sight Distances - Bicycles (51)

	Stopping Sight Distances for Downhill Gradients of:			
Design Speed	0%	5%	10%	15%
mph	feet	feet	feet	feet
10	50	50	60	70
15	85	90	100	130
20	130	140	160	200
25	175	200	230	300
30	230	260	310	400

- Grades: The maximum allowable slope or grade on a ramp should be 8:33 percent, with lesser grade preferable. (63)
- Cross-Slope: A cross-slope of two percent or less is preferred.
- Graspable Handrails: Handrails capable of being securely grasped should be provided on portions of the project with grades or slopes. Preferably the handrail should extend continuously along the approaches and across the structure.
- Curb Cuts and Ramps: Curb cuts and ramps are required at appropriate locations.
- Landings and Platforms: Level platforms must be provided at the top and bottom of ramp runs, and intermediate landings or rest areas should be provided on long ramps.

7.3 DESIGN STRATEGIES AND TREATMENTS

7.3.1 Introduction

For each proposed crossing of a barrier there are usually a very large number of possible solutions. Ensuring that as many potential alternatives as possible have been given consideration, and choosing the one that is most applicable, is difficult for the designer. An effective method often used in practice is to examine a number of existing designs and solutions applied elsewhere for suggestions as how to best approach the situation being analyzed.

Recommended design treatments have been developed as part of this research study to serve as a catalogue of potential strategies, and as a means of illustrating key design points. The design solutions have been grouped according to the major headings derived as part of the crossing classification and other aspects of the study described in Chapter 5. Design requirements have followed from the Field Evaluations discussed in Chapter 6. The following portions of this section have been organized as follows:

- New projects - generic design strategies
- Retrofit projects - generic design strategies
- End conditions
- Non-structural solutions to crossing problems
- Unusual treatments, innovative designs, and new technologies

Generic design strategies are defined for the purpose of this study as typical solutions to frequently encountered crossing problems. They are approaches to both new and retrofit situations that have been derived from a number of case studies and are generally applicable to a majority of crossing conditions.

Eight generic or prototypical types of new facilities were selected based on a review of the 72 case studies analyzed in the course of this study and using the classification described earlier in Section 5.3.1. These are as follows:

- Overcrossing Shared with Motor Vehicles (4 lanes or more, heavy traffic)
- Overcrossing Shared with Motor Vehicles (2 - 4 lanes, light/ medium traffic)
- Underpass Shared with Motor Vehicles (4 lanes or more)

- Underpass Shared with Motor Vehicles (2 lanes)
- Tunnel Shared with Motor Vehicles (light traffic)
- Bicycle and Pedestrian Bridge (over 100 feet long - 30.5M)
- Bicycle and Pedestrian Bridge (less than 100 feet long - 30.5M)
- Minor and Major Bicycle and Pedestrian Undercrossings (Underpass and Tunnel)

Similarly, six generic prototypical types of retrofit facilities were selected:

- Cantilever Addition of Bicycle and Pedestrian Facilities to an Overcrossing.
- Addition of Bicycle and Pedestrian Facilities to an Undercrossing by use of Traffic Barriers.
- Upgrading of Bicycle and Pedestrian Facilities on an Overcrossing by Removing Existing Railings and Adding Traffic Barriers and Cantilevers.
- Expansion or Upgrading of Existing Bicycle and Pedestrian Facilities.
- Adding of Non-Motorized Travel Facilities While Widening an Existing Motor Vehicle Overcrossing.
- Conversion of an Existing Over or Undercrossing to Exclusive Use for Bicyclists and Pedestrians.

The end conditions that can be combined with a particular approach and structure situation are numerous. In order to simplify presentation of the prototypical solution, potential end conditions have been grouped into a separate section of this report for ease of graphical presentation and discussion.

Crossing problems can often be alleviated or even eliminated by non-structural solutions such as traffic control strategies; alternative routes; alternative travel modes; new technologies, and land use planning. Illustrative examples for each of these strategy areas are described later in this chapter.

The generic design strategies and prototypical alternatives have applicability to the majority of crossing situations. In some limited instances, unusual designs and techniques may prove to be the most effective. A number of these are presented below to encourage consideration of atypical solutions to non-motorized travel problems by providing designers with some insight into effective innovative treatments which have been utilized elsewhere.

7.3.2 New Projects - Generic Design Strategies

For illustrative purposes it was determined that five generic prototypical types of new non-motorized facilities were the most basic. These are as follows:

1. Overcrossing Shared with Motor Vehicles (4 or more lanes, medium to heavy traffic)

2. Underpass Shared with Motor Vehicles (4 or more lanes, medium to heavy traffic)

3. Bicycle and Pedestrian Bridge (over 100 feet - 30.5M long)

4. Bicycle and Pedestrian Bridge (less than 100 feet - 30.5M long)

5. Bicycle and Pedestrian Undercrossing (underpass and tunnel)

Each prototypical solution illustrated on the following pages in Figures 25 to 29 contains a problem statement and a detailed graphical illustration of one or more solutions to the crossing problem. Key design considerations are noted on the illustration and outlined in detail by crossing element: end conditions, approaches, and the structure. Standard features common to the design of the prototypical over and undercrossings are presented in Table 12. Special features are noted, and the advantages and disadvantages of the solution are compared. Reference is made by number to those of the 72 Case Study Sites that most closely correspond to the prototypical solution, so that an actual design and cost data can be examined, if desired. A list of the 72 Case Study Sites with their corresponding reference numbers is included in the appendix.

FOUR LANE OVERCROSSING SHARED WITH MOTOR VEHICLES

PROBLEM STATEMENT

To incorporate two-way bicycle, pedestrian and handicapped facilities in the design of a new overpass or bridge, whose main puruose is conveyance of motor vehicles. The project has heavy motor vehicle traffic with four or more lanes, speeds of 35 mph or more.

Selected for illustrative purposes as shown in Figure 15 are the following characteristics:

- A four lane bridge spanning a river.
- Bicycle and pedestrian facilities on one side only.
- End conditions are continuation of a major highway for the motor vehicle portion, with an existing or proposed bicycle and pedestrian trail.
- The structure is steel plate girders with a reinforced concrete deck.
- The approaches are long and on earth fill.

DESIGN CONSIDERATIONS FOR CROSSING ELEMENTS

Ends

- Stripe center lines on all approaches where pathways intersect. Continuous center line may be necessary for high usage.
- Install guide signs at pathway intersections to provide directional information.
- Install pedestrian railing 4.5 ft. minimum along the river embankment adjacent to the pathway intersection to prevent turning bicyclists from going off the path into the river.
- Make curve transitions between approaches and end conditions smooth and avoid sharp turns.
- Make the transition between grades as smooth as possible and avoid abrupt transitions.
- Refer to the discussion on End Conditions beginning on page 125.

Approaches

- Preferred approach path material is asphaltic concrete because of jointless construction.
- Install pedestrian rail a minimum of 4.5 ft. high along outside edge of path if shoulder area is narrow and slope is steep.
- Place beam guardrail or traffic barrier between path and roadway if separation is less than 5 feet.

NOTE: To convert to metres multiply feet x 0.3048.

Structure

- Width of the pedestrian and bikeway facilities varies from 8 ft. up to 16 ft., depending on anticipated volume of two-way bicycle and pedestrian traffic.
- Traffic barrier (half "Jersey" type) between roadway and bike/ped, with mesh fencing or tubular railing for total height of 4.5 ft.
- Outside railing is 8 ft. high curved or vertical chain link or mesh if over a roadway to prevent trash from being thrown. If over water, a 4.5 ft. (min.) height pedestrian railing should be provided.
- Refer to Table 12 for standard features, such as pathway width, cross slope, clearances and handrail placement. (see page 124)

SPECIAL FEATURES AND CONDITIONS

- Provide level grade breaks or rest areas on long grades and long structures.
- The area between the traffic barrier and outside curb may act as a "trap" for both debris and water, unless carefully planned and constructed.
- Lighting fixtures should be located outside of the clear width, such as behind the fencing or recessed in the fencing.

DESIGN STRATEGY ADVANTAGES AND DISADVANTAGES

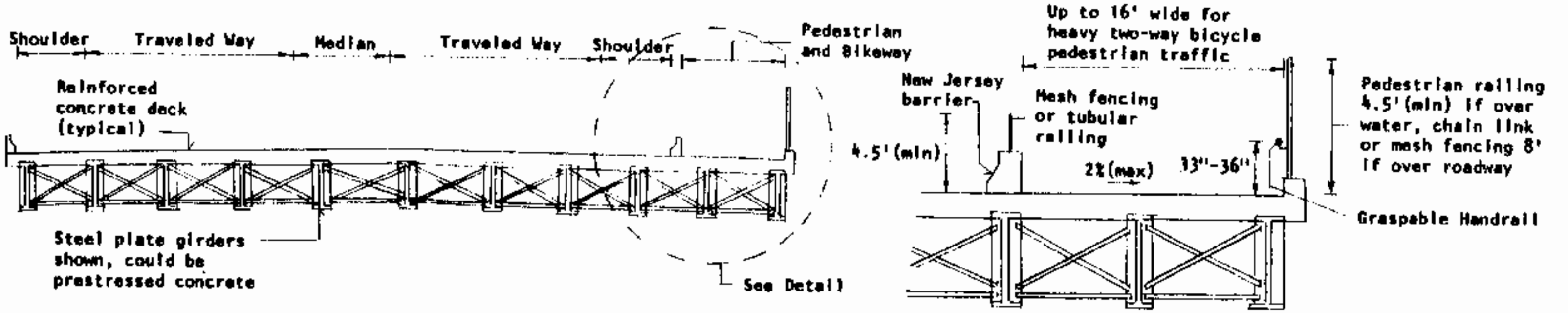
Advantages

- Lower cost due to combining bike and pedestrian facilities with construction of motor vehicle project.
- Facility on one side is less costly than a facility on both sides of structure.
- One-sided facility provides continuity with single trail on approaches.
- Full separation of non-motorized traffic from motor vehicle traffic.

Disadvantages

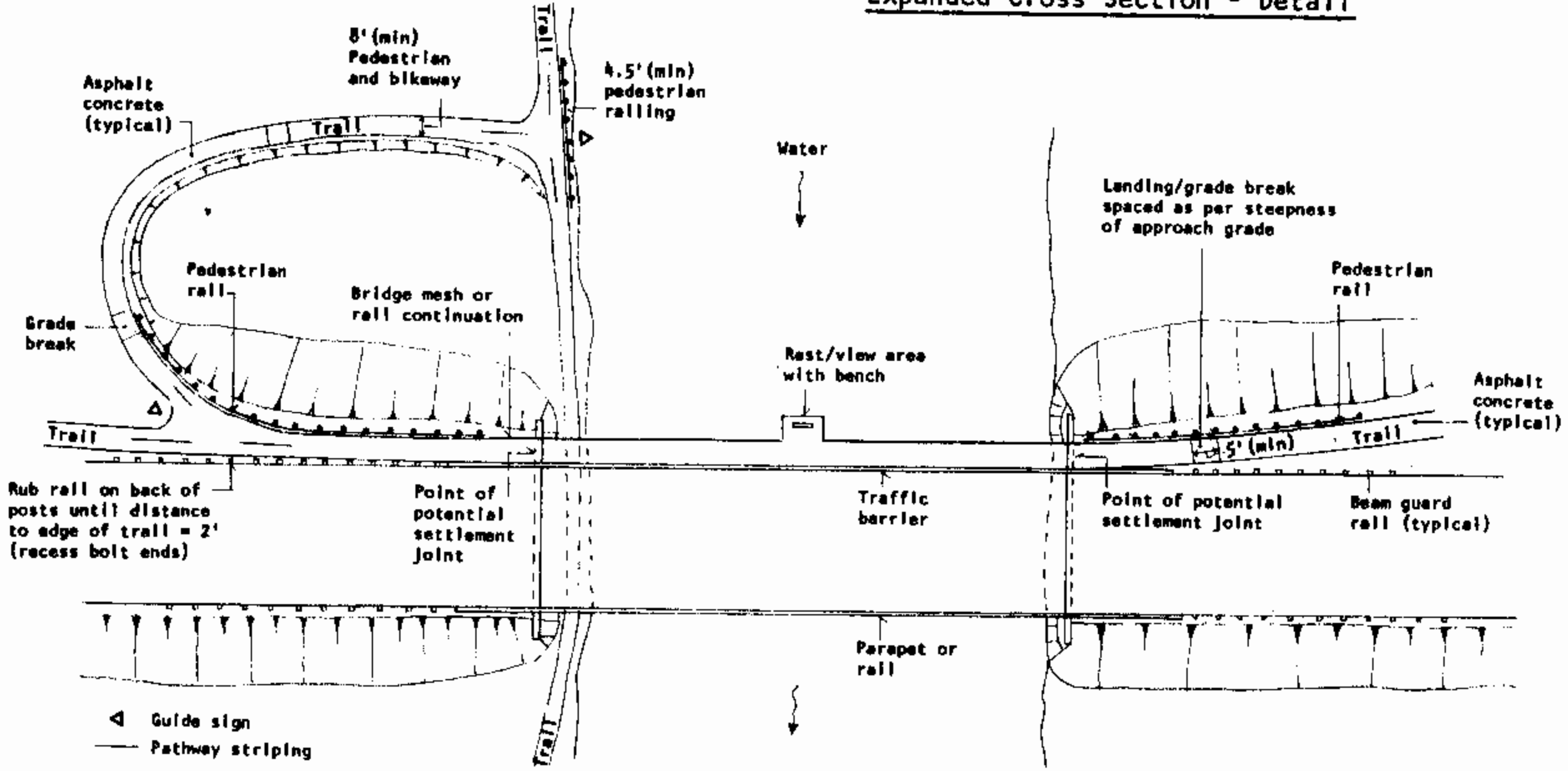
- Aesthetic and psychological discomfort from sharing facility with heavy motor vehicle traffic; noise, air pollution.
- Interaction between bicyclists and pedestrians may cause operation and safety problems.
- One side facility may complicate end conditions in returning to existing sidewalk and street patterns.
- Non-motorized travel may be lengthened by sharing a structure located primarily to optimize motor vehicle travel.

CASE STUDY REFERENCE
No. 35, 40, 45, 63, 69 (See appendix)



Typical Cross Section (Mid-span)

Expanded Cross Section - Detail



Plan View

Figure 15. NEW PROJECT 1 - FOUR LANE OVERCROSSING SHARED WITH MOTOR VEHICLES

NEW PROJECT 2

FOUR LANE UNDERPASS SHARED WITH MOTOR VEHICLES

PROBLEM STATEMENT

To incorporate bicycle, pedestrian and handicapped facilities on both sides of the roadway as part of the design of a new motor vehicle underpass. The underpass is a major project, with four or more lanes of heavy motor vehicle traffic, and speeds in excess of 35 mph. It crosses beneath a railroad or highway. End conditions are a continuation of the roadway.

Selected for illustrative purposes as shown in Figure 26 are two configurations, labeled as Alternative A and Alternative B, having the following characteristics:

Alternative A - Depressed Roadway

The overcrossing is sufficiently long to allow the bicycle and pedestrian ways to be located away from the roadway. The overcrossing spans a depressed roadway.

a. Roadway is depressed so pedestrian and bikeway can be located on the cut slope with both vertical and horizontal separation used to minimize grades.

b. Roadway is depressed so pedestrian and bikeway can be elevated along the wall to provide a safe vertical separation from the adjacent roadway, as well as to reduce grades for pathway users.

Alternative B - At-Grade Roadway

Retaining walls are required to reduce the bridge span, thereby restricting the space available for bicycles and pedestrians. The overcrossing is elevated from the surrounding ground surface and spans an at-grade roadway.

a. Roadway is at-grade so pedestrian and bikeway needs only horizontal separation from the roadway.

b. Roadway is at-grade, therefore adjacent sidewalk requires positive physical separation to ensure safety.

DESIGN CONSIDERATIONS FOR CROSSING ELEMENTS

Ends

- Continue the bike and ped way and the pedestrian sidewalk configuration until rejoining the existing pedestrian and bike system.
- Continue the traffic barriers and pedestrian rails until there is no grade or normal ground level is reached beyond the underpass.
- Refer to the discussion on End Conditions beginning on page 125.

NOTE: To convert to metres muitiply feet x 0.3048

Approaches

- A pedestrian railing 4.5' high should be supplied on the outside edge of the elevated bike and pedestrian ways, and a traffic barrier with rail to a height of 4.5' on the traffic side of the roadway level bike and pedestrian ways.
- Refer to Table 12 for standard features such as pathway width, cross slope, clearances and handrail placement. (see page 124)

Structure

- Refer to Table 12 for standard features such as pathway width, cross slope, clearances and handrail placement. (see page 124)

SPECIAL FEATURES AND CONDITIONS

- The sidewalks and bikeway placed on the slope or elevated from the roadway reduce the change in elevation required to pass from ground level underneath the structure. This makes the crossing much easier in terms of effort for all non-motorized travelers.
- If sufficient space cannot be found on each side, the wide median in the center should be explored as an option for a pedestrian and bikeway.
- May require supplemental lighting, depending upon length of underpass and location of pathway.

DESIGN STRATEGY ADVANTAGES AND DISADVANTAGES

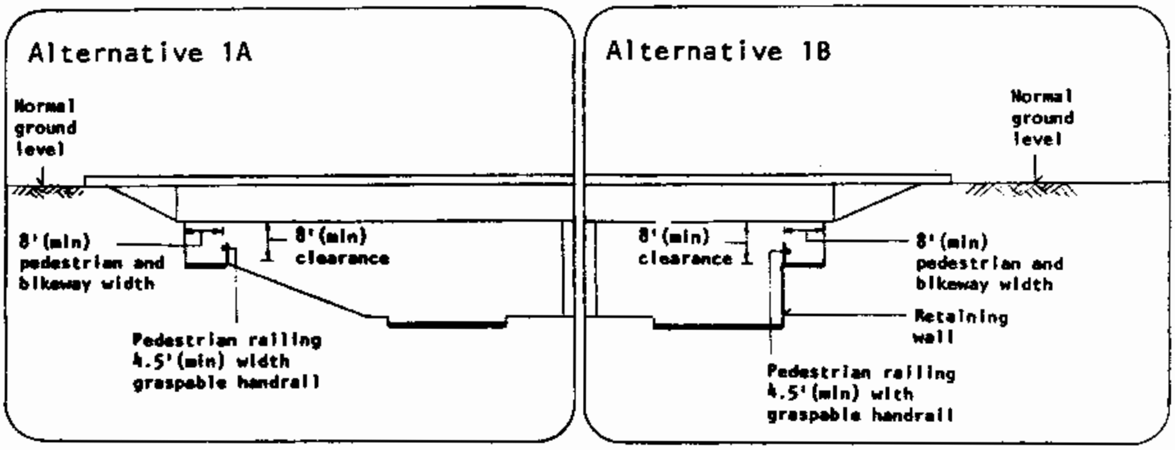
Advantages

- Lower cost due to combining construction of motor vehicle project with bike and pedestrian facilities.
- Full separation of motor vehicle traffic from non-motorized traffic.
- Maintenance of the bicycle and pedestrian facilities is done as a part of the motor vehicle project maintenance.
- Grades minimized to facilitate non-motorized travel.

Disadvantages

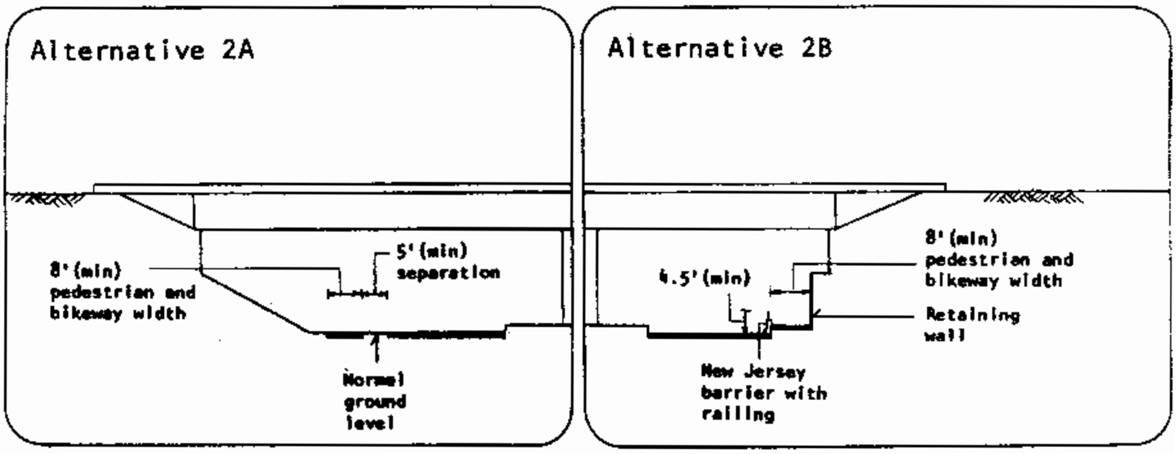
- Aesthetic and psychological discomfort from sharing facility with heavy motor vehicle traffic; noise, air pollution.

CASE STUDY REFERENCE
No. 71 (See appendix)



Alternative 1 - Section View

Bicycle and Pedestrian Ways Separated from Depressed Roadway



Alternative 2 - Section View

Bicycle and Pedestrian Ways Adjacent to At-Grade Roadway

Figure 16. NEW PROJECT 2 - FOUR LANE UNDERPASS SHARED WITH MOTOR VEHICLE

BICYCLE AND PEDESTRIAN BRIDGE OVER 100 FEET LONG

PROBLEM STATEMENT

To incorporate a long span overcrossing or bridge to exclusively serve two-way bicycle, pedestrian and handicapped travel over water, a roadway or a railroad. This is a structure with a span of greater than 100 feet.

Figure 17 shows cross-sections of four potential structural and configuration types for exclusive bicycle and pedestrian overcrossings.

DESIGN CONSIDERATIONS FOR CROSSING ELEMENTS

Ends

- Use centerline to delineate all approaches to the intersection between pathways.
- Stripe crosswalk and centerline on adjacent street.
- Install advance warning signs to indicate pedestrian crossing. Use school crossing signs and markings where applicable.
- Install guide signs to provide directional information to potential overcrossing users.
- Refer to the discussion on End Conditions beginning on page 125.

Approaches

- Refer to Table 12 for standard features such as pathway width, cross slope, clearance and handrail placement. (see page 124)
- Protect pedestrians and bicyclists from steep slopes at the edges of approaches with 4.5 foot high fencing.

Structure

- Rest areas should be considered as part of the design.
- Apply non-skid surfacing to the structure decking and ramped approaches.
- Provide lighting well protected from vandalism.
- Refer to Table 12 for standard features such as pathway width, cross slope, clearance and handrail placement. (see page 124)

NOTE: To convert to metres multiply feet x 0.3048.

SPECIAL FEATURES AND CONDITIONS

- Cost and aesthetic advantages may be realized by sharing the crossing with utilities.
- View screening may be necessary to preserve residential privacy.
- Shielding of certain lighting fixtures may be required to reduce impact on residences.
- Spiral ramps could save space.
- The area adjacent to the spiral ramp may be suitable for mini park.

DESIGN STRATEGY ADVANTAGES AND DISADVANTAGES

Advantages

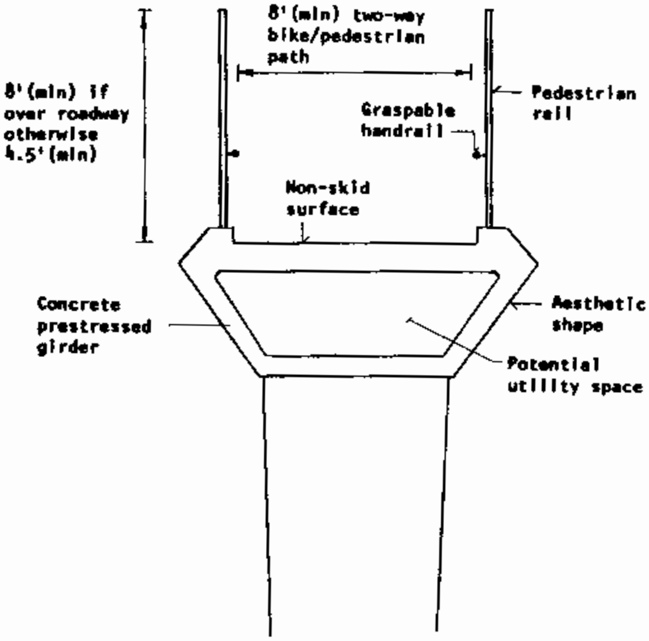
- Complete separation from motor vehicle traffic; safety; reduction in noise and air pollution.
- More direct access to bicyclist and pedestrian destinations.

Disadvantages

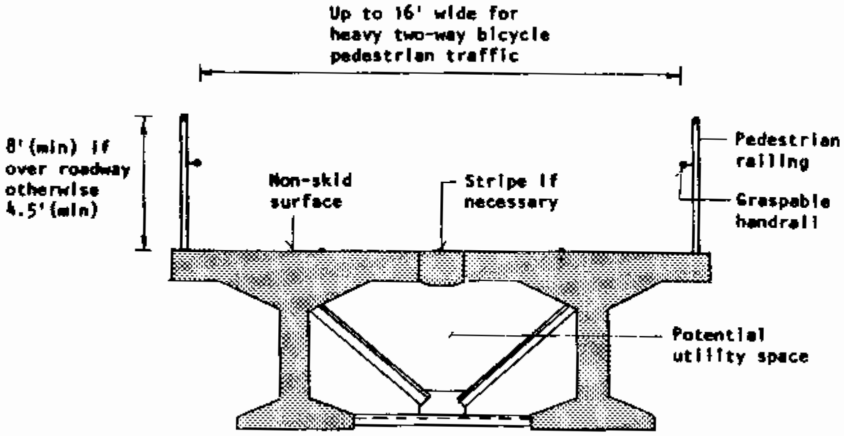
- Possible operational difficulties in rejoining the existing street and pedestrians travel system.
- Higher cost than facility shared with motor vehicles.
- Separate maintenance arrangements required.

CASE STUDY REFERENCE

Nos. 33, 34, 35, 38, 44, 47, 49, 56, 64, 65, 66
(See appendix)

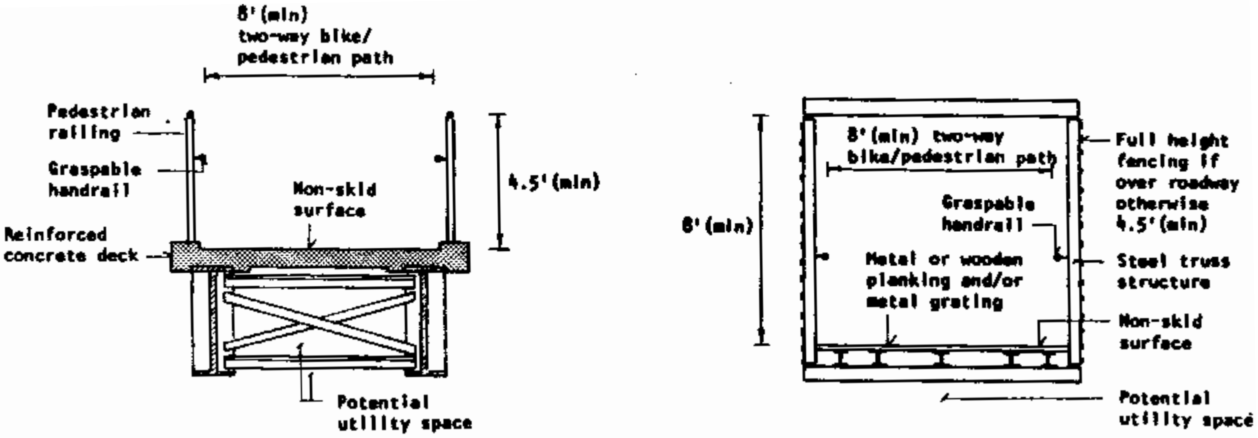


Prestressed Concrete Girder



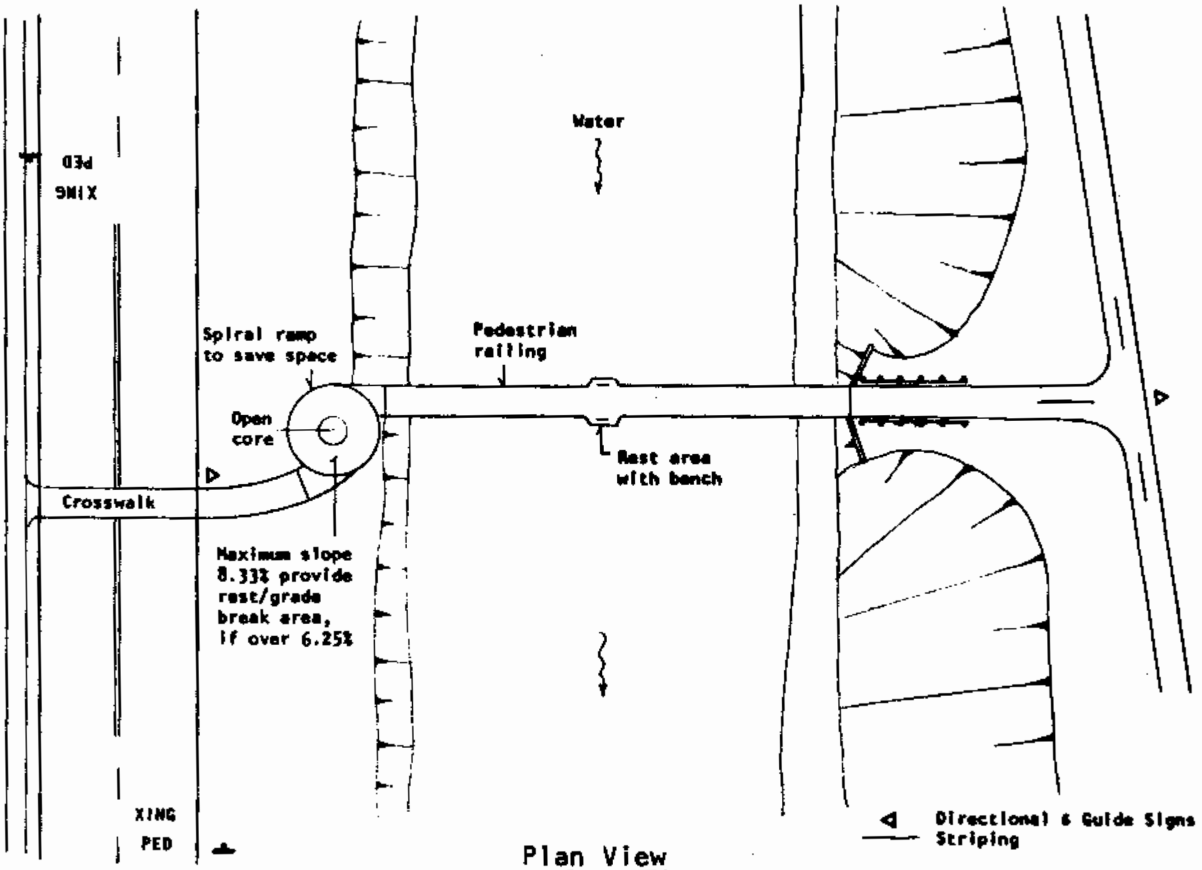
Prestressed Concrete Double Tee

Figure 17. NEW PROJECT 3 - BICYCLE AND PEDESTRIAN OVERCROSSINGS



Welded Steel Plate Girders

Steel through Truss



Plan View

Figure 17. NEW PROJECT 3 - BICYCLE AND PEDESTRIAN OVERCROSSINGS (Continued)

BICYCLE AND PEDESTRIAN BRIDGE LESS THAN 100 FEET LONG

PROBLEM STATEMENT -

Incorporate a medium or short span overcrossing or bridge for two-way bicycle, pedestrian and handicapped travel. The length of the structure is less than 100 feet.

