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# PEDESTRIAN AND BICYCLE ISSUES AND ANSWERS

NOT FOR PUBLICATION

JULY 1981

Final Report



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16. Abstract

This report identifies 24 critical issues related to pedestrian and bicycle facilities and programs, summarizes the state-of-the-art on each issue as it is contained in the published literature, and provides a concise commentary on each critical issue. A critical issue is an issue of significant and recurring importance to people involved in pedestrian and bicycle programs or those planning and designing pedestrian or bicycle facilities. The issues are arranged by the essential elements of a comprehensive pedestrian or bicycle program: engineering (planning, design, construction, and maintenance), education, enforcement, and evaluation. Each section addressing a critical issue synthesizes a major portion of the pedestrian and bicycle literature dealing with that issue which was published during the past decade. The report includes a reference list of primary information sources for each critical issue and a numbered bibliography of all primary and secondary references.

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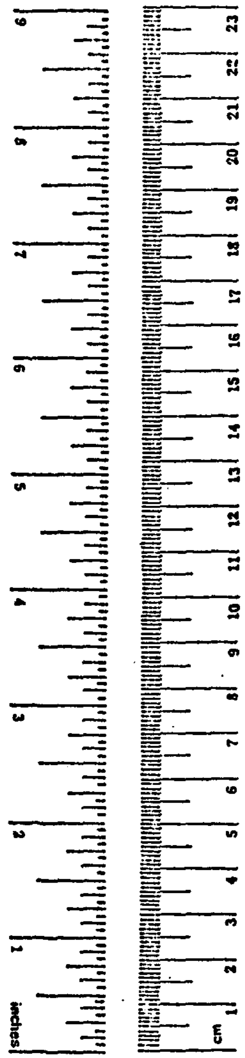
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

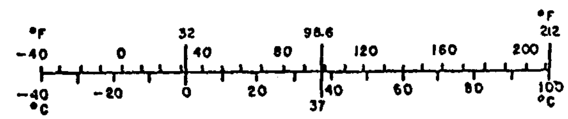
| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (weight)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| Tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (exact)** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.




## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (weight)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



## PREFACE

This report deals with issues important to anyone interested in pedestrian or bicycle activities or concerned with the planning and engineering of pedestrian or bicycle facilities, educating pedestrians or bicyclists, enforcing pedestrian or bicycle laws, or evaluating pedestrian or bicycle programs.

In the United States, 3.8 million people walk to work every day and another one-half million ride a bicycle. This represents only about 5 percent of the nation's commuters. Automobile trips are the bulk of all travel, and most of these trips are under 5 miles. With encouragement and individual volition, walking and bicycling could account for a much larger percentage of all travel.

The Federal Highway Administration (FHWA) sponsored this report in order to collect and disseminate information on specific pedestrian and bicycle issues; these issues are called critical issues. The issues are arranged by the essential components of a comprehensive pedestrian or bicycle program: engineering, education, enforcement, and evaluation. Each section addressing a critical issue synthesizes a major portion of the pedestrian and bicycle literature dealing with that issue and supplies a list of references for those wishing to pursue further research. In this regard, the report is a review of the state-of-the-art in pedestrian or bicycle programs as it is contained in published literature.

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# INTRODUCTION

With the enactment of the Highway Safety Act of 1966, the Federal Highway Administration (FHWA) began to study the highway-related aspects of pedestrian safety. It was about this same time that pedestrianization became an important word in cities across the country as planners, designers, and engineers began to develop urban systems which responded to the needs of the walking public. In Boston, Portland, and Minneapolis, for example, well-designed pedestrian malls offer a quick and pleasant connection between public transportation and commercial facilities. As the scope of FHWA involvement in pedestrian affairs broadened during the 1970's, it began to include research efforts in pedestrian planning, safe pedestrian design, accident countermeasures, and other areas of growing concern. Today, the FHWA continues to investigate pedestrian issues as these issues relate to the structural and human needs of the highway network.

Rising gasoline prices and the introduction of the lightweight multi-speed bicycle in the early 1970's contributed to a renewed interest in the bicycle as a form of transportation. The Bicycle Manufacturers Association indicates that bicycle sales have outpaced automobile sales in every year since 1972, and that Americans purchased 103 million bicycles during the 1970's, double the number purchased during the 1960's. In 1972, the University of California's "Bikeway Planning Criteria and Guidelines" marked the first fullscale attempt to promote special bicycle facilities to handle the increasing ridership. To improve this art, the FHWA initiated a program of bikeway research which resulted in two user's manuals documenting the requirements of bikeway planning, location, design, and safety. This was followed closely by the publication of the American Association of State Highway and Transportation Official's "Guide for Bicycle Routes." The art of bicycle facility design and bicycle program development is still evolving. Currently, the FHWA is evaluating bicycle facilities and establishing new bicycle facility design and construction guidelines.

Sometimes the problems of pedestrians and the problems of bicyclists demand a solution which cannot be met with new or improved facilities, a solution which lies in comprehensive planning, educational programs, or legislation and law enforcement. This report is one of a series of FHWA technology sharing reports aimed at providing solutions to transportation problems; it summarizes much of the literature written since 1970 on issues important to those involved in pedestrian or bicycle facility development and program implementation. Within the past ten years, the literature supporting and reinforcing the state-of-the-art in pedestrian and bicycle facilities and programs has increased steadily. Because of the volume of published material, the FHWA sponsored this synthesis report, condensing the available literature on specific pedestrian and bicycle critical issues and disseminating a reference work of value to the traffic engineer, the transportation planner, the motorist, the biker, the walker, and the interested citizen.

This report identifies 24 critical issues related to pedestrian and bicycle facilities and programs, summarizes the state-of-the-art on each issue as it is contained in the published literature, and provides a concise commentary on each critical issue. A critical issue is an issue of significant and recurring importance to people involved in pedestrian or bicycle programs or those planning and designing pedestrian or bicycle facilities. The critical issues were selected on the basis of a preliminary review of the literature, a review of the expected outputs from government-sponsored research, and discussions with national and local organizations of transportation engineers, planners, program managers, pedestrians, and bicyclists. From a long list of possible issues, 24 were chosen because of their current relevance and frequent appearance in the literature. The report includes a numbered reference list of primary information sources for each critical issue which corresponds to a numbered bibliography of all primary and secondary references.

The report treats the critical issues in three ways. First, there are issues dealing with either a specific bicycle or a specific pedestrian concern. Issues like bicycle parking (Issue P-6) and safe pedestrian levels of operation (Issue P-3) are examples of this type of issue.

Second, there are issues which discuss pedestrian and bicycle issues jointly. Joint treatment occurs because, when treated within the general context of transportation, pedestrians and bicycles will share problems in common with other modes of transportation. For example, the responsibility for designing the facilities (Issue D-1), the relationship between engineering, education, and enforcement (Issue UE-1), and the methods used to evaluate facilities or programs (Issue E-1) are all issues which pedestrians and bicycles share in common with all other modes of transportation.

Third, there are issues which discuss pedestrian and bicycle concerns separately. When treated within their own contexts as separate transportation modes, solutions to pedestrian or bicycle problems will differ. Planning factors (Issue P-1), demand estimation (Issue P-2), user education (Issue UE-2), accident prevention (Issue UE-4), and law enforcement (Issue RE-1) are all issues that will differ by transportation mode. In such instances, this report treats the pedestrian and bicycle aspects of an issue separately under a single issue heading.

The critical issues are divided into four topics: engineering, education, enforcement, and evaluation. Engineering, being the broadest topic, is subdivided into the subtopics of planning, design, construction and maintenance. Each topic and subtopic has a corresponding code:

P -- Planning
D -- Design
C -- Construction
M -- Maintenance
UE -- Education
RE -- Enforcement
E -- Evaluation

A number follows each code and designates a particular critical issue; UE-1, for example, is the code for the first issue in the education section. The issue codes provide a shorthand way of identifying primary and secondary references in the bibilography.

The issue codes serve as guides to the use of this report. Because most references devote themselves to more than one topic, the bibliography lists primary and secondary issue codes after each reference. Scanning the bibliography for a particular issue code will provide primary and secondary sources of information on a particular issue.

The footnoting in the text alludes to the references in the bibliography. The reference list after each issue contains the primary sources of information for that issue, but an issue's footnotes may allude to references for other issues. The footnoting serves as an aid to independent research.

# I. ENGINEERING

## A. PLANNING

A county commissioner once said: "Planning is a plate of public prognostication with a dash of technical mumbo-jumbo." It is also hard work. Many pedestrian and bicycle facilities were developed in the absence of a plan, a new arcade here, a new bike path there. The absence of a plan usually indicates a very subjective decision making process. Subjective decisions are a part of planning, but only a part. Subjective decision making takes place only after the planning process has received policy guidance, technical knowledge, and public participation.

This section of the engineering chapter looks at some of the things which go into the effort to develop a comprehensive pedestrian or bicycle plan. The first issue looks at the overall picture and discusses the important factors to consider when planning a facility network. The second issue talks about estimating the demand for a facility. The third issue considers the safe operating levels for a pedestrian facility. Issues four, five, and six cover more specific areas in bicycle planning; respectively, they deal with the bicycle's use of shoulders on highway rights-of-way, stimulating commuter cycling, and providing bicycles with a secure parking place.

## P-1. WHAT FACTORS SHOULD BE CONSIDERED IN PLANNING PEDESTRIAN OR BICYCLE FACILITIES?

Transportation planning follows certain common work elements which are called the planning process. While specifics may vary, the planning process for pedestrian and bicycle facilities follows these steps:

A. Identify Problems
B. Set Goals and Objectives
C. Estimate Demand
D. Establish Planning Areas
E. Conduct Area Studies
F. Evaluate Potential Improvements
G. Select Alternatives

Within this process there are many factors which can affect local efforts at pedestrian and bicycle planning. This section is interested in the first two steps of the planning process, the identification of problems, and the setting of goals and objectives.

### PEDESTRIANS

Planning for pedestrians often involves the design of standard facilities as an adjunct to the local street system, a very general and haphazard approach. It is only within the past ten years that researchers have devoted themselves to the study of pedestrian planning. For the most part, these studies follow the standard planning process and incorporate both vehicular and pedestrian traffic. (See Figure 1.) Whether or not these studies actually result in improved design and construction is a matter for further research. At least there is a recognition that pedestrian planning is needed.

Before comprehensive pedestrian planning, civic officials were concerned with pedestrian safety, and pedestrian safety was the impetus behind signalization and the delineated crosswalk. Despite the best efforts of traffic engineers, however, about 8,000 pedestrians are killed every year and about 200,000 are injured.[187] Therefore, the primary problem area and factor for consideration in pedestrian planning is still safety, both to reduce accidents with motor vehicles and to reduce the chance of street crime.

To date, the pedestrian planning studies have pointed to visible improvements in specific cities brought about by a return to pedestrianization, the enhancement of central cities to create attractive walking space. Nicolet Mall in Minneapolis and the Mid-America Mall in Memphis are examples.

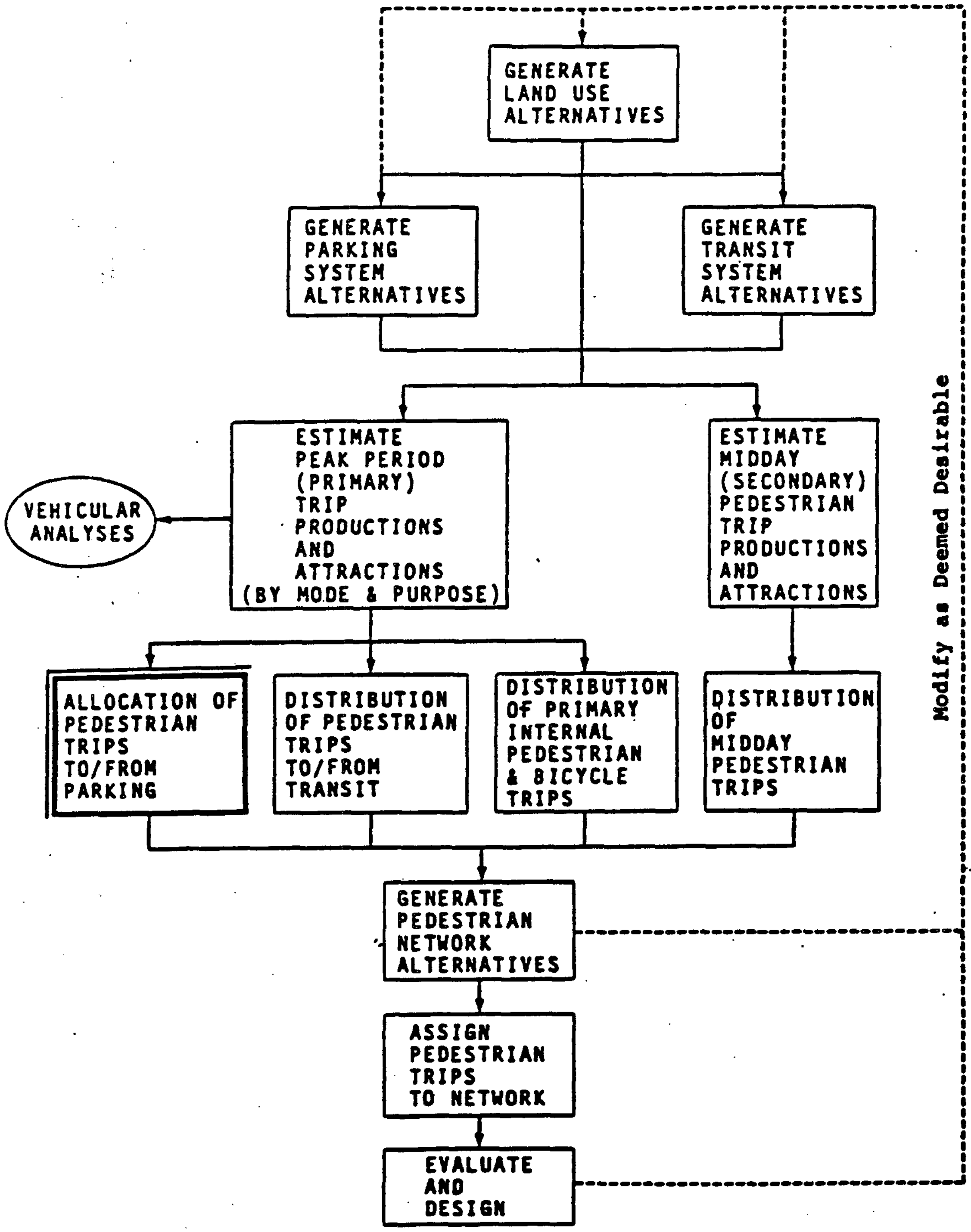


FIGURE 1
A GENERALIZED PEDESTRIAN PLANNING PROCESS

Source: Pfefer, Ronald C., et al., "Some Considerations in Planning for Safe and Efficient Pedestrian Facilities," International Conference of Pedestrian Safety, December, 1976.

Other pedestrian problems are commonplace in urban and suburban areas. Poor physical planning and static design concepts often result in barriers to pedestrian movement.[6] Still worse, in certain areas sidewalks have been reduced to allow for greater vehicular flow; this not only minimizes the pedestrian's safe walking space, but it places him in closer proximity to the vehicular traffic. One often overlooked problem is the pedestrian himself and his hazardous behavior patterns. Children under the age of seven have difficulty judging the speed and distance of approaching traffic, yet they routinely witness adults dodging traffic in the middle of busy roads.[128] The goals of a good pedestrian plan should avoid these problems and include the segregation of pedestrians from motor vehicle traffic, the improvement of the sidewalk environment, and special attention to areas with high concentrations of children and the elderly.[81, 84, 131]

The pedestrian plan must seek to develop not just a system of facilities but a pedestrian program with objectives designed to meet the plan's goals. It is essential to know the kind of pedestrian you are planning for, his trip purpose and destination. Some pedestrian objectives might be: (1) increased safe crossings -- mid-block crosswalks, for example, provide the pedestrian a chance to cross the street without the inconvenience of the walk to an intersection; (2) enforcement of speed limits in residential and shopping areas -- three quarters of all accidents involving children occur in residential areas; (3) the removal of pedestrian barriers; (4) incentives to adjacent land users to provide facilities for pedestrians; (5) educational programs for the elderly and child pedestrian; (6) child protection programs such as play streets and crossing guards; (7) sidewalk separation to accommodate different types of pedestrian uses without interfering with pedestrian flow; and (8) the provision of attractive and functional street furniture which encourages walking but does not constrict the normal walking flow.[74, 90, 94]

There are, of course, a number of cost factors to consider in the planning of pedestrian facilities. These cost factors -- outlined in Table 1 -- will often dictate a selection from among competing alternatives. It should be apparent at this point that no one individual can adequately develop a pedestrian plan; it requires a variety of expertise working together to consider all of the important planning factors.

TABLE 1

COST COMPONENTS OF PEDESTRIAN FACILITIES

1. Design and architect costs
2. Financing costs and legal fees
3. Site preparation
    - Real estate acquisition
    - Demolition
    - Drainage
    - Grading
    - Utilities relocation
    - Foundation
4. Construction
    - Height, width, and length of facility
    - Length of span (if any)
    - Method of support
    - Enclosures (if any)
    - Materials
    - Construction method used
5. Finishing touches
    - Walkway paving, curbs
    - Lighting
    - Street furniture
    - Amenities
    - Landscaping
6. Operation and maintenance
    - Cleaning
    - Gardening
    - Maintenance and repairs
    - Lighting
    - Security
    - Taxes

Source: Braun, Ronald R. and Marc F. Roddin, "Quantifying the Benefits of Separating Pedestrians and Vehicles," (NCHRP Report 189), Transportation Research Board, National Research Council, Washington, D.C., 1978, p. 32.

BICYCLES

Planning for bicycles is a relatively new art. While bicycle planning follows the standard planning process, it has one overriding consideration which is often overlooked: the bicycle is a vehicle. Most state laws do not recognize the bicycle as a vehicle;[86] nonetheless, as a wheeled machine driven on the roadway under human power, the bicycle is a vehicle for planning purposes. This perspective is important because it colors the way planners think of bicycle facilities and, of course, how they plan for them. For example, planning for the bicycle as a recreational device suggests facilities which segregate the bicycle from motor vehicles; planning for the bicycle as a vehicle suggests, instead, roadway improvements, traffic accommodations, and enhanced maintenance procedures.

The FHWA has sponsored research which identified safety and locational criteria for bicycle facilities.[226] Those criteria are certainly factors for consideration in planning bicycle facilities:

- Potential Use
- Basic Width
- Connectivity and Directness
- Safety
- Grades
- Barriers
- Attractiveness
- Image Projection
- Air Quality
- Pavement Surface Quality
- Truck and Bus Traffic
- Cost/Funding
- Use Conflicts
- Security

One prevalent idea which dominated bicycle planning in the past decade was the classification of bikeways into Class I, Class II, and Class III facilities in proportion, respectively, to their segregation from motor vehicle traffic.[26] Prior to 1979, virtually every bicycle planning and facility development handbook alluded to these special facility classifications. It became apparent, however, that while the classification scheme was useful, it did little to promote effective planning; the classes were too broad and many local situations required variations and exceptions.[232]

The current thinking broadens the classifications and talks of a range of facilities based on usage, user types, and trip purposes. In this regard, the bicycle planner's job corresponds to standard transportation data collection.[21] In brief, who rides what, where, when, and how often.[21] This data points to problem areas which certain types of facilities might improve. If, for example, data collection revealed young children using a roadway with high average daily traffic volumes, the plan might seek to build a separate bike path connecting their street to a local park (or establish an education program, or close the street to motor vehicles, or reroute traffic, or some combination of approaches based on the range of alternatives).

Improving bicycling safety is always a planning objective. Analyzing accident data can point to possible safety improvements. Accident data, by itself, can be misleading, but it does serve to identify corridors in need of special treatment or avoidance.[45] Remember that police accident data relating to bicycle and motor vehicle collisions only occurs when there is serious injury or property damage. Many bicycle accidents go unreported because they were not severe enough to warrant an accident report, or because the accident reporting procedures themselves fail to properly recognize the bicycle as a vehicle, often recording the bicyclist as a pedestrian.[10] In almost all cases, bicycle/bicycle and bicycle/pedestrian accidents are never recorded.

With the planning objectives now fortified with measurable criteria from the data collection effort, the planner can begin to weigh the alternatives formulated in the area plans. Naturally, cost factors will play a significant role in determining which alternatives are implemented. Bicycle facility cost factors closely resemble the pedestrian facility cost factors in Table 1, with the addition of vehicle-related costs such as signing, parking, and mapping. Maintenance is a necessary and crucial cost for bicycle facilities. Because the bicycle is vulnerable to a wide variety of road hazards, the plan must ensure the method, scheduling, and responsibility for periodic facility maintenance.[253]

Lastly, the bicycle plan should become a part of the overall state, regional, or local transportation plan. Only in this way will it receive the persuasive policy support it will need to compete with other transportation modes.

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## P-2. HOW IS THE DEMAND FOR PEDESTRIAN AND BICYCLE FACILITIES ESTIMATED?

Since a plan serves as an instrument to guide future policy decisions, demand estimation, forecasting the size, frequency, and location of future travel, is an essential part of the planning process. Demand estimation combines existing demand, the number of people using a facility, with potential or latent demand, the number of people who might use a facility (if conditions were improved, if they perceived a time or cost savings, etc.). Observation and counting are used to obtain figures on the existing demand, while survey research and modeling techniques can be used to estimate latent demand.

Because existing demand can be readily calculated, most of the literature on demand estimation in the pedestrian and bicycle fields concentrates on estimating latent demand. Demand estimation is broken into three distinct phases, trip generation, trip distribution, and trip assignment. Trip generation looks at how many trips a new facility may produce, trip distribution examines where those trips may take place, and trip assignment attempts to forecast where the trips will take place.[138] In general, pedestrian and bicycle planners have used survey research and direct observation to estimate trip generation, and pedestrian researchers employed various mathematical techniques to simulate trip distribution and make trip assignments.

### PEDESTRIANS

To the casual observer in an urban area, pedestrians distribute themselves in random patterns, yet they adhere to measurable criteria common to transportation data gathering. Data collection for pedestrian demand estimation usually includes:

- Origin and Destination
- Time of Day
- Trip Length
- Trip Frequency
- Surrounding Land Use
- Trip Purpose
- Travel Path

Data collection efforts in pedestrian studies rely on aerial photography, time-lapse photography, direct observation, and counting. User characteristics, trip purposes, and land uses, therefore, result from measurement and observation. Researchers have then related these criteria to measurable characteristics of the physical environment such as office floor space, retail and commercial shopping opportunities, parking and transit facilities, and other sidewalk attractions. Calculations and analysis then try to relate these trip generators to the ebb and flow of pedestrian traffic. Findings from the recent studies of pedestrians should aid future demand estimation effort. Some of these results[200] include:

- Pedestrian traffic follows peak periods similar to automobile commuting patterns; this has implications for the design of urban space.

- Walking distance is related to age and sex. Younger people walk further than older people, men walk further than women.

- The average walking distance for most pedestrian trips is under one-half mile and is closely related to a mode transfer: walking to the car, the bus stop, the transit station.

Many of the pedestrian demand estimates to date have employed the gravity model or multiple regression analysis for trip distribution and trip assignments. The gravity model uses trip generation and attraction points called centroids; it mathematically estimates the attraction between centroids based on observed data and land use categories.[138] Several recent studies have utilized multiple regression analysis, a statistical technique used to predict the value of a dependent variable -- in this case, the number of pedestrians -- by its relationship to a series of independent variables such as the number of parking spaces, the number of bus stops, etc. Studies conducted in New York,[200] Milwaukee,[11] and Orebro, Sweden [210] used multiple regression techniques to establish the relationship between the number of pedestrians on the street and the surrounding land uses. This information was then used to predict the number of pedestrians using the street system in some future year; from this number, planners could calculate the demand for pedestrian facilities within sectors of the city.

BICYCLES

The data collection effort for the demand estimation phase of the bicycle planning process includes the following items:[21]

- Origin and Destination
- Trip Purpose
- Trip Length
- Trip Frequency
- Land Use
- Environmental Conditions
- Age of Users
- Bicycle Counts
- Bicycle Ownership

Because their needs will vary, it is useful to break bicycle facility demand into utilitarian and recreational users. Utilitarian bicyclists travel to the same termini as motor vehicles and use the quickest, most direct routes when they perceive them safe and convenient. The recreational cyclist may or may not have a destination in mind, and his trip length and time may not be important to him. One step toward estimating bicycle facility demand, therefore, is to separate utilitarian from recreational riders and break the recreational riders into a destination/ non-destination classification.