Figure 18 shows cross sections of five potential structural configurations for exclusive bicycle and pedestrian overcrossings of short length. The following characteristics and features are illustrated as common for all the structural types:

- Eight foot minimum clear width for two-way bike and pedestrian traffic.
- Pedestrian handrails a minimum of 4.5 in height.
- Graspable handrails on both sides.
- Deck or approach cross slope of two percent maximum.
- Application of non-skid surfacing materials.

DESIGN CONSIDERATIONS FOR CROSSING ELEMENTS

Ends

- Refer to the discussion on End Conditions beginning on page 125.

Approaches

- Continue pedestrian railing or fencing for a short distance to channelize users onto bridge.
- Area adjacent to the bridge may be suitable for off-path rest area or view point. Additional fencing may be necessary along the top of the creek embankment if this area is used.
- Refer to Table 12 for standard features, such as pathway width, cross slope, clearances and handrail placement. (see page 124)

Structure

- Deck cross slope is not necessary with wood plank or metal grating, because water drains through.
- Refer to Table 12 for standard features, such as pathway width, cross slope, clearances and handrail placement. (see page 124)

NOTE: To convert to metres multiply feet x 0.3048.

SPECIAL FEATURES AND CONDITIONS

- Handrails and beams constructed of wood may be subject to vandalism.
- Utilities could also use the same crossing with cost and aesthetic benefits.
- Prefabricated structures can shorten construction times and reduce costs.

DESIGN STRATEGY ADVANTAGES AND DISADVANTAGES

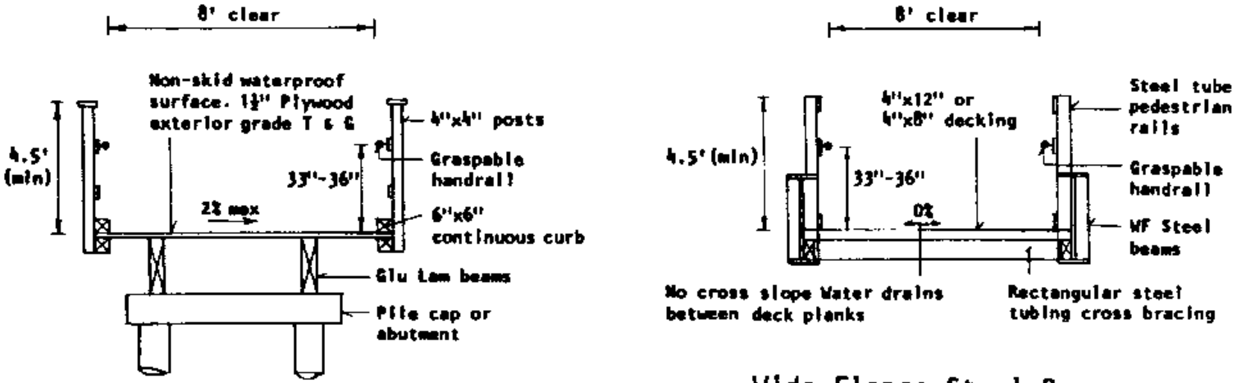
Advantages

- Complete separation from motor vehicle traffic; improvement in safety; reduction in noise and air pollution discomfort.
- Relatively low cost structure constructed without interruption of motor vehicle traffic.

Disadvantages

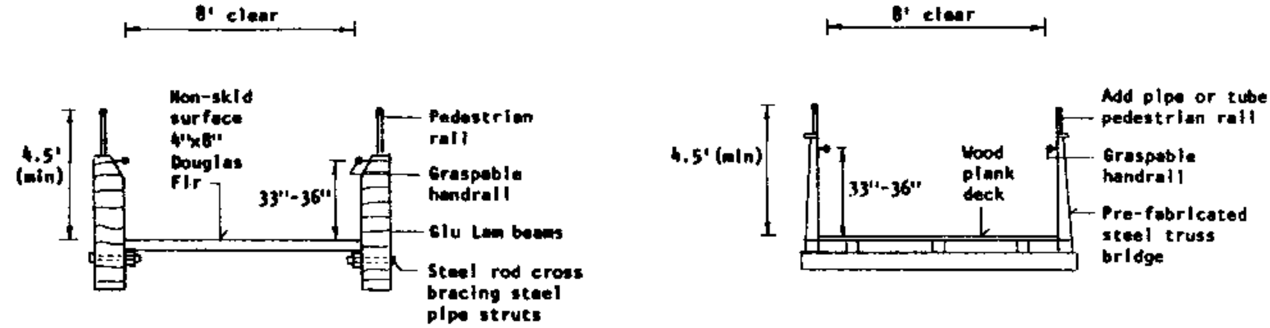
- Possible operational difficulties in rejoining the existing street and pedestrian travel system.
- Higher cost than a facility shared with motor vehicles.
- Separate maintenance arrangements required.

CASE STUDY REFERENCE
Nos. 26, 27, 28, 29, 31, 32, 39, 42, 54, 60
(See appendix)



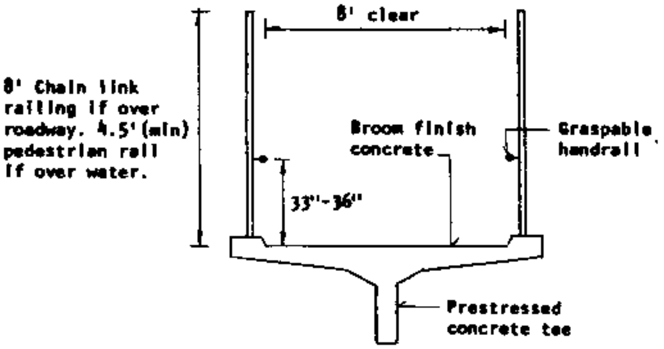
Glu Lam Beams with Plywood Deck

Wide Flange Steel Beams with Wood Plank Decking



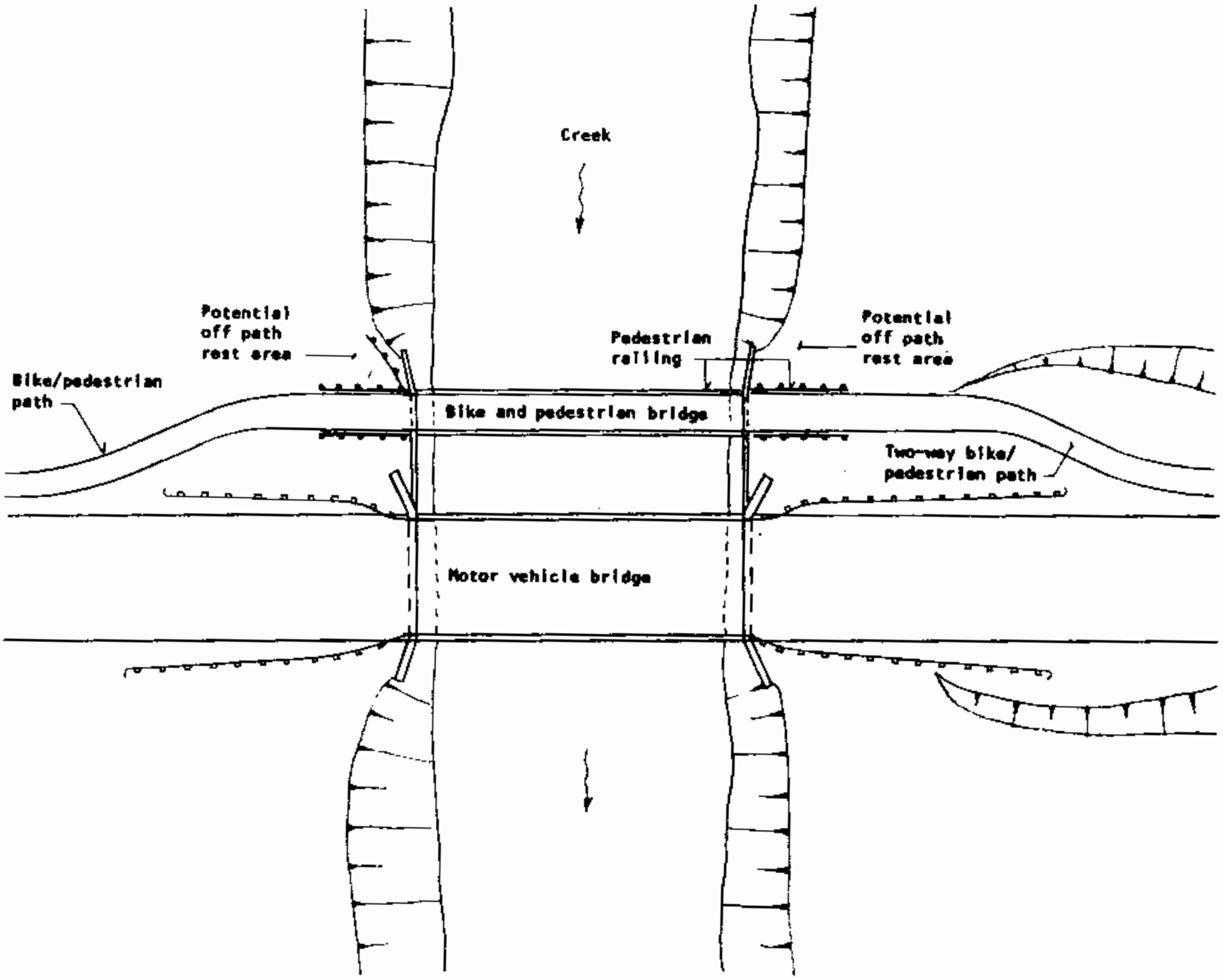
Glu Lam Beams with Wood Plank Decking

Pre-Fabricated Steel Truss with Wood Plank Decking



Prestressed Concrete Tee

Figure 18. NEW PROJECT 4 - BICYCLE AND PEDESTRIAN OVERCROSSING LESS THAN 100 FEET LONG



Plan View

Possible Layout of Short Span Bike and Pedestrian Bridge

Figure 18. NEW PROJECT 4 - BICYCLE AND PEDESTRIAN OVERCROSSING LESS THAN 100 FEET LONG (Continued)

BICYCLE AND PEDESTRIAN UNDERCROSSING

PROBLEM STATEMENT

To incorporate a two-way travel bicycle and pedestrian underpass or tunnel beneath a railroad, roadway or other barrier. Structures are differentiated by length, with lengths greater than 100 feet considered to be long structures.

Figure 19 shows cross sections for an arch-type tunnel structure and a narrow underpass. The following characteristics and features are illustrated:

- Eight foot minimum clear width for two-way bicycle and pedestrian traffic.
- Pedestrian handrails a minimum of 4.5 in height in areas where there is slope.
- Graspable handrails on both sides.
- Two percent maximum cross slope.
- Lighting installed if the structure is long. Protect lighting well from vandalism.

DESIGN CONSIDERATIONS FOR CROSSING ELEMENTS

Ends

- Consider connecting pathways between the pedestrian and bikeway using the undercrossing and the roadway above.
- If connecting pathways are installed, directional guide signing will be necessary at both ends.
- Refer to the discussion on End Conditions beginning on page 125.

Approaches

- Centerline striping may be needed to emphasize travel relationships approaching undercrossing.
- Handrail should extend a minimum of 10 feet from the undercrossing and may be extended further, depending upon the grade.
- Refer to Table 12 for standard features such as pathway width, cross slope, clearances and handrail placement. (see page 124)

NOTE: To convert to metres multiply feet x 0.3048.

Structure

- Satisfactory drainage facilities should be built with grates and inlets compatible with bicycle and pedestrian usage.
- Provide vandal proof lighting in tunnels or long underpasses.
- Refer to Table 12 for standard features such as pathway width, cross slope, clearances and handrail placement. (see page 124)

SPECIAL FEATURES AND CONDITIONS

- Care must be exercised in maintaining adequate sight distance for bicyclists when entering or leaving the underpass or tunnel.
- Side slopes approaching or within the undercrossing should be designed so that earth, gravel or other surface treatments are not a source of pathway debris.

DESIGN STRATEGY ADVANTAGES AND DISADVANTAGES

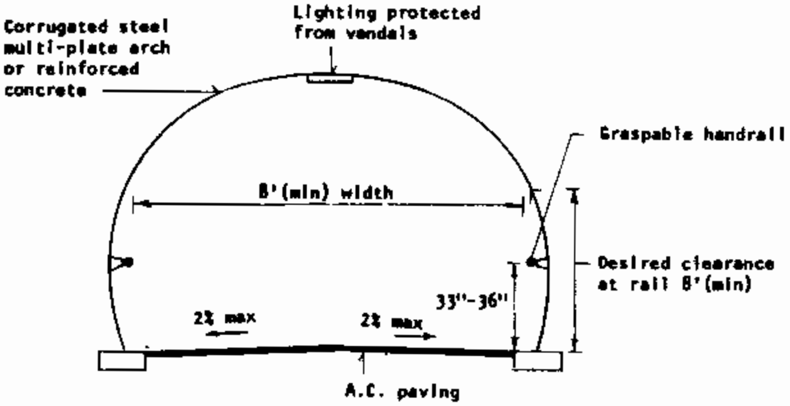
Advantages

- Complete separation from motor vehicles; improvement in operational safety; reduction in noise and air pollution discomfort.
- Gentler grades and less vertical height differential possible in undercrossing compared to overcrossing.
- Less visible and less obtrusive than an overcrossing.

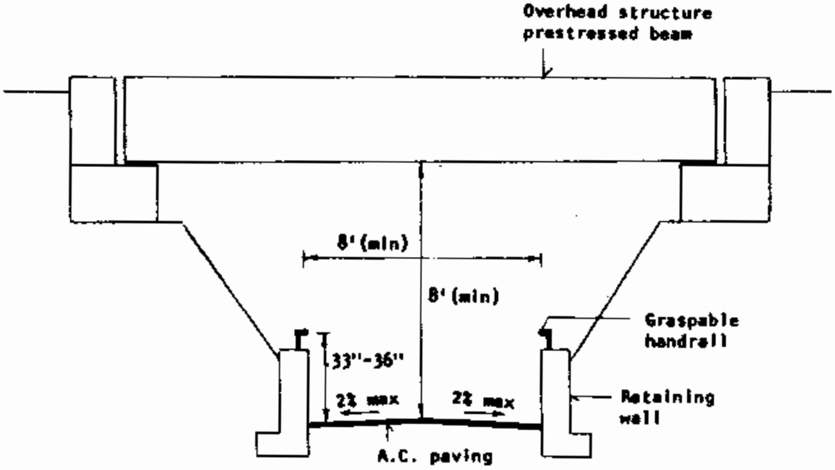
Disadvantages

- May be higher construction cost than overcrossing in certain settings or a facility shared with motor vehicles.
- Separate maintenance arrangements required.
- May be perceived as being dark, remote and having unpleasant environment subject to vandalism or loitering. This is especially true if the approaching users cannot see entirely through the underpass.
- Small arch-type tunnels may be perceived as being overly restrictive unless used for only short distances and built to exceed the minimum width requirement.

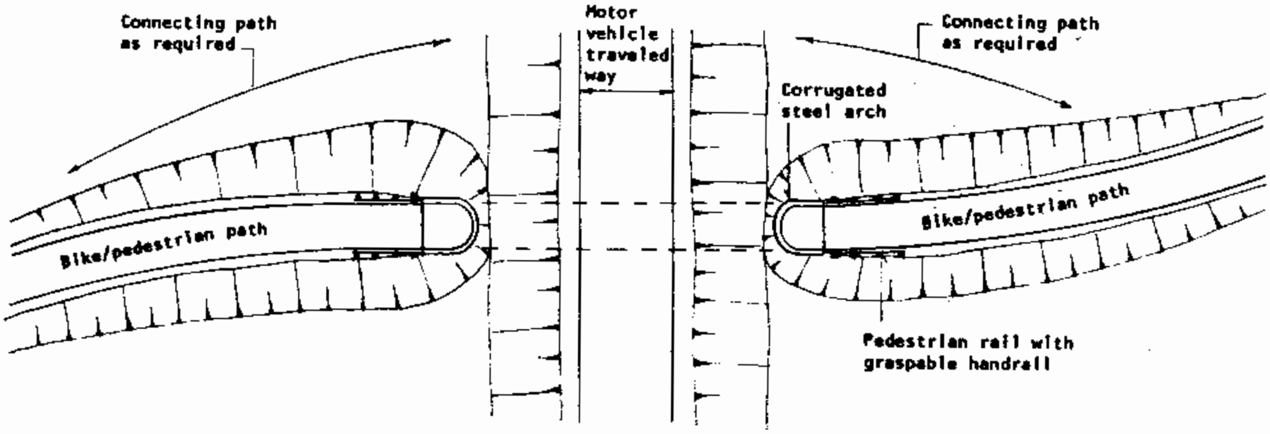
CASE STUDY REFERENCE
48, 50, 52, 58, 59, 67, 70 (See appendix)



Arch Tunnel Structure - Cross Section



Underpass - Cross Section



Tunnel-Type Structure - Plan View

Figure 19. NEW PROJECT 5 - BICYCLE AND PEDESTRIAN UNDERCROSSING

Table 12. Design Guidelines for Prototypical Over- and Undercrossings*

End Conditions

- Curb cuts and ramps are constructed to facilitate access. Minimum width should be 3 feet (0.8M) for one direction and 4 feet (1.2M) for two-way travel and 5.5 feet (1.7M) to enable two wheelchairs to pass. (61)
- Striping, signing and signals are installed to mitigate operational difficulties.
- Barriers are placed on exclusive paths to prohibit use by unauthorized motor vehicles.
- Sight distance at pathway and street intersections are free from obstacles. (See Table 11)

Approaches

- Minimum pathway width is 5 feet (1.5M) for a pedestrian way or one-way path, and 8 feet (2.4M) for a combined pedestrian and bikeway. (22, 65)
- Maximum grade is 8.33 percent, with 5 percent the desirable max. (51, 52, 63)
- Maximum pathway cross slope is 2 percent. (64)
- Grades in excess of 6.25 percent have grade breaks, landings or rest areas spaced periodically with a minimum landing depth of 5 feet (1.5M). (61)
- Preferred pathway surface is asphaltic concrete because of its jointless construction and all-weather serviceability.
- Fencing or protective barriers placed to separate non-motorized users from adjacent steep slopes and high speed traffic.
- Graspable handrails 33"-36" (0.8-0.9M) above the pathway surface wherever fencing is used. (61)
- Minimum lateral clearance to obstacles is 1 foot (0.3M), with 2 feet (0.6M) desirable. (22, 65)

Structure

- Pathway width, grade, cross slope criteria identical to approaches.
- Graspable handrails 33"-36" (0.8-0.9M) above the pathway surface constructed continuously across structure. (61)
- Physical barrier placed between two-way pathway and adjacent traffic lane.
- Minimum fence height is 4.5 feet (1.4M) with bicycle usage. (65)
- Non-slip surfacing used on pathway surface.
- Vertical clearance minimum is 8 feet (2.4M).
- Drainage gratings placed outside of pathway.

*These guidelines were assembled from various sources and do not necessarily coincide with the adopted standards for any one agency.

7.3.3 Retrofit Projects - Generic Design Strategies

For illustrative purposes it was determined that three generic prototypical retrofit solutions were the most basic. These are as follows:

1. Cantilever addition of Bicycle and Pedestrian Facilities to an overcrossing
2. Expansion or upgrading of Existing Bicycle and Pedestrian Facilities
3. Conversion of an Existing Over or Undercrossing to Exclusive use of Bicyclists and Pedestrians

Each prototypical retrofit solution contains a problem statement and a detailed graphical illustration of one or more solutions to the crossing problem. Key design considerations are noted on the illustration and outlined in detail by crossing element-end conditions, approaches, and the structure. Special features are noted, and the advantages of the solution are compared. The three generic prototypical types of retrofit projects are depicted in Figures 20, 21 and 22.

Design strategies for retrofit projects act in a complementary manner to the ones for new projects, since features shown in one strategy could be applicable in another situation.

Again, reference is made by number to those of the 72 Case Study Sites that most nearly correspond to the prototypical solution, so that actual designs and cost data can be examined, if desired. A list of the 72 Case Study sites with their corresponding reference numbers is in the Appendix.

7.3.4 End Conditions

As stated earlier, grade crossings have been defined for the purposes of this study as having three components: end conditions, approaches and the structure (see Figure 2). End conditions are further defined as being: that portion of the traveled way which is adjacent to the physical limits (on both ends) of an over- or undercrossing and which affects the ability of non-motorized travelers to use the crossing. All too often, primary attention is given to the design of the structure and its approaches, while the design at the end condition is neglected in comparison. It is important to re-emphasize that the three grade crossing components must not only provide smooth linkage between themselves, but should be viewed in the context of the service provided within the surrounding system of non-motorized facilities.

The purpose of this section is to define the basic types of end conditions and to describe potential problems and treatments. End

CANTILEVER ADDITION OF BICYCLE AND PEDESTRIAN FACILITIES TO AN OVERCROSSING

PROBLEM STATEMENT

To incorporate a protected two-way pedestrian facility on an existing motor vehicle bridge. Bicyclists would have to either walk their bikes across, if the facility is one-side only, or ride across the motor vehicle portion at the edge of the traveled way. There is insufficient room on the bridge deck for a non-motorized facility.

Partial section views of five cantilever structural configurations are shown in Figure 20. Possible methods of attachment on three reinforced concrete bridges or overpasses and two steel bridges or overpasses are illustrated. A plan view with the following characteristics is also shown.

- A two-lane bridge spanning a river.
- A pedestrian sidewalk on one side only. Bicycles must be walked across.
- End conditions are a continuation of the roadway for the motor vehicle portion, and a continuation of the sidewalk.
- Beam and post guardrail exists on both approaches.

DESIGN CONSIDERATIONS FOR CROSSING ELEMENTS

Ends

- Continue beam guardrail, as necessary, to protect walkway users.
- Refer to the discussion of End Conditions beginning on page 125.

Approaches

- Install a pedestrian railing a minimum of 4.5 ft. high on the outside edge of the path if the slope is steep.
- A beam guardrail or traffic barrier should be placed between the approach path or sidewalk and the motor vehicles if the separation is less than five feet, or if traffic is heavy or operates at high speed.
- The approach shoulder may have to be widened to support the path behind the guardrail. A retaining wall may be required for the extra fill material.
- Refer to Table 12 for standard features such as pathway width, cross slope, clearances and handrail placement. (see page 124)

NOTE: To convert to metres multiply feet x 0.3048.

Structure

- Even with structural limitations, every effort should be made to meet or exceed the 4 foot minimum clear sidewalk width.
- Opposing two-way travel on one side must be infrequent for a narrow sidewalk to function properly.
- The existing abutments may have to be extended or modified to support the walkway.
- The walkway deck could be constructed of wood planking, aluminum planking, steel grating, steel checker plate, precast concrete, or reinforced concrete poured in place. Surfaces should have an application of skid-proofing materials if they are slippery when wet.
- The 4.5 ft. pedestrian rail should be carried across the walkway on the outside edge.

SPECIAL FEATURES AND CONDITIONS

- If conflicting two-way patronage is expected to be heavy, then a wider walkway should be constructed, or if that is infeasible, walkways should be constructed on both sides of the structure if compatible with approaches.

DESIGN STRATEGY ADVANTAGES AND DISADVANTAGES

Advantages

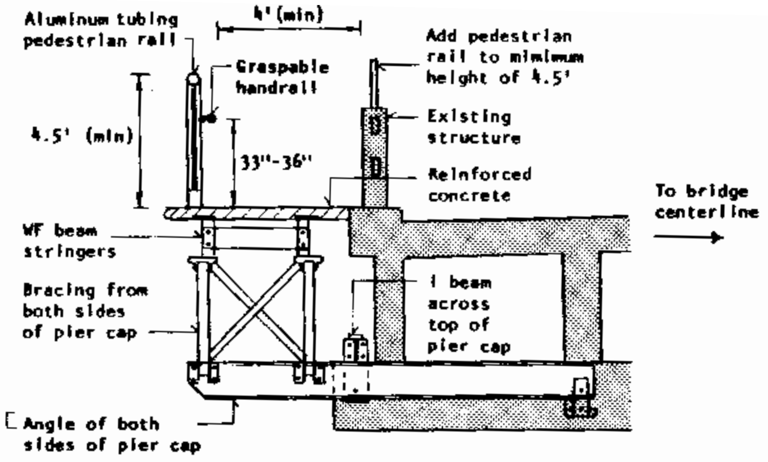
- Non-motorized users are fully protected from motor vehicle traffic while originally there was insufficient space on the overcrossing.
- Construction costs and disruptions are minimized.

Disadvantages

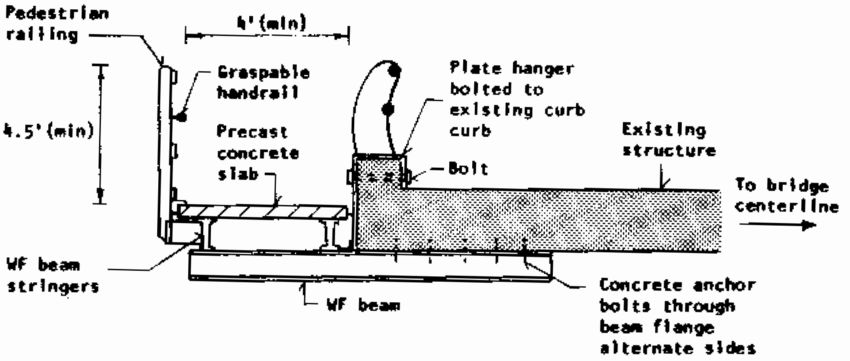
- Bicyclists may choose to ride in the roadway rather than walk their bikes across the cantilevered facility.
- One side facilities only may complicate the operational safety at the end conditions.
- Structural limitations may create substandard width walkways.

CASE STUDY REFERENCE

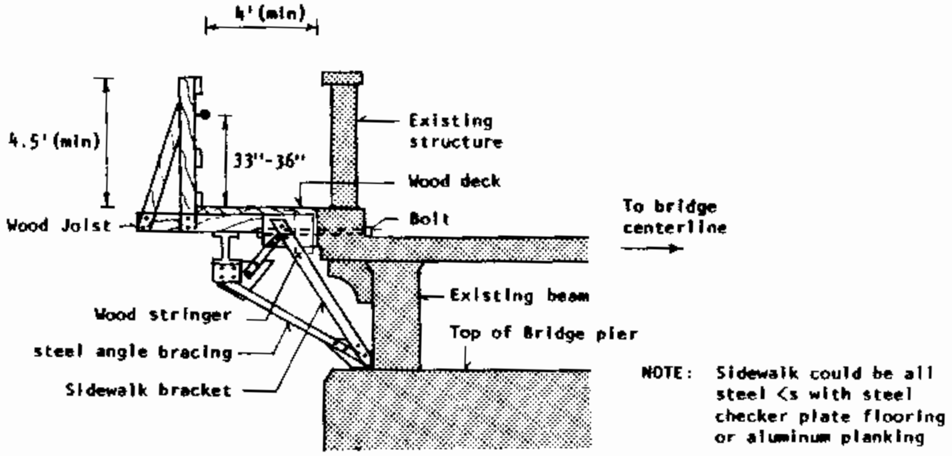
Nos. 4, 5, 11, 12, 13, 14, 15, 17, 22, 23
(See appendix)



Reinforced Concrete bridge - Partial Section View



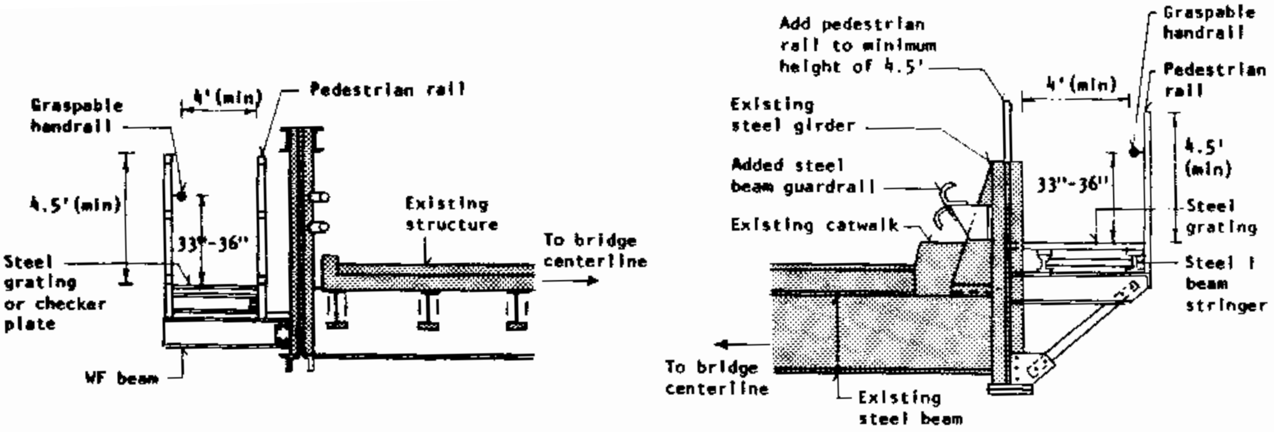
Reinforced Concrete Bridge - Partial Section View



NOTE: Sidewalk could be all steel <s with steel checker plate flooring or aluminum planking

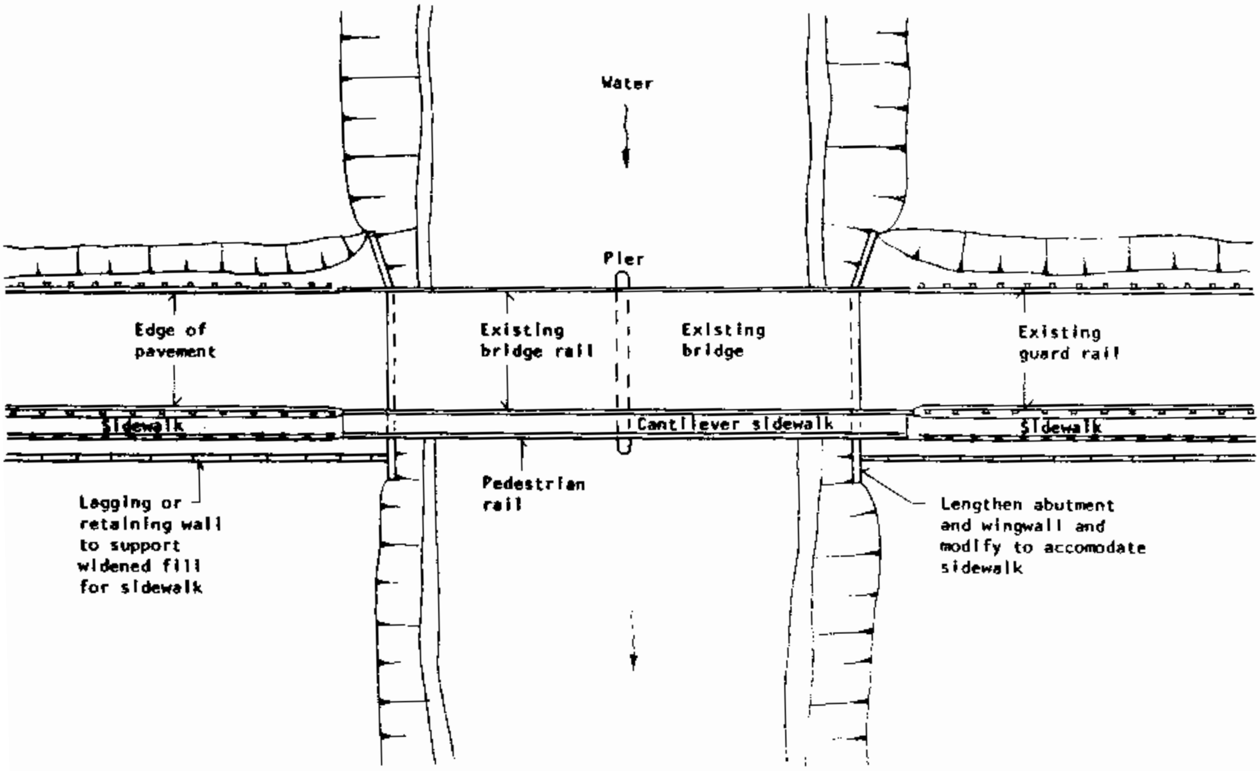
Reinforced Concrete Structure - Partial Section View

Figure 20. RETROFIT PROJECT 1 - CANTILEVER ADDITION OF BICYCLE AND PEDESTRIAN FACILITIES TO AN OVERCROSSING



Steel Truss Structure Partial Section View

Steel Girder Structure Partial Section View



One Side Cantilever Sidewalk Solution - Plan View

Figure 20. RETROFIT PROJECT 1 - CANTILEVER ADDITION OF BICYCLE AND PEDESTRIAN FACILITIES TO AN OVERCROSSING (Continued)

EXPANSION OR UPGRADING OF EXISTING BICYCLE AND PEDESTRIAN FACILITIES

PROBLEM STATEMENT

To provide protected bicycle and pedestrian facilities on both sides of an existing underpass. The underpass has five-foot sidewalks on each side of a four lane divided roadway.