The Bicycle Manufacturers Association estimates that one half of the American population owns a bicycle, and a Pennsylvania survey indicates that more than half of all bicycle owners in that state ride at least once a year. By gathering similar statistics for a local area, establishing a profile of present cyclists, and comparing their user characteristics -- age, trip frequency, trip purpose, etc.-- to the bicycle-owning population within the planning area, it should be possible to estimate the potention attraction of a new facility within the area.[180] Here the purpose of the planned bicycle facility itself helps the planner to estimate types of users and rates of usage. A new facility may be designed to serve the utilitarian cyclist: a commuter bike route, for example; or the facility may be intended for the recreational cyclist with specific destination in mind: a bike lane connecting several points of interest, for example; or the facility may be constructed strictly for recreational cyclists out for fun or exercise: a bike path within a park, for example. The planner should try to match the purpose of the facility to the type of user.

* "Pedestrian and Bicycle Considerations in Urban Areas -- An Overview," FHWA Training Course, Northwestern University and Barton-Aschman Associates, Inc.

Planners have utilized survey research and direct observation and measurement techniques to estimate bicycle facility demand.[33] Because the volume of bicycle travel is often low, it has proven essential to survey the local communities within each planning area to assess their riding habits and establish a base from which to project future ridership. This is time consuming. Another, faster method of demand estimation compares a study population to a similar population with an already existing facility and adjusts for dissimilarities. Bicycle facilities are not common enough or bicycling populations similar enough in their riding habits to have allowed this strategy to function well to date. Until additional data on bicycle demand estimation is available in the literature, local bicycle planners must rely on adaptations of demand estimation techniques contained in transportation planning and research documents and guard against overestimating or underestimating usage by offering a range of facility demand estimates.

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## P-3. WHAT ARE THE SAFE OPERATING LEVELS FOR TYPICAL PEDESTRIAN FACILITIES?

Very often, pedestrian planners and engineers do not provide pedestrians with adequate walking space. Studies in many major cities have shown that pedestrian facilities are haphazardly planned and often inadequate; this can lead to uncomfortable, and sometimes unsafe, operating conditions. For example, inadequate storage space at a signalized intersection can force pedestrians off the curb and into the street.

In pedestrian planning, there are many similarities between pedestrian flow and motor vehicle flow. Walking speed, for example, is determined by the density of the pedestrian traffic; so is pedestrian spacing -- the greater the speed, the further apart the pedestrians. Pedestrians also tend to travel in imaginary but defined paths on the right hand side of the walkway. Research in this area has revealed that pedestrian "paths" should be anywhere from 2.5 to 3 feet wide (0.8 to 1.0 m).[175] Pedestrians also maintain a reasonable distance from fixed objects like buildings; design limits suggest another 18 inches (0.5 m) should be added to the sidewalk for this distance, 36 inches (1.0 m) where window shopping is prevalent.[44]

Because they often travel in groups, pedestrians create moving pockets of different densities (sometimes called platoons) which can impede the overall flow of a pedestrian facility. These are not a problem until high densities of pedestrians occur simultaneously; this can lead to crowding, delay, unsafe conditions, and a variety of psychological imbalances from frustration to claustrophobia. Pedestrian facilities, particularly sidewalks, must provide a certain level of pedestrian service which allows comfortable pedestrian flow. Flow is defined as the number of pedestrians passing a point in a given period of time. Because the width of the sidewalk is an important capacity determinant, flow is usually expressed as pedestrians per foot width per minute (PFM). The effective sidewalk width can be determined by dividing the number of pedestrians per minute by the PFM. Figure 2 shows that efficient pedestrian flow depends upon effective pedestrian space. Dr. John J. Fruin has postulated six levels of service to describe pedestrian walkways:[105]

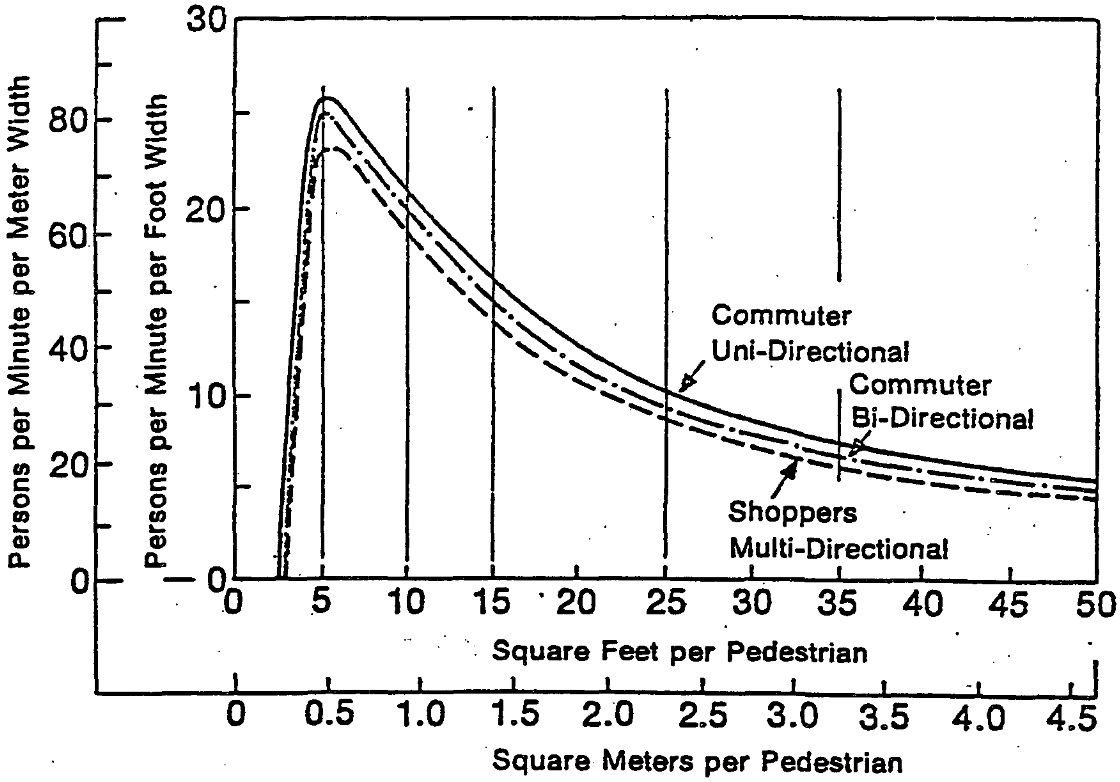


FIGURE 2.

PEDESTRIAN FLOW VS. PEDESTRIAN SPACE

Source: Fruin, John J., "Pedestrian: Planning and Design," MAUDEP Conference Report, New York, 1971.

Level A: Average Flow Volume: 7 PFM or less
Average Speed: 260ft/min.
Average Pedestrian Area Occupancy:
35 sq.ft./person or greater
Description: Virtually unrestricted choice of speed; minimum maneuvering to pass; crossing and reverse movement are unrestricted; flow is approximately 25 percent of maximum capacity.

Level B: Average Flow Volume: 7-10 PFM
Average Speed: 250-260 ft/min.
Average Pedestrian Area Occupancy:
25-35 sq.ft./person
Description: Normal walking speeds only occasionally restricted; some occasional interference in passing; crossing and reverse movements are possible with occasional conflict; flow is approximately 35 percent of maximum capacity.

Level C: Average Flow Volume: 10-15 PFM
Average Speed: 230-250 ft/min.
Average Pedestrian Area Occupancy:
15-25 sq.ft./person
Description: Walking speeds are partially restricted; passing is restricted but possible with maneuvering; crossing and reverse movements are restricted and require significant maneuvering to avoid conflict; flow is reasonably fluid and is about 40-65 percent of maximum capability.

Level D: Average Flow Volume: 15-20 PFM
Average Speed: 200-230 ft/min.
Average Pedestrian Area Occupancy:
10-15 sq.ft./person
Description: Walking speeds are restricted and reduced, passing is rarely possible without conflict; crossing and reverse movements are severely restricted with multiple conflicts; some probability of momentary flow stoppages when critical densities might be intermittently reached; flow is approximately 65-80 percent of maximum capacity.

Level E: Average Flow Volume: 20-25 PFM
Average Speed: 110-200 ft/min.
Average Pedestrian Area Occupancy:
5-10 sq.ft./person
Description: Walking speeds are restricted and frequently reduced to shuffling; frequent adjustment of gait required; passing is impossible without conflict; crossing and reverse movements are severely restricted with unavoidable conflicts; flows attain maximum capacity under pressure, but with frequent stoppages and interruptions of flow.

Level F: Average Flow Volume: 25 PFM or more
Average Speed: 0-110 ft/min.
Average Pedestrian Area Occupancy:
5 sq.ft./person or less
Description: Walking speed is reduced to shuffling; passing is impossible; crossing and reverse movements are impossible; physical contact is frequent and unavoidable; flow is sporadic and on the verge of complete breakdown and stoppage.

Too often pedestrian networks were designed for a subjective peak period capacity based on a planner's judgment. These six levels of service provide a method for the qualitative evaluation of pedestrian facilities. Used in conjunction with demand estimates, they offer a chance for effective design based on a comfortable pedestrian flow in an urban environment.

Recent work on pedestrian movement in shopping malls has suggested that normal walking patterns on urban sidewalks or in transportation terminals do not account for the random walking patterns of shoppers. This work produced Table 2, a comfort index; levels of service based on pedestrian density.[40]

All of the pedestrian planning efforts point toward unique conditions within selected pedestrian environments. This means that conditions will vary by city and within segments of the city. Individual pedestrian studies are required to assess particular planning areas.

TABLE 2

PEDESTRIAN DENSITY VS. LEVEL OF SERVICE

| Space per Person (square feet) | Level of Service |
|---|---|
| 10 or less | Delay, Conflicts |
| 12 | Crowded |
| 15 | |
| 20 | Constrained |
| 30 | |
| 60 | Impeded |
| 120 | |
| 130 | Free Flow |

Source: Adapted from: Braun, Ronald R. and Marc F. Roddin, "Quantifying the Benefits of Separating Pedestrians and Vehicles," (NCHRP Report 189), Transportation Research Board, National Research Council, Washington, DC, 1978, p.68.

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## P-4. CAN ROAD SHOULDERS ON LIMITED-ACCESS ROADWAYS SERVE AS LEGAL, SAFE BIKEWAYS?

Transportation routes should increase in efficiency as they seek to connect increasingly more important terminals. To this end, the connection between two major points should be direct, should limit access to remove unnecessary delays, and should allow for high-speed traffic within safe design limits. The nation's primary highways (state roads and interstates) were designed for safe and efficient vehicular travel. The bicyclist can share in the convenience of the highway by using the highway shoulder as his bikeway. At the present time, however, legal barriers prevent the bicyclist from using the highway shoulder in many states.[66]

The legal restrictions against the use of bicycles on limited-access highway shoulders stem from safety considerations, although there is very little data to support or maintain such a ban. California, which has systematically begun allowing bicycles on its interstate highways, recorded only 6 bicycle accidents on freeway shoulders in the four-year span between 1973 and 1976. California now has over 1000 miles of interstate highway open to bicycles.*

The Uniform Vehicle Code (UVC), a national attempt to unify the individual state motor vehicle codes and followed in part by 23 states, does not prohibit the operation of any vehicle on the highway shoulder unless there is a specific traffic control device prohibiting it. The UVC does state in Chapter 11-313: "...The (State Highway Commission) by resolution or order entered in its minutes, and local authorities by ordinance, may regulate or prohibit the use of any controlled-access roadway (or highway) within their respective jurisdictions by any class or kind of traffic which is found to be imcompatible with the normal and safe movement of traffic." In effect then, the states can and do prevent bicycle access to certain highways. A survey conducted by the Federal Highway Administration (FHWA) in 1978 showed that 41 states, the District of Columbia and Puerto Rico now prohibit the bicycle from interstate highways: Montana, Minnesota, South Dakota, and Wyoming, and five states allowed the bicycle to use the interstate highways: North Dakota, Idaho, Oklahoma, Oregon, and Texas. In only seven states, however,

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* Pro Bike '80 Proceedings, Workshop 9: "Bicycles and Controlled Access Facilities," 1981.

was the bicycle actually prohibited by law from using the interstates (Florida, Louisiana, Maryland, Michigan, Nebraska, Ohio, West Virginia); most other prohibitions were due to highway regulations.

The bicyclist views the use of highway shoulders as a necessity where there are no alternate routes and as a denial of his right to the road when states prohibit their use. This denial becomes crucial when an interstate highway is the only road crossing a river or bay.[222] Several states have taken steps to correct the total bicycle prohibition by granting highway access in those areas where no acceptable alternate routes exist. Colorado has devised evaluation criteria which uses a subjective point system to measure objective roadway conditions, traffic conditions, and travel time. This allows their planners to judge which section of the interstate they should open to bicycle traffic.

The highway access issue in New Jersey is still unclear. When New Jersey sought to encourage bicycle use on its roadways, it first studied the feasibility of using road shoulders in lieu of building separate facilities.[27] Up until 1977, they allowed bicycles to ride on freeway shoulders; this changed in 1978, now New Jersey allows bicycle riding on freeway shoulders only if the owner obtains a state permit. They are hoping to eliminate the permit system shortly.

A limited-access highway does not guarantee that the cyclist will find acceptable riding conditions on the shoulder. A recent National Cooperative Highway Research Program (NCHRP) study showed that 80 percent of the states use a 10 foot shoulder on their freeways, and most states pave the shoulders on their interstate and major highways. But most states do not maintain the road shoulder, and in those states that schedule shoulder maintenance, that maintenance applies only to unpaved shoulders.[73] Some low cost shoulder treatments such as asphalt slurry can make the shoulder an acceptable riding surface, but they cannot replace regular maintenance as an inducement to bicycle traffic.[174]

The North Carolina Department of Transportation has begun a policy of constructing, improving, and maintaining paved shoulders to accommodate the bicycle. Their bicycle plan best sums up the feelings of most bicyclists: "Paved shoulders are encouraged along highways for the safety of all highway users, and to this end paved shoulders should be designed in a manner which will accommodate bicycle traffic."[258]

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P-5. WHAT CAN BE DONE TO STIMULATE COMMUTER BIKING?

The latest national figures on commuter biking come from a 1975 Bureau of the Census survey; it showed an average of about 470,000 bicycle commuters, approximately 0.6 percent of all commuters. The recently published "Bicycle Transportation for Energy Conservation" from the U.S. Department of Transportation estimated that some 3.8 million people could have commuted in 1975 if given the proper incentive. Table 3 examines how the report arrived at that figure.

TABLE 3

ESTIMATE OF POTENTIAL BICYCLE COMMUTERS
(MILLIONS)

| | Automobile | Mass Transit |
|---|---|---|
| Commuters with trips within bicycling range (per Table 111-2) | 11.6 | 1.9 |
| Reductions for: | | |
| • Auto dependence (8 percent) | -0.9 | - |
| | 10.7 | |
| • Physical limitations (40 percent) | -4.3 | -0.8 |
| | 6.4 | 1.1 |
| • Environmental conditions (50 percent) | -3.2 | -0.5 |
| | 3.2 | 0.6 |
| Estimated potential bicycle commuters by mode (1975) | 3.2 | 0.6 |

Source: "Bicycle Transportation for Energy Conservation," U.S. Department of Transportation, Washington, DC, April 1980, p.29.

The report went on to develop a comprehensive bicycle transportation program with the goal of increasing bicycle use through improved operator awareness and competence, improved institutional and professional responsiveness, and an improved transportation system. They also used the program to establish a target of between 1.5 and 2.5 million bicycle commuters by 1985.[19]

It is obvious that commuter bicycling saves energy normally used by the automobile or mass transit, but its appeal must have a broader base if it is to increase. Perhaps bicycle commuting's best asset is its low cost. Estimates on the cost of bicycle trips run from 2 to 4 cents a mile compared to the automobile's average of about 27 cents a mile. It is likely that the bicycle commuter will still own a car with certain fixed costs, but he can save substantially on fuel and parking fees. An appeal to the pocketbook of the commuter seems in order.

Other benefits of bicycling to work include the good exercise, the convenient parking, door-to-door service, and often, a savings in travel time.[119] An Oregon Department of Transportation study demonstrated that a bicyclist of less-than-average ability can travel ten to fourteen miles an hour using a multi-geared bike. Since the majority of commuting trips are under five miles, most trips would require less than a half hour bicycle ride. Surveys of commuter travel in Chicago and Minneapolis reveal very little difference in travel time between an automobile and a bicycle on the same trip.

With so many good reasons behind it, why are not more people commuting by bicycle? The answer lies in the many personal and institutional obstacles working against the potential bicycle commuter. These obstacles include the lack of safe parking facilities, the lack of showers or lockers at a destination or modal switch point, the perceived or real need for a safe route, the fear of traffic, the fear of crime, the distance, the weather, darkness, real physical barriers like bridge crossings, the terrain, the lack of riding skill, a poorly maintained road surface, and inadequate funds for promotion or facilities. The DOT report, mentioned earlier, cited the greatest obstacle to bicycle commuting as the low level of public acceptance. Because bicycle commuters are rare and most are between the ages of 18 and 50, some bicycle commuters have been criticized for "reverse snobbery," exuding a sense of moral superiority or promoting a chic trend. A study in Davis, California showed that the rate of bicycle use as a mode of transportation was lowest for managers and those working in transportation, utilities, communications, finance, real estate, and insurance.[162] In general, any profession which requires the use of a car for daily transactions is not a likely target for a bicycle commuting promotion.

Aside from improvements to the transportation network, which tend to cost a great deal, there are a number of low-cost strategies for stimulating commuter bicycling. Promotion and media campaigns can utilize public service space in the newspapers, radio, and television. In this regard, it pays to adapt the ideas and material used by other bicycle campaigns in cities like New York and Washington. (Bicycle activists in New York City prepare for and greet transit strikes with a media blitz promoting the bicycle as a working vehicle.) Mapping safe commuter routes into the urban areas is a good idea. These maps can be coded to coordinate with specific routes, although there is some feeling that signing or marking bike routes only serves to inspire overconfidence among cyclists and motorists and can lead to negligent behavior if they view these routes as safer than others. Other transferable ideas include a bicycle hotline to inform the commuting public; this could be combined with a program of "bike buddies," finding another cyclist to ride with a new commuter on the way to work. Large, local employers can add promotional material to paycheck envelopes or use company bulletin boards. Since road maintenance is an omnipresent problem, complaints and "pothole postcards" to local highway departments and public officials let them know that bicyclists are using their roads in increasing numbers.

On the high cost side of stimulating bicycle commuting, improvements can include wide curb lanes, resurfacing, barrier removal, and the elimination of design hazards. Proposed federal guidelines suggest constructing the right hand lane of the roadway between 12 and 14 feet (3.6 and 4.2 meters) wide to permit safe operating conditions for the motorist and the bicyclist. Barriers and design hazards like freeway ramps and bridges will require a substantial political and fiscal commitment before they are eliminated, but some cities have used abandoned bridges as pedestrian and bicycle crossings so alternatives may be available. Adequate parking, while not a high cost item ordinarily, can be a costly but necessary incentive for stimulating bicycle commuting. (See next issue.)

Today's bicycle commuters have already made their accommodations with little public support, it is the new bicycle commuter who needs encouragement, and small incentives may prove as beneficial as large and costly ones.

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## P-6. WHAT CAN BE DONE TO PROVIDE SECURE PARKING FOR BICYCLES?

Bicycle security and bicycle parking issues go hand-in-hand; bicycle theft most often occurs after the bicycle is parked and the owner preoccupied. Several recent studies[19,205] have shown a close connection between bicycle use and the existence of secure bicycle parking. Some people have cited the lack of secure parking as a reason for not commuting by bicycle; others credit their use of the bicycle for solely recreational purposes to their fear of having the bicycle stolen if they used it for commuting or other utilitarian purposes. Unlike automobile theft, the bicycle owner has little chance of recovering his bicycle. One study in Pennsylvania cited a bicycle recovery rate of only 18 percent. A Denver study cited 23 percent recovery for bicycles and 90 percent for automobiles.[41]

Fear of bicycle theft is a real fear and prevents many energy-saving bicycle trips. There are many common sense things to do to protect bicycles. The Bicycle Manufacturers Association of America's tips for bicycle theft prevention include:

- Lock your bike to a stationary object.
- Use a heavy-duty, case-hardened lock and chain.
- Lock your bike in a conspicuous place.
- When necessary, remove the front wheel and take it with your.
- Never leave your bicycle out overnight.
- Lock both wheels and the frame.
- Record the serial number.
- Register your bike with the local police.
- Take a color photograph of your bike for identification.
- List your bike on your homeowner's or tenant's insurance policy.
- Never leave your unlocked bike unattended.

Secure bicycle parking is the essential element which prevents bicycle theft. The bike boom of the early 1970's encouraged manufacturers to produce a variety of bicyle parking racks and facilities. Bicycle parking facilities come in many designs. As in most engineering designs, some work better than others. For purposes of establishing the proper location of parking facilities, bicycle parking devices or hardware have been classified according to three levels of security:

CLASS I: High-security, long-term parking which offers complete protection from vandalism and weather. Bike lockers or attended covered parking fall into this category.

CLASS II: Medium-security parking which allows you to secure both wheels and the frame with only a simple, user-supplied lock.

CLASS III: Minimum-security "bike racks" or fixed objects that hold a bike upright and require a user-supplied lock and a cable or chain.

Naturally, different sites have different security needs. A Class III facility may be all that is required at a public place like a fast food restaurant, convenience store, or playground. Table 4 examines the relative security of certain site and hardware combinations.

One development in bicycle parking is worth special notice; some cities are experimenting with parking fees to defray the cost of a parking facility. This seems to work best with bicycle parking lockers that are rented from the city or county so that they do not encourage coin-box vandalism. The situation in Washington, DC is illustrative. Washington has 100 lockers at eight of its Metro stations which it rents for $90.00 a year -- they also rent on a quarterly, semi-annually, and nine-month basis. At the present rate each locker space (there are two parking spaces per locker) will pay for itself in three years. About 90 percent of the lockers are rented, and they are in the process of ordering several hundred more. In the two years since they installed the lockers, they have had only three bicycle thefts from the lockers, and they believe two of those were the fault of the renters. While the lockers provide excellent security, cities that have used them have run across some unusual problems. People have used the lockers as an all-purpose storage facility and as derelict housing. They have also served as a vehicle for bomb threats and as a canvas for graffiti. There was even a case of someone stealing an entire locker. All these are isolated instances, however.

TABLE 4

BICYCLE PARKING HARDWARE AND LOCATION MATRIX

| Hardware \ On-Site Location | Remote (Not Surveyed) | Convenient (And Surveyed) | Covered or Garage Surveyed by Attendant or TV | Bicycle Room or Enclosure | Used In Conjunction With A High Security Lock |
|---|---|---|---|---|---|
| No Hardware, Only Space | — | Δ | Δ | Δ | Δ |
| Stationary Metal Object, Class III | Δ | Δ | ☆ | ☆ | ○ |
| Standard Rack, Class III | Δ | ○ | ☆ | ☆ | ○ |
| Standard Rack, Class II | Δ | ○ | ☆ | ☆ | ☆ |
| Shielded Lock, Class II | ○ | ☆ | ☆ | ☆ | ☆ |
| Bicycle Locker, Class I | ☆ | ☆ | ☆ | ☆ | ☆ |
| High Security Bicycle Lock | ○ | ☆ | ☆ | ☆ | — |

Δ Minimal Security

○ Medium Security

☆ High Security

Source: "Parking for Bicycles: A Guide to Selection and Installation," Mountain Bicyclists' Association for the City and County of Denver, Fall, 1979.

It is a bit more difficult to estimate the number of bicycle parking spaces a particular building or complex requires. Some suggestions in this regard run from demand estimation techniques to simple ratios such as 10 percent of the automobile parking spaces at a given location. In general, it is better to overestimate the need, since bicycle parking tends to generate bicycle riding. The FHWA's "A Bikeway Criteria Digest" recommends installing parking facilities based on 110 percent of the peak parking demand.[21]

Bicycle parking experience in various cities in the country reveals some standard practices to follow when locating parking facilities:

1. Use a weather-protected site whenever possible.

2. Put the parking close to a building entrance or next to a guard station or both.

3. Check local ordinances against parking bicycles on sidewalks.

4. Segregate bicycle parking from automobile parking.

5. Allow enough space between bikes (at least two feet) so they do not become entangled and damaged.

6. Do not interfere with pedestrian traffic.

7. Use the best available hardware within budget constraints.

8. Relate parking facilities to public transit terminals.

In some cities, bicyclists are actively lobbying for an ordinance to require the provision of bicycle parking at all public parking lots and garages. They are also searching for the "ultimate" bike rack; one that provides maximum security, operates on one key or one lock, is easy to use, low-cost, well-built, aesthetic, and allows for flexible site development. It is beyond the scope of this report to recommend specific bicycle parking and storage hardware, but the criteria for the "ultimate" bike rack provides a checklist for use when comparing a manufacturer's hardware to your parking needs and parking budget.

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## B. DESIGN

In discussing bicycle and pedestrian facilities, planning and design go hand-in-hand. Planning tends to account for the intangible considerations which were analyzed in the previous section, things like: Is there a need for a facility? How many people will use it? What can be done to assure its use? Design, on the other hand, tends to mean the nitty-gritty structural elements within the plan, the blueprints from which the facilities will rise. In reality, design is planned art and a part of the overall planning process, that broad concept which starts with an idea and continues into operation and evaluation.

This section tries to balance the art of design and practice of planning by focusing on the human element which employs them -- Issue 1. On bicycling, the section examines whether there is a fundamental need for special bicycle facilities -- Issue 2, points to the spectrum of current bicycle facility designs -- Issue 3, and dwells on the design problem of putting a bikeway through an intersection -- Issue 4. Lastly, in Issue 5, the section defines those variables which may point to the necessity of designing and building a separate structure -- an overpass or an underpass -- which would expedite the flow of the non-motoring public.

## D-1. WHO SHOULD DESIGN PEDESTRIAN OR BICYCLE FACILITIES?

Many human endeavors require a variety of people working together toward a common goal; the design of pedestrian and bicycle facilities is no exception. It falls to the prime movers of an idea to take the responsibility for the realization of that idea. Both the pedestrian and the bicyclist share the need to attract public attention to what they feel is a glaring deficiency in their respective programs or facility system.

To the pedestrian and cyclist the keys to effective facility design are community involvement and organization. Aside from the pedestrian or bicycle organizations themselves, the list of possible actors -- the responsible individuals -- in the design of pedestrian and bicycle will include:[42,163]

- GOVERNMENT OFFICIALS (LOCAL, STATE, FEDERAL)
    - Elected Representatives
    - Administrators
    - Planners
    - Engineers
    - Program Managers
- BUSINESS PEOPLE
    - Managers
    - Marketing Analysts
    - Architects
    - Realtors
    - Financial Specialists
- COMMUNITY GROUPS
- SOCIAL AND CIVIC ORGANIZATIONS
- ACADEMIC INSTITUTIONS
- COMMUNICATIONS MEDIA
- INTERESTED CITIZENS

The actual design of the facility, the blueprint, emanates from the well of the public or private planner, engineer, or architect, but the responsibility of communicating the idea in its general shape must fall to the principal actors. These actors bring their design to the drawing table hammered into its rough shape. In other words, they have held organizational meetings dedicated to the proposition that pedestrian or bicycle facilities are needed.[37] It is at these organizational meetings that the functional questions -- who, what, where, why, when, how, and how much -- first gain the floor.

Once tentative answers (often called feasibility studies) reach the stage, the planning process begins, the organizations lend direction, and the actors play their roles. Studies show that bicycle and pedestrian facilities have developed from the objective criteria of planners and engineers, the political will of elected officials, the benevolence of civic organizations, and the profit motives of the business community. Any of these actors, therefore, may formulate the responsibility, but all segments of the community should participate in facility design.

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## D-2. ARE SPECIAL BICYCLE FACILITIES NEEDED?

Ever since the renaissance in bicycle facilities, roughly 1972 A.D., a debate has raged over the need for special bicycle facilities. Taking the affirmative position are federal, state, and local bicycle program specialists and taking the negative are a vocal group of experienced cyclists. As in any debate, there are crossovers on both sides, especially when the question hinges on particular facilities in certain locations. There are also any number of subtle connections to be made between points in the total argument; a better appreciation of these subtleties can be gained by reading this entire report with this argument in mind. This overview is a brief background and a sketch of the debating agenda.

For a variety of reasons, the bicycle returned to fashion during the early 1970's. Assisted by government support and funding, communities in every state of the nation designed and built special bicycle facilities, often in the name of safety and convenience. Experienced cyclists began to question the design and presumed benefits of these facilities. A period of retrenchment and evaluation began and is still underway.[148,160,161]

Both sides in the debate agree that there are problems with current bicycle facilities. Some of these problems are:

a. Poor Design -- improper alignments, poor sight and stopping distances, inadequate curve radii, etc.

b. Safety and Hazards -- motor vehicle/bicycle conflicts, inadequate road maintenance, potholes, confusing signs and markings, etc.

c. Little Connectivity -- no provision for direct access or routing.

d. Poor Location -- site selection remote from the actual demand.

e. Recognition -- inadequate signing and marking.

f. Cost -- from hundreds to thousands of dollars per mile with little discernible increase in ridership.

The solutions are what the debate hinges on. The facility school says that mistakes were made, but now there is an understanding of the methods which will correct those mistakes. The no-facility school says that the mistakes should teach us that special facilities are a mistake. Both sides recognize the bicycle as a vehicle with an obligation to follow the rules-of-the-road; they differ on how the road system should adequately and safely accommodate both motorized and non-motorized vehicles in the same traffic stream.[101]

Bicycle facility evaluations to date have lead the facility school of bicycle experts to mitigate their position. Their accent now is on good local planning with the consideration of alternatives such as wide curb lanes, smooth highway shoulders, and adequate parking.[135,172] With these, the facility school has yielded substantially to the no-facility school; the no-facility school views these alternatives as standard highway design elements and not special bicycle facilities.

One failing of the no-facility school seems to be their inability to properly account for other than adult, utilitarian cyclists. Recreational and child cyclists require a different set of accommodations, and often, special facilities appear to be the answer. The no-facility school points to the special needs of the recreational rider, child or adult, as a problem separate from highway engineering, a problem attended to by recreational departments, education, and local ordinance. The bicycle, however, is a virtually unregulated form of transport which can readily admit unprepared recreational riders to the well-paved and convenient streets.[122] Special facilities, when properly designed, channel these cyclists along relatively safe routes where they can develop their cycling skills or simply enjoy the exercise.

Both schools agree on the need for cyclist and motorist education, and bicycle curriculum elements are beginning to coalesce around mutually acceptable criteria.[61,102] The need for enforcement again finds both houses in substantial agreement on police training, licensing of bicyclists, and bicycle registration. The literature of the past ten years reveals that a gradual amalgamation of the two schools of thought is occurring.[222,225] Diplomatically, it might be said that there have been frank discussions on substantive issues, and there is continued progress on those points upon which there is disagreement.

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D-3. WHAT ARE THE BIKEWAY DESIGN ALTERNATIVES?

Since the systematic development of bikeways first began in the early 1970's, there have been very few design guides with authority to command nationwide attention. Perhaps the first was the 1972 University of California effort "Bikeway Planning Criteria and Guidelines." This was followed by the Federal Highway Administration's "Bikeways -- State-of-the-Art, 1974,"[26] and the American Association of State Highway and Transportation Official's "Guide for Bicycle Routes."[4] The most recent publications of note (c.1978) are the FHWA's "A Bikeway Criteria Digest,"[21] and the California Department of Transportation's "Planning and Design Criteria for Bikeways in California."[196] As the debate over the need for bicycle facilities continued during the decade, a corresponding debate over the design of effective bikeways was also in progress. As of today, the FHWA has proposed new bikeway design and construction criteria which incorporate the best thinking and evaluation results available; the FHWA should publish these sometime in 1981.* This issue examines in summary fashion the latest considerations and engineering design criteria.

The term "bikeway" is a broad term which means any travelway specifically designated for operating a bicycle. Bikeway design, therefore, should include the safe and effective methods of accommodating the bicycle on a "bikeway." This leaves the range of possible bikeways open to common sense and engineering; most bikeway designers have expanded the Class I, II, and III structure of the past into a flexible approach which allows for existing circumstances.[232] Once the planning process has rated specific corridors for their appropriateness as bicycling streets (see Issue P-1), then the design choices fall into two major categories: roadway improvements and bicycle paths. (Do not confuse design choices with planning alternatives; there are other alternatives which do not require facilities. Street mapping, media campaigns, law enforcement, and organizational efforts are examples.)

In most cases, roadway improvements are an essential consideration in bicycle planning. The bicyclist battle cry is: "Every street is a bicycle street!"[108] Unfortunately, the plan cannot improve every street economically in hopes of encouraging cycling, but here is a list of the hazardous conditions* which should be improved on every roadway:

* Proposed FHWA Bikeway Design and Construction Criteria, Federal Register, August 4, 1980.

a. Drainage Grates -- These are known hazards when their openings face in the same direction as travel; weld 1 inch by 1/4 inch (25 mm x 6 mm) steel cross straps 4 inches (102 mm) apart or, better still, replace the grate with a bicycle-safe model.

b. Railroad Crossings -- These can be improved with better surfacing in some instances, but many require warning signs.

c. Pavements -- The bicycle needs a smooth surface for optimum efficiency, hence patch potholes and smooth gaps and ridges to no more than 3/8 inch (10 mm) high when parallel to travel or 3/4 inch (19 mm) high when perpendicular to travel.

d. Signals -- The bicyclist requires the same consideration at traffic signals as the motorist; phase the signal and install detectors whenever necessary.

Under the category of more-costly-but-desirable roadway improvements are shoulder treatments, wide curb lanes, bicycle routes, and bicycle lanes. But before designating a street as a bikeway under these improvement categories, first eliminate the four hazardous conditions that were just discussed.

Shoulders are often an easy way to create instant bikeways; any paved road shoulder can become a decent bikeway if it is at least 4 feet wide (1.2 m), has a smooth surface, and is delineated by a pavement edge line. Truck blast is a problem on some highway shoulders. Truck blast is the aerodynamic force exerted on the cyclist by a passing truck.[21] The experienced cyclist leans into the truck blast, but can still be sucked into the traffic flow by the drafting action behind a truck. At highway speeds, proposed federal guidelines recommend a shoulder width greater than 4 feet (1.2 m).*

One way to accommodate the cyclist in urban areas is to improve and widen the curb lane. Many cyclists believe wide curb lanes should be a highway design standard.[135] Today, lane width varies depending on the speed of the auto traffic. In some instances it may be possible to reduce auto speed limits and widen the right-hand lane for bicycles. In general, the right-hand lane should be at least 12 to 14 feet wide (3.7 to 4.2 m).* At greater widths, motor vehicles are tempted to use the lane for an additional traffic lane.

* Ibid.

A bicycle route (formerly called a Class III bikeway) is simply a route signed and, hopefully, prepared for bicycle traffic. The Manual on Uniform Traffic Control Devices (MUTCD) provides various methods of signing a bicycle route.[166] It is wise to include additional information on bicycle route signs such as the distance to various destinations. These signs can also be coded to correspond with a route mapping strategy.

Bicycle lanes (formerly called Class II bikeways) cover the range of on-street bikeway designations, although bike lanes can sometimes be included within bike routes. Evaluations have shown that two types of bicycle lanes, bicycle lanes with raised pavement markings or barriers, and bicycle lanes which permit two-way traffic, are the worst examples of the genre; the former because raised markings breed accidents and barriers hide the cyclist from the motorist,[232] and the latter because it forces the cyclist to ride against traffic in one direction, a proven danger.[62] Figure 3 depicts the three most common methods of designing bicycle lanes. Please note that the suggested widths are minimum widths.

All of the bikeways discussed so far sooner or later must cross an intersection. Intersections are where most bicycle/motor vehicle accidents occur, and they are of prime concern to the bicycle engineer. Intersections are discussed in greater depth under Issue D-4.

The bike path (formerly called a Class I bikeway) is a separate facility designed to accommodate bicycles -- and, sometimes, pedestrians -- within an exclusive right-of-way. The bike path is primarily a recreational installation, but a bike path can provide excellent encouragement to bicycle commuters when the path parallels motor vehicle routes. As a piece of traffic engineering, the bike path borrows the same techniques used in highway design. These design considerations* include:

a. Width and Clearance -- The path itself should be at least 8 feet (2.4 m) wide, but 10 feet (3.0 m) is better. You should also maintain a vertical clearance of 8.5 feet (2.6 m).

b. Design Speed -- In general, design for the speed of the fastest rider, that is, 20 mph (32 km/h) on straightaways and 30 mph (48 km/h) on downslopes.

* Ibid.

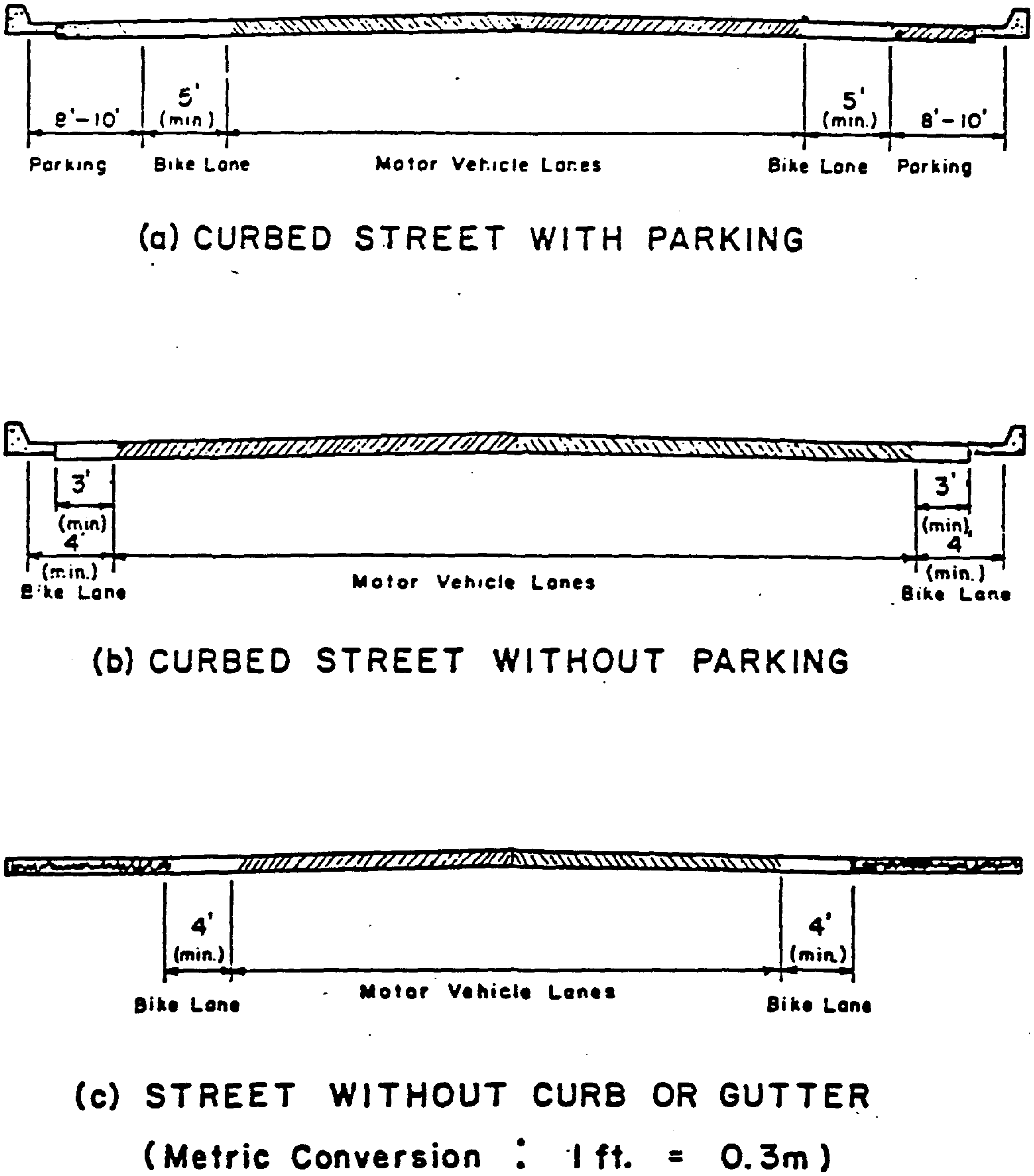



FIGURE 3

TYPICAL BIKE LANE CROSS SECTIONS

<u>Source</u>: Proposed FHWA Bikeway Design and Construction Criteria, <u>Federal Register</u>, August 4, 1980.

c. <u>Horizontal Alignment and Superelevation</u> -- The bike path should have at least a 2 percent side slope to allow for drainage; this slope or banked curve is referred to as superelevation. On curves, a cyclist travelling within the design speed should have no problem negotiating a properly designed curve. Table 5 gives the minimum bike path curvature design radii.

TABLE 5

MINIMUM BIKE PATH CURVATURE DESIGN RADII
(WITH 2 PERCENT SUPERELEVATION)

| DESIGN SPEED MPH (KM/H) | MINIMUM RADIUS FEET (Meters) |
|---|---|
| 10 (16) | 15 ( 5.7) |
| 15 (24) | 35 (10.7) |
| 20 (32) | 65 (19.8) |
| 25 (40) | 100 (30.5) |
| 30 (48) | 140 (42.7) |

Source: "Design Criteria of Bikeways in California," California Department of Transportation, 1976.

d. <u>Grades</u> -- Grades are slopes. Since most bike paths serve as recreational facilities, hills with more than 5 percent upslope may inhibit casual use but are fine for short distances.

e. <u>Sight Distance and Lateral Clearance</u> -- Bike paths are often found in parks and open spaces. In such locations, sight distance is an important design factor both for stopping and for avoiding obstacles, other cyclists, or pedestrians. Figure 4 shows the stopping sight distances for a variety of design speeds. On flat ground at 20 miles per hour (32 km/h) it would take a cyclist 125 feet (38.5 m) to perceive an obstacle, react, and come to a complete stop. Naturally, it is a good idea to keep a certain distance from fixed lateral obstructions and still be able to

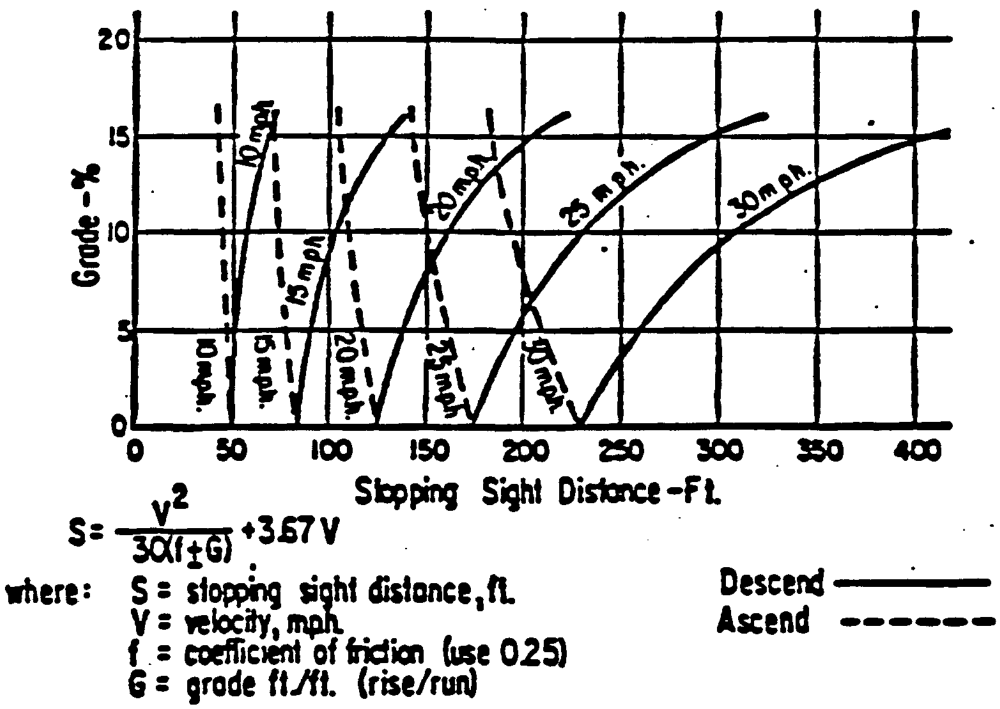



FIGURE 4

STOPPING SIGHT DISTANCES

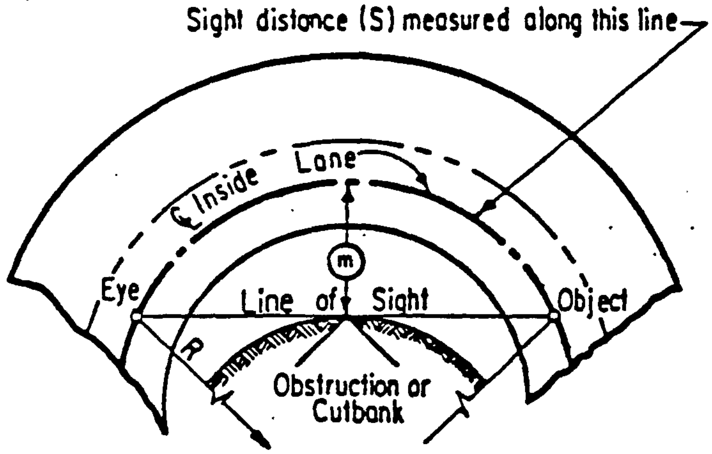
Source: Oregon State Department of Transportation.

come to a stop when rounding a curve; this requires an adequate sight distance for a particular design speed. Figure 5 gives the formula and a chart for determining lateral clearance. If, for example, a cyclist is 25 feet (7.7 m) from an obstruction on his right and rounding a curve with a radius of 75 feet (23 m), his sight distance is roughly 125 feet (38.5 m), then using the previous example, he should be able to stop if he is travelling within a 20 mph (32 km/h) design speed. If the radius of the curve were widened, his sight distance -- and his ability to stop -- would improve.

Evaluations of bike paths have shown that multi-use bike paths and sidewalk bike paths provide less than ideal facilities. Mixing pedestrians and bicycle on multi-use bike paths promotes accidental meetings between the two and detracts from the recreational enjoyment of either party. Widening the bike path or providing separate facilities is a possible, but not probable, alternative given the cost of construction. Since a hard, flat surface is ideal for both modes of transport, there is no real solution to this problem short of adequate signing and human tolerance.

Sidewalks often serve as multi-use bikeways. Most sidewalks are generally not designed to accommodate anything but pedestrian traffic at low speeds, and they present numerous points of conflict at driveways and intersections. Sidewalks can and do present an important design alternative wherever there are child cyclists,[86] but couple their use with bicycling education, and encourage their use only along streets with very low traffic volumes.

Certain circumstances may dictate variations and combinations of facility designs. The planning process should weigh the design alternatives along with other strategies for each particular planning area. In one area of Cupertino, California, for example, they use nighttime parking lanes as daytime bike lanes.[113] In Washington, DC, they allocate the right-hand lanes along some commuter routes to bicycles during normal rush hours. In short, the range of possible bicycle facility alternatives is enhanced, not limited, by the requirements of safe and effective design.




Line of sight is 2.0' above ℄ inside lane at point of obstruction.

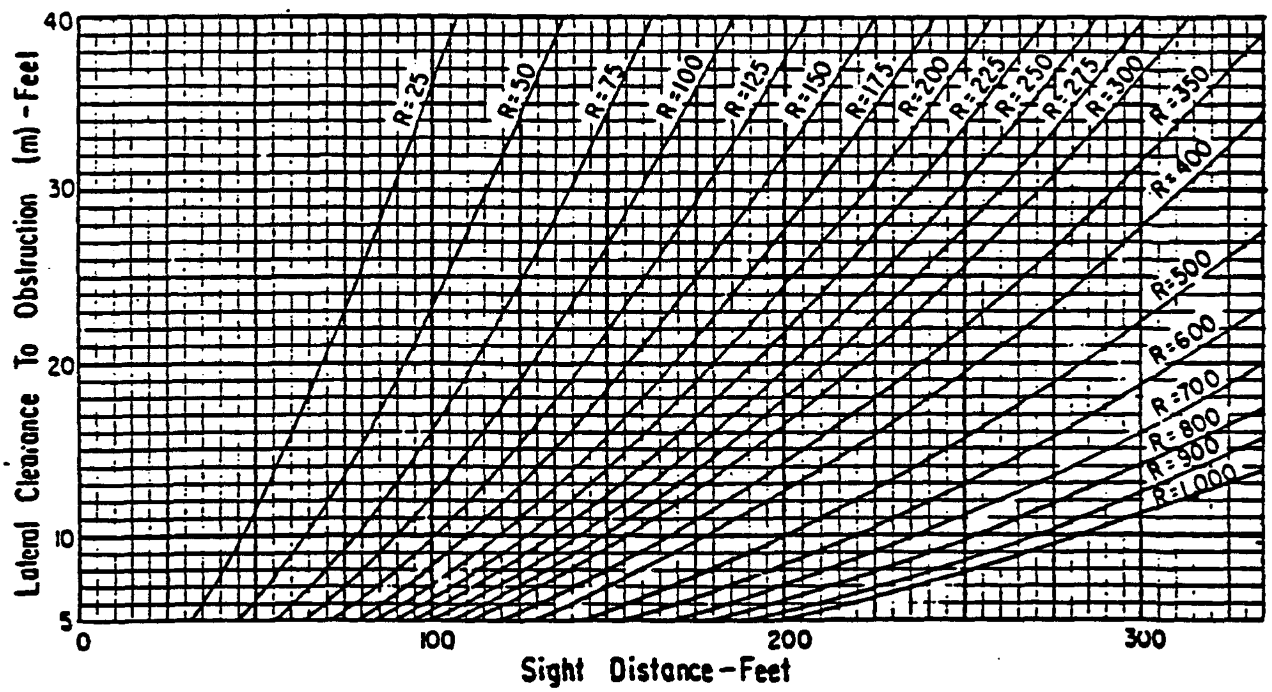
S = Sight distance in feet.
R = Radius of ℄ inside lane in feet.
m = Distance from ℄ inside lane in feet.
V = Design speed for S in mph.