DESIGN SOLUTION

An entirely new widened sidewalk constructed away from the roadway is one solution. A second solution involves widening the existing sidewalk and installing a physical barrier between the sidewalk and traffic. (See Figure 21)

Alternative A

Relocation to an up slope position is more favorable for a sidewalk along a depressed roadway since it minimizes grades. The existing sidewalk can be removed or may be retained if it provides an essential safety feature for emergency use of motor vehicle occupants.

Alternative B

Widening of an existing sidewalk adjacent to the curb is equally applicable to at-grade, as well as depressed roadway designs.

DESIGN CONSIDERATIONS FOR CROSSING ELEMENTS

Ends

- Continue the traffic barrier until there is no grade from the depressed roadway or normal ground level is reached beyond the structure.
- Conform to existing pedestrian and bikeway facilities at each end.
- Refer to the discussion on End Conditions beginning on page 125.

Approaches

- The minimum width for simultaneous bike and pedestrian traffic is eight feet.
- Construct a pedestrian rail 4.5 ft. high on the outside of the (Alternative I) bike and ped path that has been moved up the slope.
- Construct traffic barrier with pedestrian railing on top to bring its height up to 4.5 feet (Alernative II).
- Refer to Table 12 for standard features such as pathway width, cross slope, clearances and handrail placement. (see page 124)

NOTE: To convert to metres multiply feet x 0.3048.

Structure

- Construct low retaining walls, if necessary, for the walkway widening.
- Refer to Table 12 for standard features such as pathway width, cross slope, clearances and handrail placement. (see page 125)

SPECIAL FEATURES AND CONDITIONS

- The area between the retaining wall and the traffic barrier can act as a "trap" for both debris and water, unless carefully planned and constructed.
- Bike lanes or shoulder stripes should be considered as a non-structural alternative or supplement where roadway space is available.
- If sufficient space cannot be found on each side, the wide median in the center may offer an option for a pedestrian and bikeway.
- May require supplemental lighting, depending upon length of underpass and location of pathway.

DESIGN STRATEGY ADVANTAGES AND DISADVANTAGES

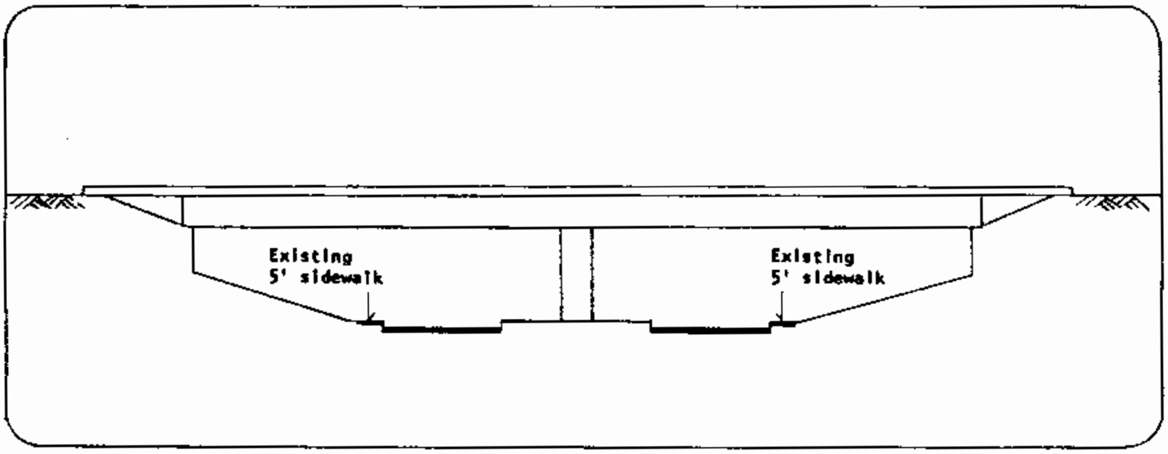
Advantages

- Two-sided facility crossing is coincident with the existing street and sidewalk patterns.
- Bicyclists and pedestrians are fully protected from motor vehicle traffic.
- Moving the path up the slope lessens its grade where the roadway is depressed.
- Retrofitting existing facilities is less costly than constructing alternative routes or separating bicycle and pedestrian facilities.

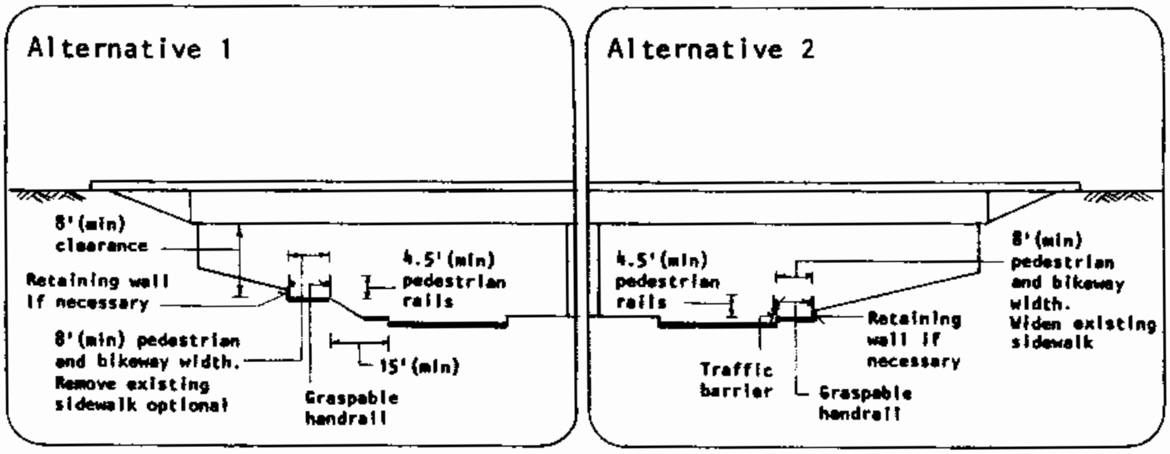
Disadvantages

- Some bicyclists may choose not to use the bike path, preferring to ride at the edge of the traveled way.
- If motor vehicle traffic is heavy, bicyclists and pedestrians may be bothered by noise and air pollution.
- Returning bicyclists and pedestrians to the existing street system may be complicated at the ends if a central median is utilized.

CASE STUDY REFERENCE
No. 71 (see appendix)



Existing Underpass - Section View



Retrofitted Underpass - Section View

Figure 21. RETROFIT PROJECT 2 - EXPANSION OR UPGRADING OF EXISTING BICYCLE AND PEDESTRIAN FACILITIES

CONVERT AN EXISTING OVER OR UNDERCROSSING TO EXCLUSIVE USE OF BICYCLISTS AND PEDESTRIANS

PROBLEM STATEMENT

To convert an existing structure (railroad trestle, highway bridge, culvert) to exclusive use by bicyclists and pedestrians. Culverts are often used informally by pedestrians as undercrossings.

DESIGN SOLUTION

Potential conversion situations are depicted in Figure 22. An abandoned railroad trestle and highway bridge are shown converted to exclusive bicycle and pedestrian use. A box culvert has been converted to facilitate bicycle and pedestrian use during low water conditions.

DESIGN CONSIDERATIONS FOR CROSSING ELEMENTS

Ends

- Operational and safety problems may occur where the ends of converted structures merge into the existing street or pedestrian and bikeway system. Signing, striping and signals may help to mitigate these potential problem areas.
- Curb cuts and ramps appropriately placed are an aid to handicapped and bicyclists in rejoining existing streets.

Approaches

Box Culvert

- Make transition into culvert structure smooth and avoid short sections of steep grades.
- Avoid curves or obstructions in approaches that could reduce sight distance.

Highway Bridge

- Protect pedestrians and bicyclists from steep slopes at edges of approaches with pedestrian rail or reutilization of metal guardrail.
- Install posts or bollards to prevent motor vehicle travel over the bridge structure.
- Repair and smooth asphalt concrete surfaces and joints.

Railroad Trestle

- Remove and salvage existing railroad ties and resurface approach paths
- Provide railings at the edges of steep fills adjacent to the structure.

Structures

Box Culvert

- Elevate path sufficiently to be above low water flows -- sidewalk or raised floor.
- The minimum vertical clearance allowable is 8 feet.

Highway Bridge

- Repair and patch the existing bridge surfaces.
- Construct pedestrian rails 4.5 ft. in height at the outside edges.
- Modify existing drainage inlets and grates as needed.

Railroad Trestle

- Construct new decking over the existing bridge ties.
- Construct pedestrian railings 4.5 ft. in height at the outside edges.

SPECIAL FEATURES AND CONDITIONS

- Vandal proof lighting should be considered for all of the structures, and particularly the converted culvert.
- Consider railing along culvert sidewalk which can be removed during flooding seasons.
- Protect pathway approaches to a culvert from stream erosion.

DESIGN STRATEGY ADVANTAGES AND DISADVANTAGES

Advantages

- Lower cost because of use of existing structure.
- Complete separation from motor vehicle traffic.
- Use bridge or trestle which would otherwise need to be removed or be subject to unsightly deterioration.
- Width of structure is more than adequate.
- May legitimize an informal crossing route.

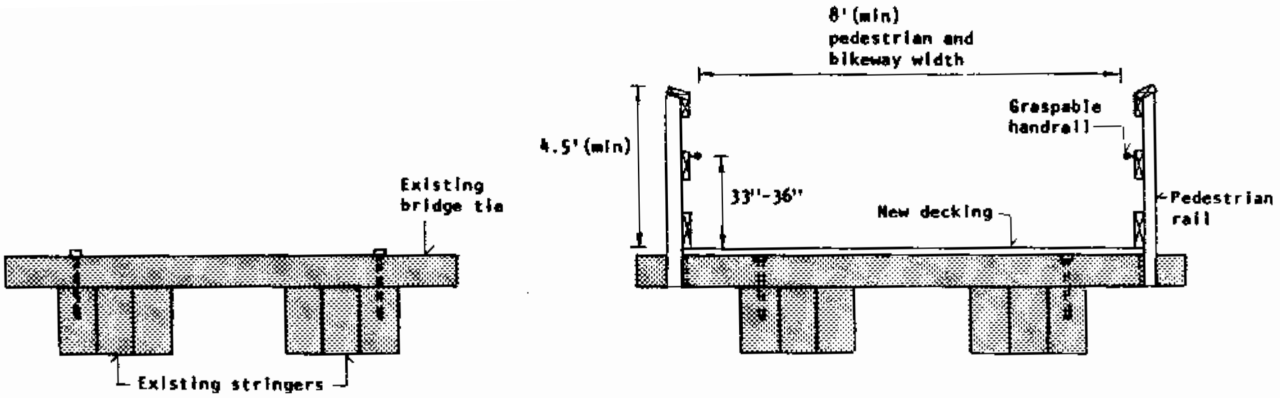
Disadvantages

- Crossing may be remote from desired travel directions of bicyclists and pedestrians.
- May require extensive repair to permit safe conversion.
- Culvert structure and pathway approaches are subject to flooding, thereby requiring increased maintenance to keep free of debris.
- Culvert may present dark and unplesant environment.
- Culvert path is not usable during periods of high water, thereby necessitating an alternate route or cessation of travel.

CASE STUDY REFERENCE

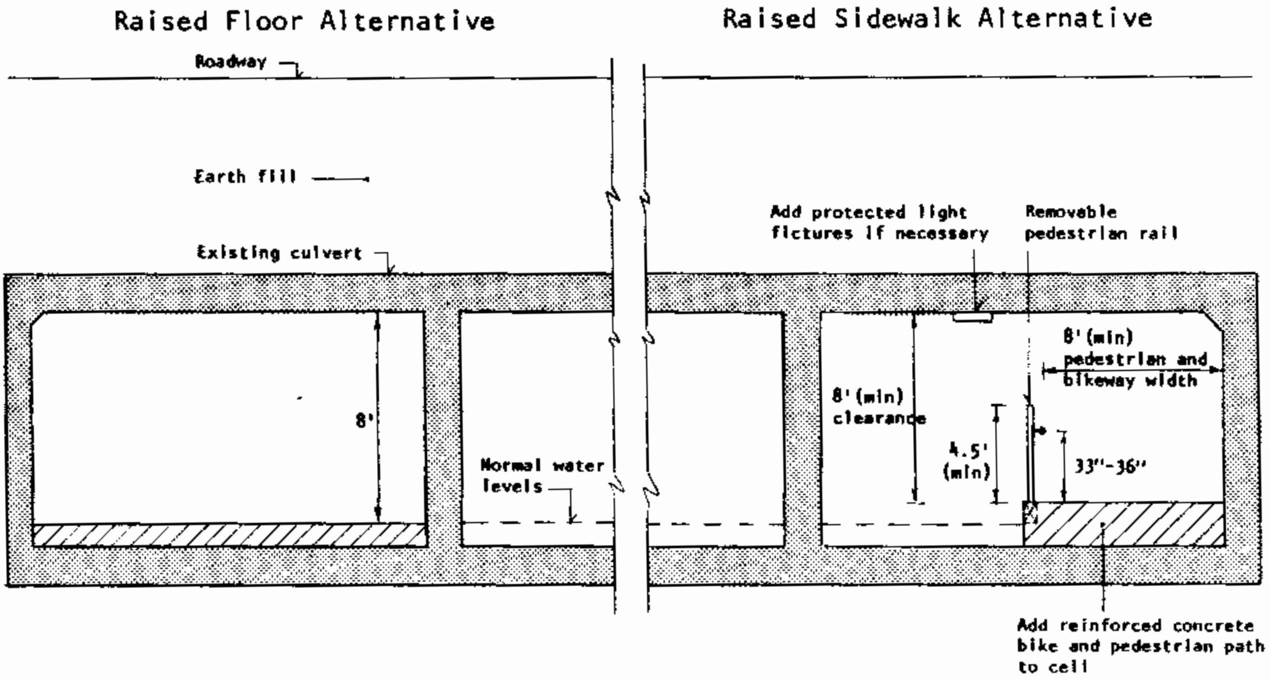
Nos. 5,6,9,67 (see appendix)

NOTE: To convert to metres multiply feet x 0.3048.



Existing Railroad Trestle Section View

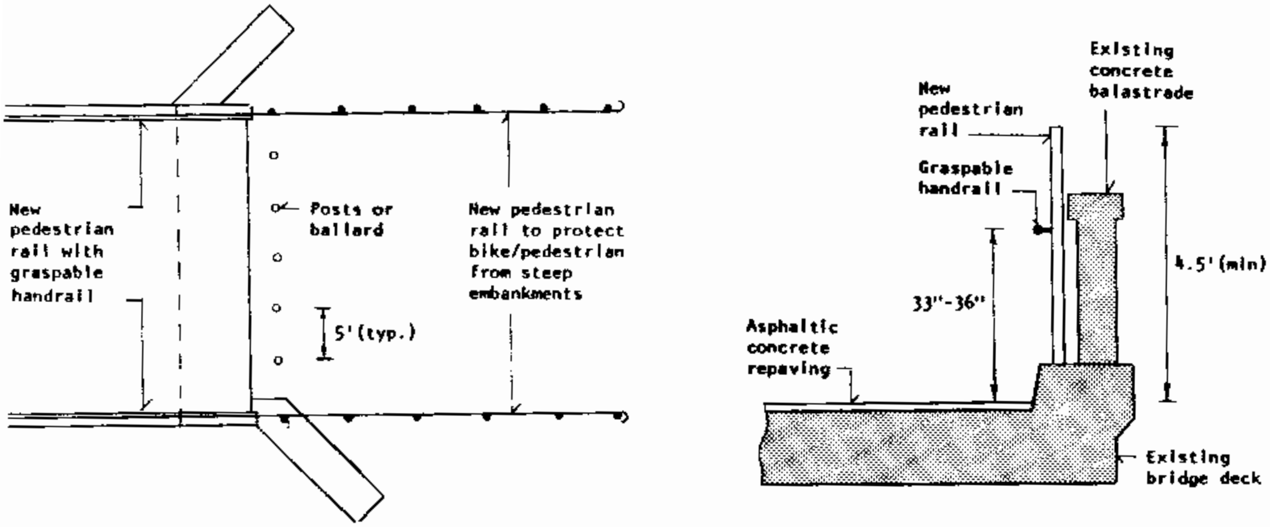
Converted Railroad Trestle Section View


Raised Floor Alternative

Raised Sidewalk Alternative

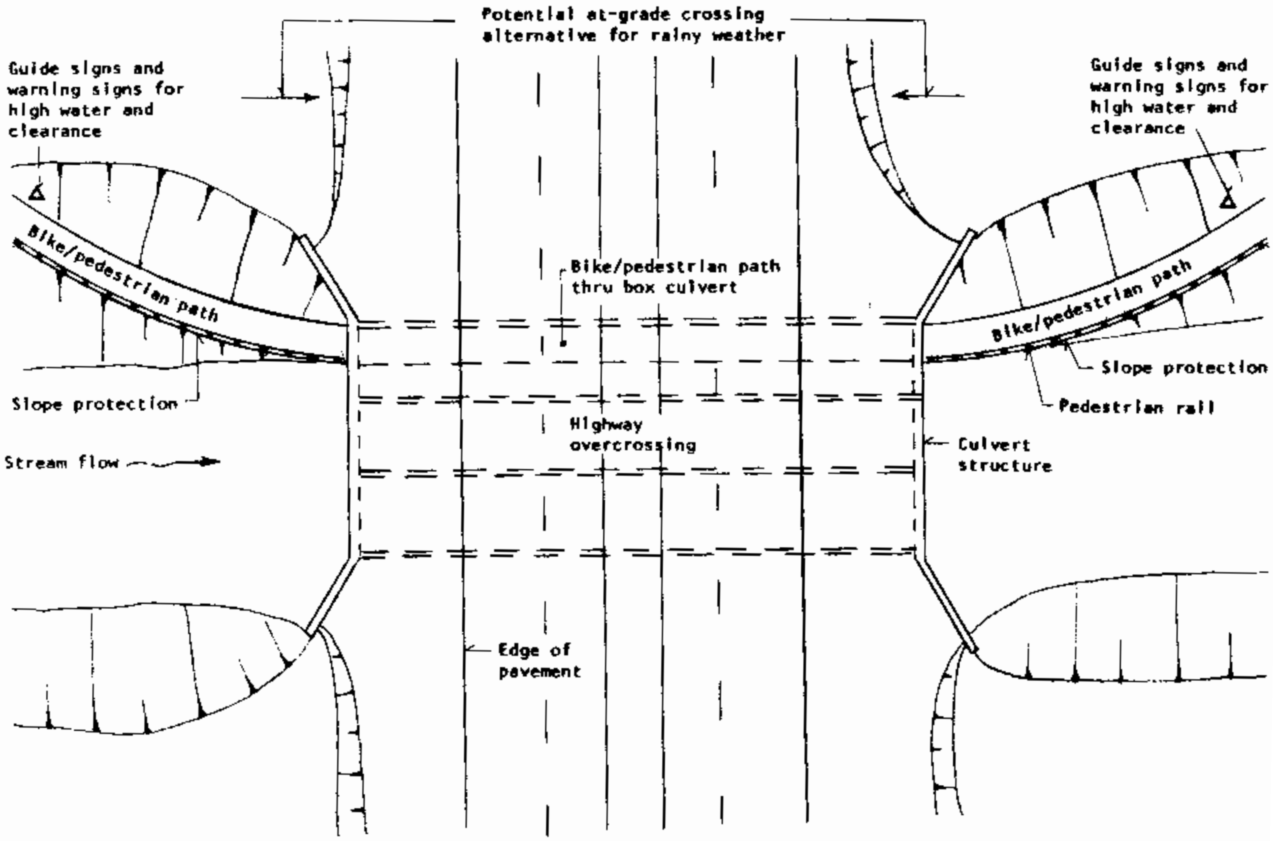
Retrofitted Box Culvert - Section View

Figure 22. RETROFIT PROJECT 3 - CONVERT AN EXISTING OVER OR UNDERCROSSING TO EXCLUSIVE USE OF BICYCLISTS AND PEDESTRIANS



Converted Highway Bridge
Plan View

Converted Highway Bridge
Parkial Section View



Retrofitted Box Culvert Structure - Plan View

Figure 22. RETROFIT PROJECT 3 - CONVERT AN EXISTING OVER OR UNDERCROSSING TO EXCLUSIVE USE OF BICYCLISTS AND PEDESTRIANS (Continued)

condition treatments discussed here should be utilized to complement the prototypical design strategies presented earlier in this chapter, thereby completing the systematic analysis of the three grade crossing components.

Basic Types of End Conditions. There are two basic categories of grade crossing end conditions associated with bicycle and pedestrian facilities. They are end conditions providing access to:

- Grade separations shared with motor vehicles
- Exclusive bicycle and pedestrian grade separations

There are five primary locations where end conditions serving these grade separations occur. These are at:

1. Intersection of roadways
2. A continuation of a roadway
3. Mid-block locations
4. Intersection of exclusive pathways
5. A continuation of an exclusive pathway

From this point there are further degrees of catagorization which could include whether the bicycle and pedestrian facilities are located on one side, both sides or within a central median. Since most of the end condition treatments can be successfully applied to a variety of situations, the discussion below will be directed toward the more common conditions of the five primary end condition locations. These basic concepts can then be applied to a particular situation at a given site.

General Concerns at End Conditions. Conclusions about end condition deficiencies drawn from the field studies and inspections can be grouped into three categories: Signs, Signals and Markings; Maintenance, and Design Features

- Signs, Signals and Markings

  The most common end condition deficiency is a general lack of signing and marking pertaining to bicycle and pedestrian facilities and providing information to non-motorized travelers and motor vehicle drivers. Another common deficiency is lack of horizontal and/or vertical clearance between a sign post or sign and the pathway edge.

- Maintenance

  Preservation of sight distance is particularly important at end conditions, as is maintaining a clean and smooth pathway surface to facilitate transitions. Maintenance is a continuing need and where deficiencies exist for prolonged periods, the effectiveness and attractiveness of the facility is decreased.

- Design Features

  Design related deficiencies for end conditions typically pertain to features which are incomplete, such as lack of curb cuts, or facilities stopping at project boundaries regardless of continuity needs or providing facilities only along one side of a roadway where two sided operations are preferable.

Uniform Features. For the purpose of this discussion, it is assumed that a number of features are always included in the end condition treatments presented in the next section. These uniform features are as follows:

- Minimum pathway widths of five feet (1.5M) for a one way path and eight feet (2.4M) for a combined bicycle and pedestrian path
- Grades not exceeding 8.33 per cent
- Curb cut and ramps installed where necessary to facilitate access to the grade separation approach
- Pathway clearances to fixed objects of at least one foot horizontally and eight feet (2.4M) vertically
- Sight distance which allows safe stopping distance for both bicycles and motor vehicles
- Proper maintenance of facilities
- Both pedestrians and bicyclists use the facility

1. Intersection of Roadways. Roadway intersections are the most critical of all the end condition types because of wide variation of traffic control and design features combined with numerous travel patterns.

- Traffic Control

  Traffic control elements applicable to the intersection and its approaches should be reviewed and modified based on current and potential traffic demands including volume and travel behavior anticipated as a result of over and undercrossing improvements.

Crosswalk locations should be confirmed and marked or deleted as necessary. Where there are crosswalk restrictions, they should be signed and physical barriers installed where appropriate to prevent usage. Intersection control should be reviewed and upgraded as required. This could include adding stop signs or installing bicycle and pedestrian actuated signals. A pathway facility in a central median is a special application of intersection control needs. Lighting should be considered where it is not already in place.

The pedestrian phase on existing signals should be reviewed to assure that timing is adequate for the type of user anticipated. Audible tones during the walk interval could be considered where blind pedestrians are frequent. Guide signs should be coordinated to identify intersecting or directional changes of bike routes and signs designating separate or shared facilities for bicyclists should be installed. Do not enter signs should be posted to discourage wrong way travel on one way bicycle facilities. Pavement markings, such as messages and directional arrows, help to clarify proper usage. The pathway should be kept free of posts and poles wherever possible.

Where one sided bicycle and pedestrian facilities are used on the approach, extra care must be taken to provide delineation and signing which facilitates the pathway users ability to return to the existing street system, and to be properly oriented for continuing travel. Pedestrian and bicyclist behavior makes this task difficult because of the tendency for straight line travel. This is why space for bicycle and pedestrian travel is preferred on both sides of a roadway.

- <u>Design Features</u>

Curb cuts and ramps should be constructed to provide full access to crosswalks even though the improvement project does not include the entire intersection. Curb cuts should be oriented so users will enter the crosswalk instead of being directed to a non-crosswalk area. Ample level space should be provided for pathway users to wait off the roadway prior to entering the intersection.

Drainage facilities should minimize ponding in crosswalk areas, and drainage grates should not be located within a crosswalk. Drainage grates located within the travelway should be designed to be compatible with bicyclists and pedestrians. In certain situations, geometric design improvements could result in safer bicycle and pedestrian crossings. Minor revisions to traffic islands which restrict the intersection could facilitate bicycle travel through the intersection. Removing high speed turning lanes where not needed, or replacing a curved off ramp with a signalized T intersection where capacity would permit are two more examples of design improvements.

2. Continuation of Roadway. This end condition presupposes that non-motorized bicycle and pedestrian travel is generally parallel to the roadway, and that there is no intersection with a roadway or other pathway. Therefore, there is normally no need for persons to cross the roadway at the end condition. Ideally, the same level of bicycle and pedestrian facilities provided on the approach would be continued, at least until the next intersection with a pathway or roadway. The least desirable situation would be to terminate the bicycle and pedestrian facilities at the end condition, thereby forcing users to directly enter the roadway, or to find their own path to continue their journey.

- Traffic Control

  With a continuous bicycle and pedestrian facility there is usually no need to install traffic control devices since the end condition is not a major decision or conflict point. On occasion, however, signing may be useful to provide advance warning or guidance information regarding the approach to the grade separation or a nearby intersection.

  Where a bicycle path transitions from an off-street location to an on-street location, such as from a sidewalk to a shoulder or bike lane, signing and striping will be necessary to inform bicyclists and delineate space on the roadway.

  When a bicycle and pedestrian facility is terminated at the end condition, a major decision point is created. Depending upon the extent of travel and the degree of difficulty necessary for users to reach suitable bicycle and pedestrian facilities, advance informational signs placed at access points on both sides of the grade separation would be useful to inform potential users of the discontinuity.

- Design Features

  Where a bicycle path transitions from off street to on street, it may require an elongated curb cut to accommodate the pathway, or a widened roadway which allows bicyclists to enter the street directly without requiring a change in their line of travel.

  Some of the problems with discontinuous facilities along a continuation of a roadway were discussed under Traffic Control. Another concern would be where a facility on one side is terminated while a continuous facility exists on the other side of a roadway. This may create a tendency for some persons "trapped" in this fashion to cross the roadway rather than continuing along an unimproved route. Completion of the missing link, advanced warning signs and barriers are possible aids in such cases.

3. Mid-block Locations. At grade, mid-block crossings of roadways by bicycle and pedestrian facilities can be relatively close to an intersection or remote as might occur in a rural or park setting. In both instances, the crossing is generally unexpected by drivers and, therefore, requires special treatment to enhance safety.

- Traffic Control

  A crosswalk should be installed in most instances to delineate the crossing. Centerline striping should be placed on the approaches for further emphasis. Advance warning signs should be installed on the roadway approaches and, at higher volume situations, the crossing may even require flashing beacons or bicycle and pedestrian-actuated signals. Lighting of the crossing should be considered. Parking restrictions should be adopted if necessary to preserve sight distance and facilitate accessibility to the crosswalk.

  Traffic control applicable to the pathway may range from nothing to advance warning signs, and/or stop signs or traffic signals. Pavement markings, such as messages, limit lines and striping patterns across the pathway, can be used to alert users of the crossing. Guide and directional signs are also important in identifying the route and alternative destinations. Posts, bollard or gates are sometimes required to prevent motor vehicles' use of the pathway. These barriers should be located on level areas far enough removed from the roadway so as not to interfere with crosswalk accessibility.

- Design Features

  Ample level space should be provided for pathway users to wait off the roadway prior to entering the crossing. Special circumstances may enable the street to be narrowed at the crossing, thereby increasing visibility relationships and decreasing the required crossing time. Where possible, pathways should be designed so that bicycle approach speeds are moderated prior to the crossing. This can be achieved by upgrades or curving alignment. Fencing or barriers may be necessary at the end of the pathway where space is limited to keep pathway users from entering the street directly. In such cases, extra space should be provided for turning movements to allow users to gain access to an offset crossing. Curb cuts and ramps, or smooth transitions are required on both sides of the roadway to assure comfortable access to the pathway.

4. Intersection of Exclusive Pathways. The intersection of exclusive pathways is the end condition to be considered next. They may occur in a remote area or fairly close to a street.

- Traffic Control

  Centerline striping on the approaches to the intersection is useful since it visually emphasizes the intersection (a definite benefit at night) and helps users to maintain correct travel positions. Ample sight distance and geometric treatments usually eliminate the need for yield or stop signs to assign intersection priority. Although there may be special situations where constraints are such that these signs are needed. Occasionally advance warning signs denoting an intersection are useful. However, the most desirable signs at these pathway intersections are guide or directional signs providing information about alternative destinations.

- Design Features

  Expanded intersections with curves between the pathways facilitate turning movements and circulation. Even a simple addition of a triangular section of pavement between two existing 90 degree sidewalks provides a noticeable benefit. Where bicycle volumes are high, pathway intersections designed as traffic circles requiring merging rather than crossing maneuvers may be an appropriate solution.

  Fencing or other physical barriers should be used in areas where there are steep slopes, nearby traffic or activity areas which present a potential hazard to persons using the pathways. The design should minimize the possibility of heavily utilized shortcut routes being developed between pathways. Corrective actions could include either formalizing the route or restricting its use if it is considered to be undesirable.

5. Continuation of Exclusive Pathway. In this situation an exclusive pathway continues away from the grade separation without intersecting an adjacent pathway or a roadway. The normal continuity would be for the exclusive pathway to continue until it intersects with another pathway or roadway.

- Traffic Control

  With a continuous bicycle and pedestrian facility such as this, there is usually no need for traffic control at the end condition location. On occasion, however, signing may be useful to provide advance warning or guidance information regarding the approach to the grade separation or a nearby intersection. Pathway striping may also be continuous through the end condition, or it may begin there and continue into the approach.

- Design Features

  There are usually no special problems with the end condition of the continuation of an exclusive pathway.

7.3.5 Non-Structural Solutions to Crossing Problems

Non-structural solutions are defined as those solutions that provide crossing access to non-motorized users without requiring construction or modification of structural features. In addition to the status quo or do nothing option, there are five categories of non-structural solutions. These include:

- Traffic control strategies
- Alternative routes
- Alternative travel modes
- New technology
- Land Use Planning

Traffic Control Strategies. Most frequently used non-structural strategies involve signing, striping, and signals to change the relationship between motor vehicles and the non-motorized user. Either some of the space on roadways previously devoted solely to motor vehicles is designated for use by the non-motorized, or motor vehicle drivers are directed to accommodate to the presence of the bicyclist and pedestrian.

- Restripe Vehicular Lanes. Vehicular lane width can be slightly reduced and the pavement restriped to gain space for the non-motorized, or the existing shoulder area itself may be sufficiently wide, and only require striping. While striping is often used to delineate bike lanes, the handicapped and other pedestrians may also benefit from this treatment, particularly if no other facilities are available. Additional signing and/or pavement marking may also be required to restrict parking or to further identify non-motorized space.

- Lane Reduction. Lane reduction is possible along under-utilized roadways. Field observations combined with capacity analysis should be undertaken to determine if such a strategy is applicable. Lane reduction could be permanent or a temporary solution allowing additional time for planning, funding and implementation of more permanent bicycle and pedestrian facilities. It may be possible to close a lane to vehicle travel during times of especially high non-motorized demand such as on a weekend in a recreational area. Cities such as San Francisco and New York close park roadways to motor vehicles at certain times thereby enhancing bicycle and pedestrian travel. While these may be localized opportunities, they deserve attention. Change from a two way to a one-way street may also allow lane reduction without adversely impacting auto travel characteristics. Under special circumstances a one way street striped for two way bicycle travel as exists in Eugene, Oregon may be applicable. (See Figure 23.)

- Remove Parking. A restriction on parking all or part of the day can recover existing space for non-motorized travel use. This strategy largely applies to an approach, since parking is rarely allowed on a grade separation.

- Reversible Traffic Lanes. Reversible traffic lanes are a traffic management tactic which can be applied successfully in special traffic situations. Creation of a reversible lane may allow space formally used by a travel lane to be designated for non-motorized travel.

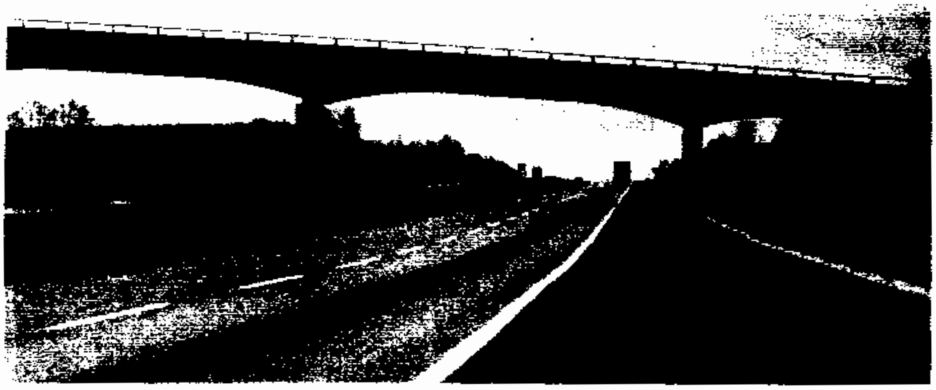
- Utilize Shoulders of Limited-Access Roadway. Such shoulders can be opened to bicycle (and perhaps pedestrian) travel in areas where alternative routes over other surface roads may be less safe. The California Department of Transportation has recently opened 175 miles of Interstate 5 in the San Joaquin Valley to bicyclists, for example.

- Create Auto Free Zones. Auto free zones include portions of streets where motor vehicles are prohibited for part or all of the day. This includes areas which are permanently auto free as well as temporary applications of that principle, such as on a weekend. Downtown Boston, Massachusetts, is an example where an auto free zone has been applied. A mall is a specialized example of an auto free zone. In Phoenix, Arizona, one-half of an arterial street between two popular parks is designated for bicycle traffic on Sundays during the high demand bike riding season. Here a temporary re-organization is achieved by placing of traffic cones and temporary signing.

- Assignment of Primary Right-of-Way to Non-Motorized Users. Primary right-of-way can be given to non-motorized users so that motor vehicle drivers must yield to them. This could be in effect along the roadway, as well as at crossings, and would be most favorable where there are low travel speeds, narrow bridges or underpasses without pedestrian facilities, and frequent non-motorized users. Application would probably be most common in park or recreation areas. Special signing, would be required to alert users of the right-of-way relationships.

- Share Transit Lanes. One version of priority right-of-way is where bicycles are allowed to use a special bus lane therefore achieving priority over automobile drivers. This option is emerging as more and more attention is being given to enhancing the travel characteristics of urban mass transit.

Lane reduction from narrow two-way street to one-way with two-way bike traffic



Shoulder a potential for use on limited access roadway

Primary right-of-way assigned to bikes

Figure 23. SIGNING AND STRIPING

Install Activated Warning Lights for Tunnels. Provision of a signal and warning signing which when activated by bicyclists alerts drivers to the presence of bicyclists in the tunnel. Such a system was designed by the State of Oregon and is successfully in operation at several tunnels along Route 2. (See Figure 24.)

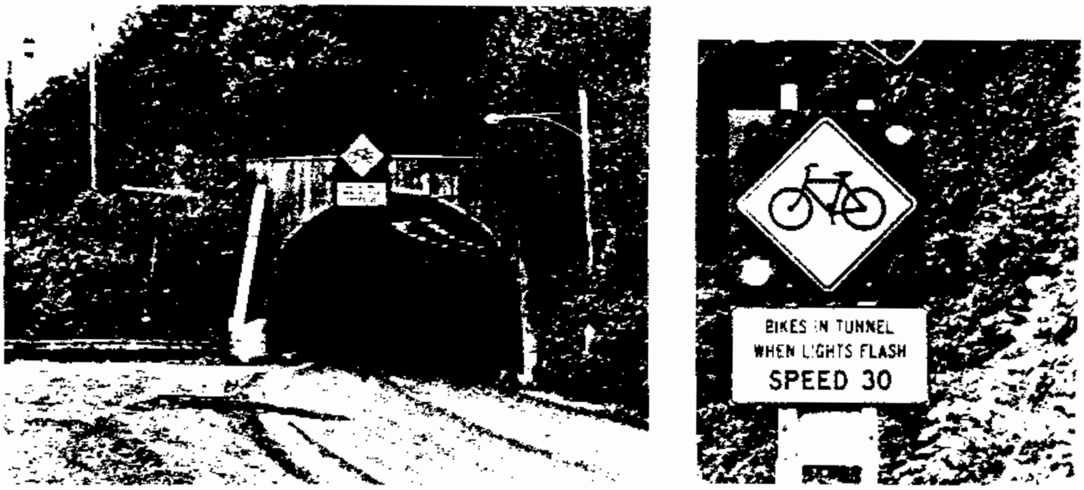


Figure 24. WARNING SIGN SYSTEM
BIKE PRESENCE IN TUNNEL

Sign or Install Other Devices at Pedestrian Crosswalks at Interchanges. Ramp geometrics in interchange areas are such that pedestrian crossings are difficult for approaching drivers to identify, even when they are striped. Some possible ways to improve the situation are as follows:

-- Install a pedestrian crossing sign at or very close to the crossing. A supplemental arrow sign pointing down at the cross walk could provide extra emphasis. (See Figure 25.)
-- Relocate a crosswalk obscured from the view of on-coming traffic to a more visible location.
-- Install a quick response pedestrian activated traffic signal.
-- Install flashing warning lights, actuated or continuous, or install rumble strips to supplement warning signing.

While these strategies may have merit in special circumstances, crosswalk delineation and warning signing should be considered first.

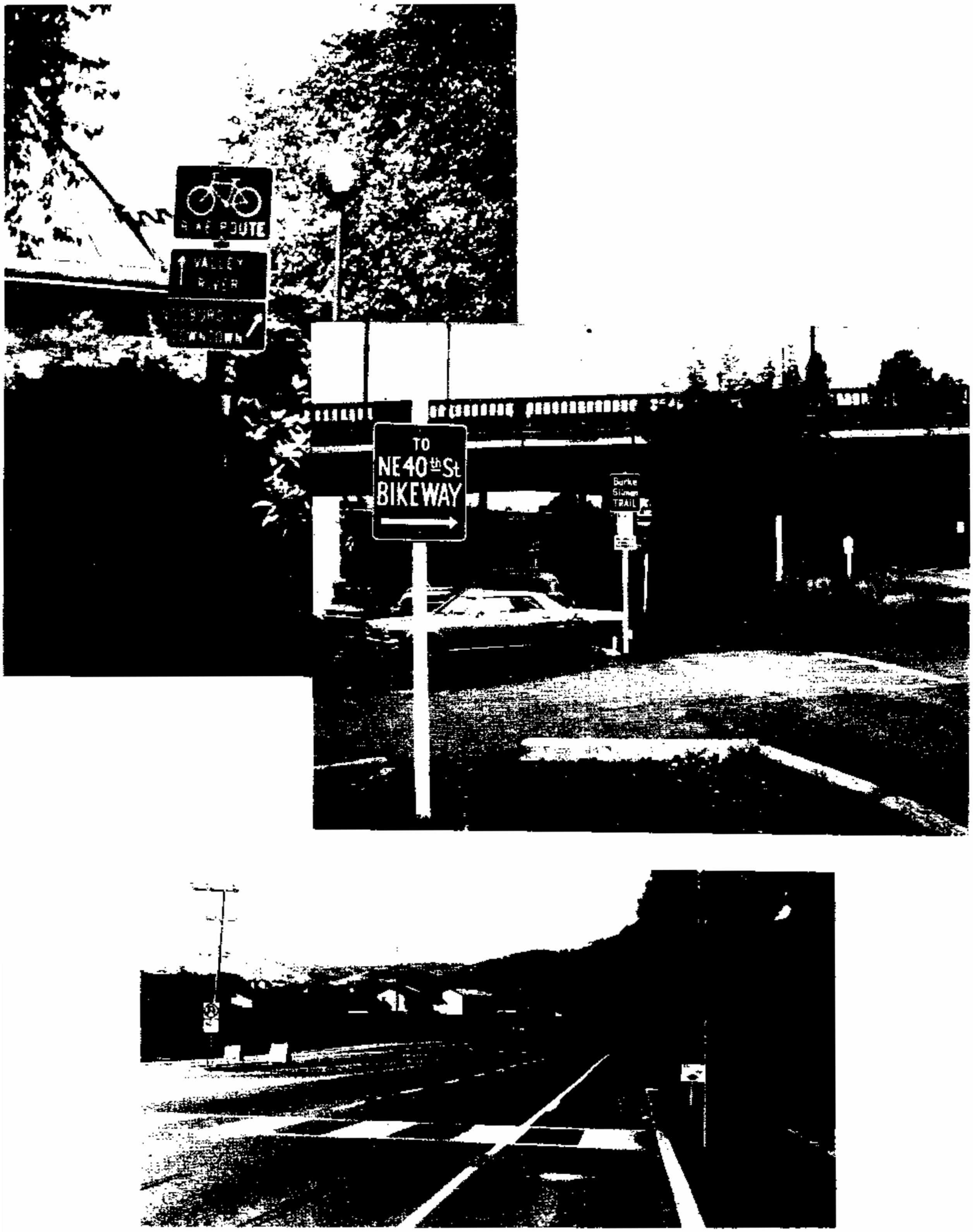


Figure 25. CROSSWALK AND GUIDE SIGNING

- Provide Information and Regulatory Signing:
    - -- Install informational signing to direct users to appropriate crossings or to provide information regarding route distance and destination. It is important that this type of signing provides a continuity of information.
    - -- Install regulatory signing mandating use of certain facilities or directing change in travel direction for the non-motorized traveler. (Note: the presence of these signs does not necessarily insure user conformance). Detailed attention is required at transition areas between unrestricted and restricted use. Transitions should be logical and lead users to the proper route.

- Delineate Rest Areas. Place a simple stripe or mark on the pavement or adjacent wall or fencing to delineate the location of rest areas, thereby making it easier for persons to determine the distance between rest areas.

- Issue Facility Use Permits to Bicyclists. Require that a permit be obtained by bicyclists prior to being allowed to utilize a vehicular bridge too narrow for bike lanes. This technique is used successfully in Eugene, Oregon, to enable qualified bicyclists to use a freeway bridge previously forbidden to all non-motorized travel.

- Improve Maintenance of Non-Motorized Facilities. Improved or more frequent maintenance is another non-structural technique which can enhance non-motorized travel. In some situations debris accumulation, particularly glass, can cause users to avoid the facility or to endanger themselves by using the vehicular lanes. Therefore, funds spent to construct access do not accrue the expected benefits. Ease of maintenance should be one of the principal considerations when designing facilities, thereby reducing features which contribute to the maintenance requirements.

Alternative Routes. Lacking a direct crossing of a barrier, non-motorized travelers usually select the most convenient native route available. Sometimes travel can be made along the same general alignment that a structure would provide and in other instances it may entail a detour of some distance. Alternative routing may result in at-grade crossings or utilization of an adjacent grade separation.

- Provides satisfactory access. Depending upon route characteristics and length of detour, an alternative route may provide an entirely satisfactory service to the majority of potential users. Therefore, a new grade separation, though technically feasible, may not be required at least for some time. In other cases, a design barrier such as stairs may be bypassed if adversely effected users have a barrier-free alternative route along which they can complete the same journey without excessive rerouting. Installation of additional signing might be necessary to effectively guide users to and along alternative routes.

- Requires upgraded access. Conversely, alternative routes may lack continuity or accessibility, may expose bicyclists, pedestrians and the handicapped to excessive traffic conflicts or may be situated such that crossing opportunities require considerable detours for the majority of the potential users. The question then becomes whether the existing system should be upgraded or whether other, more direct, non-structural or structural solutions are more appropriate.

Alternative Travel Modes. In some specialized instances, buses, vans, and transit trains can be used as an alternative crossing method.

- Provide Regularly Scheduled Transit. Regularly scheduled transit can provide service across structures which do not have facilities for non-motorized travel. Buses with wheelchair lifts are especially helpful to certain groups of handicapped persons. Buses can also be equiped with bicycle-carrying facilities such as racks or a trailer providing separate holding facilities. Bay Area Rapid Transit (BART) allows bicyclists to obtain a permit to carry their bicycles onto the last car of the train during off-peak times. Ferryboats also can accommodate bicyclists. (See Figure 26.)

- Provide Special Transit Service. Special transit service can be provided across structures where there are no facilities for non-motorized travel or to serve persons not able to utilize a grade separation. Various combinations of fixed route and demand-responsive systems are possible, ranging from those provided by transit companies to institutional or group-sponsored services.

It should be noted, however, that for short trips waiting time may exceed the travel time necessary for a person to utilize an alternate route unless transit service is frequent or particularly convenient for individual needs.

New Technology. Improvements in the wheelchairs currently utilized by handicapped persons appears to be an area where new efforts could increase mobility potential.

- Devices to Enable Wheelchairs to Mount Curbs. Devices could be developed which permit wheelchair users to mount curbs which do not have wheelchair ramps. This might be achieved by designs which inflate a cushion which "absorbs" the curb and raises the wheelchair up to a level even with the top of the curb. Another concept to achieve a similar effect would be a device composed of rods or "feet" operated by means of hydraulics and gearing. This device would be designed to raise the wheelchair and then "walk" it over the curb or, conceivably, up a short flight of stairs.

Shuttle bus with bike rack

Bicyclists first to leave ferry at landing

Van with trailer serving as commuter bicycle shuttle

Figure 26. UTILIZING ALTERNATIVE TRAVEL MODES

- Wheelchair Power. Development of improved power sources and gearing systems for motorized wheelchairs could improve reliability and range of mobility.

- Better Braking Systems Can Be Developed. Wheelchair braking systems can also be improved, particularly for the manual wheelchair.

- Wheelchair Leveling Devices. A device to level a wheelchair in motion would be helpful to lessen the effect of grades or cross slopes on wheelchair occupants, and could simulate a level rest area for wheelchair users stopped on a grade.

Land Use Planning. Considering facilities for the non-motorized in future land use, transportation, and recreational facility plans, could eliminate some barriers.

- Facilities Location. School, shopping, recreation and work trips can be oriented along pedestrian and bikeways, which in turn are designed to minimize conflicts with motorized traffic. Attempts can be made to locate certain types of pedestrian and bicycle traffic generators (such as schools) on the same side of potential barriers (freeways, railroad tracks) as residential dwellings.

  However, the idea of locating housing for the disabled close to activity centers is not compatible with the "mainstreaming" concept. People should have a choice of living areas without forced segregation because of being disabled. While the convenience of having key activities near home cannot be denied, it should not lessen the effort directed toward reducing accessibility barriers elsewhere throughout the system.

7.3.6 Design Innovation and New Techniques

The results of this research study indicate that there is no immenent technological breakthroughs that will drastically change the development of non-motorized facilities on overcrossings and undercrossings. However, as briefly outlined in Chapter 5, there are a number of modifications or enhancements of existing methodology and procedures which are innovative, and which may have application to specific problems.

This section of the Final Report is intended to familiarize designers and other interested individuals with innovative and unusual designs not commonly used. The concepts and features presented represent examples of actual existing projects, as well as untried ideas, and is intended to stimulate consideration of unconventional approaches as well as the more commonly and strategic.

Unusual Locations and Facility Configurations. In some instances, changing the placement of a non-motorized facility on a structure, slightly altering standard design procedures or improved utilization of existing structures can provide the solution to a particular crossing problem. Some of the techniques that are illustrated have application to both new and retrofit project situations.

- Non-Motorized Facility Location

  - Placement of a pedestrian path and bikeway within the truss portion of the structure above a highway bridge is a concept which may be applicable where expansion of the deck is impractical. The structural members will usually be strong enough to support a supplemental pathway deck. However, there may be some difficulty overcoming grade differentials unless hilly topography allows the pathway to enter at a high level.

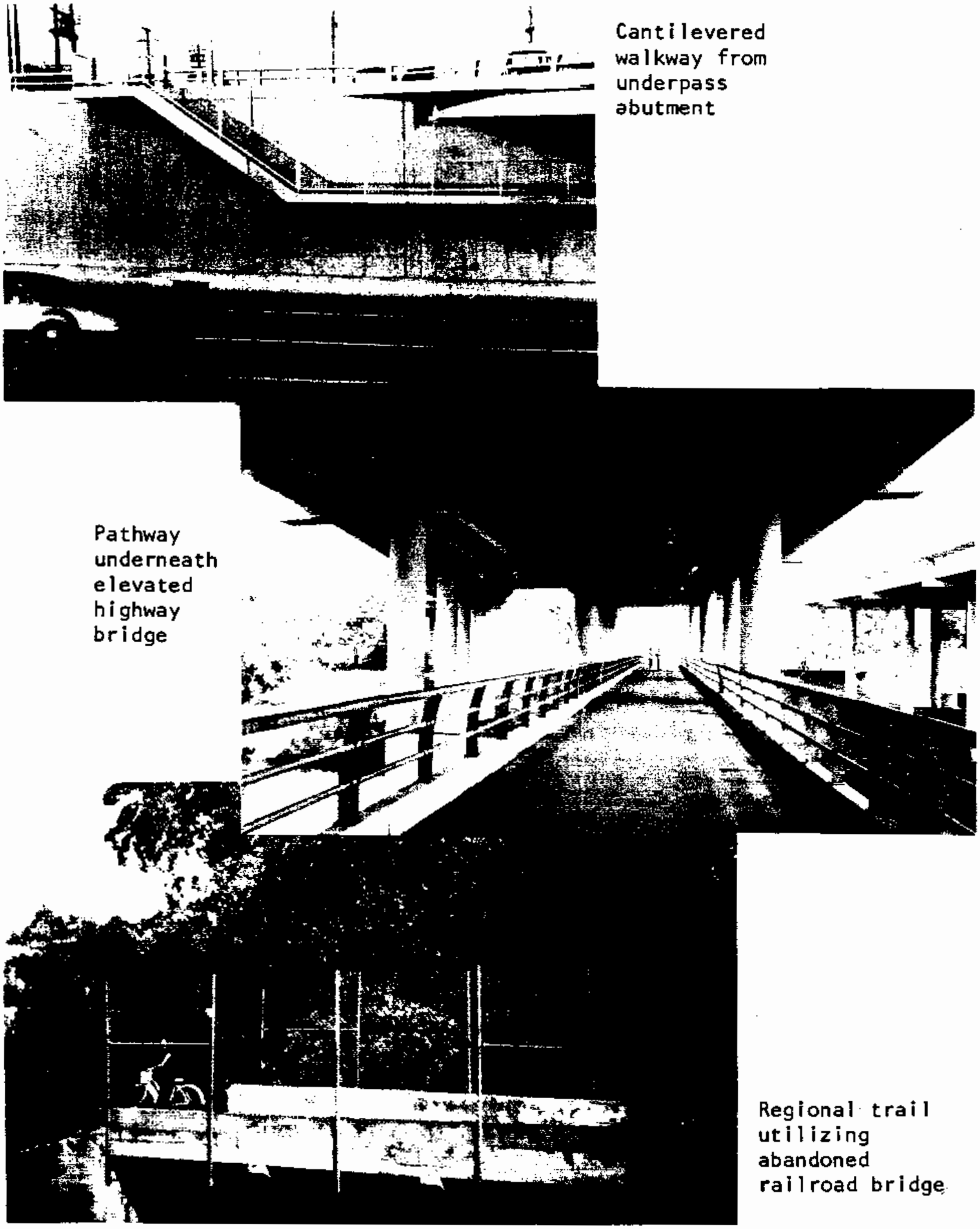
  - Underneath bridge structures with girders which are at least 8.5 feet (2.6m) there is an opportunity to replace cross-bracing with horizontal bracing at the top and bottom, thus creating an opening large enough to accommodate a pathway. While lighting, surveillance, ventilation, and access are special design concerns, the treatment is an alternative to consider where deep structural girders are present.

  - On bridge designs utilizing concrete box girders with depths of at least 8.5 feet (2.6M), it may be possible to use the open space within the box for a pathway. To improve surveillance and decrease the tunnel effect, openings could be cut in the outer wall. While interior lights would probably be required, wall openings would be helpful. As with other underneath or aerial strategies, access would most likely required special design features.

  - A pathway structure could be hung from the bottom of an overcrossing. Care would have to be exercised to maintain clearance requirements beneath the overcrossing. Access to the pathway would be another design problem.

  - It is possible to utilize the lower crossing bracing connecting overcrossing piers as support for a pathway surface. In this case, the pathway would be well below the main structure and in the open, with the bridge deck serving as a canope. The low level pathway would be easier to gain access to where adjacent ground levels are also low. Clearance requirements beneath the structure might be a problem. (See Figure 27.)

  - At one site in Bakersfield, California, a walkway cantilevered from a parking lot to an office building on the other side of a railroad. Without this unique treatment, parking lot users would have a considerable detour to reach the regular walkways through the undercrossing. A pedestrian overcrossing alternative spanning the railroad would have been considerably more



Cantilevered walkway from underpass abutment

Pathway underneath elevated highway bridge

Regional trail utilizing abandoned railroad bridge

Figure 27. UNUSUAL FACILITY CONFIGURATIONS

expensive, as well as requiring users to overcome a height differential roughly double that of the cantilevered undercrossing treatment. (See Figure 27.)

- Tunnel construction is expensive and, therefore, space is rarely available to retrofit non-motorized facilities within the tunnel wall. However, it may be possible to recover enough space outside of the regular travelway in areas used for ventilation or previously occupied by a pilot tunnel. Ventilation, security, lighting, and access are some of the problems which must be solved.

- <u>Utilization of Existing Structure</u>

  - Abandoned highway bridges, tunnels and railroad trestles represent a potentially valuable resource for use as part of bicycle and pedestrian systems. Often only minor modifications will make them suitable for use by the non-motorized. When a decision is made to abandon such facilities, ways of utilizing the structures, rather than demolishing them, should be explored.

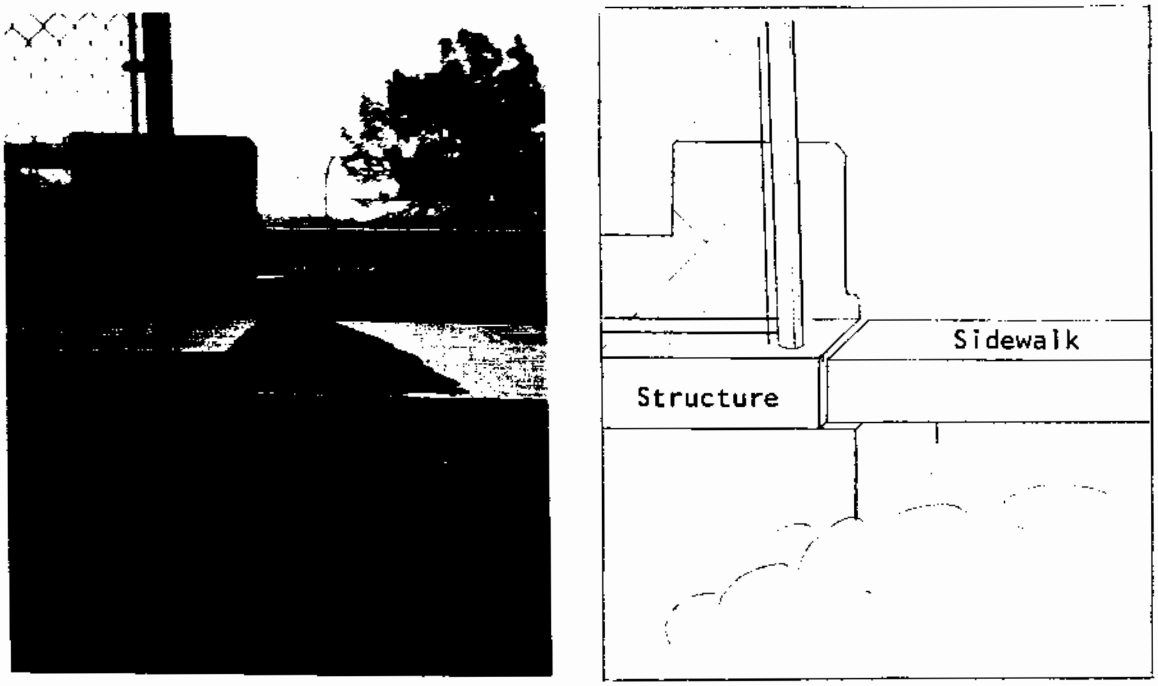
- <u>Bridges for Areas Subject to Flooding</u>

  - In North Dakota, a bridge built over a river with a wide flood plain was designed to be lifted onto adjacent temporary higher piers to avoid being washed away during high water. Cranes are utilized to lift the bridge at times of anticipated flooding. This technique allowed development of small bridges serving a regional bikeway, rather than requiring much larger and more expensive structures capable of withstanding flood conditions. An alternative plan for the smaller bridge scheme was to have the bridge designed with a lift to move up and down on its own supports. Though technically feasible, this was a more expensive plan and therefore was not implemented.

  - Another flood plain design strategy is to construct bridges which are extraordinarily sturdy. Then, if they are washed off their abutments, they can be retrieved and re-set without being irreparably damaged.

- <u>Differential Sidewalk Settlement</u>

Differential settlement at the point where the approach path or sidewalk meets a structure is a common problem. Repairs usually consist of placement of a wedge-shaped asphalt or concrete patch. This treatment reduces the problem, but it may require additional attention as settling continues. On new structures, the problem can be corrected for concrete walks by designing the abutment so the approach sidewalk rests on it rather than the adjacent soil. This creates a bridging effect spanning the area most susceptible to settlement. Asphalt walks are flexible and do not have the bridging strength that concrete does. A short section of concrete walk could be used to provide the transition to the structure, or additional care should be taken on subgrade preparation to minimize the degree of settlement. (See Figure 28.)



Problem

Solution

Figure 28. DIFFERENTIAL SIDEWALK SETTLEMENT

- <u>Driveways Intersecting Sidewalks</u>

  Driveways intersecting sidewalks oftentimes create uneven surfaces across the entire sidewalk; othertimes the driveway only partially penetrates the sidewalk. While this leaves a level area for bicyclists and pedestrians, it may steepen the driveway slope to a point where it adversely impacts drivers. There are several alternative approaches which could be used to reduce this problem. (See Figure 29)

  - Create a widened sidewalk to allow the full travel surface to bypass the area affected by the driveway slope.

  - Design the driveway slope to be completed before intersecting the sidewalk. This means that the sidewalk, at least near the driveway, must be set back from the edge of the roadway rather than being adjacent to the curb line.