Angle is expressed in degrees

$$m = R\left[\text{vers}\left(\frac{28.65S}{R}\right)\right]$$

$$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R-m}{R}\right)\right]$$

Formula applies only when S is equal to or less than length of curve.




**(Metric conversion: 1ft. = 0.3m.)**

FIGURE 5

LATERAL CLEARANCES ON HORIZONTAL CURVES

Source: Proposed FHWA Bikeway Design and Construction Criteria, Federal Register, August 4, 1980.

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## D-4. HOW SHOULD A BIKEWAY CROSS AN INTERSECTION?

Intersections cause problems for the bicycle facility designer; they are where the mix of vehicles and pedestrians is most acute, and consequently, they are where the most accidents occur.[62] Except when it uses bike paths built on exclusive right-of-ways, all bicycle traffic encounters intersections. All intersections require some form of traffic control whether it be signals, signs, markings, or grade separations. The bicycle, as a vehicle, must observe these traffic control devices, and this means that the bicyclist must understand the proper use of his vehicle and obey the law.[66] Bicycle facility designers have studied the behavior of the bicyclist at intersections in order to make road crossings safer for all concerned.[50,95] But the designer cannot compensate for incorrect behavior, he can only facilitate the execution of proper bicycling technique.

The experienced cyclist anticipates possible panic situations at intersections and knows how to execute an emergency stop or turning maneuver. The skilled biker also adjusts to traffic conditions, makes eye contact with overtaking motorists, and executes vehicular maneuvers using prudent judgement.[255] When approaching an intersection to execute a turn or to proceed straight ahead, he follows proven procedures. The roadwise cyclist rides his bike the same way when there is a bike route or bike lane as when there is just unaltered street.[103] In fact, it is by observing the skilled biker that traffic engineers have learned to adapt intersections to bicycle traffic. This discussion of designing an intersection for cyclists is based upon good technique properly employed. Of course, proper design adds a margin of safety to decisions at intersections, and intersection treatments are a planning alternative.

A cyclist faces three choices at the normal four-cornered intersection: right, left, and straight ahead. The right-hand turn presents the least concern since the cyclist will normally approach from the right-hand side of the street and turn to the right-hand side of the cross street. At signed or signalized intersections, the cyclist should follow the same procedures as the motorist. Unfortunately, a right-hand turning motorist and a right-hand turning cyclist often get into a squeeze play with the cyclist pinned to the right-hand curb. Curb cuts at these corners can serve as escape routes for the squeezed cyclist. Right-turn-only lanes, particularly when they permit continuous merge with cross traffic, allow the motorist and the cyclist to queue in the turn lane, and these also facilitate right-hand turns.

What happens when the cyclist wishes to go straight ahead and there is a right-turn-only lane? Figure 6 addresses four approaches to just such a problem. Again, the figure uses a bike lane for illustration, but the educated cyclist follows the same procedure without a bike lane: at midblock the cyclist looks for a gap in traffic, adjusts his speed to compensate for the approaching gap, and maneuvers into the opening between vehicles. In this case, the traffic engineer or highway designer should plan the intersection around the correct human behavior.

The bike lane should end before the intersection or approach the intersection as a dashed line.[67] Either option allows the cyclist to enter the flow of motor vehicles and make a left turn or proceed straight ahead. Except at busy, unsignalized intersections, the easiest way for the cyclist to proceed straight ahead is to heed the traffic control devices and proceed directly across the intersection. At busy, unsignaiized intersections the cyclist should become a pedestrian and walk his bike across when the gaps in traffic allow.

By far, the trickiest problem for the designer of bicycle facilities is how to encourage good behavior when the biker wishes to make a left-hand turn. Regardless of the number of lanes to the right of the median line, the experienced cyclist plans a left turn maneuver in advance and merges to the left before the intersection. The cyclist is then in a position to execute a direct turning movement across the opposing lane to the right side of the cross street. Had the cyclist stayed to the right until he came to the intersection, he would then have to cross the entire roadway. On one or two lane highways, the designer may choose to end the bike lane before the intersection or use a dashed-line up to the intersection, thus leaving the cyclist with the responsibility of properly executing a left turn. When there is a left-turn-only lane, the designer situates the bike lane to the right of the left-turn-only lane without interfering with traffic proceeding straight ahead. Since left-turn-only lanes at intersections usually have their own signalization, this allows both cars and bicycles to cross the opposing lane of traffic without incident.

Experience with separate bicycle signals has yielded mixed results. Bicycle signals have been used to allow bikers to make both right and left-hand turns and are especially prevalent in European countries. Some bicycle signals are activated by the cyclist and others work automatically through the use of loop detectors buried in the pavement. Warrants for bicycle signals require at least 150 bicycles per hour in one direction, a relatively infrequent occurrence.[93]

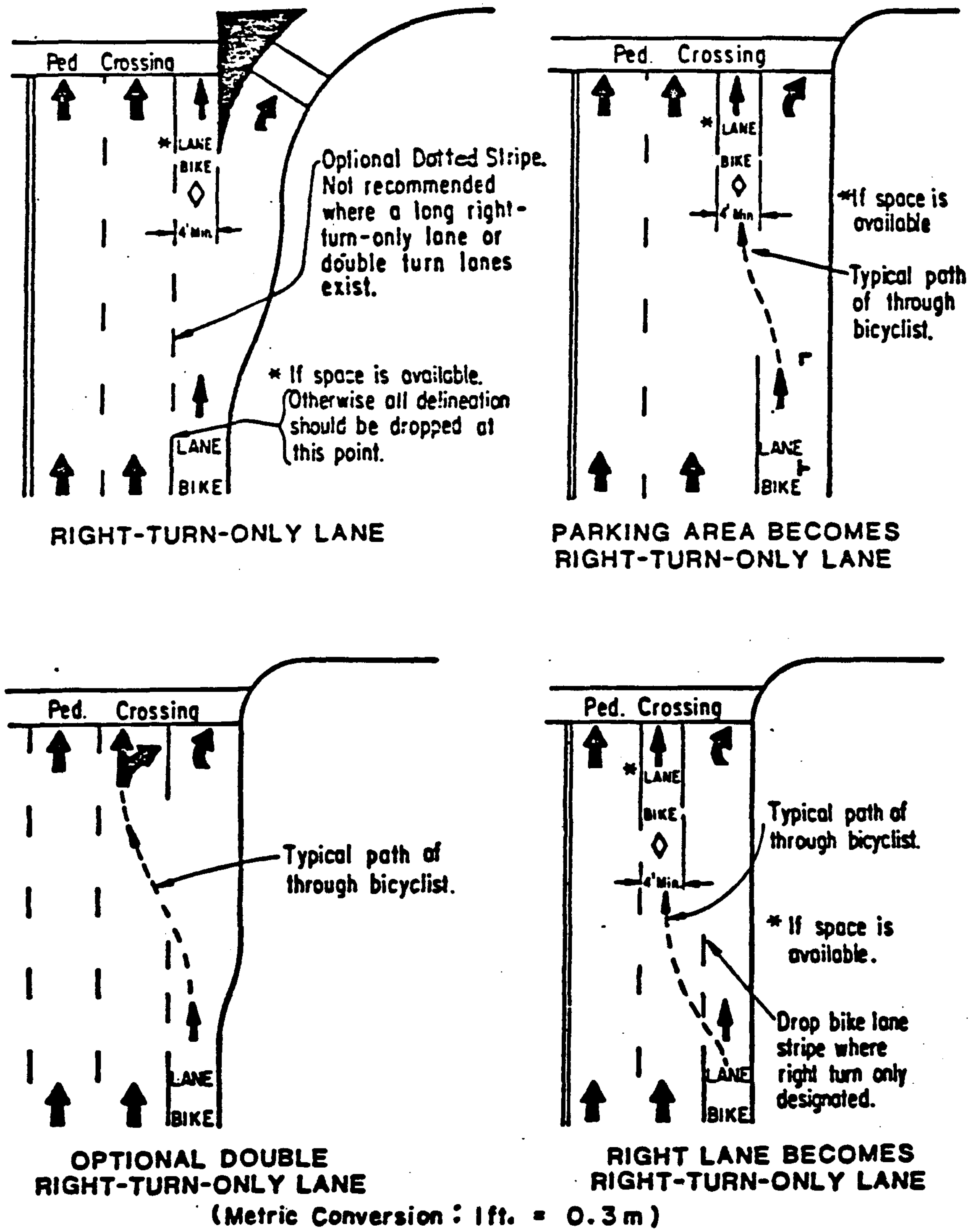


FIGURE 6

BIKE LANE DESIGN AT RIGHT-TURN-ONLY LANES

Source: Proposed FHWA Bikeway Design and Construction Criteria, Federal Register, August 4, 1980.

Loop detectors, however, can work just as well with regular traffic signals and can eliminate the need for special bicycle signals. These signal actuators work by electrical inductance and formerly had trouble detecting the small amount of metal in a bicycle. Cupertino, California has solved many of these problems by utilizing a more sensitive loop amplifier. One detection problem involves the cyclists themselves; they must cross the detector at the proper points in order to be detected, usually riding directly over the coils works best.[114]

It is important to consider these three facets -- extension, minimum, and delay -- when installing a bicycle-oriented loop detector system. The Cupertino system, for example, extends detector output up to 7.75 seconds in 0.25 second increments, provides up to 15.5 seconds of minimum green in 0.5 second increments, and delays detector output up to 15.5 seconds in 0.5 second increments. In the Cupertino system, there is one loop detector 100 feet (33 m) from the intersection and another at the intersection. As the cyclist crosses the first loop, the detection system extends the green light until the cyclist arrives at the intersection; the system then allows the cyclist time to pass through the cross street. At a red light, the system minimizes the waiting time, and the delay feature allows a vehicle to make a turn without delaying other traffic.[114]

The bicyclist must always observe traffic control devices for motor vehicles. On bicycle facilities, there is a special set of signs and markings contained in the Manual on Uniform Traffic Control Devices (MUTCD) which pertains exclusively to designated bikeways. These signs and markings follow the standards set for motor vehicle traffic, and the MUTCD details their placement and sizes.[166]

Where special bicycle facilities are a part of the planning alternatives, the correct design of intersections is the most significant part of an on-street bikeway plan. Because intersections are bastions for the best and worst examples of cycling behavior, implementing this alternative requires education and enforcement. Bicycling education fosters the best and enforcement corrects the worst. Focusing on good intersection design makes good sense.

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D-5. WHAT VARIABLES GOVERN THE NEED FOR PEDESTRIAN AND BICYCLE OVERPASSES AND UNDERPASSES?

There are certain times when a variety of conditions thwart the planning process and its list of simple design alternatives. If no facilities represent one end of the spectrum, then grade-separated facilities, overpasses and underpasses, represent the opposite extreme, especially where cost is concerned. There is no doubt that grade-separated facilities for pedestrians and bicyclists are costly propositions. There is also no doubt that peculiar circumstances demand grade-separated facilities. During the planning process, it may prove necessary to justify the need for a pedestrian and bicycle bridge or tunnel. This need can be based upon empirical criteria; the build or no-build decision is then left to the best informed judgement of the local authorities.[254]

In traffic engineering, sets of definable criteria governing the need for certain facilities are called warrants. Transportation engineers design warrants to eliminate some of the analytical work that follows data collection activities; in other words, warrants provide a formula for quickly evaluating data. In certain European countries, for example, bikeways are warranted when hourly bicycle traffic exceeds 200 vehicles per hour on roads where hourly motor vehicle traffic exceeds 2000 vehicles per hour and speeds are in excess of 40 mph (64 km/h). Recent studies, however, revealed that no country has developed warrants for pedestrian and bicycle overpasses and underpasses.[93]

Having gone through the first steps in the planning process: collected information on specific planning areas and formulated design alternatives, the facility planner may include a grade-separated facility among his list of alternatives. Some of the reasons for a grade-separated facility are:

a. <u>Safety</u> -- This is by far the most compelling reason for grade-separated structures. Overpasses spanning a limited-access highway from a residential neighborhood and designed to protect school children would be a prime example.[8]

b. <u>Delay</u> -- Instances where signalizations, signs, or markings might handle the congestion of pedestrians or motor vehicle traffic but not both.[194]

c. Economics -- When applying a cost/benefit ratio to the construction and maintenance of a grade-separated facility, benefits given dollar values should include safety considerations and the alleviation of delay as well as the lower costs of improved travel time and the costs of alternative traffic control mechanisms.[189]

d. Design -- Under certain conditions, it may prove more aesthetic to build overpasses and underpasses, especially when they are an integral part of a larger plan to channelize pedestrian and bicycle travel. New town planning in Stevenage, England employs this concept.[234]

Deciding to build a grade-separated facility involves balancing considerations of transportation safety with those of engineering, design, and economics. Analyzing accident data for a transportation corridor can help clarify the scope of the safety problem. The number, type, frequency, and severity of accidents may point to a particularly hazardous spot along the right-of-way.[189] A grade-separated facility represents a spot safety measure; as long as people come to that spot and use the overpass or underpass, they are in no danger from vehicular traffic. But accident data often points to several hazardous crossing areas. Here a more linear safety program might appear in order, one that involves numerous signed, marked, or signalized crossing points. Pedestrians are more exposed to risk with the at-grade solutions of a linear safety program, but accident data may favor many linear improvements over one spot improvement on a scale weighing costs and benefits.

An orderly planning process demands assigning relative weights to important criteria when considering a grade-separated structure. Transportation departments in Seattle, Washington[189] and the State of New Jersey have adopted point systems for determining pedestrian grade-separated facilities. New Jersey even has computer programs which evaluate the selection criteria (pedestrian and vehicle volumes, distance to alternate crossing, sight distance, trip generation, etc.), but in the final analysis, every system for locating grade-separated structures requires the informed judgement of planners, engineers, and political decision-makers.[8]

Overpasses and underpasses must follow pedestrian and bicycle design criteria with adjustments predicated on the anticipated demand. In general, following the bikeway design elements (See Issue D-3.) will allow for the freedom of movement of both walkers and bikers. Studies in England, however, have shown that pedestrians tend to prefer overpasses, while bikers prefer underpasses.[234] Because the bicycle carries greater velocity with it, it is easier for the moving cyclist to enter the downslope of an underpass and maintain sufficient momentum to pedal the upslope exiting the tunnel. In the minds of many pedestrians, underpasses, particularly long ones, encourage vandalism and crime. On the practical side, tunnels also tend to be more costly than overpasses.

The threat of vandalism and crime in tunnels points to the larger problem of overcoming human reluctance to use a grade-separated structure, overpass or underpass. In a Los Angeles study, fewer than 2 percent of adults used an overpass across a busy noncontrolled-access highway.[189] In London, pedestrian accident analysis revealed that nurses from a local hospital were crossing a bustling highway function rather than use the available tunnel network.[63] It appears that only hard designs such as channelizing structures or interlocking networks of grade-separated structures can overcome the human propensity to take the most direct and convenient route, whether or not it is perceived as safer than the properly designed alternative overpass or underpass.[7]

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## C. CONSTRUCTION AND MAINTENANCE

The planning and design alternatives may require constructing pedestrian or bicycle facilities. The alternatives should examine the cost of providing a facility, the construction methods, and the maintenance procedures that facility will require. Costs are a variable not only by the material utilized in construction but by geographic location and availability. There are also a number of attendant facilities or procedures which may accompany a particular project; barriers, striping, street furniture, parking, and security are examples. All these costs (see Table 1 under Issue P-1) may cause a reconsideration of other alternative strategies: facility improvements, expanded programs, legislation, etc. Either the possible construction choices will proceed, or the plan must look to other strategies.

This section of the engineering chapter discusses bike lane and bike path construction choices (Issue C-1). It also examines the use of physical barriers to channelize and protect pedestrians (Issue C-2). Bicycle facility maintenance is an often overlooked subject, largely because it usually occurs as an afterthought. Issue M-1 treats bicycle facility maintenance as a normal consideration in the planning process. Issue M-2 then looks at ways to estimate pedestrian and bicycle facility maintenance costs before building starts.

## C-1 WHAT ARE THE BIKEWAY CONSTRUCTION ALTERNATIVES?

It is useful to start the discussion of bicycle facility construction by differentiating between actual construction and scheduled maintenance. Bicycle facility construction is closely related to highway construction; they both accommodate vehicles, although some vehicles weigh more and travel faster than others. Construction usually means a new development in an exclusive right-of-way; hence highway construction involves the building of new roads in corridors where there may never have been any overland transport. Maintenance, on the other hand, is used to mean improvements in existing right-of-ways which enhance the corridor's operations or simply keep it operational. Some major improvements are called reconstructions and are treated like construction projects.

How does this relate to bicycle facilities? Bicycle facility design alternatives include options such as widened curb lanes, paved and stabilized shoulders, and the installation of signs and markings. Many state and local transportation department budgets consider these options maintenance projects, not construction projects. Federal government funding mechanisms allow for the cost of constructing highway and adjacent bicycle facilities; they leave maintaining those faciliites up to state and local governments. Bicycle facilities receive special consideration on federally funded highway projects, but the states ultimately determine how much money they will spend on bicycle facilities. What it boils down to then is this: the planning process must decide whether to initiate a construction project or include bicycle facility considerations on scheduled highway maintenance projects.

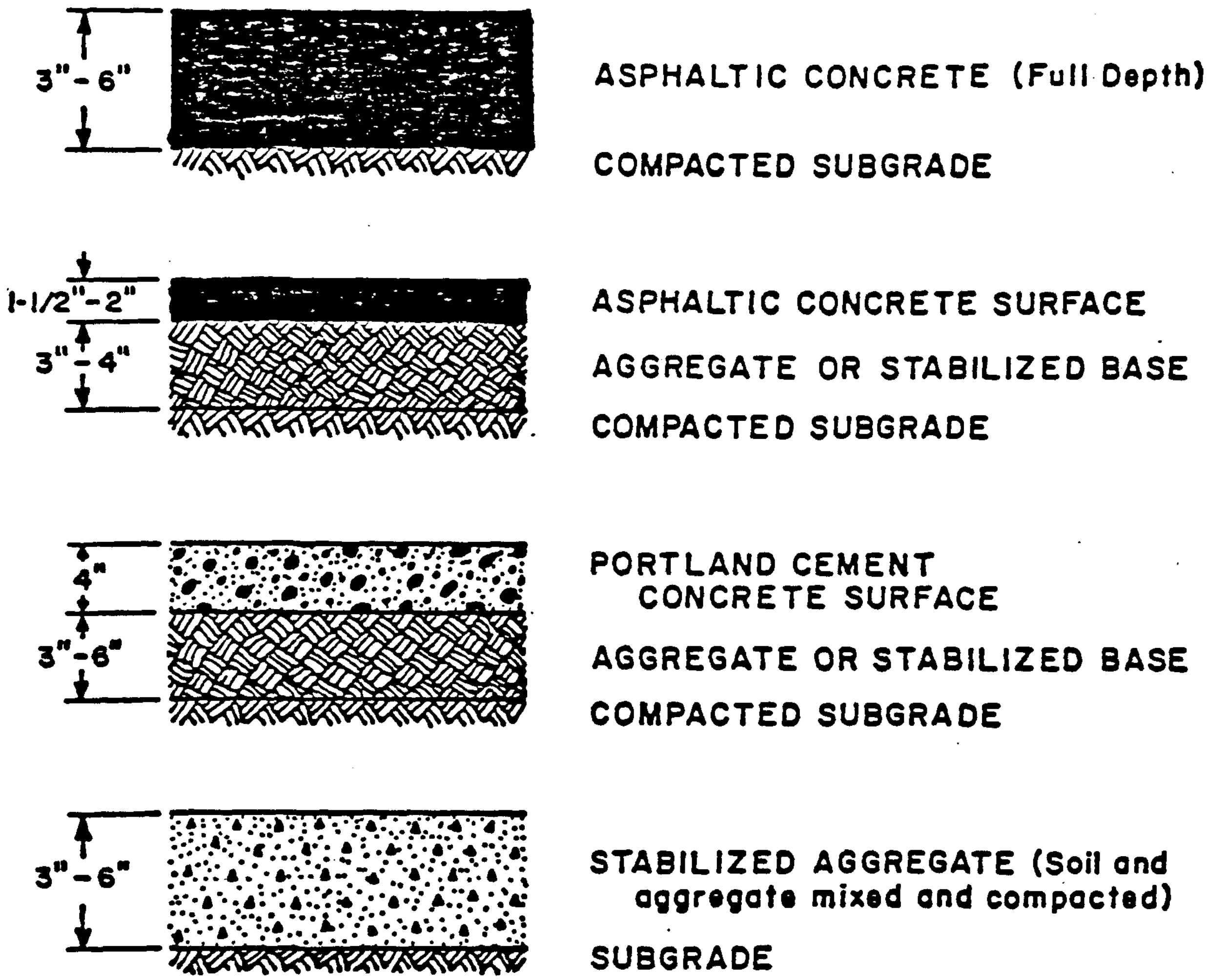
The following discussion treats both construction and maintenance projects like construction projects, but one must be aware that there are cost implications and differing procedures surrounding these planning and design alternatives.

The bicycle facility construction alternatives fall within the common categories of bike routes, bike lanes, and bike paths. Bike paths are the only alternative which requires separate right-of-ways. Bike routes and bike lanes use existing streets that have been designated and improved for bicycle travel. A bike route can include bike lanes within it. While both bike routes and bike lanes may use signs, the bike lane uses roadway markings to set it apart from motor vehicle space. Wide curb lanes and highway shoulders are common bicycle facilities and encompass both the bike route and the bike lane.

Wide curb lanes in urban areas allow the bicycle to operate separately within the traffic stream. Wide curb lanes are a reconstruction project, however, when minor alterations to roadway design -- for example, restriping the roadway to narrow the left-hand lanes for motor vehicles -- will not accommodate both bicycles and motor vehicles safely. Quite naturally, reconstructing the roadway will require adhering to the design standards for motor vehicles. Since these standards exceed those for bicycle traffic, reconstructing a roadway with widened curb lanes is an ideal circumstance. Most states consider accommodations like widened curb lanes on a project-by-project basis before reconstruction begins. The bicycle planning process should parallel state and local transportation planning for just such opportunities.

A highway shoulder can provide an excellent opportunity to construct a successful bicycle facility. Studies have shown that stabilizing and paving shoulders is a low-cost way of decreasing the amount of regular highway shoulder maintenance.[172] Various shoulder treatments, however, do not permit effective usage by bicycles, while paving the shoulder to the same standards as the roadway tends to encourage motor vehicle encroachment. The answer seems to lie in a middle ground, a shoulder surface, delineated from the roadway by an edge line, good enough for bicycle use but alerting the motorist by its texture that is not a part of the roadway. Certain emulsified asphalts or slurry seals do an adequate job in this regard. Emulsified asphalts -- asphalts electrochemically suspended in water -- have been around for over 50 years, but it is only recently that they have received widespread use as a shoulder overlay. Tests in Maryland reveal that slurry seals provide a well-drained surface with low maintenance characteristics. The production rate using a front-end loader and two slurry seal machines was about 100 feet per minute (33 m/min.).[174,223]

Because it will occupy its own right-of-way, the bike path requires a complete engineering design and construction effort. Experience gleaned from the past ten years shows that a variety of construction materials will permit acceptable bicycling.[150] Local circumstances -- terrain, drainage, soil hydrology, and available surfacing materials -- play the most important roles in determining the actual construction plan. Figure 7 offers four examples of possible bike path pavements. The bike path pavement must be strong and stable enough to support the bike and biker and the occasional maintenance vehicle, police patrol car, or other emergency vehicle.




(Metric conversion: 1 in. = 25 mm.)

FIGURE 7

TYPICAL BIKE PATH PAVEMENTS

Source: "A Bikeway Criteria Digest," Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., April, 1979, p.50.

Bike path construction starts with a stable subgrade. This is usually soil. Depending upon the local terrain, this soil will need to be dug out and compacted to provide stability and drainage. While it is not advisable to raise the bike path above the surrounding terrain, this may prove necessary in some areas to allow for ditching and catch basins. Replacing uprooted vegetation adjacent to the bike path is necessary for proper drainage.

Once members of the construction crew have prepared the surface, they may either lay a base course of aggregate such as gravel, slag, fly-ash, or crushed stone, and then the riding surface, or they may lay 3 to 6 inches (75 to 105 mm) of asphaltic concrete or Portland cement concrete directly depending on the local soil conditions.[152] The base course of aggregate with a thin riding surface is a less expensive alternative than the full-depth asphalt or cement concrete treatment.