  - Design the sidewalk to slope down to meet the driveway at a consistant grade and at gentler slopes (maximum 8.33 percent) than those now used which have varible slopes some of which

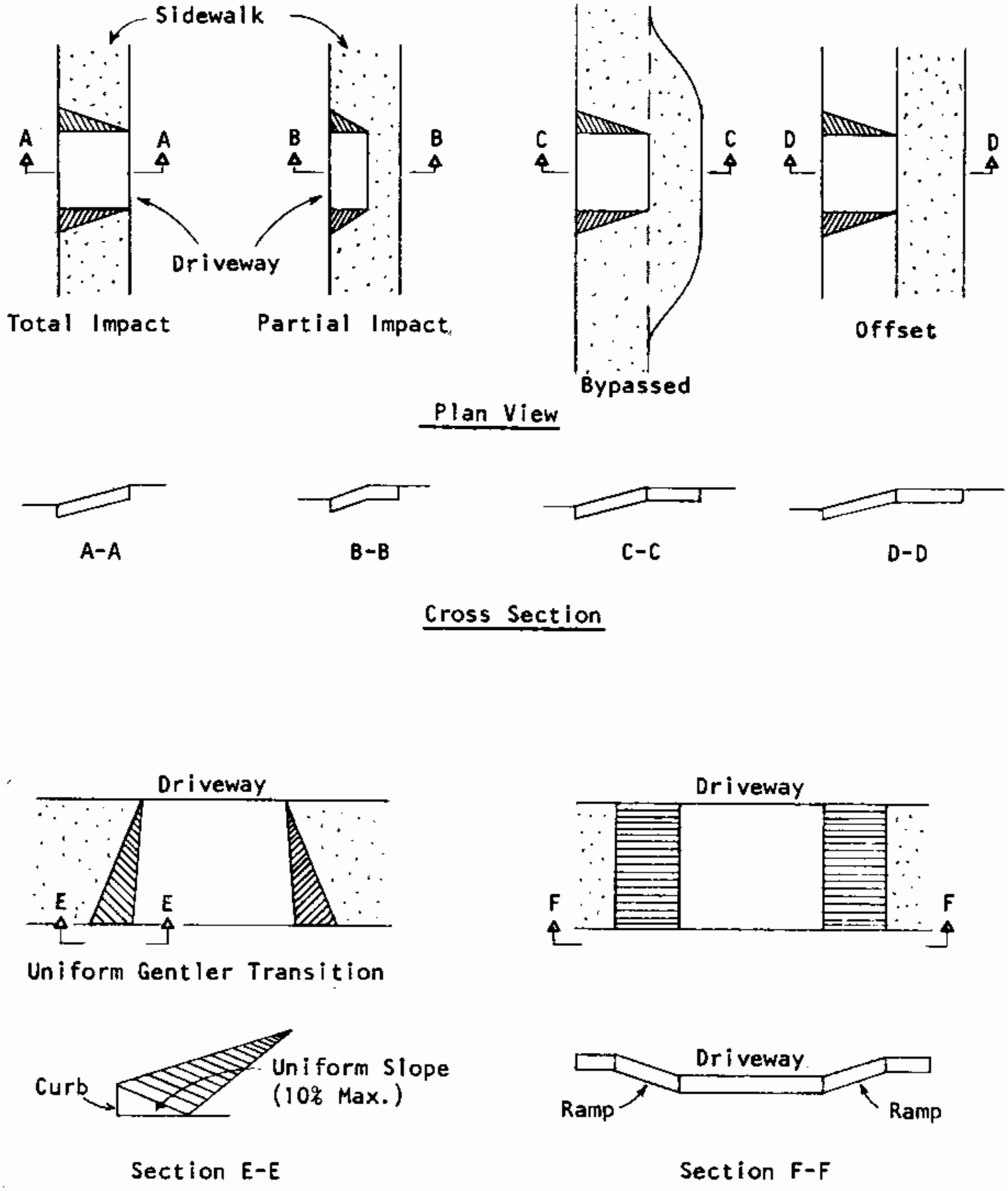


Figure 29. SIDEWALK/DRIVEWAY RELATIONSHIPS

exceed 15% for short distances. A special case of this type treatment is where a major driveway is designed like a street and the entrance sidewalk width is ramped down to meet the roadway grade.

- Rest areas are often parts of ramped approaches to structures. For new facilities the rest area can be a special constructed feature. Two important considerations are whether the rest area should be in the travel way or adjacent to it, and the spacing between rest areas. Retrofiting rest areas to existing structures may prove difficult because of established grades and features. Some alternatives to traditional rest area designs are illustrated in Figure 30 and can be described as follows:

    - Hold bars imbedded in the wall which allow persons to grasp them or to clip themselves onto as a rest stop.

    - A bar imbedded into the wall which could be pulled out to a position perpendicular to the direction of travel.

    - Slots in the pavement parallel to the direction of travel could be positioned in such a fashion as to allow a wheelchair user to insert one wheel. The slot would then serve as a wheel stop, allowing the wheelchair user to stop and rest. Slots could be positioned along both sides of the ramp at intervals of 10-20 feet (3.1-6.1M), so as to serve the varying needs of wheelchair users. Care should be taken to locate the slots close enough to the side of the pathway so as not to pose a potential danger to bicyclists. In some cases the slots would be located adjacent to the pathway in narrow widened areas. A self-cleaning design or maintenance will be necessary to maintain proper slot depth.

    - Small blocks (about 1 inch (25.4 MM) high) positioned at the edge of ramped pathways or immediately adjacent to the wall or fence might be an effective wheelblock for a wheelchair. This treatment should not be used where a sidewall or fence are lacking, since bicyclist and pedestrians would then have the freedom to occupy the entire path and the blocks may constitute an obstruction.

    - Sitting places can be developed as indentations into the structure sidewall, or the wall section can be thickened or cantilevered to form a seat.

    - "Vee" shaped niches can be constructed in the walls where wheelchair users could stop perpendicular to the wall while still retaining their original direction of travel.

    - A folding seat could be installed which is normally flush with the side walls until used. It would fold out perpendicular to

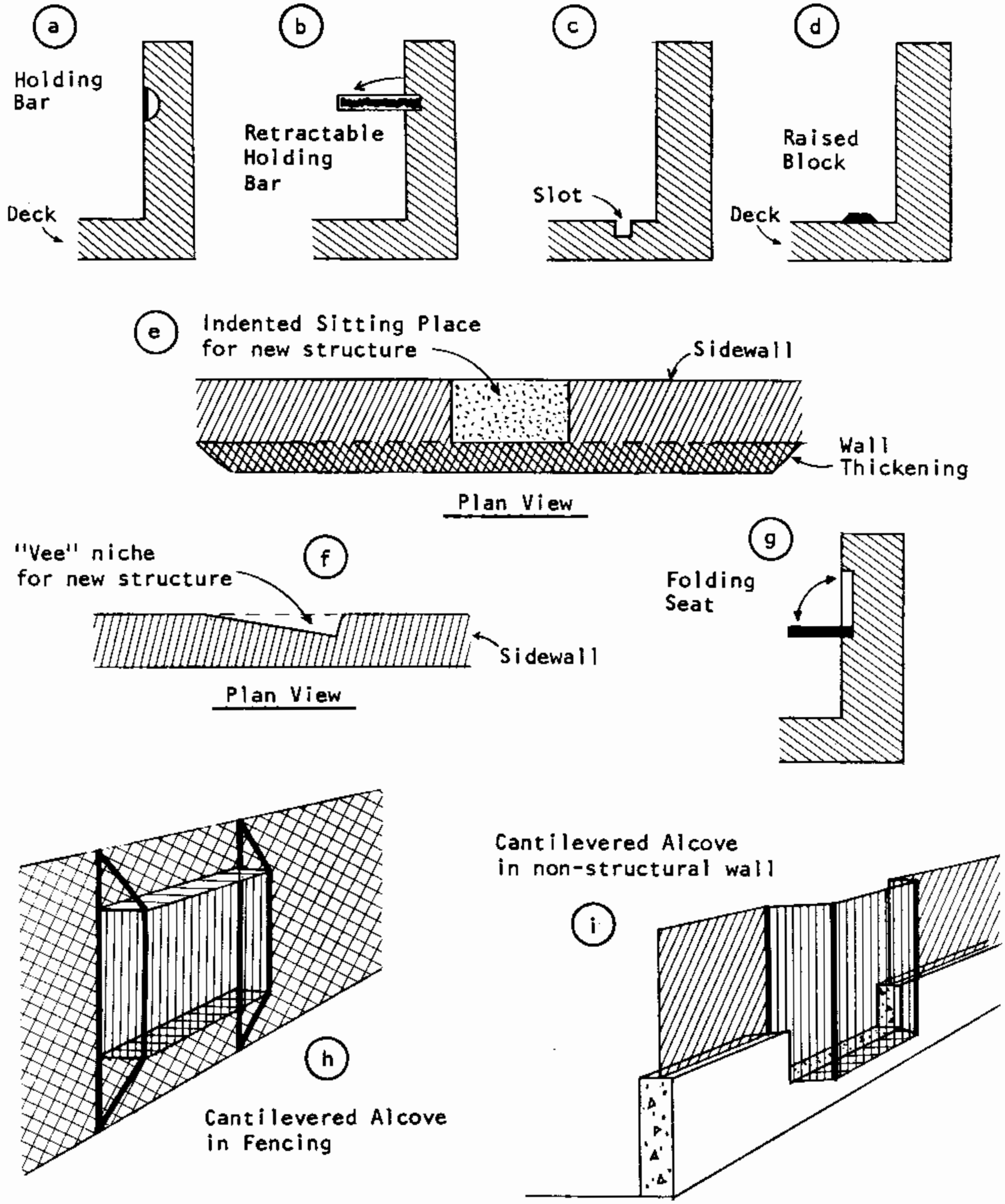


Figure 30. CONCEPTUAL REST AREA ALTERNATIVES

the wall and a spring-loading device would return it to its original position after use. The seat could be utilized equally well on solid or fenced walls. A disadvantage to this design would be its potential susceptibility to vandalism.

  - Sitting spaces can be developed in fence walls by construction of an alcove. This applies to both new and retrofit situations. The position of the seat could be level or could parallel the ramp grade.

- Increased user awareness through improved user education can also pay dividends. For instance, successful techniques for ascending and descending ramps could be explained to handicapped persons. An example would be for a wheelchair user to park perpendicular to the ramp slope thereby creating a stable "rest area" when needed where no special physical feature exists.

- Dissemination of information regarding accessible routes and modes of transportation would increase the users' ability to select the transportation system elements most suited to their travel needs.

Recycled Materials. Most grade crossing projects are constructed with new materials; however, there are circumstances where use of recycled materials can produce a final product which is both functional and cost-effective.

- Railroad flat cars are often up for sale once their useful life is over. Structural properties of a flat car make it suitable to serve as a bridge. It can be placed on abutments and new decking, handrails can be added as required. (See Figure 31.)

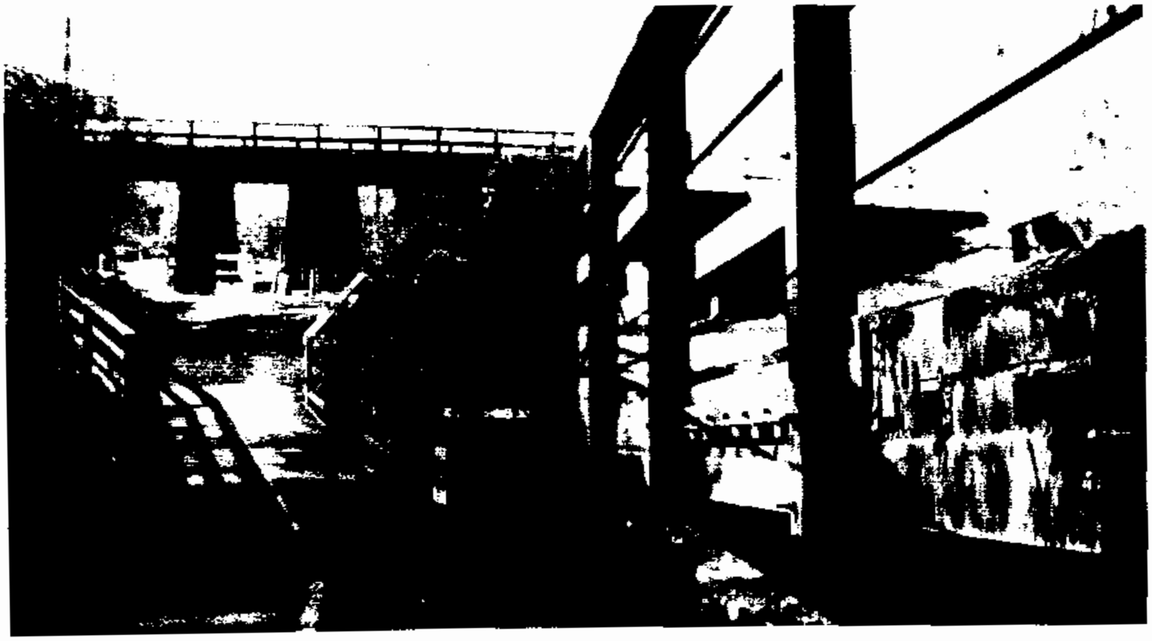


Figure 31. RAILROAD FLAT CAR BRIDGE

- Trailer truck beds are another recycled source of bridge-like structures which may constitute a special application. (See Figure 32.)

Figure 32. TRAILER TRUCK BEDS (POTENTIAL BRIDGE)

- Barges may have some applications in providing a foundation for a floating structure, although their potential use does not appear to be as widespread as that of railroad flat cars or trailer truck beds.
- Large size culvert pipe could serve as support columns for a bicycle/pedestrian bridge.
- Salvaged bridge beams from replaced structures represent a potential source of building material which may be particularly suited to support decking for an exclusive bicycle/pedestrian bridge. Timber beams, planking and utility poles may also have similar application, under special circumstances. In some cases entire structures have been salvaged, intact, and made available for use at other sites.

Imaginative reuse of material available at little or no cost can mean an economically justified improvement, where traditional approaches would result in solutions which are too expensive to implement.

Construction Techniques. Improvements in construction techniques relating to bridges and tunnels can reduce the cost and increase the feasibility of installing facilities for non-motorized travelers. Many of these techniques are mature, having been used during the construction of major projects over several years. Their application to bicycle and pedestrian facility construction has been limited or untried. Some potential techniques include the following:

- Structural and other project elements can be manufactured on-site using "Factory" techniques. This allows more efficient use of fulltime employees and maximizes benefit derived from workers brought in to perform specialized tasks.
- Standardized design for similar facilities can minimize engineering design effort, facilitate fabrication, simplify erection and make maintenance more efficient particularly if standardization of features occurs at a number of different sites within the same jurisdiction.
- Prefabrication of major structural elements can minimize the need for storage space and erection time. This is of prime importance in urban areas where traffic delay or detour can be of major concern.
- Simple and standarized erection procedures can be developed for use by relatively unskilled crews. This could allow public works employees in a jurisdiction to assemble certain structures without the need of highly paid outside specialists.
- Maximize use of local materials to minimize transportation costs.
- Use grouts to stabilize soils and to exclude water from excavations, making it more economical to construct underpasses in difficult soil conditions.
- Pipe jacking is a mature construction process. This technique could be used for jacking underpasses for bicyclists and pedestrians as an alternative to tunneling or cut and cover-type construction. It might also be possible to apply the vibration techniques used in some pile driving applications to jacking, perhaps further enhancing its usefulness.

Alternative Methods of Conveyance. In some special instances providing other means of conveyance may be a more satisfactory solution to crossing a barrier than constructing special bicycle, pedestrian, or handicapped facilities. They may be particularly useful for accommodating handicapped persons. Some of these possibilities are as follows:

- Elevators, while commonly used in buildings, are rarely applied to grade separations, unless they are associated with a transportation terminal. It appears that where vertical separation to be overcome is great (16 feet (4.9M) or more), that the construction cost of stairs supplemented by an elevator are cost-competitive with a solution providing only ramps at a 10 percent grade or less. Elevators can be erected in internal or external configurations and take little space. Maintenance, operating costs, user access, and security are all issues which must be addressed before a final decision can be made. However, it appears that there may be situations where elevators should be seriously analyzed as a potential solution.

- Escalators and moving sidewalks again are common to circulation systems within buildings and along high-use corridors, such as are found within transportation terminals or at major spectator sports complexes. However, it should be noted that space and maintenance requirements appear to discourage use of escalators as a viable solution for overcoming steep grades at all but a very few specialized locations. In addition, certain handicapped persons may have difficulty with access and egress to escalators on grades.

- Stair climbers are track-mounted seats which provide the user mechanical assistance as an alternative to a stairway. The typical application today is in residences to serve the elderly or to overcome a long steep grade from the garage to the house. This is a proven system which may have application at certain grade separations.

- The principle employed in a typical automobile jack may be applicable, or at least merit further investigation. It potentially could result in a manually operated elevator device. Similarly, the hydraulic jacking principle is another area worthy of exploration.

7.3.7 Improved Designer and User Understanding

The findings of this study indicate that the planning, design and operation of non-motorized facilities on over and undercrossings can be considerably enhanced if technical personnel and facility users achieve a better understanding of the subject matter. This section discusses a number of possible educational and information communication techiques which can help in this regard.

Planners and Designers. In some cases, the requirements and characteristics of non-motorized travelers have not received sufficient attention from those responsible for planning, design and maintenance of under and overcrossings. Technical staffs have to become more sensitive to the needs of bicyclists, pedestrians and the handicapped. Once this necessity of including non-motorized travelers in the process is recognized, then a means must be found for insuring that the operational consequence of standard designs is properly understood. Two of the techniques utilized in carrying out this study can help achieve both these objectives. These were the site evaluation visits by technical staff and the use of a panel made up of members with varying disabilities to evaluate facilities for handicapped travelers.

The techniques developed to evaluate the six sites in detail were successful and should be considered for further use. They facilitated orderly accumulation of site specific information in a relatively short time. The use of two engineers with varying backgrounds, in this case civil engineering and traffic/transportation, helped to broaden the observational base as did the dual approach of independent and combined evaluation. While there was a good deal of overlap between basic problems, it was evident that each site often possessed unique features which must be individually considered if a successful facility is to be built. The techniques used in the field observation increased the awareness of design consequences. They also can be exercised in the office during plan conceptualization and review to identify potential problem areas susceptible to location, design, construction and maintenance deficiencies. The important consideration is for the designer to view the facility as conceived from the different viewpoints of each of the three user groups.

Data in this report will help to increase the designer's level of awareness and sensitivity to problems, but it should not be considered as a final answer. Preferably, this report can be used as a building block in a continuing process of learning and advancement of the state of the art.

Where possible, evaluations should be made after construction of a facility to identify features which perform especially well or those which cause problems. While it may be difficult to devote large blocks of time to these efforts, it should be possible to glean useful information from routine maintenance and inspection activities as well as citizen input expressed in letters or telephone calls. These data would provide additional insight into local experience which could form the basis for modifying design standards and policies to be even more sensitive to the needs of bicyclist, pedestrians and the handicapped. Periodic preparation of brief summaries of these findings for internal circulation or for publication in technical journals would even further enhance the benefits gained from local experience.

Users. Increased user awareness through improved education and communication should be a goal of agencies and organizations responsible for over and undercrossing facilities intended to improve the accessibility of bicyclists, pedestrians and the handicapped.

Initially information should be circulated to potential users by means of various media such as newspapers, pamphlets, flyers, newsletters, radio and television. Direct contact with user group organizations and agencies is also desirable. The information should be addressed to all users with emphasis on special features such as might be required by certain handicapped persons.

The means of crossing the barrier should be explained and a description should be provided regarding special features, alternatives. if available, and the relationship of the facility to the adjacent transportation system. For instance, a map showing location of wheelchair ramps would be helpful to a person requiring ramp access.

Knowledge of the transportation system will increase the user's ability to select the transportation routes most suited to their travel needs.

7.3.8 Handicapped Considerations

Some particularly noteworthy additional points pertaining to handicapped travelers on over- and undercrossings are summarized below.

The handicapped are a heterogeneous group with varied mobility limitations and needs, extending over the following range:

1. Persons fully able to utilize any facility accessible to bicycles and pedestrians.

2. Persons requiring certain features such as ramps and handrails but who otherwise can manage to utilize regular bicycle and pedestrian facilities.

3. Persons requiring special features such as low ramps, rest areas, or elevators to be able to use a grade separation.

4. Persons who would not be able to use the facility regardless of the improvements provided.

To accommodate the first two categories of handicapped persons, little or no extra costs are involved in improving or building a structure beyond what would be required for standard bicycle and pedestrian facilities. The third category may require substantial design modification and costs, while the fourth group of persons would not benefit at all from construction of an over- or undercrossing, even one acessible to other handicapped persons.

Once the likelihood of usage by the above-defined groups of handicapped persons is identified, it is possible to select the range of design elements which most closely serves these needs.

Structural versus Non-Structural Solutions. It appears that many over- and undercrossings specifically designed and built to accommodate the handicapped will still be a physical or psychological barrier to certain persons. For instance, excessively long ramps are a deterent to usage even though grades are less than the recommended national standards. For example, the desirable maximum grade of 5 percent creates a 67 percent longer ramp than an 8.33 percent grade ascending the same vertical separation.

Where the vertical separation is 20 feet (6.1M), such as required over a freeway, the difference in ramp length between a 5 percent and an 8.33 percent grade is a 400 foot (121.9M) long ramp compared to a 240 foot (73.2M) long ramp. If both ramps to the overcrossing are similar, total ramp travel is lengthened by at least 320 feet (97.5M) or 67 percent. Persons in manual wheelchairs or with muscle control or breathing difficulties would probably not be able to use such a facility unless elevators were provided.

Therefore, it should be re-emphasized that non-structural solutions to crossing situations are valid and must be thoroughly evaluated as an alternative or a supplement to a structural solution. For example, it may be found that an alternative mode of transportation such as provided by rerouting bus service or an alternative route crossing made accessible by installing wheelchair ramps and traffic control devices can be more viable and cost-effective solutions, providing access to a larger proportion of the handicapped population than would have benefited from an over- or undercrossing.

Identification of Handicapped Needs. As noted in the previous section, one area which seems to be promising is the use of a panel of handicapped advisors to identify travel needs of the disabled. The advisory panel can be of valuable assistance during the planning, design and decision-making processes. Handicapped panel members can provide insight to site specific needs based upon their own perspectives as well as being spokespersons for an advocate group. To be most effective, the advisory panel should be organized officially with a specific set of goals and responsibilities so their participation fits in smoothly into the design and decision-making process. The use of local active handicapped persons with varying disabilities for panel members is highly recommended.

In addition, the panel could logically shoulder the responsibility of alerting the entire handicapped community to the project being contemplated, as well as assuring that input is presented not only from activist groups and individuals but from handicapped persons who, although they require improved accessibility, would normally not participate in the public input process.

Implementation Priorities. The question of where and when handicapped facilities should be implemented is important. It includes consideration of site specific as well as system factors. It is obvious that an over- or undercrossing made accessible to the handicapped is usually of little use if the surrounding transportation system is not also accessible. Therefore, with regard to over- and undercrossing situations, areas rather than just facilities should be made accessible. This means that more attention should be focused on the demand tributary area to identify potential barriers and to develop mitigating measures. In some cases, such as between compact clusters of activity, a preferred route within an area made accessible might satisfy the needs (61).

Priorities for implementation of facilities to enhance handicapped accessibility should be based upon density of existing and anticipated use by the handicapped. Based upon discussions with handicapped participants in this study, the following order of priority was developed:

- Central shopping, services and employment districts.
- Special purpose facilities.
- Satellite shopping.
- Residential with high percentage of handicapped.

In practice, a balanced program of expenditures in each area will probably result, but with emphasis based on usage by the handicapped.

Other Considerations. It should be remembered, however, that even if the ideal design or plan is conceived, it will be necessary to monitor construction to assure that features are completed properly.

As a general observation, it is believed that as travel barriers decrease the travel behavior of the handicapped will approximate that of the general public.

7.3.9 Current Design Strategies - Adequate and Inadequate.

Examples of both adequate and inadequate crossing treatments were identified as a part of this study. These are summarized below, classified according to their presence on the structure, approach or end condition and the following subject groupings:

1. Sidewalks
2. Railing and Fences
3. Structure
4. Traffic Control
5. Maintenance

Treatments in each of these groups were segregated into Adequate or Commendable Design Strategies (Table 13) or Inadequate or Undesirable Design Strategies (Table 14). Adequate or commendable treatments include many features related to sidewalks. For example, this included the use of curb cuts; increased width; removal or relocation of street furniture and plantings; separation of motorized and non-motorized travel paths; and improved drainage. Another large category included various innovative structural treatments. Inadequate or undesirable design strategies again included sidewalks as a major category. Deficiencies in width, grade and drainage surface were the most common. Problems dealing with structures ranged from lack of facilities to building structures in wrong locations. Suggestions for corrective action have been made and are included opposite each inadequate or undesirable design strategy listed in Table 14.

The data in Tables 13 and 14 are presented so that designers have an opportunity of quickly reviewing both the good and the deficient treatments found elsewhere in actual practice and thereby be more aware of treatments which may help to improve the specific site under consideration.

Table 13. Current Design Strategies Adequate or Commendable

	Component			
	Structure	Approach	End	Adequate or Commendable Design Strategy
SIDEWALKS	X	X		Sidewalks on one or both sides.
		X	X	Curb cuts on approaches and end conditions.
		X		Inclusion of ramps versus stair only access.
	X	X		Conscious effort to minimize gradient.
	X	X	X	Increased width for shared facilities.
	X			"Heated" structures to minimize effect of snow/ice.
	X	X		Design elements such as grating to minimize snow effect and effect of debris.
	X	X		Barriers between sidewalk users and travel lane.
	X	X	X	Providing satisfactory horizontal clearance for pathway users.
	X	X		Rest areas on approaches and structures which enable certain groups of handicapped persons to utilize the structure where before there was no space designed for persons of limited stamina to rest.
	X	X		Creation of points of interest, such as sitting areas, playgrounds, view vistas, etc., adjacent to structure, such as at approach or within a vehicle ramp.
		X		Construction of stair and ramp access to structure to allow users a choice of which mode best satisfies their needs.
	X	X		Placing street furniture trash recepticles, etc. along side of pathway rather than on pathway, thereby decreasing the effective travel width.
	X	X		Separation of motorized and non-motorized travel paths and crossings, such as by taking advantage of natural or manmade topography. New town and green belt corridors exhibit many successful examples.
		X		Specially designed "ramps" to allow bicycles to be rolled or pushed up stairways.
		X		Paving or formalizing "short cut" routes forged over time by users. (This only occurs if the "short cut" route provides safe service.)
		X		Construct drainage ditches along toe of embankment slope to catch run-off before it flows across pathway. This also indicates treatments that will probably have less problems with erosion.

Table 13. Current Design Strategies Adequate or Commendable (Continued)

	Components			
	Structure	Approach	End	Adequate or Commendable Design Strategy
RAILING	X			Revised fencing height where bicyclists are anticipated to at least 4.5 feet (1.4M).
	X	X		Provision of sight barriers to preserve privacy of adjacent residents. These barriers have a dual function as a noise barrier, which helps residents as well as blind users.
		X		Placing handrails along approaches to structures, especially where stairs are involved.
STRUCTURE	X			Carry usable shoulder through structure for safety reasons as well as serving bicyclists.
	X			Upgrading bridges and providing space for non-motorized needs.
	X			Retrofitting existing structures, thereby improving service to non-motorized users.
	X	X	X	Concentration of effort at "critical" sites.
	X	X	X	Willingness to design special facilities to serve uniquely local characteristics. Example: Provision of Fisherman's Bridge adjacent to sidewalk carrying pedestrians over a regular highway bridge.
	X			Spanning difficult or scenic area, by unusual treatments. • "Flexible" wooden bridges over marshy area. Unstable soils create differential settlement/heaving. Pile supports are designed to enable deck jacking. • Removable structure built in a flood plain designed to be (raised) removed by crane on threat of flood. • Trail bridges over-designed to be very structurally strong to enhance durability during floods where bridge is "swept" away or dragged to one side. • Cantilevered pathways along the top portion of a paved drainage channel, allowing a trail to be established between two cities through an outwardly unfeasible route.
	X	X	X	Carrying non-motorized improvement from the structure to the approach and end treatment to establish continuity of route.

Table 13. Current Design Strategies Adequate or Commendable (Continued)

	Components			
	Structure	Approach	End	Adequate or Commendable Design Strategy
STRUCTURE	X	X		Utilization of abandoned RR right-of-way, as well as refurbishing RR bridges to serve for non-motorized crossings. • Pave over wooden deck • Create new wooden deck overties
	X	X		Use abandoned highway bridges with minor pavement repair to serve non-motorized.
		X		Increase embankment width to serve as partial or full support for pathway leading to the structure.
	X	X		Create multi-purpose "pathways" serving non-motorized demands, as well as facilitating emergency vehicle access. For example, a centrally located bicycle/pedestrian facility designed to allow emergency vehicles to use the path to gain access to distressed motorists.
	X	X		Increase bridge span length to allow a pathway to be constructed on the embankment underneath.
	X	X		Special use bridges/overpasses to separate various types of travel. • Earthen overcrossing with corregated metal pipe undercrossings separating horse travel at race-track from pedestrian and vehicular movements.
	X			Developing multi-functional structures serving exclusive non-motorized needs, as well as carrying utilities across the barrier.
	X	X		Combining structural aesthetic with function.
	X	X		Innovative use of recycled materials, such as steel beams, timber and fill material to improve cost-effectiveness and enhance the visual characteristics of the facility.
	X	X		Utilization of flood plains during dry season, rather than building a structure or as an alternative until a structure can be financed.
TRAFFIC CONTROL	X	X	X	Traffic controls at street or ramp crossings, stopping vehicles, thereby allowing pedestrians and bicyclists a better opportunity to cross a street without conflicts.
		X	X	Designs channelizing users onto structures, rather than allow opportunities to cross the barrier at-grade. This could be accomplished by alignment or construction of physical barriers.

Table 13. Current Design Strategies Adequate or Commendable (Continued)

	Component			
	Structure	Approach	End	Adequate or Commendable Design Strategy
TRAFFIC CONTROL	X			Use of existing one-way traffic bridges to accommodate two-way non-motorized travel.
	X	X	X	Making non-motorized travel a priority on streets during certain hours of the day or days of the week.
	X	X	X	Actuated traffic control allowing non-motorized travel to compete with motor vehicles.
		X		Striping of shoulder area and gore to facilitate bicycle weaving maneuvers.
	X			Require bicyclists to dismount and walk where design is substandard. (For example, at certain points on the Golden Gate Bridge.)
	X	X	X	Marking, retrofitting or designing drainage inlets to reduce hazard to cyclists.
MAINTENANCE	X	X	X	Lighting of structures, approaches and intersections.
	X	X		Overlaying steel decking plate with layer or membrane of "rough" paving to serve as anti-slip surface during wet conditions. This is not effective, however, with snow and ice accumulation.
	X			Applying preservatives to a new Glulam wooden bridge to reduce problems caused by persons writing on the wood and then cleaning it, only to have preservative added absorbed more by the cleaned areas. The result is a "permanent" disfiguring.
	X	X	X	Landscaping that does not encroach upon the pathway, thereby requiring maintenance to preserve the quality of travel.
	X			Design light standards to be attached on the structure outside of the railing or fencing.

Table 14. Inadequate or Undesirable Design Strategies

	Component				
	Structure	Approach	End	Inadequate or Undesirable Design Strategy	Corrective Action
SIDEWALKS		X		Sidewalk on structure but not on approach and demand is evident.	• Build after determining if one side or two side is best.
	X	X	X	Sidewalks, but no curb cuts or ramps at crossings.	• Build (curb cut or ramp).
		X		Sidewalk on approach effected by differential settlement at interface with structure.	• Use abutment as foundation for sidewalk slab.
		X	X	Rough surfaces where the sidewalk crosses a railroad track.	• Install special treatment and align for perpendicular crossing.
	X	X	X	Inadequate shy distance outside of pathway.	• Relocate obstruction, modifying pathway or place shoulder stripe indicating adequate clearance.
	X	X		No "rest" areas on approaches or structure.	• Retrofit. Education to teach proper travel techniques.
	X	X		Steep grades.	• Develop new approach; add rest areas or special equipment.
	X	X	X	No sidewalk and no shoulder.	• Build after determining if one or two side is best.
		X		Approaches encourage or do not prevent random crossing movements by persons not wishing to utilize an exclusive bike/pedestrian structure.	• Channelize to minimize random crossings.
	X	X	X	Cross slopes on sidewalks too steep, thereby impeding or endangering handicapped.	• Fence or lessen grade.
	X	X	X	Hostile pedestrian environment created by fast moving, high volume traffic where noise, speed, fumes and associated debris tend to intimidate non-motorized users to the point where these features actually become the deterrent to certain groups.	• Adequately sign; keep in top condition; inform users of route destination, distances, etc.
	X	X		Sidewalk only on one side of structure where approaches serve travel on two sides; thereby potential conflicts are created on the approach or users are forced to continuing on the same side, competing for space with vehicles.	• Sign and barricade sidewalk to prevent usage leading to the side without sidewalks on the structure. Add facility on second side as an alternative.
	X	X		Design of switchback ramps which require most structure users to go out of their way. Poorest examples have resulted in users disconnecting railing to create a short cut along a more direct line. This not only creates a hazard or inconvenience for some users who must use the handrail, but has a deleterious effect upon the structure's image and operational performance.	• Maintain, possibly retrofit to provide facility in line with user path.

Table 14. Inadequate or Undesirable Design Strategies (Continued)

	Component			Inadequate or Undesirable Design Strategy	Corrective Action
	Structure	Approach	End		
SIDEWALKS	X			Protrusions into the pedestrian space, such as light standards, light fixtures, signing, structural supports and the thread end of bolts, decrease travel space. These features present intermittent hazards or impedances, which should be minimized when retrofitting or designing new structures.	• Schedule replacements or install protective devices such as a rub rail to cover volt protrusion. Review and modify design standards appropriately.
	X	X	X	Lack of level area on sidewalk prior to using wheelchair ramp.	• Retrofit "level" area by adding pavement on or adjacent to sidewalk.
		X	X	Roadway super-elevation, such as occur at on and off-ramps, is difficult for certain persons to overcome. This may require additional thought as to where pedestrian crossing should be located or how design could be changed to facilitate pedestrian crossings.	• Relocate crossing to more suitable location. • Special care given to configuration of the pathway on both sides of ramp to remove as many of the impediments as possible.
		X		Only limited entrance space to sidewalk is available through or around guard rail protection on bridge approach.	• Create an opening by overlapping guard rail to facilitate access by all users.
	X	X		Longitudinal planking on decks is more difficult for bicyclist to ride because of tendency to "track" in the grooves between the boards. Also, if a board fails, a longer portion is in line with bicyclist travel, which increases the hazard of "falling through" the decking with a wheel.	• Overlay with plywood or other sheet surface, or install perpendicular planking.
	X			Wide joints in the sidewalk on structures are often difficult for wheelchair users to negotiate.	• Correct by installing new joint sealing material or a cover plate.
		X	X	Pedestrian access from structure very close to street with little warning that street and moving traffic is so close.	• Provide fencing to prevent users from going directly into traffic.
		X		"Zig Zag" maze at entrance to structure, if used, should be built on the level so it is not as difficult for wheelchair bound persons to use. Bicyclists may also have problems negotiating the zig zag maze.	• Remodel or remove maze. Test ride to assure workability. Avoid putting on slope.
		X	X	Problems with facilities not conforming at jurisdictional boundaries. Improvements should be coordinated to provide full access at least to nearest end condition, even if a temporary treatment must be utilized.	• Coordinate planning and construction so there are smooth transitions at jurisdictional boundaries.

Table 14. Inadequate or Undesirable Design Strategies (Continued)

	Component				
	Structure	Approach	End	Inadequate or Undesirable Design Strategy	Corrective Action
SIDEWALKS		X		"Cute" architectural or landscape elements which limit or reduce the operational capacity or function of a pathway/walkway facility should be eliminated and replaced with acceptable design. Example: Include bulbing planters and extraordinarily winding sidewalk alignment.	• Pay specific attention to designs in planning stage. Establish policies and designate review responsibility.
			X	Location of curb ramps in unacceptable positions with respect to handicapped, as well as ambulatory, users.	• Construct new ramps in appropriate positions.
	X	X		Narrow sidewalks with two-way travel without a barrier separating motorized from non-motorized travel.	• Install barrier and consider retrofit to increase space.
			X	Poor sight distance at end condition crossing.	• Correct or mitigate with traffic control measures, pathway realignment or pruning.
		X		Stair access only to structure.	• Explore potentials for providing a ramp. Consider alternatives such as elevator or non-structural solutions.
		X		Alignment of the approach pathway is noticeably different from the path on structure. This creates a potential conflict point close to moving traffic and usually decreases the effective pathway width.	• Realign approach and widen at interface.
			X	Intersections or path divergences close to structure where sight distance is very poor.	• Extend point of divergence.
	X	X		Approaches which have different design pavements, one which is snow free (grating) and another on which snow/ice accumulates. This problem occurs where snow free surfaces are not continuous. An example would be on stairs where a portion is grating and the remainder is concrete. This disconformity creates a sharp change in slipperiness.	• Design entire stairway to have same qualities.
	X	X		Drainage which either drips, splashes or ponds, thereby making structure usage more difficult or unpleasant. Results of poor drainage also causes more problems during freezing weather.	• Correct problems by channelizing drainage and construct splash boards where roadway wash is a problem.

Table 14. Inadequate or Undesirable Design Strategies (Continued)

	Component				
	Structure	Approach	End	Inadequate or Undesirable Design Strategy	Corrective Action
RAILINGS & FENCES	X			Pedestrian railings at 3.5 (1.1M) where bicyclists are riding on sidewalks and require higher railings or fencing.	• Install higher (4.5' min. (1.4M)) railings commensurate with usage and hazard.
	X	X		Railing heights and types which are difficult for the handicapped to grasp.	• Take care to design proper railings; replace retrofit where necessary.
	X			Pedestrian railing on "inside" of retrofitted bicycle fence which allows persons to climb up on railing.	• Solution required only if climbing becomes a problem. Add height and or curve to top of fence.
	X			Fencing on structures which have a space between the deck or railing where objects can still be pushed through onto the roadway below.	• Fix if dropping objects become a problem; use tie-downs to bridge deck or add small strip of wire to fence with its bottom touching the bridge deck. Berms or angle iron may also be effective.
		X	X	"Head-on" fences to prevent straight access from over/undercrossing to street are often too close to other fencing or do not allow adequate space for turning. Marking of fences is also poor, thereby taking users by surprise.	• Expand turning area and sign or delineate fence to enhance its visibility.
	X	X		Railing designs that terminate in such a fashion as to "pinch" the hand of persons using it. This is particularly hard on blind persons. Railings which are connected with pieces which interrupt the smooth railing surface are another example.	• Retrofit with triangular ground fitting. Go through the mental exercise during design of "using" the handrail and thereby identify problems which should be corrected prior to construction
STRUCTURE	X			Approach shoulder not carried through structure.	• Best handled during design.
		X		Long and out of the way approach ramps which make the user feel that the straighter at-grade path would be better.	• Consider formalizing short cut routes where they are safe.
	X			Improper placement of the structure so that little or no non-motorized travel utilize it. Usually stems from incomplete understanding of travel desires and land use trip generation.	• Re-evaluate to assure that alternative routes are better or if they should or can be closed. Relocate overpass if possible.
	X			Unaesthetic or "ugly" structures which offend the community sense of self-image.	• Identify and modify the most objectionable features. Fencing, facia, color.
	X	X		Not retrofitting or constructing a new facility along a major demand corridor.	• Contruct based on priorities. Provide interim alternatives.

Table 14. Inadequate or Undesirable Design Strategies (Continued)

	Component				
	Structure	Approach	End	Inadequate or Undesirable Design Strategy	Corrective Action
STRUCTURES	X	X		Remote, "out of public view," approaches and underpasses which exacerbate fears of the unknown, such as meetings with "dangerous strangers," tend to reduce usage, particularly at night.	• Schedule extra maintenance. Establish higher level of patrol, consider lighting.
			X	New structures may create parking and traffic problem in areas where only neighborhood usage occurred prior to construction.	• Establish parking regulations to be compatible with the policy to restrict or to promote parking. Enforce regulations.
			X	Access points to structures are susceptible to being blocked by parkers.	• Adopt and enforce parking regulations. Install barrier to prevent blockage.
	X	X		Underpasses generally have a greater tendency to foster crime/vandalism than do overpasses. One of the major contributing factors is that the structure, and sometimes a portion of the approaches, are not in the normal range of public view. Some jurisdictions have even been forced to physically close underpasses because of continuing social problems.	• Patrol and maintain to levels higher than required at ordinary over or undercrossings. Consider formalizing alternative routes. Thoroughly consider potential or perceived crime/vandalism problems and try to mitigate during design.
TRAFFIC CONTROL		X		Poorly "channelized" approaches which do not keep users from using or falling off slopes.	• Provide adequate channelization and fencing.
	X	X	X	Lack of traffic control devices with which to warn or regulate motorists at non-motorized crossings.	• Install warning or regulatory devices as required - signs, flashers, pavement marking.
		X	X	Signs and street furniture create hazard when in walkway.	• Relocate or remove these items from the pathway; change design policies.
		X	X	Lack of signing where formal pathway begins or ends. This could include informational, as well as directional or warning, signing to help persons select the most appropriate route.	• Provide adequate signing along route, especially where occasional or unfamiliar users are common.
		X	X	Lack of signing at one end of structure to tell persons that either the non-motorized facilities are continuous or are not continuous. A distance sign might also be helpful along certain routes to help persons prejudge whether the trip is within the range of their physical capabilities.	• Provide adequate guide and directional signing at the end condition, especially where occasional or unfamiliar users are common.
	X	X		Lack of reinforcing signing on long route to renew the confidence of users as they travel the route.	• Provide adequate signing along route, especially where occasional or unfamiliar users are common.

Table 14. Inadequate or Undesirable Design Strategies (Continued)

	Component				
	Structure	Approach	End	Inadequate or Undesirable Design Strategy	Corrective Action
TRAFFIC CONTROL			X	Signing indicating pedestrian crossing at intersection adjacent to where over or undercrossing creates a mid-block crossing which is not marked. This tends to present approaching driver with confusing situation to the disadvantage of the over/undercrossing user. Mid-block crossing should be marked.	• Revise signing to include and/or emphasize mid-block crossings.
	X	X	X	Insufficient time allocated to the pedestrian phase of a traffic signal.	• Review and revise timing based upon local characteristics.
		X		Signing - such as DO NOT ENTER signs on ramps positioned so as to obscure view of and sight distance from persons crossing freeway ramps.	• Review and revise sign locations as required. Modify sign installation instructions accordingly.
		X		Lack of guide signing for bicycle route on approach or at end conditions. This is especially important for unusual situations.	• Provide adequate signing.
MAINTENANCE	X	X	X	Inadequate lighting at crossing areas.	• Review lighting requirements and install where required.
	X	X	X	Debris accumulation in gutters and sometimes on sidewalks requires frequent maintenance. This problem is magnified by inadequate drainage facilities and structural features which "catch" dirt and debris.	• Identify areas of consistent maintenance needs and correct the source problem where possible in addition to providing adequate maintenance. Modify design standards as necessary.
	X	X		Lighting fixtures which are within reach of pedestrians or which protrude into the walking space and offer temptation for vandalism. This is common practice in smaller pipe type underpasses.	• Retrofit lighting system to be free of vandalism where frequent problems occur. Modify design standards.
	X			Lighting in underpasses keyed to outside day/night conditions when it is actually dark inside the tunnel prior to nighttime.	• Test lighting requirements and modify equipment and lighting schedule where deficiencies are identified.
	X			Use of inappropriate materials can create early and continuing maintenance problems. For instance, paving tile and readily unboltable fixtures or materials of special value or local use, such as boards, are extraordinarily susceptible to vandalism, whether mischievous or malicious.	• Potential vulnerability of design features to vandalism should be determined during the design stage and replaced with more durable features.
	X	X	X	"Debris begets debris"	• Establish a reasonable maintenance program.
		X		Lack of slope protection resulting in eroding materials being deposited on the pathway.	• Correct problem areas with ditches, walls, plantings, reshape slope, relocate path.
		X		Driveways crossing approach are not paved satisfactorily and therefore dirt, mud, gravel and debris are tracked across an otherwise clean bikeway or pedestrian way.	• Limit the amount of debris by paving at least 50 feet (15.2M) along the driveway approach.

GLOSSARY

ARCH CROWN - The highest point or vertex of an arch.

BALUSTRADE - A coping or handrail on a bridge parapet supported by small pillars.

BEAM GUARDRAIL - A rail to prevent motor vehicles from accidently leaving the roadway. Constructed of a steel beam with a "W" shaped cross section mounted on wood, concrete, or steel posts.

BICYCLE - A device propelled exclusively by human power upon which any person may ride, and having two tandem wheels.

BIKEWAY - Any trail, path, part of a highway or shoulder, sidewalk, or any other construction designated for bicycling use.

BOX GIRDER - A steel or reinforced concrete girder having a hollow rectangular cross section.

CANTILEVER - A beam or girder fixed at one extremity and free at the other.

CHORD - One of the main structural members which lie along the top or bottom edge of a truss framework.

COLUMN BENT - Two or more columns at a common support location tied or connected at the top so as to form a frame supporting a bridge, overpass, or trestle deck.

CORRUGATED STEEL PLATE ARCH - Large curved structural plates with corrugated surfaces that can be bolted together to form arch shaped structures; often used for the construction of tunnels, culverts, and small underpasses.

DESIGN STANDARD - These are criteria which serve as a means of determining what a thing should be, thereby enabling construction of features which have consistent qualities even though they may be constructed at a different time or place.

DESIRABLE MAXIMUM - As applied to design criteria, this defines the level which should not be exceeded if at all possible. However, there may be situations where the desirable maximum must be exceeded and may reach the maximum acceptable design level if the facility is to be considered feasible.

DIFFERENTIAL SETTLEMENT - Unevenness or vertical height differences between parts of the same structure or adjacent structures caused by varying settlement of the supporting soils.

DOUBLE TEE BEAM - Two side-by-side rectangular cross section reinforced concrete beams joined at the top by a common section of reinforced concrete slab so as to appear as a double "T" in shape.

EXPANSION JOINT - A joint between two parts of a structure to allow these parts to expand with temperature variance without distorting laterally.

FASCIA - A wide, flat member of a framework supported by columns. (The vertical surface of a bridge deck.)

GLU LAM - Structural grade glued laminated timber assemblies of selected and prepared wood laminations bonded with adhesives. A wide variety of shapes, including curved, and sizes are available. These are often used where a combination of structural strength and aesthetics is considered desirable.

GRADE SEPARATION - Vertical isolation of travel ways through use of a structure, so that traffic crosses without interference.

GUIDELINE - An indication or an outline of a suggested course of action which within the context of this report is seen as being flexible and allowing variation depending upon the circumstances, rather than being a rigid mandate.

GUSSET PLATE - A steel plate used for connections, as in a steel truss connecting the members framing into a joint.

HANDICAPPED - For purposes of this report "handicapped" includes those individuals who use wheelchairs; have impaired hearing or vision; walk with difficulty, with or without prosthetic aids; have diminished agility, stamina, or reaction time: are of unusual body size, including those who are very small or large; have upper extremity impairments, including those with arm, hand, and neck impairments. The definition may encompass the elderly, very young individuals, and those with temporary injuries or impairments, in addition to those who are permanently disabled.

JOIST - A horizontal beam of timber or steel used with others as a support for a floor and/or ceiling or a deck.

MEDIAN - The portion of a divided road or highway separating the traveled ways for traffic in opposite directions.

MUD SILL - The lowest horizontal timber block or the like serving as a foundation of a wall, house, small bridge, or other structure, usually placed in or on the ground.

NAILER - A timber that has been fastened to a steel or other metal beam or structural member to allow other wood boards or timbers to be nailed to it.

NEW JERSEY TRAFFIC BARRIER - A reinforced concrete barrier with a sloped surface shape that returns motor vehicle wheels to the roadway when struck in a "sideswipe" type collision.

NON-MOTORIZED TRAVELER - A person whose mode of transportation is by other than a motorized vehicle; includes bicyclists, pedestrians, and handicapped persons. For the sake of this report, a motorized wheelchair user is included within this classification.

PARAPET - A low wall along the edge of a bridge or overpass or a roof.

PEDESTRIAN - A person whose mode of transportation is on foot.

PLATE GIRDER - Large steel plates that have been riveted or welded together to form a girder.

POLICY - A defined course of action adopted as being expedient. Typically a policy would be followed without requiring additional research to substantiate its validity. An example of a policy would be to always provide shoulders along a limited access highway.

PRESTRESSED CONCRETE - Concrete poured around strong steel cables, wires, etc., which are kept under tension until bonded to the concrete, and when the tension is released it produces compressive stress and greater strength in the concrete.

REINFORCED CONCRETE - Concrete in which steel bars (reinforcement) are embedded in order to provide increased strength.

RETROFIT - The modification of an existing over- or undercrossing in some manner, either structurally or otherwise, to facilitate its use by bicyclists, pedestrians, or the handicapped.

ROADWAY - That portion of the highway included between the outside lines of the sidewalks, or curbs and gutters, or side ditches, including the appertaining structures and all slopes, ditches, channels, waterways, and other features necessary for proper drainage and protection.

SAFETY CURBS (BARRIER CURBS) - Relatively high and steel faced curbs designed to inhibit or discourage vehicles from leaving a roadway.

SHOULDER - The portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses.

SHY DISTANCE - The distance between the edge of a bikeway or the edge of a motor vehicle travel way and any fixed solid object. There is also a psychological aspect of shy distance where users select a travel zone on a pathway depending upon the space available and their assessment of how far they must be away from an obstacle to be comfortable.

SPALLED CONCRETE - Pieces of concrete that have chipped or splintered off; in reinforced concrete this is often caused by corrosion and subsequent expansion of the embedded reinforcing steel.

SPANDREL - The space between the haunches and the road decking of an arch.

SPANDREL WALL - A wall constructed upon the extrados (top surface) of an arch.

STRINGER - A long, horizontal member in a structural framework.

STRUT - Any light structural member or long column which sustains an axial compressive load.

SUPERELEVATION - Raised outside edge of a roadway curve for the purpose of overcoming the force causing a vehicle to skid when maintaining speed. Often this is called a "banked curve."

TRAFFIC BARRIER - A fence, rail, wall, or other device erected in a roadway to prevent movement of motor vehicles from or into an area.

TRAVELED WAY - The portion of a roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

TREATED WOOD OR LUMBER - Wood piles, beams, or other structural or non-structrual members that have been treated with preservative chemicals, such as coal tar creosote, to prevent decay due to exposure to water, weather, marine organisms, or insects.

TRUSS - A combination of members such as beams, bars, ties, or the like, arranged usually to a triangle or collection of triangles joined together so as to form a rigid framework, and used in bridges (bridge truss), roofs (roof truss), etc., to give support and rigidity to the whole or part of the structure.

GLOSSARY (Continued)

VIADUCT - A structure consisting of a series of short span bridges in line supported on intermediate piers carrying a roadway or railroad across a wide, deep valley.

WARRANTS - A warrant is one means by which the relative need for a facility can be evaluated. Warrants provide guidance in the decision-making process. The fact that a warrant is met is not conclusive evidence that a facility is needed, since the review of warrants is only one step within the needs assessment process which considers all pertinent facts.

WEB - A solid or open system connecting the chords or flanges of structural members, such as a steel plate connecting the top and bottom flanges of a steel beam.

WIRE MESH RAILING - A pedestrian or bicycle barrier railing consisting of a steel or wood framework with extruded or other metal mesh closing the open parts of the frame.

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  - 1.1.2 **Ease of Walking**
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  - 4.3.1 **Community Activities**
  - 4.3.2 Adaptability to **Future Urban** Development **Plans**
  - 4.3.3 **Construction** Period.

Source: Braun and Roddin (60)

APPENDIX A

PEDESTRIAN FACILITY EVALUATION VARIABLES

APPENDIX B

CASE STUDY SUMMARY AND IDENTIFICATION NUMBER

				Est. Usage						
Number	LOCATION	New	Retrofit	Vehicles	Bike	Pedestrian	Handicapped	Land Use	Innovative	COMMENTS AND FEATURES
1	Nogales, Arizona		X	M	L	H	L	U		One side sidewalk
2	Austin, Texas over the Colorado River		X	H	H	H	L+	U	X	Deck replacement with prestressed concrete beams Reconstruction to BEGIN SPRING 1978
3	Dover, N. H.		X	M	L	H	L	U		Widen and protect sidewalk
4	Swanzey, N.H.		X	M	L	H	L	R		Cantilever 3' wide sidewalk both sides
5	Calamine-Piatteville Wisconsin		X	-	H	H	L	R		Conversion of existing railroad trestle PLANNED FOR 1978
6	Okoboji, Iowa		X	-	H	H	L	R		Converstion of existing railroad trestle. Expected 1978
7	Glenwood Springs Colorado		X	M	M	M	L	U		Cantilever new sidewalk on one side.
8	Eugene, Oregon (Ferry St. Bridge)		X	H	H	M	L	U	X	Construct new access ramp from bridge to park.
9	Montgomery Co. Maryland		X	-	H	M	L	R		Rehabilitated old structure as bikeway; Concrete Patching, Repairing guardrails, repaving.
10	Peachblossom & Trippe Creek, MD		X	M	M	L	L	R		Removed balustrade and curb; install new railing
11	Jefferson County Oregon		X	M	-	M	L	R		Construct 6' wide walkway on one side of bridge connecting to footpath to river
12	Rickreal, Oregon		X	M	L	L	L	R		Construct 8' wide sidewalk. Remove existing curb, fence, and barrier rail
13	Arlington County, Virginia		X	H	L	L	L	U		Construct 5' cantilevered walkway on one side
14	Culpepper County, Virginia		X	M	L	L	L	R		Construct 3'10" clear width cantilevered sidewalk on one side.
15	Bland Co., VA		X	M	-	L	L	R		Cantilever 5' sidewalk from one side.
16	Tazewell Co., VA		X	M	-	L	L	R		Cantilever 5' sidewalk from one side.
17	Giles Co., VA		X	M	-	L	L	R		Cantilever 4'10" sidewalk from one side.
18	Westminister, California		X	H	L	M	L	U		Construct a parallel bridge to make 4 lanes plus 2 sidewalks to conform with approaches (NOT YET BUILT)
19	Vandalia, Ohio		X	H	M	M	L	R		Construct 12' bike/ped way on one side (NOT YET BUILT)
20	Eugene, Oregon		X	M	M	M	L	R		Widened embankments for new 4' sidewalk
21	Pismo Beach, CA		X	H	M	M	L	R		Widen existing bridge and ramp to accommodate 8' wide bike/ped path
22	Hampton, New Hampshire		X	M	L	M	L	R		Widen embankment, relocate guardrail, construct sidewalk and cantilever walkway on structure
23	Henrico Co, VA		X	M	L	M	L	U		Cantilever sidewalk on one side.
24	Alexandria, Virginia		X	-	L	M	L	U		Connected walkway under overpass to tunnel under tracks as alternative to putting sidewalks on bridge
25	Pearl City Oahu, Hawaii		X	-	H	M	L	U		Fenced and Curbed existing wooden plank vehicle bridge.
26	Stockton, California	X		-	M	M	L	R		To be constructed 1978. Construct bike/ped bridge over river. Glulam Beams. serves mobile homes. Non-skid coating on deck.
27	Plantation, Florida	X		-	M	M	L	U		Construct bike/ped bridge over canal serves as access from parking lot to ballfield @ school.
28	Anchorage, Alaska	X		-	M	M	L	U		Construct bike/ped bridge over creek; Glulam Beams
29	Fairbanks, Alaska	X		-	M	M	L	U		1978 construction. Bike/ped bridge over creek; use of salvaged beams; flat bridge 72' long.

APPENDIX B

CASE STUDY SUMMARY AND IDENTIFICATION NUMBER (Continued)

				Est. Usage						
Number	LOCATION	New	Retrofit	Vehicles	Bike	Pedestrian	Handicapped	Land Use	Innovative	COMMENTS AND FEATURES
30	Champaign County Ohio	X		M	L	M	L	R		5' walkway on one side of bridge. Gravel approaches. State park nearby. Dam site.
31	Los Altos, CA	X		-	M	M	L	U		Glulam Bridge over creek serves school and trail.
32	Los Altos, CA	X		-	L	M	L	U		Arched Glulam Bridge. Along one side of Fremont Blvd.
33	Fargo, North Dakota	X		-	M	M	L	U	X	Prefabricated steel bridges built on flood plain. Can be raised during high water. Serves regional trail, parks, college. Completed Spring 1978. 152' long
34	Eugene, Oregon	X		-	H	M	L	U		Prestressed concrete beams. 528' long. Connecting to river bank trails. Complete Feb. 1978. Deck widened at piers for benches.
35	Keene, New Hampshire	X		-	M	M	L	R		Bike/ped bridge 155' long over Ashuelot River. Recreational. Underconstruction Fall 1978.
36	Marinette, Wisconsin	X		M	L	M	L	U		New bridge with 9-foot sidewalk for bike/ped on one side. Supplemented by special fisherman's bridge. Some problems with approaches.
37	Portland, Oregon	X		H	L	L	L	U	X	Central bike/pedway/emergency access road over Columbia River 6000' long.
38	Eugene, Oregon	X		-	H	M	L	U	X	Bike/ped bridge/shared with utility. 667' long. Benches at piers. Autzen Bridge.
39	Medford, Oregon	X		-	M	L	L	R		Reinforced concrete bridge over Bear Creek. Serving trail. 8% grade. Super elevation on curve.
40	Loch Haven Reservoir, Maryland	X		M	M	M	L	R		Bike/ped bridge together with traffic bridge on one side. Pave two way approaches separated by barrier from travel lane.
41	Delaware County, Ohio	X		M	L	L	L	R		Walkway on one side of the bridge separated by concrete barrier. Alum Creek Reservior.
42	Palo Alto, CA	X		-	M	M	L	U	X	Cantilevered bike/ped way off from a drainage canal. Connects two neighborhoods.
43	Sunnyvale, CA	X		-	M	M	L	U	X	Bike/ped bridge over 101. Designed with rest areas.
44	San Clemente, California	X		-	M	M	L	U		TO BE BUILT. Slopes to 15%. State architect recommended deletion of handicapped feature since alternative flat crossing was close by.
45	Tempe, Arizona	X		H	M	M	L	U		Two 10' sidewalks included on both sides of new bridge.
46	Pompano Beach, Florido	X		-	M	M	L	U		Helical ramps to overcrossing structure. Steep ramps. Serves school.
47	Miami, Florida	X		-	M	M	L	U		Ped/bike overpass. Long ramps connecting neighborhoods severed by freeway.
48	Sacramento, CA	X		H	H	H	L	U		Underpass 90 foot Armco arch
49	San Francisco, California	X		H	-	H	L	U	X	Helical open ramp connecting parking lot to United Airlines maintenance facility. Heavy use during shift changes. 10.6% grade. 11 foot wide. Warning sign
50	Anchorage, Alaska	X		-	M	M	L	U		Underpass Armco superspan 85' long 13'9" wide.
51	Anchorage, Alaska	X		H	M	M	L	U		Bike/ped overpass 7' wide 140' long over Northern Lights Boulevard.
52	Anchorage, Alaska	X		H	M	M	L	U		Underpass Armco Superspan 92' long;15' interval for lighting. Serves trail.
53	Anchorage, Alaska	X		H	M	M	L	U		90' long Glulam Overpass. Stairs. Connects bike paths.
54	Anchorage, Alaska	X		H	M	M	L	U		Glulam beams. Bridge 5' clear distance between handrail. Switchback ramp. IN PLANNING STAGES.

APPENDIX B

CASE STUDY SUMMARY AND IDENTIFICATION NUMBER (Continued)

				Est. Usage						
Number	LOCATION	New	Retrofit	Vehicles	Bike	Pedestrian	Handicapped	Land Use	Innovative	COMMENTS AND FEATURES
55	Columbus, Ohio	X		H	L	M	L	U	X	Aluminum arch 120' long. Stair access along a school route over Hamilton.
56	Columbus, Ohio	X		H	M	M	L	U		Prestressed concrete box beam construction. Connects school and residential neighborhood over Rte. 71. 10% slopes.
57	Franklin County, Ohio	X		H	M	M	L	U		Overpass of Rte 315. Children using culvert drain pipe to reach school. 550' long, 7'6" wide between handrails.
58	Wyoming, Michigan	X		H	M	M	L	R		Underpass Armco pipe deleted from plans for fear of vandalism.
59	Louden, New Hampshire	X		M	M	M	L	R		Underpass created for trail path by lengthening highway bridge.
60	Austin, Texas	X		H	M	L	L	U	X	Construct bikeway thru interchange. 2 bridges (8'wide) modify guardrail, handrails, signing, striping, wooden planking. UNDER CONSTRUCTION 1977.
61	Keene, New Hampshire	X		M	M	M	L	R		Bike/ped 8' wide on one side of new bridge (268' long) Separated by barrier. PLANNED 1977-78. FAP project.
62	Arlington, Virginia	X		H	M	M	L	U	X	Structural steel box truss. Ramp and stair on same side. Checker plate/grating floorway. Residential to school.
63	Cuyahoga Co, Ohio	X		H	L	L	L	U		Bridle path on one side of structure.
64	Portland, Oregon	X		H	M	M	L	U		Bike/ped overcrossing of I-5. 155' long. Access ramps are perpendicular to structure.
65	Polk County Oregon	X		M	M	M	L	R		Bike/ped overcrossing 200' long 10' wide. 5.72% grade. Spanning Highway 22.
66	Alexandria, Virginia	X		H	L	M	L	U		Bike/ped ramp overpass. High screening. Compromise location. Ugly.
67	Rte. 183 Randolph Rd. Maryland	X		H	M	M	L	R	X	Modified box culvert to create elevated pathway. UNDERPASS.
68	Eugene, Oregon	X		M	L	L	L	U		Overpass built to cross railroad tracks. Overdone and not wholly useful. 328' long. 10% grade. At $66,000 it was cheap.
69	San Bernardino California	X			L	L	L	U		Ped/bike path 8' wide on one side. 1600' long. Separated by barrier. Under RR. UNDERPASS
70	Eugene, Oregon	X			H	H	L	U		Underpass. precast prestressed concrete box under RR connecting to Autzen Bridge.
71	Hayward, California	X			M	M	L	U		Underpass. Explored alternative pathway alignments and selected bike lane on both sides rather than one side off street alternative. Under RR.
72	Pleasanton, California	X		M	L	H	L	U	X	Ped/bike/vehicle underpass of Horse overcrossing.

DESIGN SELECTION CRITERIA WORKSHEET

Non-Structural Versus Structural Solutions

The following items are potential alternatives to constructing or modifying a grade separation to serve non-motorized travel. Do the following appear to be practical substitutes for a structural crossing solution?

	YES	NO
• Traffic Control Strategies (signing, striping, signalization, parking removal, channelization, reversible lanes, auto free zones, separate bicycle travel from pedestrians, one way streets, issue permits to qualified users, use freeway shoulders)	☐	☐
• Alternative Travel Modes (transit, paratransit, demand responsive transit)	☐	☐
• New Technology (improved wheelchair capability, communications systems, vehicle design and power economy, surveillance capabilities)	☐	☐
• Land Use Planning (new towns, urban development and redevelopment to reduce barriers, reduce need to travel, emphasize corridors)	☐	☐

If all or most answers are NO, then a structural solution is favored. YES answers indicate potential for non-structural solution. Further describe the actions to be considered with each YES answer.