The least expensive bike path treatment involves a densely graded mixture of soil and aggregate. This type of surface is fine for slow-moving recreational cycling, but it prevents all-weather operation and requires considerable maintenance. The type of soil and aggregate mixture is also a major concern. Wisconsin constructed its Elroy to Sparta Bike Trail using limestone screenings, a byproduct of rock crushing. It provides a stable base and adequate riding surface, but when wet, the lime/soil mixture clings to the bicycle's moving parts encrusting them with a tenacious film which requires a thorough cleaning to remove.

Actual construction of the bike path follows roughly the same procedures as highway construction. After the preliminary terrain cuts and fills along the design lines of the bikepath, finegraders and tailgate spreaders, adjusted to the width of the bikeway, compact the subgrade and lay the aggregate. A slipform paver then lays the top coat of asphalt or cement concrete. For cement concrete, this riding surface mixture should be dense-grade with not more than 10 percent entrained air. Ironically, slipform pavers were developed in the late forties to pave farm roads in Iowa to the exact dimensions of today's bike paths, 10 feet wide (3 m) and 6 inches deep (150 mm). On a recent project, slipform pavers constructed an 8-foot wide (2.5 m), 4-inch thick (100 mm) bikepath at the rate of 500 feet per hour (154 m/h).[201]

The construction of bike paths will demand significant resources. One often overlooked aspect of bike path construction is the amount of ancillary services and support facilities they can require to encourage and accommodate public use. Lighting fixtures, rest stops, parking racks for bikes, and parking lots for cars are just some examples. But bike paths do have their place within the scheme of bicycle facilities; at the very least, they encourage novice riders to perfect their skills within a safe and aesthetic cycling environment. Planning priorities should include programs for both the recreational and utilitarian bicyclist, and bike paths effectively promote recreational cycling.

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C-2. HOW CAN THE USE OF PHYSICAL BARRIERS ENHANCE PEDESTRIAN SAFETY?

Physical barriers contain and channelize pedestrian traffic. Viewed from the perspective of the designer or the pedestrian, barriers either keep pedestrians in or keep pedestrians out. Channelizing pedestrians is usually done to facilitate the flow of walking traffic between two or more points; a line of wooden barriers from a parking lot to a transit stop is an example. In this case, the barrier serves to keep pedestrians moving in a more or less straight line, effectively transferring between transportation modes. Transportation engineers may erect barriers for predominately safety reasons; here the purpose of a barrier is to keep pedestrians away from a safety hazard like a busy street or railroad tracks. Many urban streets in Europe and a few in the United States have employed pedestrian barriers along urban blocks to prevent mid-block crossings and direct the walking public to signalized intersections.[93] Studies in Israel reveal that when pedestrian barriers are integrated into the total design of an urban area (that is, their use is widespread and commonplace), barriers can reduce pedestrian accidents up to 30 percent.[142]

Pedestrian barriers seem to have two distinct drawbacks; first, unless they are designed and arranged correctly, barriers frustrate and inconvenience the pedestrian.[107] This often has the effect of circumventing their safety features; the pedestrian penetrates the barrier and performs an unsafe street crossing. Second, inadequate and unconscientious design can hinder sidewalk maintenance and pedestrian traffic flow.[181] In these circumstances, the barriers become obstacles, instead of channelizing pedestrians flow they disrupt and disperse it. The answer to both problems lies within the mind of the urban designer; pedestrian barriers must be both aesthetically pleasing and effective.

The use of pedestrian barriers in the design of open air and enclosed shopping malls has reached a refined state-of-the-art.[59] Aesthetically designed barriers -- planters, benches, stairs, gazebos, porches, fountains, sunken rest areas, sculptures, colored tiles and lights -- direct shoppers along carefully laid-out commercial streets. Marketing studies have shown correlations between shop locations and likely pedestrian walking patterns. Mall designers disrupt these walking patterns, in effect, channelizing pedestrians through the mall. For his part, the pedestrian may feel inconvenienced, but he is seldom aware that he is being manipulated.

Urban designers can take a note from the shopping mall designers and apply nondisruptive channelizing techniques to the urban street setting. Their purpose would be pedestrian safety, but in the properly designed environment, there is little reason for the pedestrian to feel inconvenienced. Of course, there are other times when pedestrian barriers should inconvenience. Urban play streets, for example, should offer a motor vehicle deterrent and invite pedestrian use, but they should allow sufficient distance between play area and street to prevent any child from charging blindly into the street while playing a game.[37]

Applying aesthetic design to pedestrian barriers eases their acceptance by the walking public. Barrier design can challenge the limits of artistic interpretation; a study of different types of barriers would reveal a variety of man-made and natural products blending into and clashing with their intended purposes. The concept of pedestrians barriers as street furniture deserves further exploration; they can both enhance the urban environment and foster pedestrian safety.

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M-1. HOW SHOULD A BIKEWAY BE MAINTAINED?

Mobilizing the community resources to build a bicycle facility should include a commitment to ensure adequate support for the facility once it is constructed. The building of isolated, unplanned bicycle facilities bears fruit called potholes, overgrowth, standing water, debris, dead leaves, drifted sand, and disuse. Bicycle facilities need the same care and attention as the family car; they need cleaning, repairs, and frequent use; in short, they need regular maintenance.

The best way to ensure bicycle facility maintenance is to plan for it and schedule it.[253] The experience of local and state bicycle coordinators demonstrates that bicycle facilities -- bike routes, lanes, and paths, require more frequent maintenance than roadways designed for motor vehicles. This need not be the case, but limited funds for bikeway construction have dictated that the resulting riding surfaces were often adequate but not ideal. Even when properly designed and constructed, bikeways, by their nature, demand a higher frequency of maintenance simply because the bicycle operates most efficiently on hard, dry, smooth pavement free of natural and man-made obstacles.[14] Motor vehicles, on the other hand, can forgive the roadway's minor deformities; their motion also causes an automatic sweeping action which deposits dirt and debris on the shoulders. For this reason, it is a good idea to construct bike lanes next to the roadway so that this sweeping action "cleans" at least part of the bike lane.

As was discussed earlier (see Issue C-1), normal highway maintenance is a rather infrequent occurrence and generally refers to somewhat larger and more costly operations like resurfacing. Vegetation and debris removal is a regular maintenance operation only on major primary and secondary roads; street sweeping is largely restricted to urban areas. In most states, however, highway maintenance is a discretionary function left to the judgement and resources of the local city, county, or state district engineer.[87] Therefore, whether planning bicycle facilities or operating existing ones, coordination with the local highway authorities is a must. Very often they will simply schedule maintenance operations like hazardous potholes or accumulated debris and complete them within a short time, especially if they perceive (with the help of cyclists) a serious unsafe condition.

Bike routes and bike lanes are within the highway right-of-way; they may or may not be considered part of the roadway, but they are subject to scheduled highway maintenance procedures and equipment. The bike path, however, because of its separate right-of-way, may be outside the jurisdiction of the highway department. While the bike path was probably constructed to bicycle design standards which will accommodate occasional motor vehicle traffic, it may not be able to accommodate mechanical maintenance equipment. Regardless of accessability, most bike paths require significant hand labor for sweeping and vegetation and debris removal.[240] In addition, soft surface paths composed of solid and aggregate mixtures will require periodic scraping and filling.

When federal funds are used to construct a bikeway, the supporting agency, usually the state, has the responsibility to maintain that facility. Similar restrictions generally apply to state and local funds. The best approach to ensuring bicycle facility maintenance, therefore, is to ensure that a facility maintenance program has governmental approval prior to construction.[253] In North Carolina, their bicycle transportation plan[258] has not forgotten maintenance:

> "It is the policy of the Board of Transportation that the state highway system shall be maintained in a manner conducive to bicycle safety, consistent with the following guidelines:
>
> a. State built bikeways and secondary bicycle facilities within the right-of-way are to be maintained to the same degree as the state highway system.
>
> b. Existing parallel drainage grates are to be replaced with bicycle safe drainage grates where bicycle usage is evidenced through bicycle traffic data, or where bicycle accidents have been recorded. All other parallel drainage grates (within the curbing) shall be painted in the manner indicated in the Manual of Uniform Traffic Control Devices.
>
> c. Other factors being equal, priority for highway maintenance (shoulder, potholes, repaving, edges, debris, etc.) is to be as follows:
>
> (1) highways with known bicycle traffic,
>
> (2) Bicycling Highways routes, and

(3) highways providing access to recreational areas."

The bicycle facility planner must be aware, of course, that bicycle facilities compete with motor vehicle facilities for resources. Until there are dramatic increases in the bicycling population, this will surely remain the case. For now, bicycle facility maintenance must accommodate itself to established highway maintenance procedures.

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M-2. HOW ARE PEDESTRIAN AND BICYCLE FACILITY MAINTENANCE COSTS ESTIMATED PRIOR TO CONSTRUCTION?

Maintenance is an investment decision. Auto mechanics are fond of delineating between the two schools of thought regarding maintenance. In one group are the vehicle owners who drive until something goes wrong, in which case they drive or tow their vehicle in for service. These people believe in emergency maintenance; they frequently get stuck with major bills. In the other group are the vehicle owners who continually maintain their vehicles; they anticipate problems and schedule regular maintenance calls. These people plan ahead for major repairs and seldom need expensive emergency servicing. Planning and constructing pedestrian and bicycle facilities has utilized both schools of thought; more often the former than the latter.

Any facility planning effort needs to examine operation and maintenance costs during the feasibility stage of the planning process.[37] For public facilities like pedestrian or bicycle facilities, however, decision-makers have often assumed that the facility will have public benefits which outweigh its costs while providing a more visible sign of action than less costly, less recognizable alternatives.[252] In medium and large cities, operations and maintenance costs for one new facility are often assumed to be a small factor when overall maintenance budgets are considered. Except for street repairs, maintenance scheduling of public facilities for pedestrians and bicyclists is a relatively new science.[198]

Private investment decisions involving facilities always include operations and maintenance for the projected life of the facility. Private investors are looking for a profitable return; this requires them to estimate both total costs and total income for the life of the facility. The methods they use to estimate maintenance costs prior to construction have a carry-over value for pedestrian and bicycle planning efforts; they use economic analysis and cost/benefit analysis to conduct a preconstruction evaluation. (See Issue E-1 for a further discussion of evaluation techniques.) The facility planner may not be after a dollar return on the facilities, but he should be able to document a project costing picture which allows the decision-makers to select alternatives.[30,87,228]

Using any preconstruction evaluation strategy, the planning process aims to determine the value of the planning alternatives using real and assumed "costs and benefits." By conducting a trade-off analysis, the planner can estimate which alternative strategy yields the greater benefits and structure his budget to accommodate the most effective alternatives.[2] If there is a $100,000 budget and five alternatives which would each cost $100,000, then the selected alternative would be the one which produces the highest benefit.

Maintenance costs have three major elements: labor, equipment, and materials. Perhaps the most effective way to arrive at a maintenance cost estimate for either a pedestrian or a bicycle facility is to simply compare the planned facility with other similar facilities already constructed and operating.[165] Pedestrian facilities like sidewalk systems are common design elements in urban areas, and maintaining bicycle facilities like bike lanes can be considered part of the street maintenance apparatus. Comparing representative city budgets for maintenance costs estimates and costs actually incurred over a number of years will give the planner comparative figures for drawing estimates.

## PEDESTRIAN FACILITIES

Pedestrian facility maintenance costs vary according to functions of:

a. Physical design

b. User characteristics

c. Accessibility by maintenance crews

d. Proximity to other publicly maintained areas

e. Public or private ownership

f. Security procedures

g. System enclosure

Using these parameters, pedestrian facilities such as sidewalks incur minimal maintenance costs, whereas more elaborate facilities such as enclosed malls and interconnecting skyways require more elaborate maintenance operations. Table 6 displays operating and maintenance cost estimates for several walkway systems in major urban centers. An FHWA study conducted in 1974 estimated that open street malls, for example, require an operations and maintenance cost of $2.25 per square foot per year. Maintenance costs will rise with the age of the facility until they reach a point where further maintenance is not justified and the facility must be replaced. Fortunately, pedestrian facilities do not have an accelerated maintenance cost curve because they do not contain mechanical systems. Essential future costs, therefore, often include only the inflated costs of labor and materials.[165]

TABLE 6

ALLOCATION OF OPERATION AND MAINTENANCE COSTS

| O & M CATEGORY | PERCENTAGE ALLOCATION |
|---|---|
| Taxes | 25 |
| Maintenance/Repairs | 41 |
| Utilities | 14 |
| Security | 14 |
| Miscellaneous | 6 |
| | 100 |

Source: RTKL Associates, Inc. estimates.

BICYCLE FACILITIES

Because the bicycle is a vehicle which uses the regular street system, bike routes and bike lanes -- as long as they are part of the roadway -- require maintenance similar to the maintenance performed on streets and highways: restriping, signing, signalization, cleaning, weeding, patching, etc. Bike lanes on the shoulder of the highway require more frequent maintenance than the roadway itself because they are not built to the design tolerances of the roadway, they accumulate dirt and debris, and they are subject to the encroachment of vegetation.[174] Studies of low-volume roads which use asphalt or bituminous surfacing (similar to highway shouldering) indicate that the riding areas should be resurfaced once every five years.[9] Except for local operating experience, there are no evaluations which suggest intervals for regular bike lane maintenance. This local experience indicates that the interval between cleaning and sweeping of the road shoulder should be more frequent where there is bicycle travel.

Bike paths on their own right-of-way present a unique maintenance problem since they require a separate and special maintenance effort which may or may not be tied into the normal highway maintenance schedule.[152] For practical purposes it may be best to consider the bike path as a mini-highway project with its own maintenance needs. A study comparing state highway department expenditures for highway maintenance in 1976 showed a wide variation, from a low of $534 per lane mile in South Carolina to a high of $3,674 in Connecticut.[169] Using the state or local highway system as a yardstick, the local planner can estimate a yearly amount for bike path maintenance. Multiply the number of miles of planned bike path times the maintenance cost per mile of a similar stretch of highway in the planning area. Dividing by the estimated total cost of constructing the bike path will provide a percentage of estimated yearly costs for the life of the bike path.

The average bike path constructed in the early 1970's cost approximately $40,000 per mile ($25,000 per kilometer). For purposes of illustration, assume that costs for bike path construction and highway maintenance have not changed since then. A planned five-mile bike path would thus cost $200,000 to construct. If a state maintained its highways at a cost of $2,500 per lane mile, the estimated yearly maintenance cost would be $12,500 for the bike path, or 6.25 percent of the total construction cost.

Until better information is available on the cost and maintenance of both pedestrian and bicycle facilities, bicycle planners will have to rely on rule-of-thumb methodology and past operating experience. For now, it is essential to include some estimate of maintenance costs with the facility planning alternatives. Only in this way can the decision-making process fully assess facility costs.

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# II. EDUCATION

Bicycle and pedestrian facilities are only a part of a comprehensive approach to meeting the needs of the cycling and walking public. Of all pedestrian and bicycle programs, an effective method of educating the public is the most important. A person who learns the rules of the road and properly executes lawful maneuvers--whether pedestrian or vehicle driver--not only avoids accidents but sets an example for others. It is often easy to violate vehicle codes and traffic ordinances; selected enforcement would curb a portion of these violations, but it is the self-regulation imposed by education which dictates each individual's proper response to hazardous situations within the public right-of-way.

This chapter first discusses the relationship between a user's education, society's enforcement, and the engineering of pedestrian and bicycle facilities. The second issue examines and compares educational strategies, the role of human factors in educational programs, and methods for reaching the adult and child cyclist and pedestrian. The third issue is an overview of the use of accident data and the behavior patterns of cyclists and pedestrians which that data suggests. Lastly, Issue Four elaborates on some of the countermeasures that researchers and engineers have developed in their effort to reduce motor vehicle and pedestrian accidents and motor vehicle and bicyclist accidents. All of the issues in this chapter are so closely related that it may be more beneficial to read the entire chapter than specific issues.

UE-1. WHAT IS THE RELATIONSHIP BETWEEN EDUCATION, ENFORCEMENT, AND THE ENGINEERING OF PEDESTRIAN AND BICYCLE FACILITIES?

The pedestrian and bicyclist's desire for a safe operating environment forms the relationship between education, enforcement, and engineering. Pedestrian and bicycle planning seek to accommodate changes which occur within the two modes of transportation. As the planning for these transportation modes has matured, so has the recognition that education, enforcement, and engineering must not be treated independently. To accomplish its safety objectives, pedestrian and bicycle planning need a set of goals which include an educated public, the punishment of unsafe behavior, and the design of facilities which complement and promote safe behavior.[214]

This interrelationship between education, enforcement, and engineering has never really gone unnoticed. In Cranford, New Jersey and Havre de Grace, Maryland, their bicycle programs have successfully combined intensive educational efforts with strict enforcement of municipal bicycle ordinances and state laws.[67] They recognize that both aspects must be continual if they are to reduce accidents--which they have--and alter the public consciousness. In Australia, the Geelong Bike Plan paints a programmatic picture composed of four "e's"--education, enforcement, engineering, and encouragement. Their plan includes facilities but downplays facilities as an answer to bicycle safety problems.[108] In the same vein, a pedestrian safety study in Riverside, Calibornia recommended improved pedestrian facilities as the city can afford them but continued education and increased enforcement in the meantime.[17] Local pedestrian and bicycle planning should emulate these efforts: initiate education and enforcement programs before, during, and after building facilities.

There is significant evidence to prove that people exposed to pedestrian and bicycle education programs have fewer accidents than those who do not have that exposure. Recent accident studies of experienced cyclists in California[102] and educated child pedestrians in West Germany[139] seem to reaffirm this conclusion. But education need not involve classroom instruction; experience is often the best teacher. Often common sense or the good example of others teaches us to avoid unsafe situations. Because unsafe behavior can have societal costs--accidents and property damage, for example, --repeated exposure to dangerous situations should bring a sterner warning. It is at such times that selective enforcement can have its greatest impact.

As we become adults, our behavior patterns solidify somewhat. It is easier, therefore, to reach and change a child's behavior after he has violated a pedestrian or bicycle law. In these situations, young children are very often not aware that they have to follow certain procedures for their own safety and for the benefit of society. A New York study of bicyclist behavior, on the other hand, found that adult cyclists know and understand the rules of the road but chose to violate them anyway.[78] For the adult violator, enforcement should serve to deter unsafe behavior.

Both the child and the adult pedestrian and bicyclist need to feel the twin forces of education and enforcement at work in order to reinforce their safe behavior, but they need to see the visual evidence of society's desire for safety. This is where proper engineering--facilities, signs, markings, and design--tie into education and enforcement; properly engineered facilities should reinforce proper behavior while preventing incorrect or unsafe behavior.[260] Pedestrian barriers and bike lanes are examples of engineering attempts to come to grips with a planning goal calling for safer walking and bicycling environments. At its best, a properly designed facility can be an instructional device. In Cupertino, California, they use a bicycle left-turn lane with a loop detector to teach inexperienced cyclists how to correctly make a left-hand turn.[114] An experienced cyclist would execute the proper maneuvers without a special facility, but the presence of the facility helpe instruct motorists and cyclists alike in what is for many an unfamiliar situation. In a similar fashion, signal actuators designed for pedestrian use help eliminate unsafe street crossings, especially by the elderly and handicapped.

Of course, the safety objectives of education, enforcement, and engineering can run into a variety of forces besides human behavior working against them. Different educational approaches can affect perceptions of proper behavior. (See Issue UE-2.) Pedestrian and bicycle laws also differ from state to state and jurisdiction to jurisdiction.[186] In some states the pedestrian always has the right-of-way, in others, pedestrians cannot assume they have the right-of-way. In order to have effective pedestrian and bicycle education and enforcement programs, therefore, the underlying laws and regulations must be reasonable, have perceived merit, reflect behavioral realism, be understandable, be enforceable, and be based on reciprocity, the mutual responsibility of motorists, bicyclists, and pedestrian for one another.[34] Despite these problems, local planning efforts can use accident data to identify vulnerable population pockets--grade schools and nursing homes, for example--and design education, enforcement, and engineering countermeasures specifically for those locations--crossing guards, safety lectures, special crosswalks, etc. The truly effective and essential relationship between the safety objectives of education, enforcement, and engineering in a pedestrian or bicycle plan find their realization in the application of creative solutions at the local level.

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## UE-2. WHAT ARE THE EDUCATIONAL PROGRAM ALTERNATIVES FOR PEDESTRIANS OR BICYCLISTS?

Education should be a primary program element in the pedestrian or bicycle plan because it is the communication of proper procedures which, through their exercise, minimize the role of law enforcement and allow for the effective utilization of facilities. Planners and educators often tailor pedestrian and bicycle education programs to meet community needs. While the community's perceived need usually involves the safety considerations of walking or bicycling, the educational emphasis has often concentrated on unsafe behavior, rather than proper techniques. Today some pedestrian and bicycle education programs make extensive use of behavioral data gleaned from observational and accident analyses, and they apply this information to real life.[142] Unfortunately, many local pedestrian and bicycle safety programs still rely on safety lectures alone to get the message across.[67] Rising pedestrian and bicycle accidents demand that preconceived ideas and old solutions give way to more comprehensive programs built on operational experience and careful evaluation.

One question common to the needs of pedestrian and bicyclists is: Who should teach pedestrian and bicycle education? While the schools seem like a logical answer, there is teacher resistance to adding pedestrian and bicycle education to an already crowded teaching agenda. Local police or community service organizations like the Police Athletic League or the Elks frequently stage one-day lectures, "rodeos," or "safety towns," but proper education demands a more reliable and consistent approach.[60] In West Germany, specially assigned teachers conduct mandatory pedestrian and bicycle education courses for all children under the age of 12.[139] This program has been highly successful, but it might appear as a luxury to some American school systems. Whether the school, the police, or some third party is responsible for pedestrian or bicycle education, accident studies continue to document the need for streetwise pedestrians and bicyclists.

### PEDESTRIAN EDUCATION

Pedestrian accidents are largely an urban phenomenon; about 85 percent of all pedestrian accidents occur in cities.[167] Some cities -- Baltimore, Denver, Milwaukee, San Diego, Washington, DC--have recently created the post of Pedestrian Coordinator in response to the accident problem. Depending on the locality, the pedestrian coordinator may take responsibility for pedestrian education, pedestrian troubleshooting, facility design information, pedestrian planning and research, and management information. The pedestrian coordinator is important to pedestrian education because he or she provides a focal point for educational information and a place where the comparative analysis of pedestrian educational programs can take place.

Pedestrian safety programs concentrate on safe methods of crossing the street, and they are aimed primarily at children under age 12 and, occasionally, the elderly. Safety themes in pedestrian education usually emphasize avoiding the street. Not playing in the street and not running into the street between parked cars are examples. To cope with unsafe behavior, some pedestrian programs attempt to teach children when they can safely cross a street in the absence of traffic control devices. This procedure involves the estimation of gap time, the difference in the time it takes an approaching motor vehicle to arrive and the time it takes the child to safely cross the street. Recent studies have shown, however, that a child's estimation of gap time is not very reliable; they have difficulty gauging the speed of oncoming vehicles, particularly in unfamiliar surroundings. Estimating gap time appears to be a learned skill which gradually improves between the ages of 5 and 12 until, as adults, it is taken for granted.[128]

Children learn from watching adult behavior. The adult approach to crossing a road relies on selecting a safe time to cross rather than on a safe place to cross. Structuring pedestrian education for children demands a program based on an assessment of a child's learning ability at a certain age. Adults differ from children in their ability to assess the road situation before approaching the curb; children are unable or unwilling to use this strategy.[112] Adults frequently start to cross before the road is clear; children are taught not to step into the street until the traffic has cleared. Adults can also gauge two streams of traffic at once, while children concentrate on only one.[127]

Pedestrian programs for children often rely on colorful posters illustrating correct and incorrect behavior. Very often cartoon characters explain the safe way to cross a street and warn against unsafe activities around motor vehicles. A research program in New South Wales, Australia, however, concluded that cartoon literature used to teach children between the ages of five and eight contradicts normal child development; that is, cartoon characters are not a positive model for real-life traffic situations; children become more involved with story content than with the safety message. During the early grade school years, children learn by rote and do not readily apply this learning to everyday life. For this reason, the study suggests that children under age eight should cross the street only under supervised conditions.[213]

Experience with pedestrian educational programs reveals that they should be continuous during the grade-school years and regularly scheduled, reinforcing previously learned behavior. For these reasons, many pedestrian education programs include activities for specific ages and grade levels. A pedestrian safety program produced by the Ohio Department of Education ties pedestrian safety instruction into regular school subjects; children learn the colors of different signs and the concepts of right and left as they receive pedestrian safety messages.[111] Recent projects by the National Highway Traffic Safety Administration include one aimed at developing pedestrian training programs for children in kindergarten to third grade and another concerned with designing and testing prototype pedestrian safety messages.