Comments: ______________________________

MADE BY ______________ DATE ________ PAGE 1 OF 5

LOCATION ______________________________

DESIGN SELECTION CRITERIA WORKSHEET

Over or Undercrossing

	YES	NO
• Site Conditions (Topography, approaches, etc.) Favor an Overcrossing	☐	☐
• Existing/Planned Vehicle Overcrossing can be shared or retrofitted.	☐	☐
• Existing/Planned Vehicle Undercrossing can <u>not</u> be shared. (State reasons below)	☐	☐
• Adopted Policy favoring overcrossings.	☐	☐

YES answers favor overcrossings to serve bicycles and pedestrians while undercrossings may be considered for NO answers.

Comments: ______________________________

Exclusive or Shared Structure

	YES	NO
• Existing Planned vehicle structure available	☐	☐
• Space on structure for bicyclists and pedestrians	☐	☐
• Retrofit appears feasible	☐	☐
• Alternative route available	☐	☐

YES answers favor shared structure while all NO answers mean exclusive structures should be explored.

Comments: ______________________________

MADE BY ______________ DATE ________ PAGE 2 OF 5

LOCATION ______________________________

APPENDIX C

DESIGN SELECTION CRITERIA WORKSHEETS

DESIGN SELECTION CRITERIA WORKSHEET

New Versus Retrofit Structure

	YES	NO
• Existing structure available	☐	☐
• Modification appears structurally feasible	☐	☐
• Serviceable life remaining should be greater than 5 years	☐	☐
• Can retrofit be included in current or future plan?	☐	☐

All answers must be YES to consider a retrofit solution.

Comments: ____________________

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Future Non-Motorized Travel

Estimate potential changes in land use that could significantly increase the demand for non-motorized travel compared to the existing situation.

	POTENTIAL INCREASE		POTENTIAL DECREASE	
Land Use	HIGH	LOW	HIGH	LOW
• Residential Development	☐	☐	☐	☐
• New or Enlarged Schools	☐	☐	☐	☐
• Employment Center	☐	☐	☐	☐
• Recreational Opportunities	☐	☐	☐	☐
• Combination of Uses	☐	☐	☐	☐

If any HIGH answers are noted, then further information regarding order of magnitude, relative location and timing will be necessary to determine if the facility is capable of meeting future needs. Designs can then be adjusted to accommodate future needs or to facilitate future modifications.

Comments ____________________

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MADE BY ____________ DATE ________ PAGE 3 OF 5

LOCATION ____________________

DESIGN SELECTION CRITERIA WORKSHEET

One-Side Versus Two-Side Non-Motorized Facilities

Facilities serving non-motorized travel on both sides of a grade separated structure shared with motor vehicles are preferred for safety reasons. However, there are certain special circumstances where non-motorized facilities on one side of the structure may be acceptable.

	YES	NO
• Structure serves one-way vehicle traffic	☐	☐
• Central pathway position is feasible	☐	☐
• All non-motorized travelers use a single separate pathway at both ends of the structure	☐	☐

A YES answer indicates a situation where a one-side non-motorized facility may be acceptable. It is very important to remember that users should not need to cross a travelway to use a one-sided facility.

Comments: ____________________

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MADE BY ____________ DATE ________ PAGE 4 OF 5

LOCATION ____________________

APPENDIX C

DESIGN SELECTION CRITERIA WORKSHEETS (Continued)

DESIGN SELECTION CRITERIA WORKSHEET

Special Features

			POTENTIAL SPECIAL FEATURES								
		Site Conditions & Usage Characteristics	Rest Areas	Special Signing	Elevators	Escalators	View Screen	Sound Barrier	Wind Screen	Surface Treatmen	Lighting
YES	NO										
☐	☐	Regular Use by Handicapped	○	○	○	○				○	
☐	☐	Long Grade > 100 feet	○	○							
☐	☐	Steep Grade > 5%	○							○	
☐	☐	Limited Approach Space	○								
☐	☐	Connection to Transportation Terminal	○	○	○	○				○	○
☐	☐	Intrusion of Residential Privacy					○				
☐	☐	High Noise Level						○			
☐	☐	High Velocity Winds							○		
☐	☐	Snow Accumulation								○	
☐	☐	Scenic View Opportunities	○	○							
☐	☐	Complex Crossing Situation		○							○
☐	☐	Many one time or infrequent users		○							

A YES answer to site conditions usage characteristics should result in a more detailed consideration of special feature(s) which may be applicable and desirable.

Comments: ______________________________

MADE BY ______________ DATE ________ PAGE 5 OF 5

LOCATION ______________________________

APPENDIX C

DESIGN SELECTION CRITERIA WORKSHEETS (Continued)

APPENDIX D

DETAILED SITE EVALUATION DESCRIPTIONS

The following descriptions present detail data relating to background, structure and costs of the six evaluation sites summarized previously in Chapter 6 of this report.

PALO ALTO, CALIFORNIA

As noted earlier, the James A. Hawkinson Memorial Bicycle/Pedestrian Bridge spanning Adobe Creek at the easterly end of Wilkie Way in Palo Alto, California, was selected as a pilot study site. The pilot study served to field test proposed procedures and techniques to be used to gather data for the other five site evaluation studies. The Palo Alto site was chosen because it was well-used and was an innovative design treatment of a new, exclusive bicycle and pedestrian facility connecting residential neighborhoods.

Background

The City of Palo Alto is an active bicycling and pedestrian community, due in some part to the presence of Stanford University. The City has a bicycle facility master plan, and is actively constructing bicycle and pedestrian facilities.

One of the barriers to travel in Palo Alto is Adobe Creek, a flood control channel. Adobe Creek runs in a northeast-southwest direction through most of Palo Alto. In the area bounded by the Southern Pacific Railroad tracks, El Camino Real, and San Antonio Road, Adobe Creek separates two residential neighborhoods from each other. The nearest crossing is on El Camino Real, a very busy major arterial. The decision was made by the City of Palo Alto to construct a bicycle and pedestrian bridge over Adobe Creek to connect the two residential developments.

Structure

At the site chosen, Miller Avenue and Wilkie Way, deadend at the Creek, offset from each other by a distance of 300 feet (33.4M). A bicycle/pedestrian walkway was constructed partially cantilevered over the edge of the Adobe Creek drainage channel. The walkway connects Miller Avenue to a bridge that spans the Creek at Wilkie Way. The walkway is supported on reinforced concrete caissons and reinforced concrete cap beams. Wood stringers, 4 x 12 inch (0.1 x 0.3M) on top of the cap beams support the 3 x 8 inch (0.1 x 0.2M) wood decking. A five foot (1.5M) high steel pipe fence with wire mesh is provided at the outside edge. A six foot (1.8M) high wood board fence is provided at the inside edge adjacent to the residential property that abuts the creek.

The bridge spanning Adobe Creek is constructed of 11 x 45 inch (0.3 x 1.1M) "glu lam" beams supported on reinforced concrete caissons and abutments at each end. Its length is 52 feet (15.8M). The cross bracing is one-half inch (12.2MM) diameter steel rod and the struts are four inch diameter galvanized pipe. Eight feet (2.4M) of clearance is provided between the insides of the glu lams. The decking is 4 x 8 inch (0.1 x 0.2M) lumber. Steel rods and wire mesh make up the pedestrian railings on each side that is fastened to the top of the glu lams. The total height of the railings above the decking is five feet (1.5M). See Figure 33 for a series of photographs taken at the site.

Construction Cost

The cost of construction in 1974-1975 was approximately $82,400 and the cost of various items are listed in Table 15.

Table 15. Summary of Construction Cost
Palo Alto, California Bridge

Item	Description	Quantity	Unit	Price	Total
1	Clearing and Grubbing	Lump Sum	L.S.	L.S.	$ 500.00
2	Asphalt Path Construction	376	Sq. Ft.	$ 1.30	488.80
3	Concrete Pier Construction	170	Lin. Ft.	43.00	7,650.00
4	Concrete Construction	10	CY	195.00	3,950.00
5	Structural Steel	Lump Sum	L.S.	L.S.	1,830.00
6	Wood Construction	15	MBFM	960.00	14,400.00
7	Glued-Laminated Beams	2	Each	4,000.00	8,000.00
8	Wood Handrail	272	Lin. Ft.	4.80	1,305.60
9	Fence Construction Chain Link	85	Lin. Ft.	6.00	510.00
10	Fence Construction Welded Wire Fabric	272	Lin. Ft.	8.00	2,176.00
11	Fence Construction Steel Rod Balusters	123	Lin. Ft.	29.00	3,567.00
12	Redwood Boards	260	Lin. Ft.	8.05	2,093.00
13	5-Inch Electrical Ducts	720	Lin. Ft.	21.00	15,120.00
14	3-Inch Electrical Ducts	690	Lin. Ft.	12.00	8,349.00
15	2-Inch Electrical Ducts	350	Lin. Ft.	8.05	2,817.50
16	1-Inch Electrical Ducts	380	Lin. Ft.	6.47	2,438.60
17	Electrical Boxes	2	Each	1,000.00	2,000.00
18	Lights	10	Each	72.00	720.00
19	Non-Skid Finish	2,700	Sq. Ft.	0.35	945.00
20	Painting Complete	Lump Sum	L.S.	L.S.	3,399.00
21	Removable Steel Posts	2	Each	56.00	112.00
	TOTAL BID				$82,391.50

NOTE: To convert to metric: Feet x 0.3048 = Metres; Sq. Ft. x 0.0929 = Sq. Metres

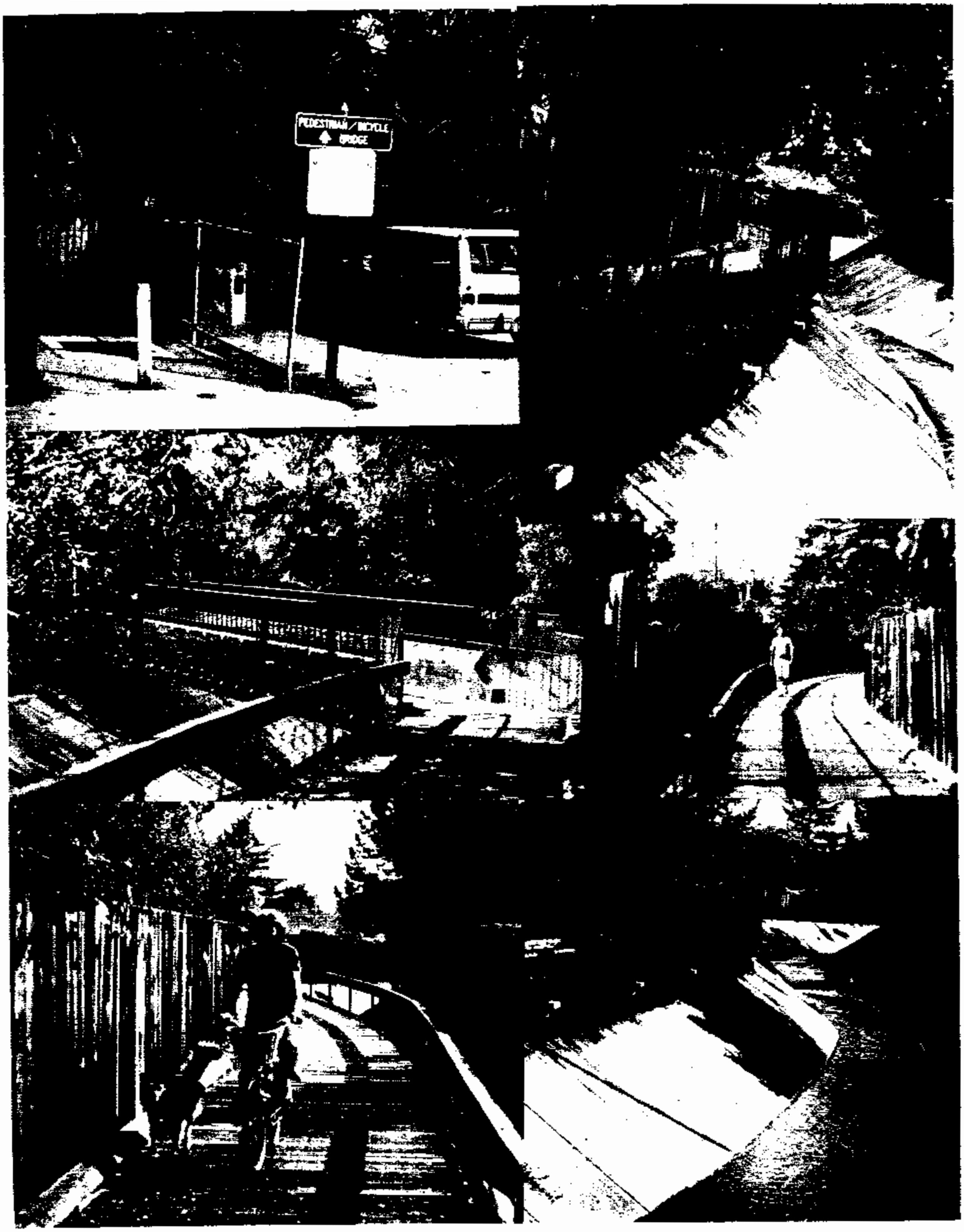


Figure 33. JAMES A. HAWKINSON PEDESTRIAN-BICYCLE BRIDGE
Palo Alto, California

SUNNYVALE, CALIFORNIA

The pedestrian and bicycle overcrossing of Route 101 in Sunnyvale, California, was selected as one of the site evaluation studies because it represents a new, exclusively non-motorized facility with examples of the latest treatment to facilitate handicapped access. The site is shown in the photographs, Figure 34.

Background

U.S. Highway 101, a six lane freeway, divides the City of Sunnyvale into two parts. The residents of the Lakewood Village Subdivision in the northeastern part of Sunnyvale were separated from various facilities south of Route 101, including the high school, shopping center, library, city hall, and community center. A particular problem was insufficient access for bicyclists and pedestrians.

It proved difficult to find an acceptable location for construction of some type of crossing. Public support was in favor of a crossing facility, but residents near the freeway did not want it located near their homes. The compromise location necessitated acquisition of two duplexes and a vacant lot. The City, in conjunction with the State, jointly financed construction of a pedestrian and bicycle overcrossing in the vicinity of Ahwanee Avenue in Sunnyvale.

Structure

The Ahwanee Avenue Pedestrian Overcrossing main structure is 393 feet (119.8M) in length and is constructed of cast-in-place prestressed concrete girders supported on reinforced concrete pile bents and abutments. There is 8 feet (2.4M) of clear space between the curbs on the span, and an 8 foot (2.4M) high chain link fence on each side of the main span. The approaches are supported on file and follow curvilinear paths to the ground level. Pipe pedestrian handrails are provided on the approaches. When the design was well advanced, the approach ramps, 174 and 205 feet respectively, were lengthened to lower their maximum slope to 8.33 percent specifically to accommodate the handicapped. Special rest areas were also designed into the project.

Construction Cost

The Ahwanee bicycle/pedestrian overcrossing cost approximately $316,000 to construct in 1977. The facility was completed within an eight month period. Approximate construction quantities are listed in Table 16.

Precast Pedestrian overcrossing spanning freeway

Approach ramp with level rest area

Level rest area adjacent to approach ramp

Figure 34. AHWANEE PEDESTRIAN OVERCROSSING OF ROUTE 101
Sunnyvale, California

Table 16. Estimated Construction Quantities-
Sunnyvale, California Bridge

Item	Quantity
Vision Screen	3,160 Sq. Ft.
Temporary Railing (Type K)	380 LF
Furnish Piling (Class 45-2)	400 LF
Furnish Piling (Class 70)	1,100 LF
Drive Pile (Class 45)	6 EA
Drive Pile (Class 70)	18 EA
Prestressing Cast-In-Place Concrete	Lump Sum
Waterstop	24 LF
Joint Seal (Type B-MR 1-1/2")	24 LF
Chain Link Railing (Type 7L)	1,114 LF
Pipe Handrailing (Post Type)	506 LF
FINAL PAY QUANTITIES	
Structure Excavation (Bridge)	275 CY
Structure Backfill (Bridge)	165 CY
Structural Concrete, Bridge Footing	60 CY
Structure Concrete (Bridge)	420 CY
Bar Reinforcing Steel (Bridge)	78,000 LB

NOTE: To convert to metric: Feet x 0.3048 = Metres;
Sq. Ft. x 0.0929 = Sq. Metres

EUGENE, OREGON

One undercrossing and one overcrossing were selected in Eugene, Oregon for detailed study. In addition, supplemental information was gathered concerning two major bicycle/pedestrian bridges spanning the Willamette River. The extensive bikeway/pedestrian path system along the Willamette River including the river crossings and the north and south bank trails lent itself to this type of expanded analysis.

The bicycle and pedestrian undercrossing of the Southern Pacific Railroad adjacent to the University of Oregon was selected as one of the two structures to be reviewed in Eugene, Oregon. The undercrossing represents an important early link in the pathway system which now extends several miles along both sides of the Willamette River.

The newly constructed ramp serving bicycle and pedestrian access from the Ferry Street bridge to the north bank pathway along the Willamette River was the second structure selected for detailed review because it represents an innovative retrofit treatment designed to facilitate bicycle and pedestrian travel between the bridge and the pathway beneath.

Undercrossing Background

The City of Eugene, Oregon, is an active bicycling and pedestrian community, due largely to the University of Oregon campus in the City. The Willamette River which flows through the City is a major barrier to bicycle circulation. In addition, the university stadium is located across the river from the campus. The construction of the Autzen Bridge for bicycles and pedestrians over the Willamette River in 1970 removed an absolute barrier to direct travel between the University of Oregon campus and Autzen Stadium. However, the main line of the Southern Pacific Railroad parallels the river at this point, and there was no formal crossing. Some 20 to 30 trains a day pass this point, at speeds up to 40 mph (64.4KPH).

To allow access to the stadium during events, a crossing was installed and a flagman provided to control the crowds. When no event was in progress, the crossing was closed by locked gates. People, however, crossed illegally; cutting holes in the railroad fences.

Undercrossing Structure

Three-way discussions to resolve the problem were initiated between the University of Oregon, Lane County, and Southern Pacific. Plans were developed for a corrugated metal arch underpass, but soils tests determined that this solution was not feasible. Southern Pacific agreed to install a standard prestressed concrete bridge unit, using its own bridge crew, with the University and Lane County funding the project.

The bridge consists of precast prestressed concrete box girders, and is 17 feet (5.2M) wide and 30 feet (9.1M) in length. The abutments are reinforced concrete. A 12 foot (3.7M) wide asphalt concrete path passes under the bridge on modest approach grades. The clearance above the bicycle and pedestrian path is 10 feet (3.1M). See Figure 35.

Undercrossing Construction Cost

The construction cost to create an undercrossing of the SPRR tracks was approximately $40,000 when it was built in 1973. Construction of the structure was completed within four weeks (detail quantities were not available for this project).

Overcrossing Improvement Background

One of the major findings of the Bikeway Master Plan Study in 1974 was that the existing highway bridges over the Willamette River were generally unsuitable for both bicyclist and pedestrian use. One such bridge was the Ferry Street Bridge.

The Ferry Street Bridge carries four traffic lanes on a 48 foot (14.6M) roadway, flanked by two 5 foot (1.5M) sidewalks. The average daily traffic on the bridge is some 40,000 vehicles. The bridge is the

S.P.R.R. Undercrossing providing linkage between the University of Oregon and the Autzen bridge

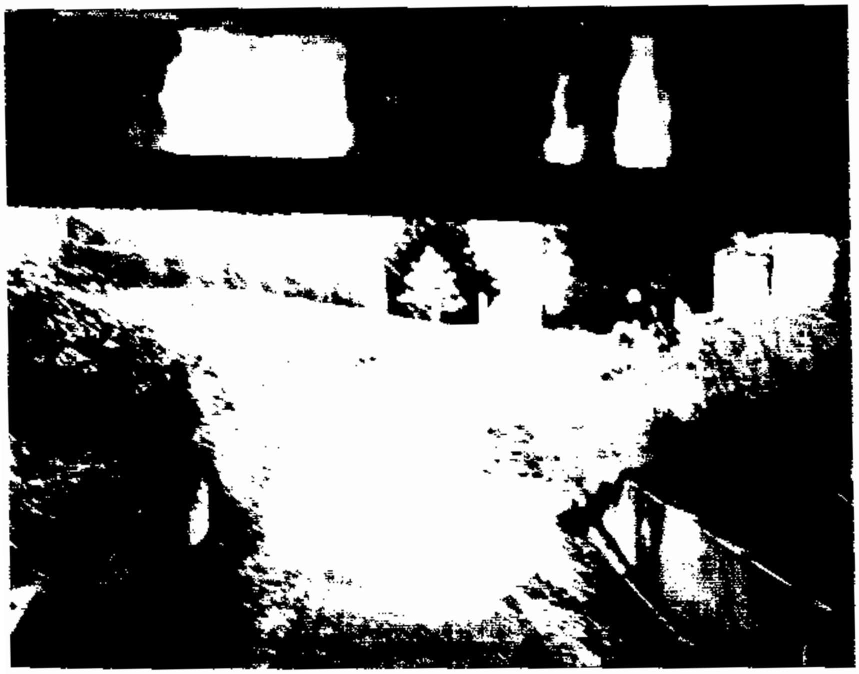


Figure 35. UNDERCROSSING OF SOUTHERN PACIFIC RAILROAD
Eugene, Oregon

major route for bicyclists from North Eugene to downtown. Bicyclists typically use both sidewalks in both directions, sharing the space with a few pedestrians. The structure is some 800 feet (243.8M) long. Over the 440 foot (134M) main span, the sidewalks are 5 feet (1.5M) wide, with barriers on both sides. On the bridge approach spans, the sidewalks are the same width but have no barrier on the traffic side.

The layout and use of the Ferry Street Bridge exhibited several deficiencies of varying concern to cyclists and pedestrian:

- On both sides of the roadway the south approach pathways joined the sidewalks at right angles, requiring cyclists to make this turn in a space of five feet (1.5M).
- The unprotected sidewalks on the approach spans were inadequate for two-way bike traffic, or mixed bicycle and pedestrian traffic.
- There was no designated or convenient route connecting the bridge with the North Bank Bike Path that ran adjacent to the river.

Overcrossing Improvement Structure

Proposals were made as part of the Bikeway Master Plan to remove the most serious deficiencies. The proposals were that a new access ramp be constructed on the north end of the structure, connecting the east side sidewalk approach with the North Bank Bike Path, that traffic barriers be installed adjacent to all the approach sidewalks, and that the approach sidewalk on the northeast be widened to 10 feet (3.1M) from the existing 5 feet (1.5M). The east sidewalk on the structure and approaches would be used by bicyclists only. See Figures 36 and 37.

Construction of the recommended improvements started in 1976. The access ramp is 190 feet (57.9M) in length and is constructed in four spans of precast prestressed double tee beams supported on precast columns. The ramp grade is 8 percent, and there is a minimum of 10 feet 9 inches (3.3M) clear between the railings. The railings are 4 feet (1.2M) in height, and made of rectangular tubular steel. Cross slopes are a maximum of 4 percent, with level rest areas provided at the two central column bents.

The northeast sidewalk approach was widened by cantilevering an additional 5 foot (1.5M) section outside of the existing sidewalk. The cantilevered section is 250 feet (76.2M) in length, and provides a clear width of 10 feet (3.1M) between the new 4 foot (1.2M) high rectangular tubular steel outside pedestrian rail and the "New Jersey" type traffic barrier with handrail on the inside. The cantilevered section is supported by welded and bolted structural steel attached to the reinforced concrete beams and columns along the outside edge of the approach structure.

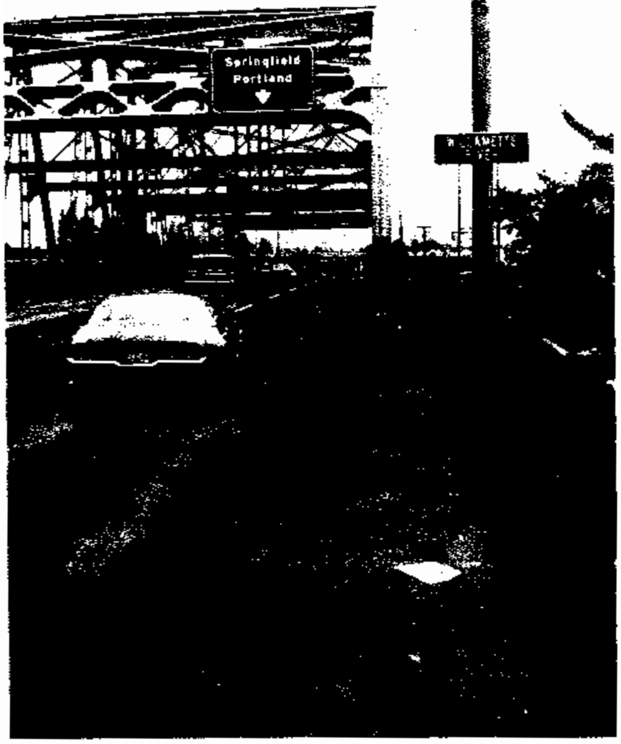
Approximately 500 L.F. (152.4M) of the "New Jersey" traffic barrier was erected, in addition to that adjacent to the cantilevered sidewalk section, on the other approach walks.

New ramp
connecting
bridge approach
to ramp

View of ramp showing level rest area
partially up the grade

Intersection of
new ramp with
original bridge
approach

Figure 36. RETROFITTED RAMP, FERRY STEET BRIDGE
Eugene, Oregon



Narrow unprotected sidewalk
before improvement

Widened sidewalk with protected barrier
after improvement

Cantilevered
supports for
widened sidewalk
after condition

Figure 37. FERRY STREET BRIDGE
Eugene, Oregon

In addition to the completed approach widening, a preliminary study and design for widening the east sidewalk on the truss main span of the Ferry Street Bridges has been completed. Additional sidewalk width would be obtained by cantilevering four feet (1.2M) of sidewalk outside of the existing walkway in a manner similar to the approach section.

Overcrossing Improvement Construction Cost

The construction cost to complete the retrofitted access ramp and sidewalk widening on Ferry Street Bridge was $171,000 in 1977. Of this, $120,000 was to construct the new access ramp and $51,000 to widen sidewalk and to erect New Jersey type traffic barriers. Completion of the entire project took five months.

Preliminary cost estimates prepared in 1977 for widening the Ferry Street bridge truss spans to create a wider sidewalk on the east side of the bridges are shown in Table 17.

Table 17. Preliminary Cost Estimates-
Eugene, Oregon Bridge
Sidewalk Widening

Preliminary Cost Estimate	Quantity	Total
Mobilization		$ 3,500
Traffic Control		1,500
Staging at Panel Points	18 Each @ $600	10,800
Remove Rail and Curb	444 L.F. @ $8	3,552
Drill Anchorage Holes in SW	54 Each @ $10	540
Grout in Anchorages	18 Each @ $30	540
Field Drill Fascia Channel	216 Each @ $3.50	756
Structural Steel in Place	27,000 Lbs. @ $1.10	29,700
Install Strut Brackets	18 Each @ $100	1,800
Paint All Steel	All	2,000
Class "A" Concrete	20 C.Y. @ $250	5,000
Reinforcing Steel	3,000 Lbs. @ $0.50	1,500
Metal Railing	444 L.F. @ $30	13,320
		$74,508
	Add 10% Contingencies	7,492
		$82,000
Engineering Fees	Design @ 7-1/2%	6,150
	Field Supervision @ 5-1/2%	4,500
	Total Cost	$92,650

NOTE: To convert to metric: Feet x 0.3048 = Metres;
Pounds x 0.4536 = Kilograms

Supplemental Eugene, Oregon Inspections

In addition to the case studies conducted at the Southern Pacific Railroad undercrossing and at the retrofitted ramp/Ferry Street Bridge complex, the study team also briefly inspected other elements of the north and south bank pathway system. The following information pertains to the Autzen Bridge and new Greenway Bike Bridge. See photographs, Figure 38.

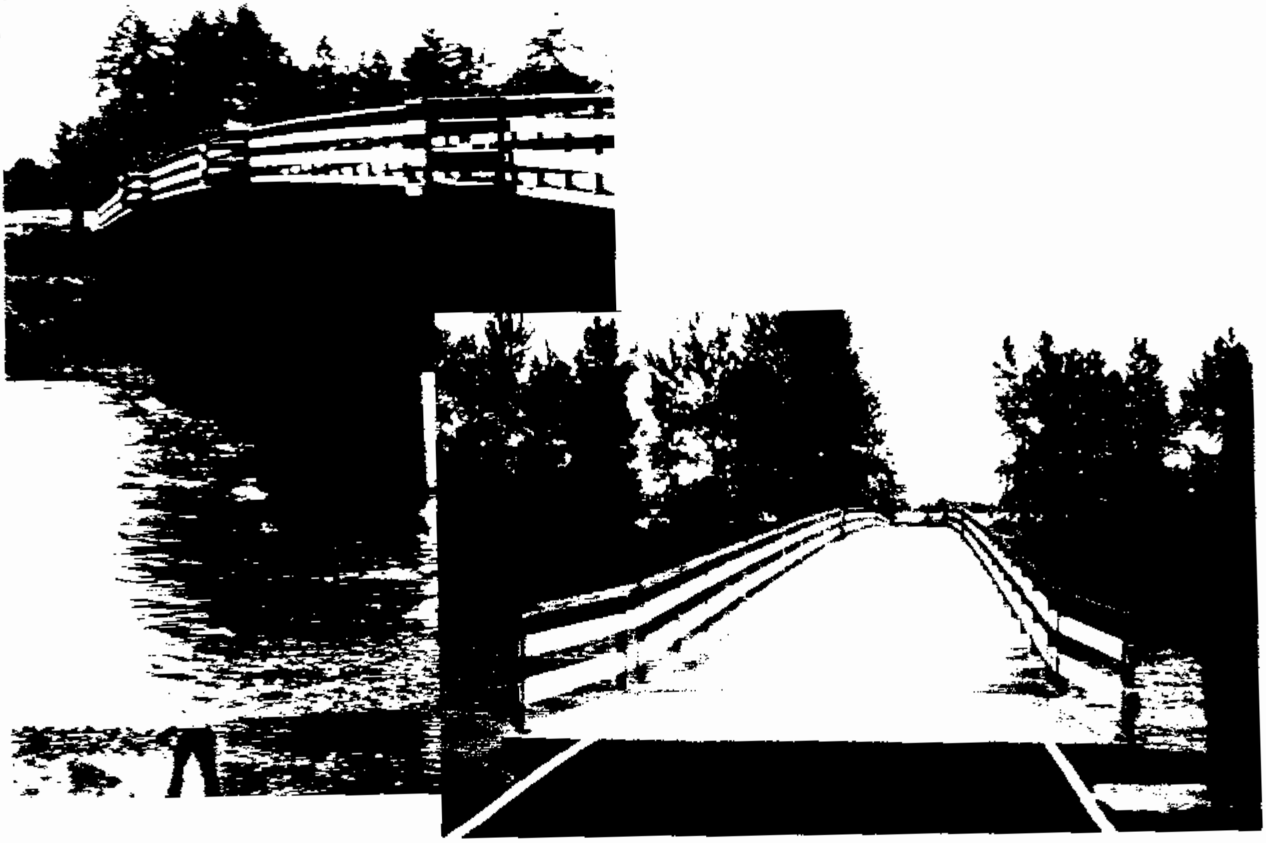
Autzen Bridge. The Willamette River which flows through the City is a major barrier to bicycle circulation. In addition, Autzen Stadium is located across the river from the University of Oregon campus. The only crossings were two highway bridges, both located some distance from the campus on each side, and both largely unsuitable for bicycle and pedestrian traffic because of safety deficiencies.

A bridge was proposed near the campus to carry utilities across the river. The community coordinated with the utility company to construct a combination pedestrian/bicycle bridge over the river, with the utility pipes slung below the bridge deck. The bridge is 667 feet (203.3M) in length and the clear railing to railing width is 12 feet (3.7M). The bridge consists of two side by side precast prestressed bulb tee beams. The four center spans are each 130 feet (39.6M) in length, and the end spans are 66 and 82 feet (20.1 and 25M) respectively. Piers and abutments are reinforced concrete. The concrete curbs with aluminum tubing and wood railing are 3.5 feet (1.1M) high. At each of the piers, the bridge deck is widened to accommodate a bench for resting and space to enjoy the views.

Total cost was $186,000 in 1970 and it was completed in a five month period. Costs were shared by the Eugene Water and Electric Board; University of Oregon Athletic Department and Lane County. Construction quantities were not available for this project.

Greenway Bicycle/Pedestrian Bridge. A recommendation was made in the Eugene Bikeway Master Plan to construct a bicycle/pedestrian bridge over the Willamette River at the point of greatest utility to the bike route network. Consideration was given to three different bridge designs: a four span prestressed girder bridge, a cable-stayed bridge, and a suspension bridge. Visual impact was an important consideration since the bridge would be visible from both banks of the river over a long distance. Other important considerations were the clearance requirements for navigation purposes and the cost of the structure.

The design selected was the four span prestressed girder bridge, with its low cost being a major factor in its selection. The Valley River Bicycle/Pedestrian Bridge is 528 feet (160.9M) in length and has a clear width on its deck of 13 feet 4 inches (4M) from inside of rail to inside of rail. The four 132 foot (40.2M) spans are supported on reinforced concrete piers and abutments. The deck spans consist of two side by side bulb tee prestressed beams. The bridge deck is widened at each pier to accommodate benches for sitting and resting. The wooden handrails are 3.5 feet (1.1M) high.



Greenway bicycle pedestrian bridge over the Willamette river

Runners on the Autzen bicycle pedestrian bridge over the Willamette river

Figure 38. SUPPLEMENTAL INSPECTION SITES
Eugene, Oregon

Federal Bicycle Demonstration Project funds (FHWA) were obtained in 1977 for the project, and the bridge was dedicated in February, 1978. Total construction cost for the project was $277,500. Construction quantities are listed in Table 18.

Table 18. Construction Quantities-
Eugene, Oregon Bicycle/Pedestrian Bridge

Item	Unit	Quantity
Mobilization	All	All
Embankment in Place	Cu. Yd.	1430
1"-0 Aggregate Base	Cu. Yd.	35
Class "C" Asphalt Concrete	Ton	20
Bark Mulch	Unit	1.5
Bridge No. 16316 Alternate "A"		
Shoring, Cribbing, etc.	All	All
Structure Excavation	Cu. Yd.	730
Special Backfill	Cu. Yd.	130
Furnish Pile Driving Equipment	All	All
Furnish 14-inch Prestressed Concrete Piling	Lin. Ft.	2018
Drive Prestress Concrete Piles	Lin. Ft.	1824
Structural Concrete, Class 3300	All	All
Structural Concrete, Class 4000	All	All
130'/135' Bulb Tee Prestressed Beams	Each	8
Reinforcement	All	All
Prestressing Steel	All	All
Structural Steel	All	All
Pedestrian Rail	All	All
Pedestrian Benches	Each	6
1-1/2 inch Electrical Conduit	Lin. Ft.	675
Loose Riprap, Class 100	Cu. Yd.	575

NOTE: To convert to metric: Feet x 0.3048 = Metres;
Pounds x 0.4536 = Kilograms

HAMPTON, NEW HAMPSHIRE

The bridge carrying U.S. Route 1 over the B&M Railroad (Bridge 163/184) in Hampton, New Hampshire was selected as one of the site evaluation studies. The bridge represents an example of a retrofit treatment.

Background

Originally built in 1936, the bridge is 120 feet (36.6M) long and has a curb-to-curb width of 34 feet (10.4M). The original construction provided only a narrow 1 foot 8 inches (0.5M) catwalk on the structure and a 2 feet 6 inches (0.8M) setback from the curb to the highway rail on the approaches. See photographs, Figure 39.

Retrofit Structure

The 1977 reconstruction provides a separation of pedestrians from the vehicles, and a wider 4 foot (1.2M) walkway on both the structure and the approaches. The existing wood guard rails on the approaches were removed and replaced with steel beam guardrails set closer to the curb. The slope area outside the new guardrails was widened to accommodate a 4 foot (1.2M) asphalt concrete sidewall. A 4 foot (1.2M) wide pedestrian walkway is cantilevered off of the outside of the overhead structure. The walkway is constructed of steel angles and beams fastened by gusset plastes to the outside of the existing steel beam structure.

Construction Cost

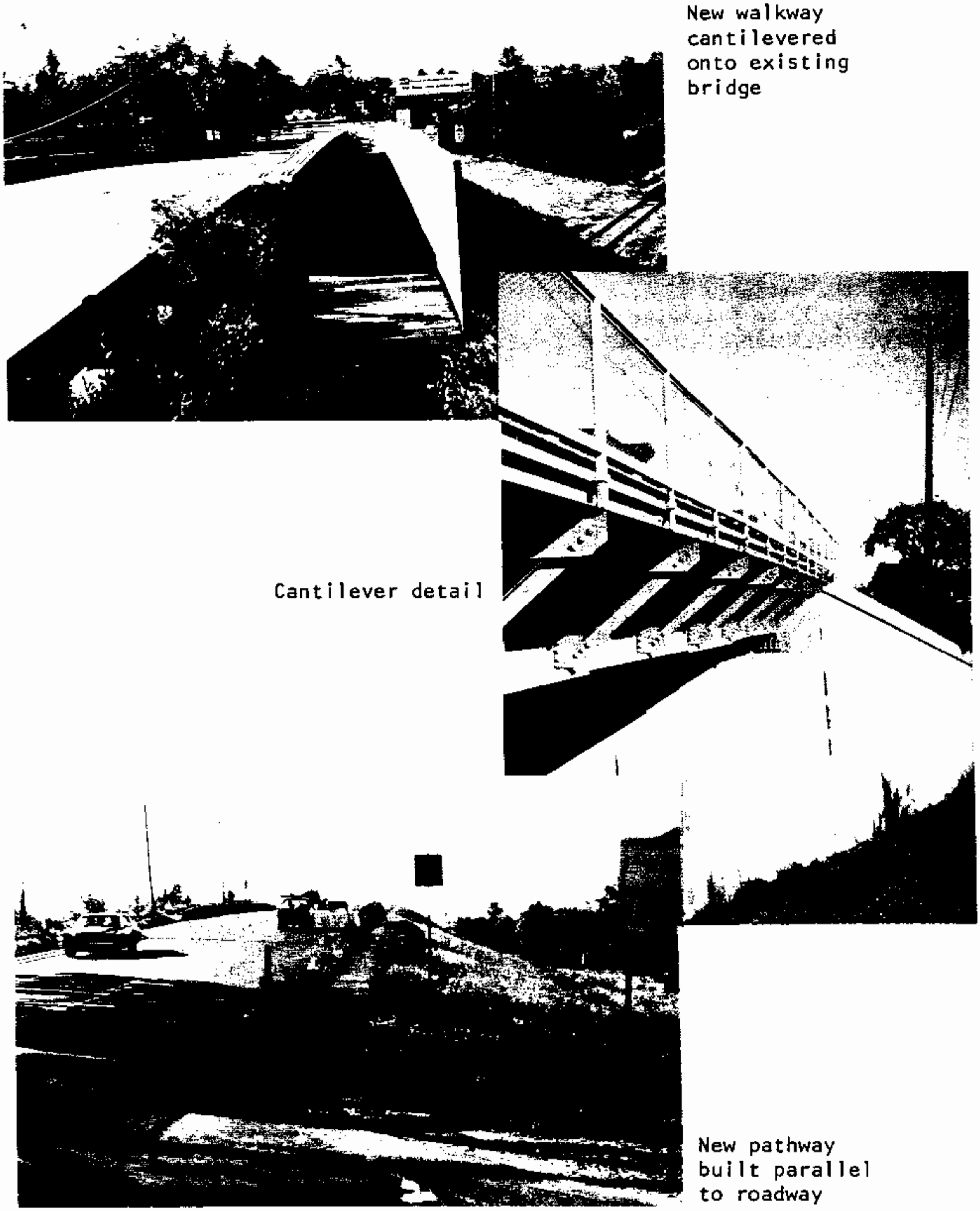
The total construction cost in 1977 to retrofit the bridge with cantilevered walkways and to develop the pathway approaches was $72,000; of this about $32,000 were required for the approach sidewalks and $40,000 for the bridge modifications. Itemized construction quantities were not available for this project.

ROUTE 183, RANDOLPH ROAD, MARYLAND

The new culvert carrying Paint Branch Creek under Randolph Road (Maryland Route 183) was selected as one of the site evaluation studies. Of special interest was the creation of a raised walkway in one of the culvert cells to facilitate trail users crossing under Randolph Road.

Background

Maryland Route 183, Randolph Road, was proposed for relocation in 1976-1977. The newly constructed road passed through a park area, dividing it into two parts. The road was considered dangerous to cross at grade level, and some provision was necessary so that hikers and bikers could more safely move from one part of the park to the other.



New walkway cantilevered onto existing bridge

Cantilever detail

New pathway built parallel to roadway

Figure 39. RETROFITTED BRIDGE
Hampton, New Hampshire

A box culvert drainage structure was part of the reconstruction of Randolph Road. A decision was made to modify one of the cells in the multi-cell culvert for the purpose of accommodating the movement of bicyclists and hikers.

Structure

The box culvert consists of four cells each 18 feet (5.5M) wide and 11 feet (3.4M) high, and is constructed of reinforced concrete. The length of the structure from headwall to headwall is 168 feet (51.2M).

In the easterly cell, a concrete slab 8 feet (2.4M) wide was constructed next to the outer wall 3 feet 6 inches (1.1M) above the culvert invert. Overhead clearance of 7 feet 6 inches (2.3M) is thus available. A 3 foot (0.9M) high pedestrian handrailing constructed of pipe is provided at the outside edge of the slab. See photographs, Figure 40.

The slab is sufficiently above the culvert floor that it is above water except under extreme flood conditions. The design also provides for lighting to illuminate the walkway within the culvert.

Construction Cost

The total construction cost of the quadruple 11 foot x 18 foot reinforced concrete box culvert, of which the raised sidewalk was a part, amounted to some $150,000. The construction took place in 1976-1977. The estimated construction quantities are listed in Table 19.

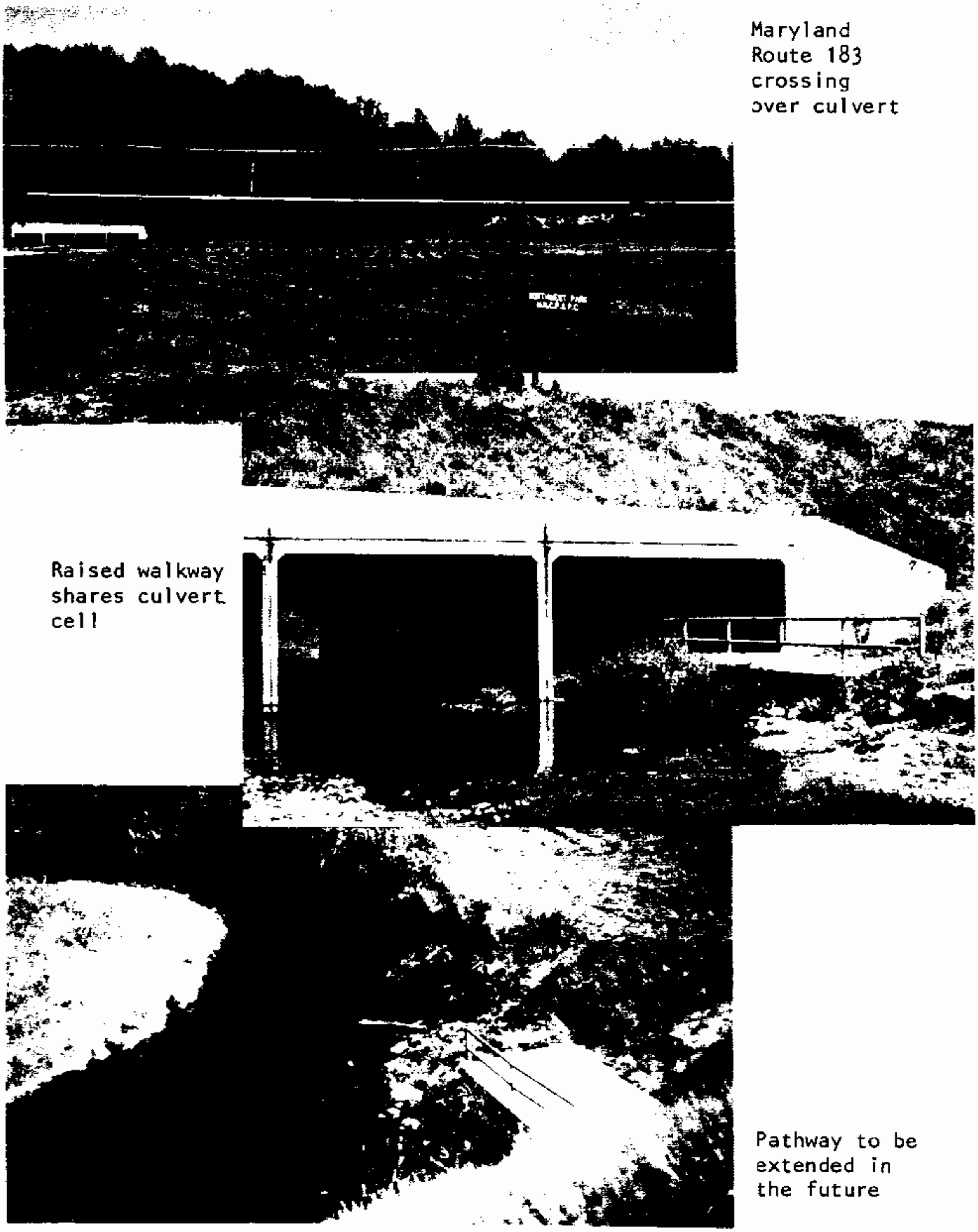
AUSTIN, TEXAS

The interchange of 5th and 6th Streets with MoPack Boulevard in Austin, Texas, was selected as one of the site evaluation studies. The interchange is a complex network of one-way streets and ramps through which special off-street facilities have been constructed to accommodate bicycle and pedestrian travel. The interchange contains an extensive pathway system together with exclusive bicycle/pedestrian overpasses and underpasses.

Background

The bicycle is increasingly used as a means of transportation in the City of Austin. The City's Comprehensive Plan establishes a policy of providing bicycle facilities where appropriate, and there is a City Bikeway System Plan.

One hazardous area frequently traversed by cyclists was the interchange of MoPack Boulevard, a six lane controlled access north-south facility, and four east-west arterial streets. Three of those streets, Lake Austin Boulevard and West 5th and 6th Streets, are primary



Maryland Route 183 crossing over culvert

Raised walkway shares culvert cell

Pathway to be extended in the future

Figure 40. BOX CULVERT UNDERCROSSING
Maryland Route 183

Table 19. Estimated Construction Quantities-
Maryland Route 183 Box Culvert

Category	Item	Method of Measurement	Estimated Quantity
Grading	Class 5 Excavation	CY	2250
Drainage	Selected Backfill Using #G Aggregate	CY	250
	Selected Backfill Using Crusher Run or Type 2 Sub-base	CY	250
	Slope Protection Using 6 In. Mix No. 1 Concrete	SY	450
	Concrete Cut Off Wall	CY	30
Structures	Class #3 Excavation for Structures	CY	1900
	Class #4 Excavation	CY	1300
	Subfoundation Concrete	CY	20
	Quadruple 18.0 Ft. x 11.0 Ft. Reinforced Concrete Box Culvert at Sta. 79+	LS	LS
	Contingent Concrete for Box Culvert	CY	10
	Galvanized Pipe Railing	LF	230
	Electric Lighting System for Hiker-Biker Underpass	LS	LS
Landscaping	Solid Sodding	SY	80

NOTE: To convert to Metric, multiply feet x 0.3048

routes for cyclists. To the west of the interchange, Lake Austin Boulevard has two lanes in each direction. It divides into two 24-foot roadways inside the interchange and these transition into 5th and 6th Streets, which continue as a one-way pair to the east of the interchange. The Lake Austin Boulevard-5th/6th Street connections have potential for increased bicycling activity. There are four residential areas for University of Texas at Austin married students located near the interchange, housing 2,800 persons. Many of these residents travel to the main campus daily along this primary route. In addition, Austin High School is located between the interchange and Town Lake. The lake, roadway connections and an adjacent railroad mainline make access to the school site very difficult for non-motorized users.

Project

The City of Austin received a Federal grant through the Bikeway Demonstration Program to mitigate the barriers to non-motorized travel created by the freeway interchange. The project was completed in 1977 and provides alternative pathways through the interchange by modifying existing structures, construction of pathways, and erection of two bicycle/pedestrian bridges. See photographs, Figures 41, 42 and 43.

Construction Cost

The cost to construct the two bicycle/pedestrian bridges and pathway through the interchange associated with the 5th and 6th Street bikeways amounted to some $210,000 in 1977. Construction duration took approximately three months, although lighting along the 5th Street pathway was still being completed in the fall of 1978. An itemized cost estimate is shown in Table 20.

Table 20. Estimated Construction Quantities-
Austin, Texas Bikeways

I. Eastbound Bikeway (5th Street)

	Est. L.F.	Unit Cost	Est. Line Cost
Bridge Rework	205'	$ 45.	$ 9,225
Bridge Work	180'	275.	49,500
Retaining Wall Work	230'	60.	13,800
Path Work	945'	4.	3,780
Path w/Fill	350'	6.	2,100
Path w/Cut	130'	8.	1,040
		I. SUBTOTAL	$ 79,445

II. Westbound Bikeway (6th Street)

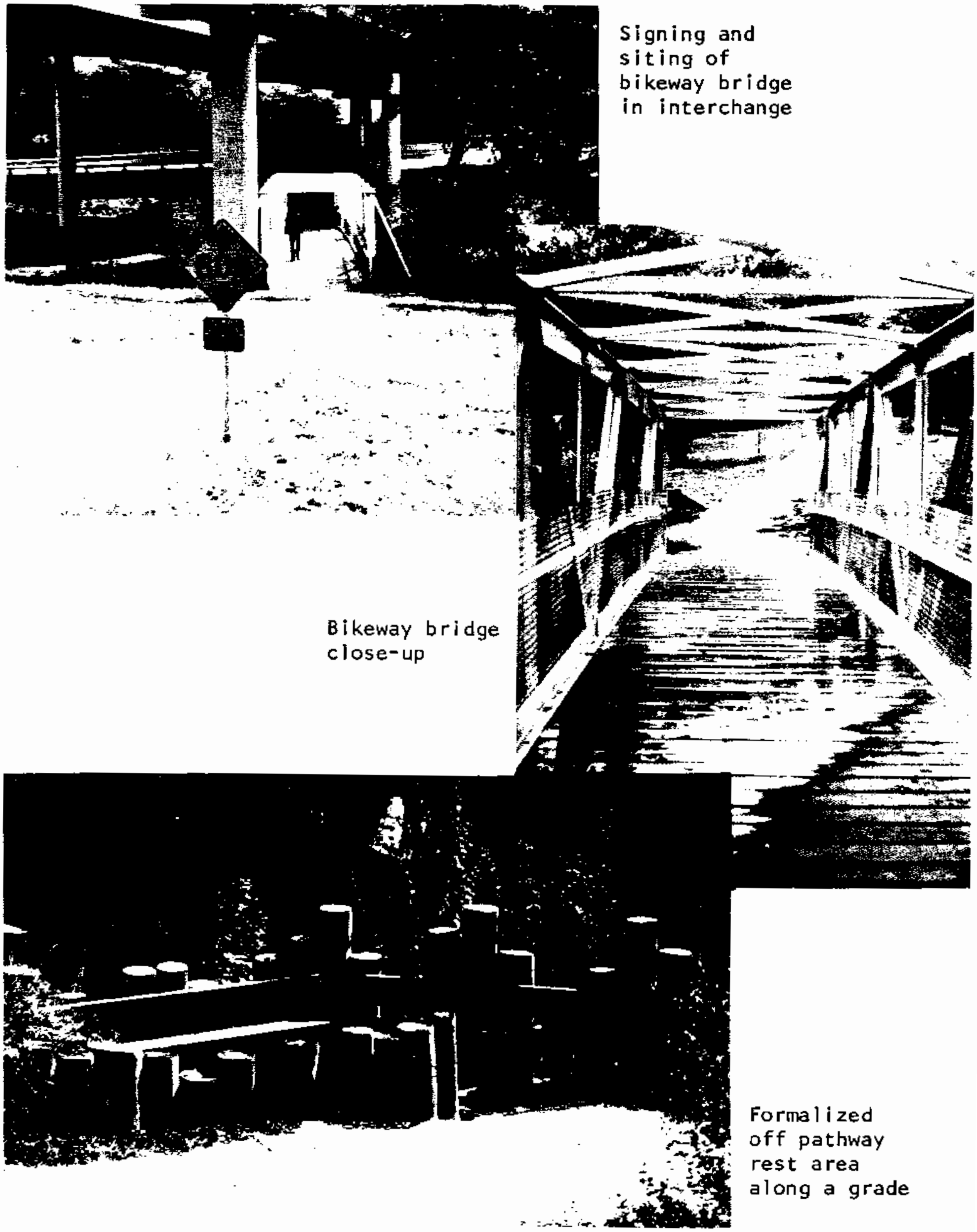
Protected Lane	760'	$ 2.50	1,900
Bridge Work	150'	275.	41,250
Bridge Rework	205'	45.	9,225
Retaining Wall Work	115'	60.	6,900
Path Work	795'	4.	3,180
		Subtotal	$ 62,445
			15,000
		II. SUBTOTAL	77,445

III. Project Total

Subtotal (I + II)	$156,900
Miscellaneous Lighting	15,000
Project Subtotal	171,900
20% Engineering + Contingencies	34,380
Project Total	206,280
Evaluation + Report	3,720
TOTAL	$210,000

Federal Share (80%) = $168,000
Local Match (20%) = $ 42,000

NOTE: To convert to metric: Feet x 0.3048 = Metres

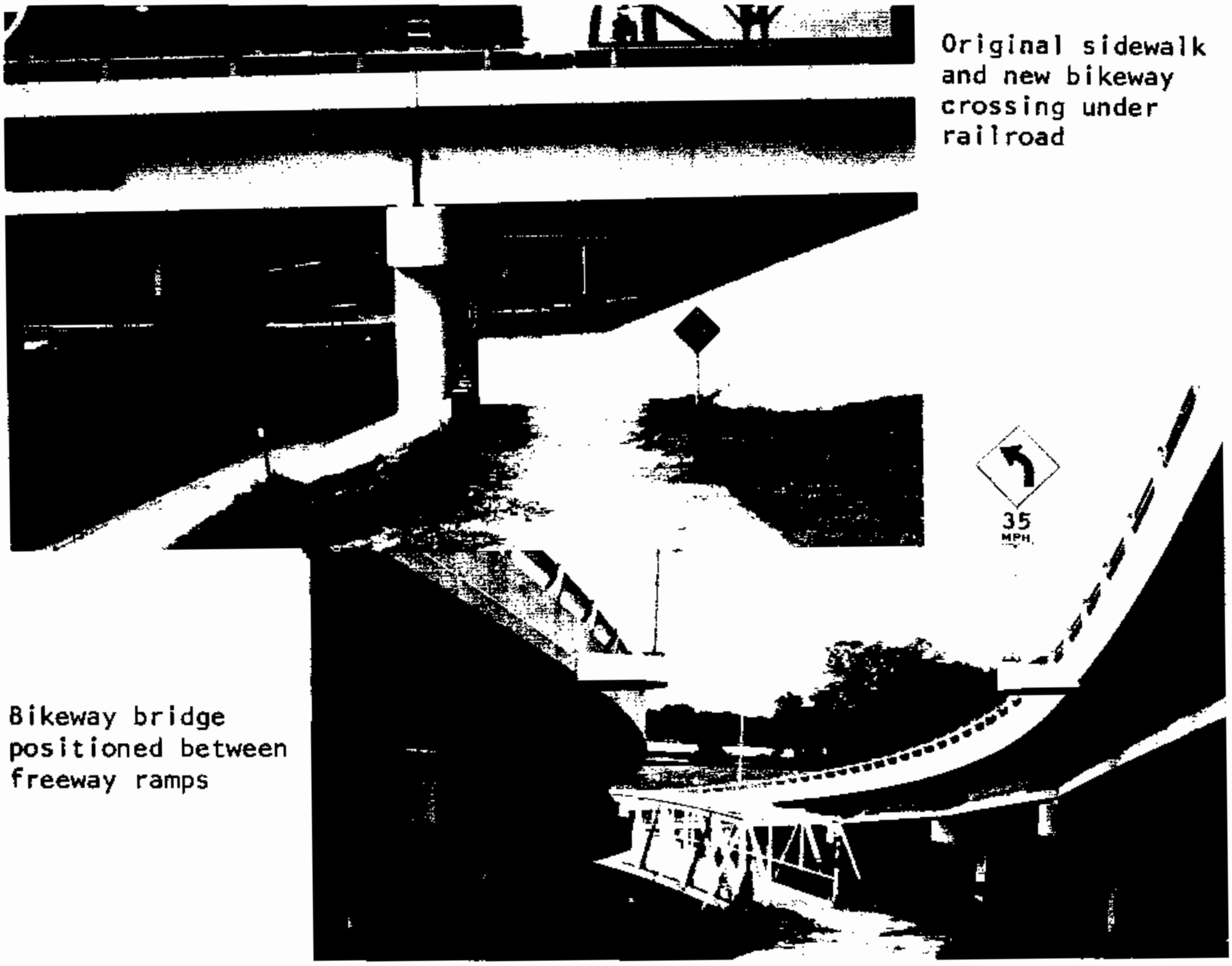


Signing and siting of bikeway bridge in interchange

Bikeway bridge close-up

Formalized off pathway rest area along a grade

Figure 41. FIFTH STREET BIKEWAY
Austin, Texas

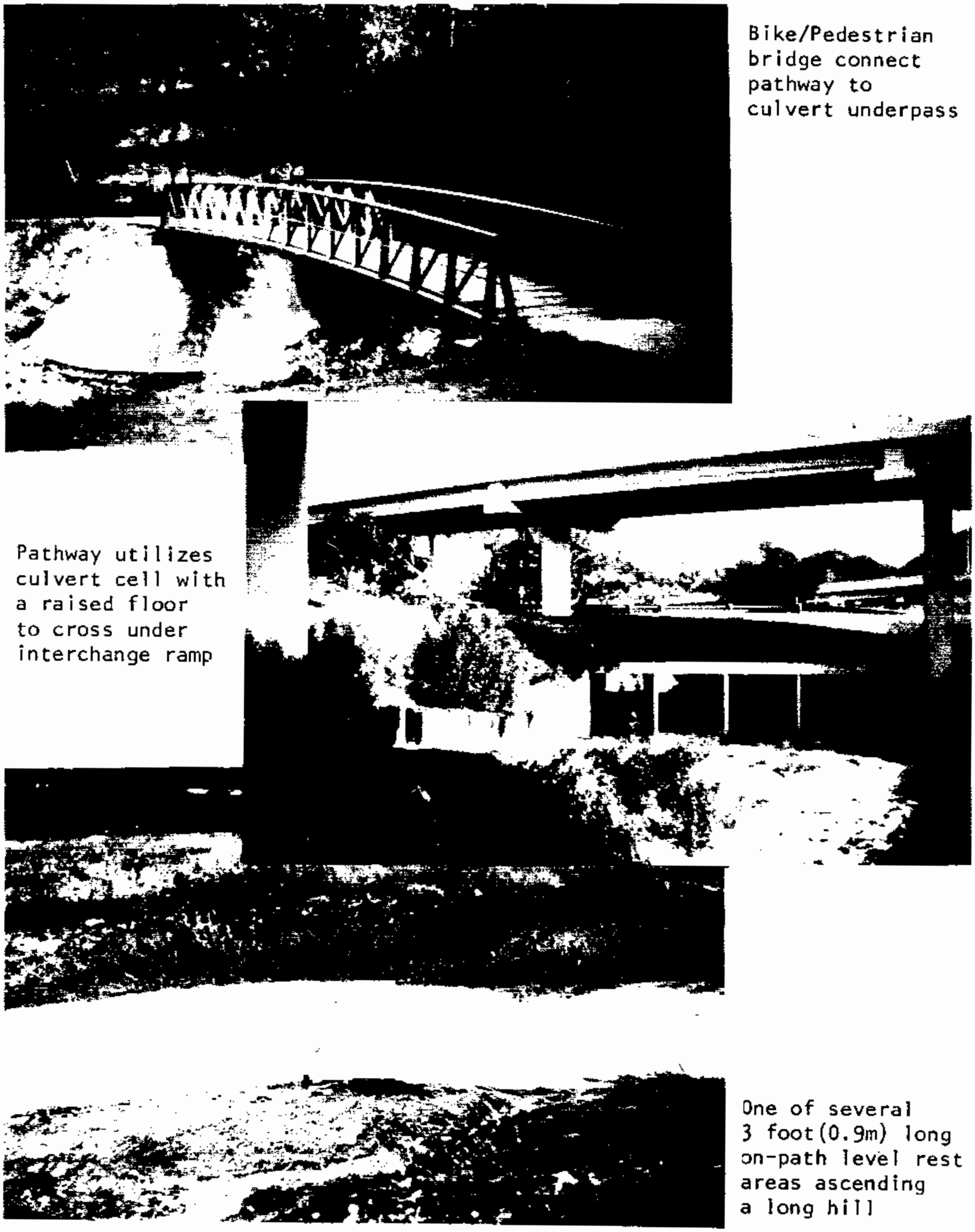


Original sidewalk and new bikeway crossing under railroad

Bikeway bridge positioned between freeway ramps

Bikeway bridge close-up. Note handrail, fencing and wood post wing walls

Figure 42. SIXTH STREET BIKEWAY
Austin, Texas



Bike/Pedestrian bridge connect pathway to culvert underpass

Pathway utilizes culvert cell with a raised floor to cross under interchange ramp

One of several 3 foot (0.9m) long on-path level rest areas ascending a long hill

Figure 43. NORTH SOUTH BIKEWAY
Austin, Texas

*U.S. GOVERNMENT PRINTING OFFICE: 1981-0-725-301/1080

FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements that affect the quality of the human environment. The goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

6. Improved Technology for Highway Construction

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

7. Improved Technology for Highway Maintenance

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

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* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.