Pedestrian education programs for adults usually consist of safety signs and markings. Some pedestrian programs in England have begun to focus on the elderly because of their proportionately high accident rate.[190] While it appears from local experience in America that some form of instruction may be helpful for the elderly, there is very little literature on the subject. Case studies and evaluations by pedestrian coordinators could pinpoint the benefits of pedestrian education for the elderly.

## BICYCLE EDUCATION

Bicycle education is driver education, and educators should treat it seriously. Unlike pedestrian education, bicycle education deals with conduct on the roadway among moving vehicles, yet many bicycle education courses have treated the bicycle as a child's toy and the bicyclist as a pedestrian on wheels.[178] That is, pedestrian and bicycle education have overemphasized the avoidance of unsafe behavior, detailed the hazards of the street, and used cartoon characters as role models. Research has shown that this is not the proper approach.[67] In a study conducted for the Consumer Product Safety Commission, elements of various bicycle safety courses were compared to bicycle accident data in an attempt to structure the important elements of a bicycle education curriculum by age groups.[149] Figure 8 depicts the result of this effort. While it is important to stress certain elements to specific age groups, it is equally important to remember that behavioral and development characteristics affect the learning process.[202]

According to several studies, children should not bicycle in the street until about the age of nine. Before age nine, children do not possess the physical dexterity and perceptual skills required to maneuver in traffic.[213] Bicycle education, therefore, should concentrate on a graduated program of skill development starting with the simplest riding and control techniques in the early elementary school years and working up toward supervised on-street riding and maneuvering at about the fourth grade. This more comprehensive method would teach the rationale behind the rules of the road as well as the behavioral techniques required to operate a bicycle in the roadway.

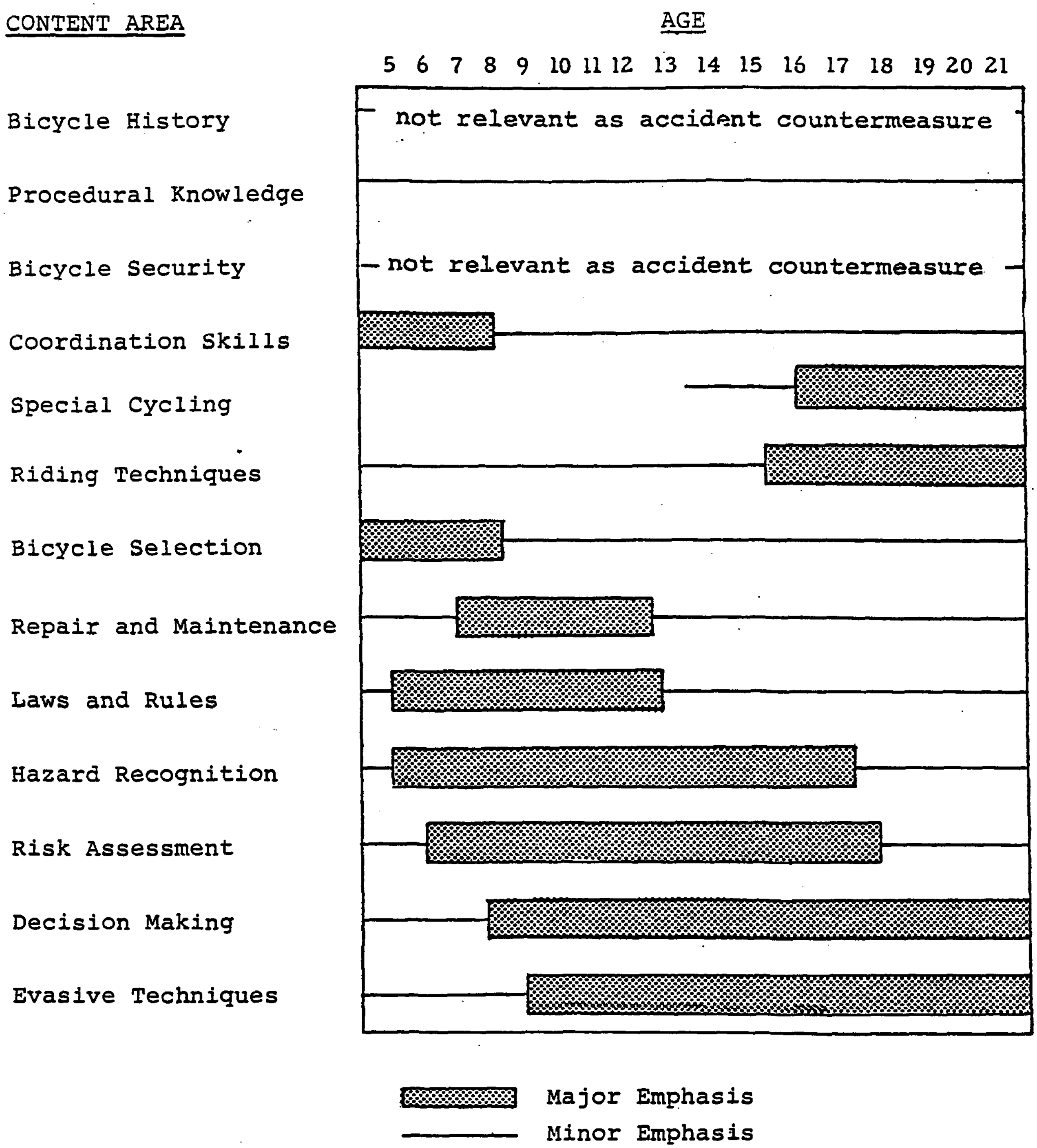


FIGURE 8

BICYCLE CURRICULUM EMPHASIS BY AGE

Source: Adapted from: LaFond, Don, "The Bicycle Safety Atlas," Maryland State Department of Education, Consumer Product Safety Commission.

Bicycle educators have identified five problem area in bicycle curriculum content:[60]

a. Message Tone -- In some bicycle courses, the subliminal message portrays the bicycle as a nuisance. Bicycle instruction should teach proper riding techniques and the responsibilities of vehicle drivers.

b. Message Focus -- Rather than concentrating on knowing the law, courses should stress obedience to the law, particularly in hazardous situations. This requires the actual on-street exercise of proper riding techniques.

c. Informational Accuracy -- There are many times when a general rule such as ride to the right does not apply, for example, at intersections. Correcting these errors requires instructional guidance from experienced bicycling teachers.

d. Delivery Methods -- Bicycling correctly demands a combination of classroom instruction and on-street experience, but the on-street experience is by far the most essential aspect of teaching.

e. Teacher Involvement -- Teacher preparation for bicycling instruction should include lesson plans and audiovisual aids. Ideally, the teacher should be a biker who has received in-service training in bicycling skills and bicycle education.

One of the most complete books of bicycling instruction is John Forester's Effective Cycling.[103] The book and the course which accompanies it concentrate on equipment and proper riding techniques. The Effective Cycling course consists of 30 hours of instruciton, with about two-thirds of the time devoted to actual on-street practice. While the book itself is geared toward the adult cycling enthusiast, it has influenced many of the new bicycling and bicycle safety courses which emphasize correct procedure and bicycling proficiency.[67] The National Highway Traffic Safety Administration is currently developing a methodology to help state and local administrators select appropriate bicycling education programs.

Bicycling is often "invisible" to those who should be most aware of its presence. When focusing bicycle education programs, the audience should include motorists, law enforcement officials, and transportation planners and engineers. Accident research shows that motorists frequently do not understand the bicycle's place in the traffic flow. Police officers and judges are often unfamiliar with the legal status of the bicyclist and reluctant to enforce a biker's violation of the normal rules of the road. The design and construction of poorly-located and underutilized bike lanes and bike paths points to the importance of including the traffic engineer and transportation planner in classes dealing with bicycling proficiency, riding techniques, and lane maneuvering.[67]

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## UE-3. WHAT DOES ACCIDENT DATA INDICATE ABOUT PEDESTRIAN AND BICYCLIST BEHAVIOR?

Unsafe behavior is a frequent occurrence, while accidents are few. Accidents which involve pedestrians and motor vehicles or bicycles and motor vehicles tell something about the behavior of the participants and the conditions which precipitated the accident. (There is, unfortunately, very little available data on pedestrian and bicycle or bicycle and bicycle accidents.) Nonaccident behavioral analysis or risk exposure analysis attempts to observe and record human behavior at certain critical areas in the street system, intersections, for example. Accident data analysis pinpoints these hazardous spots and looks at critical patterns of human behavior. This particular issue is concerned with accident data and not risk exposure analysis; for a discussion of risk exposure analysis, see Issue E-2; for a discussion of the interconnection between education and observed behavior, see Issue UE-2.

Accident data, usually taken from police files, are subject to the biases of the reporting police officer, the participants themselves, eyewitnesses, and the format of the reporting system.[10] These biases seem to run against children and cyclists.[45] It is useful, therefore, to compare accident data with risk exposure data. This comparison will focus on specific populations or specific areas where remedial education, enforcement, and engineering strategies can do the most good.[78]

PEDESTRIANS

Pedestrian accidents are characterized by certain aspects similar to motor vehicle accidents: the frequent influence of alcohol and increased risk during darkness and wet weather. Pedestrian accidents are much more severe, however, and occur primarily in cities. About one-sixth of the national highway death toll in any given year is comprised of pedestrian fatalities, and 85 percent of all pedestrian accidents occur in urban areas.[187] The National Highway Traffic Safety Administration has categorized pedestrian accidents into approximately 30 specific types.[68] Of these, seven types account for 60 percent of all urban pedestrian accidents:

a. Dart-Out (33 percent) -- A pedestrian appears suddenly from the roadside, perhaps from between parked cars, is not seen by the motorist, and is struck.

b. Intersection Dash (8 percent) -- A pedestrian runs across a marked or unmarked intersection; the driver does not see the person and strikes him.

c. Vehicle Turn/Merge with Attention Conflict (6 percent) -- The driver is turning into or merging with traffic and strikes a pedestrian approaching from a different direction. The driver's attention was diverted so that he did not see the pedestrian.

d. Multiple Threat (3 percent) -- A pedestrian is crossing in front of a stopped vehicle when a second vehicle, approaching in another lane, does not see him and strikes him.

e. Bus Stop Related (3 percent) -- A pedestrian, crossing in front of a bus which has stopped to discharge passengers, is struck by a vehicle.

f. Vendor-Ice Cream Truck (2 percent) -- A vehicle strikes a pedestrian while he is going to or from a street vendor.

g. Backing Up (2 percent) -- A vehicle backing out of a driveway or parking space strikes a pedestrian.

These types of accidents suggest a failure by the pedestrian to adequately search the point of crossing and detect oncoming vehicles. Search and detection failures characterize most pedestrian accidents.[231] In other instances, the pedestrian knowingly violates the law to save walking time or fails to estimate the gap time between vehicles which would allow him to cross safely. A study of accident data in Portland, Oregon (Table 7) showed that almost four times as many pedestrian accidents occur in or within 50 feet (15 m.) of a crosswalk as outside it.[132] Pedestrians often perceive the crosswalk as safe; whereas, pedestrians crossing outside the crosswalk exercise search and detection procedures before attempting to cross.[124]

Studies of English school children have demonstrated the accident data greatly underestimates risk exposure, but that the accidents involving school-aged children were due to crossing behavior and not exposure to risk. As physical skills increase with age, the learned behavior of properly or improperly crossing the street continues. Exposure to risk actually increases with the age of the pedestrian while the comparative accident statistic declines.[128] It is, therefore, important to analyze risk exposure and accident data together when planning safety programs and facilities.

The trip to and from school serves as a focal point for accident prevention efforts, but--and perhaps because of this--few pedestrian accidents involving children occur during the school trip. Children do account for 40 percent of all pedestrian accidents, however, and three-quarters of these occur in residential areas.[187] Accidents involving children might be less severe if their behavior patterns

TABLE 7

PEDESTRIAN ACCIDENTS BY SIDE OF THE STREET
AND DISTANCE FROM THE INTERSECTION

| Distance From Intersection | Side of Street | | |
|---|---|---|---|
| | Near | Far | Total |
| 0 to 50 feet (15.2 meters) | 333 | 218 | 551 |
| 50 feet to mid-block | 93 | 61 | 154 |
| Total | 426 | 279 | 705 |

Source: Jennings, Roger D., et al, "Behavioral Observations and the Pedestrian Accident," Journal of Safety Research, Vol. 9, No. 1, March, 1977, p. 27.

could be modified. A study conducted with school children in Salt Lake City, Utah succeeded in modifying their behavior by positively reinforcing correct behavior with smiles, candy, congratulatory remarks, and certificates of recognition. Appropriate street crossings rose from 5 percent to 60 percent during the experiment.[202] Unfortunately, the researchers conducted no follow-up evaluation.

## BICYCLES

The Consumer Product Safety Commission (CPSC) estimates that there are over 400,000 bicycle-related injuries per year. Accidents involving motor vehicles and bicycles probably account for at least 40,000 disabling injuries and 1,000 deaths each year. While the bicycle/motor vehicle accident results in the most serious injuries, the CPSC attributes most bicycle accidents to loss of control due to carelessness, improper braking, double riding, striking bumps or ruts, and mechanical or structural failure. In fact, according to the CPSC, the bicycle is number one in product-related injuries.

It is precisely because the motor vehicle and bicycle collision is so serious that the most study has revolved around its causes and the ways to prevent it. A study conducted by Dr. Kenneth Cross for the National Highway Traffic Safety Administration[62] categorized bicycle and motor vehicle accidents into 37 different types in seven self-explanatory classes:

Class A - Bicycle Rideout: driveway, alley, and other mid-block

Class B - Bicycle Rideout: controlled intersection

Class C - Motorist Driveout

Class D - Motorist Overtaking/Overtaking Threat

Class E - Motorist Unexpected Turn/Swerve

Class F - Motorist Unexpected Turn

Class G - Other

Accident data and follow-up analysis have revealed that in motor vehicle and bicycle accidents it is usually the cyclist who violated a traffic law and caused the accident. Researchers in Santa Barbara, California studied accident data and conducted survey research to discern the knowledge of traffic laws and the attitudes of both motorists and bicyclists toward each other. They discovered a basic disregard for traffic laws among bicyclists with violation rates approaching 90 percent.[182] A later study of bicycle/motor vehicle accidents in California, however, discovered that negligent actions and disregard for traffic laws decline with the age of the bicyclist. Up through age 12, about 92 percent of the bicyclists caused the accidents; while after age 25, only about one-third were at fault.[125] Familiarity with the rules of the road and riding experience play an important role in the behavior of older bicyclists.

The study of bicycle accidents also reveals that the child cyclist does not understand the consequences of his actions or his responsibilities as a vehicle driver. Table 8 bases its summation on the earlier work of Dr. Cross; it examines the estimated number of bicycle accidents occurring prior to any formal bicycle education. It appears that local bicycle plans should begin education programs in grade school and continue them through high school.[61]

The number of bicycle fatalities per vehicle mile of travel is alarmingly high when compared to the same statistics for motor vehicles. Bicyclists travel about 34 million miles or 55 million kilometers per year (1975 Bureau of the Census estimate); motor vehicles travel about 1.5 trillion miles or 2.4 trillion kilometers per year (1977 Federal Highway Administration estimate). There are about an equal number of bicycles and motor vehicles in the country, 100 to 120 million of each, and there are approximately 1,000 bicyclist fatalities per year compared to 40,000 motorist fatalities. Assuming these estimates are fairly accurate, motor vehicles kill one cyclist for every 34,000 miles of bicycle travel (55,000 kilometers) compared to one motorist for every 37.5 million miles of motor vehicle travel (60 million kilometers). In countries accustomed to bicycle travel the statistics are not so lopsided. A recent study of the bicycling habits of Israelis showed that the accident risk per kilometer of bicycle travel was the same or lower than that for passenger automobiles.[143] The disportionately high number of American bicycle fatalities compared to motorist fatalities demonstrates yet again the need to change the behavior patterns of bicyclists and motorists (education), press compliance with traffic laws (enforcement), and accommodate the bicycle in the design of transportation facilities (engineering).

TABLE 8

BICYCLE ACCIDENTS PRIOR TO BICYCLE EDUCATION
(ESTIMATED BY SCHOOL GRADE LEVEL)

| | GRADE LEVEL | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | K | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| CYCLIST EXITED DRIVEWAY INTO MOTORIST'S PATH | 16% | 22% | 29% | 36% | 43% | 52% | 60% | 67% | 74% | 82% | 85% | 88% | 93% |
| MOTORIST EXITED DRIVEWAY INTO CYCLIST'S PATH | 11% | 16% | 18% | 27% | 33% | 38% | 43% | 47% | 52% | 55% | 58% | 65% | 72% |
| CYCLIST FAILED TO STOP/YIELD AT CONTROLLED INTERSECTION | 1% | 6% | 10% | 15% | 20% | 28% | 34% | 38% | 50% | 65% | 72% | 76% | 80% |
| CYCLIST MADE IMPROPER LEFT TURN | 1% | 3% | 8% | 10% | 15% | 19% | 27% | 38% | 46% | 57% | 63% | 67% | 72% |
| CYCLIST RODE ON WRONG SIDE OF STREET | 1% | 3% | 6% | 9% | 13% | 16% | 18% | 27% | 39% | 52% | 58% | 65% | 71% |
| MOTORIST COLLIDED WITH REAR OF CYCLIST | 0% | 0% | 0% | 0% | 0% | 0% | 3% | 10% | 16% | 22% | 26% | 30% | 45% |
| MOTORIST FAILED TO STOP/YIELD AT CONTROLLED INTERSECTION | 0% | 0% | 0% | 1% | 4% | 5% | 7% | 8% | 9% | 15% | 22% | 26% | 30% |
| MOTORIST MADE IMPROPER LEFT TURN | 0% | 0% | 0% | 0% | 0% | 1% | 3% | 4% | 6% | 10% | 17% | 23% | 25% |
| MOTORIST MADE IMPROPER RIGHT TURN | 0% | 0% | 1% | 3% | 4% | 4% | 7% | 10% | 13% | 17% | 19% | 23% | 28% |
| MOTORIST OPENED CAR DOOR INTO CYCLIST'S PATH | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 6% | 8% | 13% | 17% | 21% |

Source: Cross, Kenneth D., "Identifying Critical Behavior Leading to Collisions Between Bicycles and Motor Vehicles," California Bicycle Safety Seminar Presentation, Sacramento, California, 1974.

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UE-4. WHAT COUNTERMEASURES REDUCE ACCIDENTS INVOLVING PEDESTRIANS OR BICYCLISTS AND MOTOR VEHICLES?

Since safety is a primary goal in pedestrian or bicycle plans, it stands to reason that if the plan succeeds in providing a safer walking or cycling environment it will reduce the risk and number of accidents. Strategies to improve safety and reduce accidents follow the general themes in this report: proper engineering, continual education, and selective enforcement. Issue UE-3 listed pedestrian and bicycle accident types that researchers have identified as the most prevalent; efforts to alleviate these accident types are called countermeasures. Accident countermeasures, to date, have often focused on the physical components of pedestrian and bicycle systems. Because they are less abstract than education and enforcement, researchers can more easily evaluate the effects of physical countermeasures. Evaluations of educational and enforcment programs show that they have as significant an accident reduction potential as physical structures, but that their effect wears off unless the programs are maintained.[202,250] Perhaps the single most important countermeasure then is the establishment of a single office responsible for the coordination and maintenance of pedestrian or bicycle activities within a state, a region, a county, or a municipality.[80] Single countermeasures may reduce some accidents, coordinated programs will reduce many more.[60,231]

PEDESTRIAN ACCIDENT COUNTERMEASURES

Pedestrian accidents happen in the roadway, hence pedestrian accident countermeasures involving physical structures concentrate on either making the roadway safer to cross or keeping the pedestrian out of the roadway. Planners in ancient Roman cities used raised stepping stones in urban streets to slow wheeled vehicles and assist pedestrians in crossing the vias. It is only in this century that traffic engineers and transportation planners have dealt with the pedestrian confronted by heavy steel motor vehicles capable of sharp turning movements and quick acceleration. They have responded by trying to balance vehicular traffic flow and pedestrian traffic flow, and in the compromise, they balance safety gains agains mobility.[107]

There are five types of common pedestrian accident countermeasures which are generally assumed to improve pedestrian safety: traffic signals, crosswalks, grade-separated facilities, one-way streets, and street lighting. Traffic signals have long been assumed to provide pedestrian safety, although studies in Detroit, Cincinnati, and New York did not show significant accident reductions at traffic signals. However, absolute numbers of pedestrian accidents did decrease at these locations. Studies in San Diego and Toronto have not established the safety benefits of marked or signed areas for pedestrian crossings.[187] While the risk of an accident is 50 percent higher outside a marked crosswalk, approximately twice as many pedestrian accidents occur in marked crosswalks as in unmarked ones.[132]

On the positive side, grade-separated facilities, when pedestrians use them, definitely reduce pedestrian accidents, 30 percent in a Japanese study.[1] It is difficult to get people to use grade-separated facilities like bridges and tunnels, however, unless they are forced by barriers or they perceive no loss of time or convenience.[142] (See Issue D-5.) One-way streets also improve pedestrian safety while facilitating vehicular traffic flow; Sacramento, New York City, and Hamilton, Ontario showed major reductions in pedestrian accidents after two-way city streets were converted to one-way.[75] Street lighting works, too. Nighttime pedestrian accidents are particularly severe; adequate street lighting can cut pedestrian accidents by about 40 percent according to a 1966 study of 64 different sites.[187]

More recently, the National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Administration (FHWA) sponsored a joint study to identify pedestrian accident types and develop effective countermeasures.[13] The study focused on nine countermeasures, but they found that five countermeasures have the greatest potential to reduce pedestrian accidents:

a. Pedestrian Mid-Block Crossing Barriers - Physical barriers along the curb line or in the median channel pedestrians to intersections where vehicular movements are controlled. (See Issue C-2 also.)

b. Mid-Block Crosswalks - Provide a mid-block crossing between widely-spaced intersections.

c. Diagonal On-Street Parking - While unsafe in terms of motor vehicle accidents, diagonal parking prevents pedestrian dart-outs, the most common type of pedestrian accident.

d. Stop-Line Relocation - Coupled with police enforcement, moving the stop-line back from the crosswalk helps prevent the accident caused by "intersection dash," the second most common pedestrian accident.

e. Far-Side Bus Stop - Locating bus stops across an intersection prevents pedestrians and right turning motor vehicles from crossing in front of the bus.

Applying what is now known about pedestrian safety and accident reduction can have a marked effect on the national highway death toll. Table 9 suggests site selection criteria for the implementation of pedestrian accident countermeasures. Of course, design considerations and specific site locations will play an important role in the selection of countermeasures.

Engineering solutions are only one-third of a total accident reduction effort; education and enforcement supply the remainder. In the City of Hamilton, Ontario, for example, strictly enforced parking regulations coupled with one-way streets have dramatically reduced pedestrian accidents in the center city area.[75] NHTSA is developing model pedestrian safety regulations directed at specific accident types which, when coupled with local enforcement, should produce significant reductions in pedestrian accidents.

Scattered efforts at pedestrian education find a home with local pedestrian coordinators. In Washington, DC, and Baltimore, Maryland, pedestrian coordinators work through neighborhood committees and advisory boards to provide outreach services and handle citizen complaints. Coordinators supplement their public information programs with classroom instruction in proper pedestrian behavior. They also use their office as a forum for pulling together planning, police, education, and recreation and parks departments. They use accidents statistics and citizen complaints to identify high-risk areas which may require immediate attention, and then, using their procedural knowledge and contact with decision makers, they oversee the improvements.

A study of elderly pedestrians in Germany indicated that while older people understand correct pedestrian behavior they have difficulty extricating themselves from dangerous situations. 243
The outreach efforts of pedestrian coordinators are beginning to encompass the elderly pedestrian, and they have made some fruitful first steps in reducing the elderly's risk of accidents. The limited success of pedestrian coordinators stands as a symbol of the need to integrate good traffic engineering with pedestrian education and enforcement.

TABLE 9

SITE SELECTION CRITERIA FOR PEDESTRIAN ACCIDENT COUNTERMEASURES

| Countermeasure | Site Selection Criteria |
|---|---|
| Preventive Markings | 1. Intersection<br>2. Pedestrian crossing against signal, accepting small vehicle gaps or in conflict with turning vehicles |
| Median Barrier | 1. Sufficient median to accommodate barrier and vehicle over-hang<br>2. Uninterrupted median (no turnabouts)<br>3. Pedestrians running into 1st and/or 2nd half of roadway at nonintersection locations |
| Crosswalk Set-Back | 1. Intersection<br>2. No driveways between corner and relocated crosswalk<br>3. Sufficient sidewalk width to accommodate pedestrian barriers<br>4. Good sight-distance at corners<br>5. Pedestrian in conflict with turning vehicles |
| Midblock Crosswalk | 1. Heavy midblock pedestrian volume<br>2. Moderate to light, slow moving traffic if crosswalk is unsignaled<br>3. Existence of a "natural path" between two pedestrian generators<br>4. Pedestrians running into or entering roadway near midblock |
| Diagonal Parking | 1. Low traffic volume<br>2. Sufficient roadway width to accommodate the through traffic lane(s) and provide a safety area behind parked vehicles<br>3. Pedestrians running out into roadway between parked vehicles |
| Meter Post Barriers | 1. Uninterrupted parking meters on both sides of the street<br>2. Heavy parking utilization without breaks for alleys, driveways, etc.<br>3. Sufficient curb height to restrict vehicle over-ride<br>4. Pedestrians entering roadway from between parked vehicles |
| Stop Line Relocation | 1. No driveway between corner and relocated stop line<br>2. At least 2 lanes of traffic approaching from the same direction<br>3. Pedestrians entering the roadway in front of stopped or standing vehicles into lane of moving traffic |
| Vendor Warning Signal | 1. Installed on truck canvassing high accident routes<br>2. Pedestrian running across road to or from vendor |
| Bus Stop Relocation | 1. Adequate geometrics to permit far side bus stop (no alley, etc.)<br>2. Pedestrians entering the roadway in front of stopped or standing buses into lane of moving traffic |

Source: Berger, W.G., et al, "Urban Pedestrian Accident Countermeasures Experimental Evaluation Studies," Biotechnology Inc., National Highway Traffic Safety Administration/Federal Highway Administration, U.S. Department of Transportation, February 1975, pp. 4-6.

BICYCLE ACCIDENT COUNTERMEASURES

An experienced, commuting cyclist in Tampa, Florida had three accidents during the past year; none was his fault. In the first instance, a truck literally blew him off the road -- cuts and bruises. The second accident occurred when he hit a pothole while coasting downhill -- a bent rim. The third and final indignity was a slap from the outside rear-view mirror on a passing bus -- headache. (Fortunately, he wears a helmet.) Only one of these accidents, the pothole, had an engineering solution. The other two accidents might have been prevented if the motoring public were educated to detect and respect the bicycle's right to the road.

Because the bicycle is a vehicle operating in the roadway, it requires facilities similar to the motor vehicle; it may even occasionally need special facilities. (See Issue D-2.) Reducing bicycle accidents, therefore, demands the same engineering countermeasures as reducing automobile accidents: signalization, adequate maneuvering room, lane width based on capacity of the roadway, stable pavements, etc. Many cyclists believe that simple design accommodations such as wide outside curb lanes and the removal of barriers will significantly reduce bicycle accidents like those the cyclist in Tampa endured. While this is true, it remains apparent that bicyclists will need to live with the present road system for quite some time.[222,253]

The key to reducing bicycle accidents does not lie solely with engineering solutions but includes effective education programs and increased law enforcement activities. Educational programs for the cyclist should focus on proper riding techniques, road etiquette, and traffic safety.[102] For the motorist, the traffic engineer, and the general public, the bicycle education program should focus on bicycling as a viable form of transportation which requires public participation and acceptance.[19] (See Issue UE-2.)

In order to adequately deal with unsafe behavior on a bicycle, it is necessary to initiate and maintain the continuous enforcement of traffic laws for every cyclist regardless of age. Perhaps the most hazardous riding surface is that stretch of paved road which forms an intersection; about one-third of the bicyclist fatalities occur there.[62] The intersection is, therefore, a logical place to focus enforcement activities, but the cruising patrol car or bicycle enforcement officer should not be hesitant to stop on-street violations.[47] Enforcement activities are discussed further in the next issue, but it is important to implement selective enforcement programs simultaneously with education programs. Tying these two program areas together modifies incorrect behavior before and after it occurs. Correct behavior will reduce bicycle accidents.

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# III. ENFORCEMENT

Governments regulate thoroughfares in order to assure the safe and efficient transportation of goods, services, and people. When people disregard the laws which govern safe conduct on these public ways; they should expect the government, through its law enforcement arm, to reprimand and punish their unsafe behavior. People have come to accept selective enforcement activities as a matter of course when they operate motor vehicles, but they seldom expect it while bicycling or walking. Enforcement is a necessary part of a pedestrian or bicycling program. It complements both educational programs and facility utilization. Enforcement is by nature and practice a negative force, but it deters unsafe behavior while reminding us of the necessity for responsible conduct in the public environment.

Issue RE-1 looks at and expands the relationship between education, enforcement, and engineering as they relate to pedestrian and bicycling activity. Next, Issue RE-2 scrutinizes the concept of the bicycle as a vehicle and examines the ramifications of applying that concept to law enforcement efforts. Issue RE-3 discusses bicycle registration and operator licensing, exploring ways to make the public more responsive and state efforts more productive.

## RE-1. HOW CAN ENFORCEMENT OF PEDESTRIAN AND BICYCLE LAWS BE MORE EFFECTIVE?

The real danger inherent in violations of traffic law by pedestrians and bicyclists is not that there are violations, but that these violations result from habitual actions. Studies of pedestrian and bicycle violators show many repeat offenders. In certain cases, 90 percent or more of the violators knowingly broke the law and, more often than not, caused an accident.[125] Habits are hard to break. When they are present and so disposed, enforcement officers can deter flagrant violations. It may also be possible to change certain laws which pertain to walking and bicycling and contribute to perpetual violations or to write new statutes to regulate this behavior. It is for these reasons that law enforcement activities should be coupled with extensive educational and public relations work.[260] Educational and enforcement activities go hand-in-hand; both must be continuous, uniform, and long-term commitments.

A host of common problems plague pedestrian and bicycle law enforcement: the most frequent violators are young people; there are very often inadequate accident reporting systems; there are no police officers assigned exclusively to pedestrian or bicycle accident prevention; courts do not uphold citations; laws vary from jurisdiction to jurisdiction; there are few remedial programs for violators.[216] There are significant problems recognized by the law enforcement, pedestrian, and bicycling communities, but they often assume a low ranking on the overall scale of priorities.

### PEDESTRIANS

It is unlikely that an enforcement campaign aimed at pedestrian violators will be continuous; there are too many higher police priorities. Selective enforcement, enforcement directed toward a specific population or location for a period of time, can have beneficial results. Miami Beach conducted a well-publicized selective enforcement effort targeted at the elderly who used certain signalized intersections. Pedestrians were observed before and after the publicity campaign and with and without a policeman present at the intersection. There was a substantial improvement in legal street crossings after the campaign. Four months later, however, pedestrians had returned to jaywalking except when a policeman was present.[250] So while selective enforcement produces improvements in walking behavior, it must be periodically reinforced; that is, it should surface occasionally like highway speed traps.

Pedestrian coordinators and city safety officials consider pedestrian law enforcement an important accident countermeasure. On an experimental basis, they have stationed school crossing guards at busy intersections frequented by the elderly. Unfortunately, aside from safe school crossings, there are very few pedestrian countermeasures which involve an authority figure with the power to reprimand violators. There is some evidence to suggest that pedestrian enforcement efforts can reduce the pedestrian's risk of an accident, but there are no studies which document a reduction in pedestrian accidents due to enforcement campaigns.[221] This is an area which deserves further research and continued local effort and innovation.

## BICYCLISTS

The bicycle is a vehicle operated in the roadway and should, therefore, enjoy the rights and duties of any vehicle. When a bicycle is operated unsafely, its owner should be reprimanded; when a bicycle is unsafe, its owner should be ordered to repair it. Police departments across the country are just beginning to recognize the truth in these statements. Enforcement campaigns run by the police or other designated enforcement personnel do seem to reduce bicycle accidents and unsafe bicyclist behavior. The California Highway Patrol found that bicycle accidents decreased in their departmental zones where bicycle enforcement actions increased.[47] In Cranford, New Jersey, a comprehensive education and enforcement campaign is having similar results.

Many cyclists think the police are unconcerned about bicycle safety and enforcement programs. Police do recognize the severity of bicycle accidents, but they are reluctant to enforce bicycle violations because of the adverse reaction of the courts, fellow officers, and the public. There are also many instances in which the police do not know or understand the law regarding the actions of bicyclists, and the law is often confusing.[122] (See Issue RE-2.) This problem has been recognized; a U.S. Department of Transportation study of bicycle safety offered this recommendation in 1975:

> "Police agencies should develop and promulgate written procedures describing methods of dealing with bicyclist violations and motorists who violate the rights of bicyclists. Police officers should be informed of the importance of their taking appropriate action against violations."

Some police departments have followed this advice. Police departments in New York City, Washington, D.C., and Santa Barbara, California have developed training films which demonstrate types of bicycle violations and the tragic consequences of police inaction. The Maryland Bicycle Law Enforcement Conference, a conference of police officers, recommended that bicycle law enforcement programs be adopted for police officer in-service training and for all cadets at police academies. The Wisconsin Office of Traffic Safety has developed a manual for police officers which discusses traffic law and bicycling and the policies and procedures which police officers should follow when dealing with bicyclists and bicycling violations.[67]

One procedure often in need of overhaul is the accident reporting system. Many state and local police accident reporting systems do not include pedestrians and bicyclists on the reporting form; and some provide a pedestrian category which is also used for bicyclists.[10] Since many safety studies use accident data as a foundation for causal analysis and the identification of countermeasure, distortions in the data can lead to erroneous conclusions and, ultimately, misdirected resources.[45] Correct accident reporting categories list the bicycle as a vehicle and characterize the movement of the vehicle, the direction of travel, and the vehicle condition.[10,157]

In addition to bicycle accidents and traffic law violations, police are concerned with bicycle thefts. Bicycle registration programs can help identify stolen bicycles. (See Issues P-6 and RE-3.) In several communities, police support of bicycle registration programs through cyclist warnings and bicycle impounding has a marked effect on bicycle theft.[55]

Enforcing traffic laws is a police function, but should bicycle violations by minors occupy a sizable portion of police time? Communities across the nation have responded to that question by assigning the policing of young cyclists to paralegal volunteers or special police hired and trained with federal, state, or local money.[12] Minnesota has 24 communities using bike patrols. These teenagers -- endearingly called "pedal pigs" -- set a good example for young cyclists. They are uniformed, carry police radios, and issue citations in triplicate for attendance at bicycling seminars (1 copy to the child, 1 copy to the parents, and 1 file copy). They teach proper cycling techniques on the spot, and they reward good behavior with stickers and reflectors. The community pays the bike patrol at the minimum wage rate. These communities also have mandatory bicycle registration; the bike patrol can impound bicycles if they are not registered. The bike patrol also guards against bicycle theft by placing warning stickers on unlocked bicycles. A special juvenile court system enforces the bike patrol's citations by sentencing violators to attend bicycling safety classes. Repeat offenders in some jurisdictions can have their bicycles impounded or receive community work assignments.

Of course, adult violators need remedial treatment also. Massachusetts issues tickets to bicycle violators which allows them to pay a fine and avoid judicial proceedings.[122] While this has a deterrent effect, it may not be as positive a remedial measure as attendance at classes on proper riding techniques and traffic law. Several other jurisdictions have equipped police cars with bicycle racks to impound unsafe bicycles or public address systems to warn cyclists that they are violating the law.[55] Remedial actions should involve bicycling education; the two go together. Until the bicycle receives uniform treatment within the nation's traffic laws, enforcement will remain a variable and localized strategy. A worthwhile bicycle planning goal is the need for no enforcement at all.

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RE-2. WHY SHOULD STATE MOTOR VEHICLE CODES DEFINE THE BICYCLE AS A VEHICLE?

Statutory law concerning vehicles evolved as the motor vehicle began to dominate the highway, and in many states the bicycle was forgotten or not properly accommodated. As states allowed teenagers to drive automobiles, they assumed people who bicycled were people who did it for fun, mostly children playing.[178] To this day, 35 states exclude the bicycle from their definition of a vehicle. Nine states and the District of Columbia treat the bicycle as a vehicle, and six other states treat the bicycle as a vehicle for the purposes of the rules of the road. Curiously enough, states where the bicycle is not accorded legal status as a vehicle consider the bicyclist operating in the roadway to have the same duties -- and often, but not always, the same rights -- as the drivers of motor vehicles.[85,86]

Effective enforcement of traffic laws depends upon the clarity of the law. The bicyclist should obey laws designed to regulate vehicles and the conduct of drivers. These laws should define consistent and acceptable behavior.[101] There are instances when the bicyclist needs separate rules to govern his behavior (operations by minors, operations outside the roadway, etc.), and these should be recognized in the statutes. Massachusetts has attempted to codify traffic laws governing the bicycle by specifically stating those regulations that apply to bicycles. The Massachusetts law provides for mandatory bicycle registration, sets up equipment requirements, cites applicable traffic rules and enforcement procedures, and recognizes bicycle usage by minors. While they have not addressed every relevant issue, Massachusetts has, at least, gone further than any other state in clarifying the legal status of the bicycle.[122]

Case law points to the confusion and ambiguity surrounding the legal status of the bicycle and the rights and duties of the bicycle driver. Case law, which is supplementary to statutory law, deals with interpretations of statutory law. In decisions affecting the bicylist, case law reveals a variety of negligent behavior and unpunished vehicular violations stemming from the ambiguity of statutory law concerning bicycles. A Florida court held that a cyclist who did not signal for a left turn was not contrary to a state statute requiring automobile drivers to do the same. In a Maine case, a bicyclist did not have to yield the right of way to approaching vehicles when exiting his driveway.[122]

The National Committee on Uniform Traffic Laws and Ordinances (NCUTLO) formulates the Uniform Vehicle Code (UVC) and the Model Traffic Ordinance (MTO) in an attempt to bring consistency to the nation's traffic laws and ordinances. While every state has adopted some of the provisions in the UVC -- except, ironically, Massachusetts -- very few states have adopted the most recent changes, which included recognition of the bicycle as a vehicle in 1975. The UVC also makes the rights and duties of the driver of a vehicle applicable to the bicyclist operating in the highway, not the roadway, that is, operating within the right-of-way (which includes the shoulder) and not just on the paved surface. The UVC goes a long way toward improving the regulation of bicycles and bicyclists, but it too needs to clarify certain issues directly relating to the legal status of the bicycle and the rights and duties of the cyclist. Issues which state statutes should address and the UVC should clarify are bicycle usage by minors, passing on the right or between lanes, mandatory bike path laws, turn signals, sidewalk and off-road riding, homicide by vehicle, and bicycle racing.[86]

Bicycle Usage by Minors -- If traffic laws apply to cyclists, are these laws applicable to minors? Findings by courts in Washington and Louisiana say yes; a California court says no.[122] The UVC states that violations by children under age 14 shall not constitute negligence per se, although a violation may be considered evidence of negligence.

Passing on the Right or Between Lanes -- Most states do not address the issue of bicyclists passing to the right (as they would when passing traffic stopped for a light) or passing between lanes of stopped or slow-moving traffic. This is dangerous behavior which the cyclist executes at his own risk. The UVC covers certain aspects of this behavior.

Mandatory Bike Path Laws -- These laws prohibit the use of the roadway and require the cyclist to use adjacent bike paths whenever they are usable. Since many bike paths were not properly designed, are not properly maintained, and may not be adjacent to the roadway, cyclists find this law objectionable and its precise meaning unclear.[66]

Turn Signals -- Most states require continuous turn signals despite the fact that the cyclist needs to maintain two-hand control of the bicycle during most of the approach and turning maneuver. The UVC recognizes the necessity for control and requires a hand signal during at least the last 100 feet before turning or while stopped waiting to turn.

Sidewalk and Off-Road Riding -- Is the bicycle as a vehicle permitted to operate on the sidewalk and, if so, what is its legal status while on the sidewalk? Most states grant the bicyclist the rights and duties of a vehicle driver only in the roadway; therefore the sidewalk, highway shoulders, bike paths, and sometimes bike lanes place the cyclist in a legal vacuum. The UVC permits sidewalk riding at local discretion and treats the bicycle operating on the sidewalk as a pedestrian.

Homicide by Vehicle -- Unlawfully and unintentionally causing the death of another person while violating any traffic law is homicide by vehicle. Homicide by vehicle is a lesser offense than involuntary manslaughter because it requires proof of simple instead of gross negligence. Many states cannot prosecute vehicular homicides when a cyclist is the victim because they do not have a homicide by vehicle law. The UVC does contain such a law.

Bicycle Racing -- Most states and the UVC prohibit bicycle racing on the highway unless approval is obtained from the jurisdictional highway authority. Because of the length of many bicycle races, its often impractical to close the highway to public use. If the highway remains open to public use, however, then traffic laws like obedience to stop signs and the use of hand signals apply, and police do not have the authority to waive them. The UVC has added this kind of authority, most states have not.

In essence then, treating the bicycle as a vehicle demands a comprehensive legislative approach which cannot simply cite the bicycle as a vehicle; it demands revision of state statutes to accommodate the special vehicular requirements of bicycles. As America enters a new stage in the history of the bicycle, legislators need to rectify the legal ambiguities concerning bicycles.[122] Effective enforcement and adjudication need to evolve ahead of this re-emerging transportation mode.

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## RE-3. ARE STATEWIDE BICYCLE REGISTRATION PROGRAMS EFFECTIVE?

Bicycle programs need policy direction, an educational element, legislative backing and enforcement, community support, and adequate public relations. One way to accomplish all these things at once is by starting a bicycle registration program. Bicycle registration provides bicycling with an air of legitimacy. It also enhances the chance of recovering stolen bicycles, can raise funds for bicycling activities, supplies accident identification data, and helps keep tabs on the number of local bicycles and cyclists.[49]

Many people use the words licensing and registration interchangeably, this section uses registration to refer to the equipment being registered (i.e., the bicycle) and licensing to refer to the permission granted the bicyclist to drive. Because the word license can describe the license plate applied to the vehicle or the registration certificate, the terms licensing and registration have some synonymous meanings in popular usage, but a license is given to do something. A person receives a license to operate a vehicle, for example, but he registers the vehicle to prove ownership. The terms create additional confusion in the bicycle world because -- with certain local exceptions -- there are no licensing procedures for the bicyclist. Many experienced cyclists believe that cyclists should be licensed to operate in the roadway.[70] But licensing would require competency testing and, unless it was applied statewide, would result in enforcement problems.

Up until quite recently, bicycle registration was strictly a local phenomenon and usually consisted of a voluntary program run by the city police or fire department. Several large cities like Denver and Washington, DC have mandatory bicycle registration programs, yet these programs function without effective enforcement efforts by police; consequently, there is little public compliance. States which run bicycle registration programs have a much better operating experience. California, Maryland, and Minnesota all have voluntary programs which allow local jurisdictions to make bicycle registration programs mandatory. In the absence of state authority, however, local registration programs remain local; no one uses the administrative data collected, costs are high, and the police cannot identify bicycles stolen and removed from the immediate area. California has tried to get around this dichotomy by having local registration programs conform to the state bicycle registration law.[216] Jurisdictions with bicycle registration programs receive separate computer identification codes. In this way, police can recover bicycles stolen from any locality using the state system.

Tying the bicycle registration program to enforcement efforts increases the effectiveness of both bicycle education and bicycle enforcement. Enforcement officials can record the serial numbers of registered bicycles when a violation occurs, and an accumulation of so many "points" could result in a fine or the impoundment of the bicycle. Depending on the the local ordinance, minors or their parents may be held culpable for bicycling violations. This straightforward and well-understood type of enforcement policy builds community support and delivers a public relations message on bicycle safety.*

Minnesota has enjoyed a favorable response to its bicycle registration program. While the program is voluntary, many municipalities which were formerly running their own registration programs joined the state system when it became clear that their administrative costs would be lower and their chance of recovering stolen bicycles much greater. Under the Minnesota system, a person registers a bicycle for three years at any of the state vehicle service divisions or appointed deputies. Anyone engaged in the sale of bicycles can be an appointed deputy. The registration information -- name, address, birth date, and the make and serial number of the bicycle -- is computerized for instant access by police departments statewide. Yearly administrative expenses average between $90,000 and $100,000. Since the start of the system in 1976, Minnesota has registered over 151,000 bicycles at a cost of $410,000. The registration system has produced $471,000 in fees, however, which covers the system's initial start-up costs and returns money to the state treasury.[57]

The success of the Minnesota system points to the necessity of a computerized statewide registration program which can identify stolen bicycles by serial number or user information. A national system of bicycle registration would, of course, be even better. There are problems with a national system at the present time. Imported bicycles do not follow a pattern of serial numbers; very often a model number is recorded as the bicycle's serial number. The result is a computer printout with a list of different owners each appearing to own the same bike. This frustrates the main purpose of bicycle registration, the identification of stolen bicycles.* There is also no precedent for federal intervention in vehicle codes, the normal prerogative of the states. Advances in telecommunications have made possible the interconnection of state criminal identification systems, however, and a similar network involving registered bicycles could become a reality as the demand for such a system grows.

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# IV. EVALUATION

In facility or program development and implementation, evaluation is often the neglected third child left to intuition and measured by citizen complaint. Without conducting facility evaluation, the planning, design, and construction of pedestrian and bicycle facilities can still be quite adequate; a crosswalk is a crosswalk, a bike rack is a bike rack; they both provide a level of service which exceed no facility at all. This attitude is unacceptable in comprehensive planning; a plan depends, after all, on a systemmatic implementation of facilities tied to specific programs. Successful programs require properly located facilities provided for maximum efficiency and effectiveness; this requires the measurement and analysis of the factors which determine efficiency and effectiveness.

This chapter discusses how to evaluate pedestrian and bicycle facilities in the first issue. The second issue looks at measuring a pedestrian's or bicyclist's exposure to dangerous situations and the subject of risk analysis.

## E-1. HOW ARE PEDESTRIAN OR BICYCLE FACILITIES EVALUATED?

During the 1970's, planners, engineers, and government officials assumed that the bikeway supplied the answer to several important questions relating to energy conservation, safety, and vehicular flow. They constructed bikeways whenever funding was available. Had they studied and evaluated the need for bicycle facilities, there might not be any poorly-designed bicycle facilities.[252] Similar lessons were learned with pedestrian malls.[82] That is, some programs or facilities cost too much, some cost too much to maintain, some have the wrong effect, and some have no effect. But the lessons of the 1970's point toward the importance of evaluation, both as starting point and as a continual process punctuated with progress reports.

Pedestrian and bicycle evaluations are looking for change; hopefully, a beneficial one, and importantly, one caused by a specific program or facility. If it is known what the evaluation should produce (cost data, alternative strategies, alternative locations, etc.) and who will make the final decisions, evaluation can use this general approach:

A. Select Evaluation Strategy

B. Collect Data

C. Analyze Data

D. Implement Findings

This approach (see Figure 9) is broad enough to fulfill most decision making needs for new and existing facilities, but the real test is the application of the approach.

### A. <u>Select Evaluation Strategy</u>

A program or facility evaluation starts with an evaluation; that is, how much time and money are available for evaluation. If the planning process went well, about 10 percent of the budget accommodates evaluation; if the process waffled, evaluations may become a part of the work routine. This is not too bad if the data collection activities are sound and up-to-date, but if they are not, they will need to be improved before the evaluation starts.

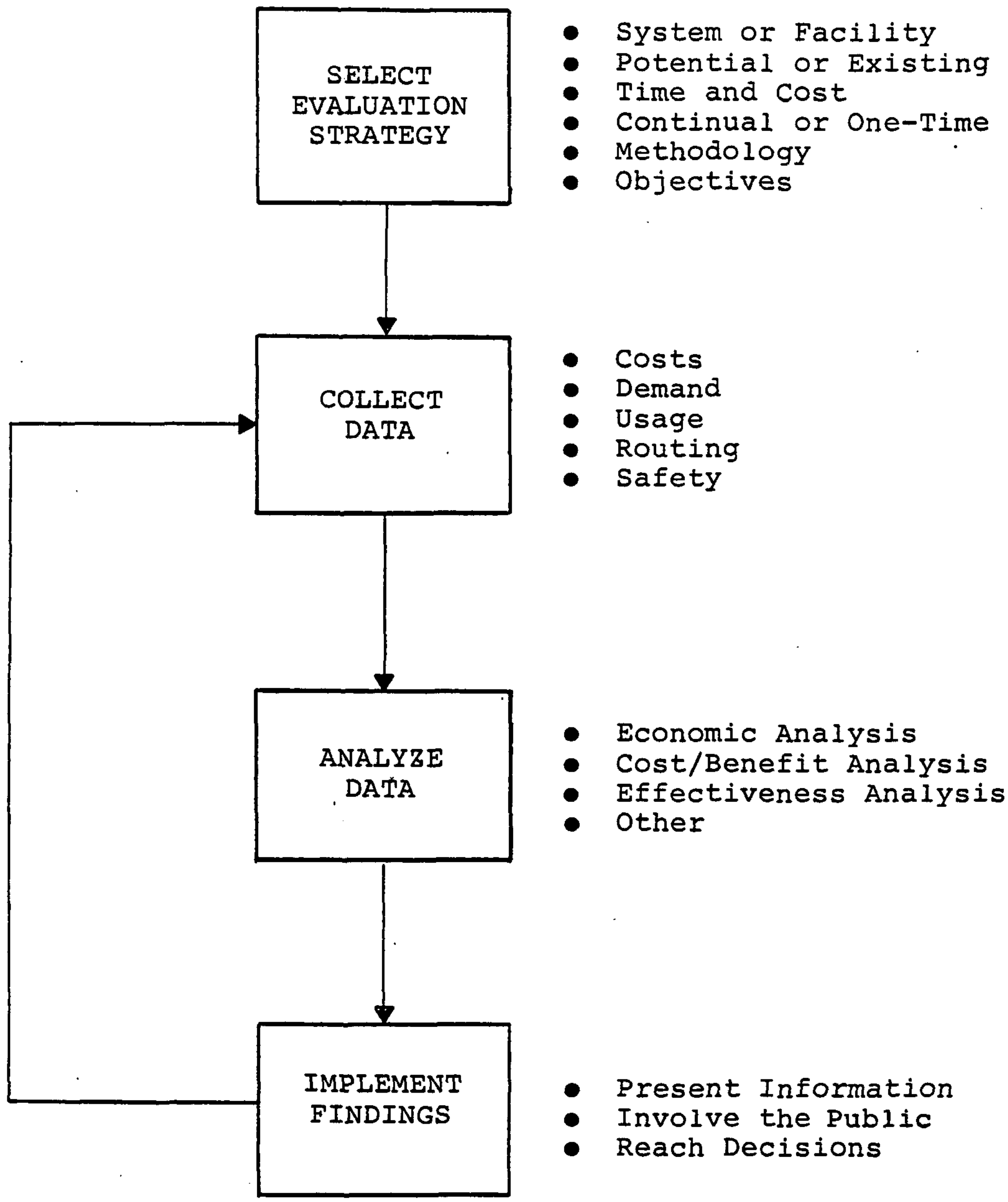


FIGURE 9
A GENERAL EVALUATION PROCEDURE

What is being evaluated? Researchers evaluate either the potential for a facility or a system of facilities, or they examine existing facilities. In general, always evaluate one facility at a time. In the case of system or program evaluation, combine the individual evaluative pieces into a system evaluation. Because of the limited scope of most pedestrian and bicycle programs, evaluations to date -- for example, in Maryland and the District of Columbia -- have focused on individual facilities.[240,22]

An evaluation strategy should determine if there is a need for continual or sporadic evaluation, and whether or not there is a need for community support or volunteer labor. This will hinge on the most important aspect of an evaluation strategy: the analysis technique. The analysis options are discussed in Step C, but the choice of the option occurs now because of the need to determine which variables to examine and how to collect that information. This is called formulating a methodology. A methodology is an idea of how to acquire and use information.

The evaluation strategy is a map for use either continuously or occasionally to chart the course of a program or measure the strength of certain facilities. It might be a part of a comprehensive pedestrian or bicycle plan; it should be.[252]

B. Collect Data

Transportation systems, regardless of travel mode, have some general measurable variables. These include costs, demand, usage, routing, and safety. (See Table 10.) Pedestrian and bicycle facility evaluations must not only examine the standard variables; they also need to look at points of conflict and the interrelationship with other forms of transportation, particularly the motor vehicle. Which variables to examine and what information to collect will hinge on the analysis procedures. Previous evaluations of pedestrian and bicycle facilities point to specific variables for data collection:[39,240]

TABLE 10

SPECIFIC PEDESTRIAN AND BICYCLE VARIABLES

| Pedestrian | Bicycle |
|---|---|
| **Costs** | |
| Design | Design |
| Financing/Legal | Financing/Legal |
| Site Preparation | Site Preparation |
| Construction | Construction |
| Maintenance | Maintenance |
| Security/Enforcement | Security/Enforcement |
| **Demand** | |
| Demographic Data | Demographic Data |
| Trip Purpose | Trip Purpose |
| Number of Trips | Number of Trips |
| Trip Length | Trip Length |
| | Bicycle Ownership |
| **Usage** | |
| Pedestrian Counts | Bicycle Counts |
| Capacity | Capacity |
| Peak Periods | Peak Periods |
| Travel Time | Travel Time |
| **Routing** | |
| Travel Corridors | Travel Corridors |
| Trip Generators | Trip Generators |
| Convenience | Convenience |
| Environment/Aesthetics | Environment/Aesthetics |
| **Safety** | |
| Accidents | Accidents |
| Causal Factors | Causal Factors |
| Crime | Crime |
| Exposure Measures | Exposure Measures |

Fortunately, most of the variables are the products of individual research -- obtain costs from the accounting and budgeting people; count the number of people using a facility; plot corridors and trip generators, and look to the police for accident reports. It is often the intangible things, however, which make or break a system concept. Things like a pedestrian's inconvenience and a bicyclist's perception of barriers or hazardous conditions render a facility inadequate.[107] To measure the intangibles, evaluators utilize survey research or direct observation. Survey research, properly applied, requires an understanding of statistics and research methods; professional help is often necessary to conduct a survey. Direct observation is easier; assumptions about personal behavior and attitudes can be made by observing how people act in real life situations.[158] Time-lapse photography* is a valuable asset here.[104]

C. Analyze Data

Depending upon whether or not data were available, there is now a chance to scrutinize the measured or collected data for its relationship to a program or facility. Pedestrians and bicyclists are hoping, of course, for success: increased usage, greater safety, shorter travel times, etc. Their evaluation strategy set certain goals with this success in mind, and their analysis sets out to determine whether those goals were met.

If a facility were to be economically justified, it would be evaluated to see if its costs were less than or equal to its revenue.[179] With the exception of certain special circumstances, this economic analysis does not apply to pedestrian and bicycle facilities. A better evaluation technique might be cost-benefit analysis. Cost-benefit analysis is a logical extension of economic analysis because other benefits are measured in dollar values along with revenues. Here all of the costs (design, construction, servicing, environmental, etc.) are weighed against all of the benefits. This presumes that every variable has a dollar value; the cost of enforcement, for example, can be measured against the benefit of accident reduction. Accidents involve costs for emergency medical services, lost income, the loss of potential productivity, and other lesser costs. The more the researcher can formulate the benefits to counter the costs, the better is the case to start or continue a program or system.[40]

* See also: Berger, W.G. and J.H. Sanders, "Guidelines for the Use of Time-Lapse Photography in Transportation Research," FHWA-RD-75-122.

Effective analysis, on the other hand, measures how the original objectives were met in relation to how much was spent. Then a measurable criterion for each objective is formulated and the results weighted by the relative importance of each objective. With an objective of the lowest possible construction costs, for example, choose a criterion of cost per mile. Assign a weight to this objective (now measured in cost per mile) in relation to the other objectives. Then compare alternatives involving all your objectives. A linear relationship would compare alternatives by adding each of the weighted objectives under each alternative. The result is a set of scores indicating the best alternative.[245]

There are much more sophisticated methods of evaluation which are often applied when large systems or national programs are under study. These techniques include decision analysis, game theory, logic models, components analysis, and linear programming. These techniques all have their place, but they require time, extensive data collection, and sophisticated analysis.

## D. Implement Findings

The ultimate purpose of an evaluation is to produce a decision-making tool. Most of the recorded evaluations in the pedestrian and bicycle literature left their findings for other people to implement because they were academic or professional research efforts. The evaluator has a responsibility to the decision maker and the public to make his findings accessible. This can only aid the quest for better pedestrian and bicycle programs and facilities.

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E-2. WHAT METHODS ARE USED TO MEASURE PEDESTRIAN AND BICYCLE EXPOSURE TO DANGEROUS SITUATIONS?

Most articles on pedestrian and bicycle safety open with several paragraphs on the frequency and magnitude of accidents involving the walking or bicycling population. It is somewhat surprising then that it is only recently the subject of exposure measures has received serious scrutiny along with the accident statistics. Accident statistics alone can only reveal a part of the total behavior pattern; exposure measures clarify that behavior. Exposure measures relate human behavior in dangerous or potentially dangerous situations to the results of that behavior. Used properly, exposure measures provide a better understanding of dangerous behavior, and they allow the development of more effective accident countermeasures by addressing the cause of dangerous behavior rather than its result, the accident.

When accident data is compared to exposure data, it should point to high risk situations.[146] These risk situations, in turn, may be the result of hazardous behavior, or they may represent normal behavior in which a few misfortunate people have an accident. To date, similar methods to measure exposure to dangerous situations or risk have been applied to both the pedestrian and bicycling community. Those methods include personal interviews with the endangered parties, on-site observations of human behavior in a variety of potentially dangerous situations, and the statistical comparison of exposure data to accident data.[62,112,127,136,159]

A research study in England investigated the exposure of young pedestrians between 5 and 11 years old. Their analysis revealed little difference in exposure between boys and girls; that exposure increased with age, but the accident rate decreased; and that the risk per vehicle was higher on major roads. Their overall assessment indicated that accident statistics considerably underestimate the risk to children under age 8.[208]

In order to measure risk, a researcher starts with an extensive investigation of the local population, identifying the relevant characteristics of the pedestrian or bicycling population -- age, sex, riding or walking habits, trip lengths, trip time, route selection, location, accompaniment, etc. Then he compares the findings to national and local accident data; this determines how the local population differs from the national sample and provides parameters or expected values for statistical procedures like chi-square or the analysis of variance.[261]

TABLE 11

SUMMARY OF BICYCLIST EXPOSURE STATISTICS

| | *Sex* | | *Age* | | | |
|---|---|---|---|---|---|---|
| | *Male* | *Female* | *0–15* | *16–20* | *21–25* | *26+* |
| Number of subjects | 112 | 43 | 53 | 59 | 19 | 24 |
| Average distance traveled (miles) | 3.57 | 3.56 | 3.30 | 3.36 | 4.35 | 4.10 |
| Percent of travel on: | | | | | | |
| one-way roads | | | | | | |
| with traffic | 1.5 | 1.2 | 0.4 | 1.2 | 5.0 | 0.4 |
| against traffic | 1.5 | 1.1 | 0.4 | 1.5 | 4.0 | 0.8 |
| Two-way 2-lane roads | | | | | | |
| with traffic | 48.8 | 65.8 | 50.4 | 56.0 | 56.0 | 50.3 |
| against traffic | 2.8 | 3.5 | 3.3 | 4.7 | 0.3 | 0.8 |
| Two-way multilane roads | | | | | | |
| with traffic | 41.6 | 26.4 | 41.1 | 33.5 | 32.4 | 45.5 |
| against traffic | 2.8 | 1.1 | 3.8 | 2.1 | 1.0 | 1.1 |
| Sidewalk | 0 | 0.5 | 0.4 | 0 | 0 | 0 |
| Off roadway | 1.0 | 0.4 | 0.2 | 1.1 | 1.3 | 1.1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Intersections encountered (average number) | | | | | | |
| Four-way | 14.3 | 11.9 | 12.6 | 11.8 | 20.1 | 15.8 |
| Traffic circle | 0.3 | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 |
| T-intersection | | | | | | |
| right-leg | 7.1 | 5.7 | 6.7 | 6.6 | 5.7 | 7.8 |
| left-leg | 6.7 | 5.6 | 5.7 | 6.3 | 6.5 | 8.0 |
| left-right legs | 0.6 | 0.5 | 0.4 | 0.7 | 0.7 | 0.5 |
| Y-intersections | 0.4 | 0.2 | 0.5 | 0.1 | 0.3 | 0.5 |
| Expressway ramps | 0.2 | 0.3 | 0.7 | 0.1 | 0.3 | 0.3 |
| Action at intersections | | | | | | |
| Straight across | 25.8 | 20.6 | 23.2 | 21.8 | 29.2 | 30.2 |
| Right turns | 2.0 | 1.6 | 1.7 | 2.3 | 2.4 | 1.7 |
| Left turns | 1.8 | 2.1 | 1.8 | 1.6 | 2.1 | 1.5 |
| Traffic control devices encountered | | | | | | |
| 1. no stop sign or signal in cyclist's direction | 16.5 | 14.6 | 15.5 | 14.9 | 17.1 | 18.7 |
| 2. stop sign or signal in cyclist's direction only | 1.3 | 0.5 | 1.2 | 0.9 | 1.8 | 0.9 |
| 3. stop sign or signal for all directions | 10.3 | 7.8 | 8.7 | 8.3 | 13.3 | 12.5 |
| 4. traffic signal light | 1.5 | 1.4 | 1.3 | 1.6 | 1.5 | 1.3 |
| Total | 29.6 | 24.3 | 26.7 | 25.7 | 33.7 | 33.4 |

Source: Adapted from Kobas, G.V., and C.G. Drury, "The Bicyclist's Exposure to Risk," Proceedings of the 6th Congress of the International Ergonomics Association, College Park, MD, July 1976.

A New York study involving bicyclist behavior, exposure to risks, and accidents compared its exposure data (See Table 11.) to local accident data. By interviewing accident participants and reviewing the accident scenes they were able to determine whether the cyclist's violation of the law was the result of ignorance or disobedience. Comparing exposure data to the accident cases revealed that more cyclists disobeyed the law than were ignorant of it. This would suggest that increased enforcement is a more important countermeasure in that locality than increased education.[78]

Measuring and evaluating risk in a local community can have positive safety benefits. It permits the allocation of program revenues to areas which promise the greatest benefits. Many communities nationwide have begun exposure studies and the Federal Highway Administration is supporting a research effort to enumerate national pedestrian trip making characteristics and exposure measures. When these research studies are documented, it will help other pedestrian and bicycle planners and coordinators to assess their local safety programs.

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## GLOSSARY

AASHTO - American Association of State Highway and Transportation Officials and including their publications.

ACCESS - The ability to pass to and from; in pedestrian and bicycle circles, freedom from barriers.

ACTIVITY CENTER - A public or private facility which acts as a trip generator.

AMENITY FACTOR - Any design feature of a bicycle facility over and above safe design which induces use, for example, weather protected parking and scenic overlooks.

BARRICADE - A portable or fixed barrier having object markings used to close all or a portion of the right-of-way to vehicular or pedestrian traffic.

BARRIER - A sanction or device used to block or channel pedestrian or bicycle traffic.

BICYCLE - A vehicle propelled exclusively by human power having two wheels in tandem or two rear wheels and front wheel.

BICYCLE FACILITY - Anything built, installed, or established for bicycling use.

BIKE LANE - Any bikeway which is part of the roadway or shoulder and delineated by pavement marking or barriers.

BIKE PATH - A bikeway completely separated from vehicular traffic and within an independent right-of-way or the right-of-way of another facility. Travelways separated from vehicles but shared by both bicycles and pedestrians may be included in this classification.

BIKE ROUTE - Any bikeway sharing its traffic right-of-way with motor vehicles and designated only by signing.

BIKEWAY - Any trail, path, part of a highway or shoulder, sidewalk, or any other travelway specifically signed or marked for bicycle travel.

CAPACITY - The maximum number of pedestrians or vehicles which can use a facility during a given time.

CHANNELIZING LANE - A line which directs traffic and indicates that traffic should not cross but may proceed on either side.

CLEARANCE - The height or width necessary for safe passage, measured in a vertical or horizontal plane.

CONE OF VISION - The area of roadway and roadside visible to a cyclist when riding seated, with hands on handlebars and eyes in direction of travel.

CONNECTIVITY - Refers to direct and continuous service to a destination.

CONTROLLED ACCESS HIGHWAY - A vehicular travelway on which access and egress locations are predetermined by public authority usually in the form of grade separation or interchange. Direct residential or commercial access to the highway is prohibited.

CORRIDOR - A strip of land between two termini within which traffic, topography, environment and other characteristics are evaluated for transportation purposes.

CROSS SECTION - A diagrammatic presentation which is at right angles to the centerline.

CROSSWALKS - Any portion of a roadway distinctly indicated for pedestrian crossing by lines or other markings on the surface.

CURB CUTS - Indentations, usually sloped, in the roadside curbing to allow wheeled vehicles to enter and exit the roadway.

DESIGN SPEED - The safe operating speed for a facility based on its curvature and alignment.

ENGINEERING STUDY - The process of gathering, compiling, and studying relative information for the purpose of producing a conclusion concerning a given problem. Likewise applies to Planning Study, Location Study, etc.

GEOMETRICS - The proportional measurement of materials and land use which comprise the physical design of a pedestrian or bicycle facility.

GRADE SEPARATIONS - Vertical structuring of travelways which permit traffic to cross without interference.

HIGHWAY (or STREET) - The entire width between the boundary lines of a right-of-way open to the public for purposes of vehicular travel.

INTERMODAL TRANSFER POINT - Any location at which a person or persons changes from one transportation mode to another.

INTERSECTION - The area embraced within the prolongation or connection of the lateral curb lines, or, if none, then the lateral boundary lines of the roadways of two highways which join one another at, or approximately at, right angles, or the area which vehicles traveling on different highways joining at any other angle may come in conflict.

ISLAND - An area within a roadway from which vehicular traffic is intended to be excluded, together with any area at the approach occupied by protective deflecting or warning devices.

LEGEND - Words, phrases, or numbers appearing on all or part of a traffic control device.

LEVEL OF SERVICE - The qualitative measure of factors such as speed, travel time, safety, travel interruptions and maneuverability.

LICENSING - The permission granted by authority to a person to perform some act, for example, drive a vehicle. In popular usage, often confused with registration.

LIMITED-ACCESS ROAD - A highway with access and egress permitted only at points designated for that purpose.

LOCATIONAL CRITERIA - Relative, predetermined standards for use in selecting and weighting bikeway corridors.

LONGITUDINAL PATTERNS - Stripes or markings placed parallel to the flow of traffic.

LOOP DETECTORS - Oblong signal activation devices buried in the roadbed for detecting metal vehicles.

MEDIAN LANE - A speed change and storage lane with the median to accommodate left-turning vehicles and sometimes used as a pedestrian refuge.

MEDIAN - The portion of a divided highway separating traveled ways for traffic in opposite directions and sometimes used as a pedestrian refuge.

METRIC SYSTEM - An international system of measurement called "The International System of Units" (abbreviated SI).

MID-BLOCK CROSSING - A pedestrian crossing located approximately mid-way between two other crossing points at the corners, usually without signalization.

MODEL - Patterns created through mathematical procedures for producing simulated relationships.

MOPED - A vehicle capable of being propelled by human power as well as by a limited capacity motor.

MUTCD - Abbreviation for the Manual on Uniform Traffic Control Devices, approved by the Federal Highway Administration as a national standard for placement and selection of all traffic control devices on or adjacent to all highways open to public travel in accordance with Title 23, U.S. Code, Sections 109-b, 109-d, and 402-a.

NCUTLO - The National Committee on Uniform Traffic Laws and Ordinances, formulates the Model Traffic Ordinance (MTO) and the Uniform Vehicle Code (UVC).

NORMAL HIGHWAY PRACTICE - Procedural treatment of a situation considered acceptable or standardized by AASHTO.

ORIGIN/DESTINATION STUDY, O&D STUDY - A survey of facility users made to determine trip frequency and termini.

PARAMETERS - Set of physical components whose values determine the characteristics or behavior of a system.

PATHWAY - Graded or improved pedestrian walkway.

PAVEMENT - That part of a roadway having a constructed surface for the facilitation of vehicular movement.

PAVEMENT MARKING - Painted or applied line(s) or legend placed on any bikeway surface for regulating, guiding, or warning traffic.

PEDESTRIAN - A person whose mode of transportation is on foot. A person "walking" a bicycle becomes a pedestrian.

PEDESTRIAN DETECTOR - A detector, usually of the push-button type, installed near the roadway capable of being operated by hand.

PEDESTRIAN PHASE - A signal phase allocated to pedestrian traffic.

PEDESTRIAN SIGNAL - A traffic control signal which is erected for the exclusive purpose of directing pedestrian traffic at signalized locations.

PELICAN CROSSING - A pedestrian light-controlled crossing. The pedestrian actuates a push-button electronic signal controller which regulates the signal phasing to shorten waiting time and give the pedestrian the right-of-way.

PLANNING AREA - A geographic district or region under common jurisdiction selected for planning objectives.

PLANNING SUB-AREA - The smallest geographic unit for which trip behavior is calculated and analyzed in transportation studies. Generally, this is part of a collection which provides conclusions for a planning area.

PRETIMED SIGNAL - A type of traffic control signal which directs traffic to stop and permits it to proceed in accordance with predetermined time schedules.

PUBLIC PARKING AREA - A parking facility available for use by the general public, with or without payment of a fee.

RECREATIONAL CYCLIST - An individual who uses a bicycle for the trip itself. Ultimate destination is of secondary importance.

REGISTRATION - A formal enrollment, for example, of a vehicle or person. Often used incorrectly to mean licensing.

RIGHT-OF-WAY - A term denoting land, property, or interest therein, publicly acquired and devoted to some purposes, e.g., transportation.

ROADWAY - That portion of a road which is improved, designed, or ordinarily intended for vehicular use.

RULES OF THE ROAD - That portion of a motor vehicle law which contains regulations governing the operation of vehicular and pedestrian traffic.

SAFETY ZONE - The area of space officially set apart within a roadway for the exclusive use of pedestrians, and which is protected or is so marked or indiated by adequate signs as to be plainly visible at all times while set apart as a safety zone.

SHOULDER - The part of the highway between the roadway and the end of the right-of-way immediately contiguous to the roadway.

SHY DISTANCE - The distance between the bikeway's edge and any fixed object capable of injuring a cyclist using the facility.

SIDEWALK - That portion of a street between the curb line, or the lateral line of a roadway, and the adjacent property lines intended for the use of pedestrians.

SIDEWALK BIKEWAY - Any sidewalk used by cyclists and pedestrians.

SIGNAL INSTALLATION - All of the equipment and material involved in the signal control of traffic at one intersection.

SIGHT DISTANCE - A measurement of visibility along the normal travel path to the furthest point of the roadway surface.

SLURRY SEAL - A thin asphalt emulsion applied over a stabilized base or shoulder to provide a smooth surface.

STABILIZED SHOULDER - The shoulder when its subgrade is compacted and surface given a light bituminous treatment.

STOPPING SIGHT DISTANCE - The total distance traveled from the instant a vehicle operator sights an object to the time the vehicle comes to rest. Perception plus reaction and braking distance equals stopping sight distance.

SUPERELEVATION - Raised outside edge of a bikeway curve for the purpose of overcoming the force causing a bicycle to skid when maintaining speed. Often called a "banked curve."

TERMINUS - The starting or ending point of a trip.

TRAFFIC - Pedestrians, ridden or herded animals, vehicles, streetcars, and other conveyances either singly or together while using any travelway for purpose of travel.

TRAFFIC-ACTUATED SIGNAL - A type of traffic control signal in which the intervals are varied in accordance with the demands of traffic as registered by the actuation of detectors.

TRAFFIC CONTROL DEVICES - Signs, signals, or other fixtures, whether permanent or temporary, placed on or adjacent to a travelway by authority of a public body having jurisdiction to regulate, warn, or guide traffic.

TRAFFIC FLOW PATTERNS - Graphic presentation of vehicular and/or pedestrian movement at a given time on given streets.

TRAFFIC MARKINGS - All lines, patterns, words, colors, or other devices except signs, set into the surface of, applied upon, or attached to the pavement or curbing or to objects within or adjacent to the roadway, officially placed for the purpose of regulating, warning, or guiding traffic.

TRAFFIC SIGN - A traffic control device mounted on a fixed or portable support whereby a specific message is conveyed by means of words or symbols, officially erected for the purpose of regulating, warning, or guiding traffic.

TRANSVERSE PATTERNS - Pavement markings perpendicular to, or at an angle to, the flow of traffic, such as stop bars, crossover stripes, and median delineations.

TRAVELWAY - Any way, path, road, or other travel facility used by any and all forms of transportation.

TRIBUTARY AREAS - Geographic locations that act as feeders to major transportation corridors.

TRIP GENERATOR - A fixed facility requiring and attracting travel.

TRUCK BLAST - The aerodynamic force applied by rapidly moving vehicles on a proximate object.

UTILITARIAN CYCLIST - An individual who uses a bicycle primarily to reach a particular destination.

VOLUME - The number of pedestrians or vehicles that pass a given point during a given amount of time.

WARRANTS - The minimum conditions which would justify the establishment of a particular traffic control regulation or device, usually including such items as traffic volumes, geometrics, traffic characteristics, accident experience, etc.

ZEBRA CROSSING - A black and white, diagonally painted pedestrian crossing used to alert motor vehicles.

PEDESTRIAN/BICYCLE ABSTRACTS

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# FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

## *FCP Category Descriptions*

### 1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration 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 keeping the demand-capacity relationship in better balance 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 which affect the quality of the human environment. The ultimate 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 of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of 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 designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

### 6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

### 7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

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* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD-2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.