PLANNING FOR PEDESTRIANS WITHIN THE HIGHWAY ENVIRONMENT

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(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

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ABSTRACT

The guidelines currently utilized to evaluate the need for pedestrian accommodations in suburban areas were reviewed and summarized. Information was obtained from the literature, a mail survey, and personal interviews. Recommendations were developed for use in pedestrian planning. A handbook was prepared to assist planners and engineers in deciding when and where a pedestrian facility should be installed or retrofitted and the kind of facility that would be most appropriate.

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INTRODUCTION

To date, highway planners and designers have placed much emphasis on providing technically efficient highway systems, but in most instances have given little attention to accommodations for the pedestrian. This limited approach to planning has resulted in travel delays for both the pedestrian and the motorist and increased safety risks, particularly for the pedestrian; and to a considerable extent it has precluded walking as an alternative to vehicular travel. Moreover, as the demands for energy resources continue to increase and supplies remain questionable, the accommodation of non-motorized travel in the highway environment becomes an increasingly important option.

In light of the above, pedestrian needs should receive proper and systematic consideration in the initial stages of transportation projects. At present, a majority of the planning for pedestrian travel is focused on activity within highly developed, densely populated areas, particularly the central business district. There, the multitude of available trip destinations within short distances and the large volumes of pedestrians make the need to accommodate pedestrian movements readily observable. On the other hand, in suburban environments the significance of pedestrian travel is not as readily apparent. In these environments, pedestrian travel is diffuse, periodic, and in lower volumes. Most suburban families use the automobile for trips their urban counterparts can make by walking or using mass transit; hence, pedestrian travel plays a minor role in the overall travel behavior of a typical suburban resident.

Currently, pedestrian facilities are provided by the Virginia Department of Highways and Transportation in response to requests from the public, local governments, and resident engineers, and where an obvious need exists. In most instances, and where deemed appropriate, at-grade pedestrian accommodations are utilized. In some cases, however, grade separations are provided where major highways or topographic features create barriers to pedestrian travel. In

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most cases decisions regarding the need for a pedestrian treatment and the type of treatment are based on engineering judgment. There is a need to define criteria, guidelines, or, if possible, warrants to assist Department engineers in these decisions.

PURPOSE, SCOPE, AND METHODOLOGY

The primary purpose of the study was to develop guidelines for the effective accommodation of pedestrians in suburban areas. These guidelines provide information that will assist planners and engineers with decisions pertaining to (1) when and where a pedestrian facility should be installed or retrofitted, and (2) what kind of pedestrian facility would be most appropriate.

The scope of the project was limited to a review and summary of existing practices.

The procedure followed in collecting the information consisted of three basic parts: (1) a literature review, (2) a mail survey of the 49 other state transportation agencies and selected cities and urbanized counties in and outside of Virginia, and (3) personal contacts with Department officials to determine existing procedures within the Department.

FINDINGS

Guidelines, criteria, warrants, and even systematic methods have been developed and are being used to determine the need for pedestrian facilities. These may be very general or may be very specific in assigning threshold numbers to certain factors indicative of pedestrian needs. In order to make this report as concise and useful as possible, all guidelines, etc., uncovered in the literature review and the mail survey are provided in Appendices A through F, which are labeled by type of facility, including sidewalks, crosswalks, signals, grade separations, refuge islands, and barriers. Also there are guidelines for school crossings. Thus a reader concerned with the evaluation of the need for a certain type of pedestrian facility should refer to the appropriate appendix for a description of general and specific guidelines being used. It is noted that in some instances guidelines are duplicated among the sources, or, in fact, may be contradictory, but this format allows maximum flexibility in the use of engineering judgement and site-specific variables.

Following in this section of the report are discussions of two other pertinent topics from the literature review, the results of the mail survey, and the Department's current activities in pedestrian planning.

Literature Review

Many of the guidelines listed in the appendices require pedestrian demand calculations and economic analyses. The information from the literature on these two topics is summarized under the succeeding subheadings.

Pedestrian Demand

The most obvious and easiest method of deriving a pedestrian demand is to conduct a field survey and count the number of pedestrians either walking along or crossing the roadway. In fact, many of the guidelines are based on just such data. Unfortunately, this procedure does not work when pedestrian demand is needed at locations where pedestrian activity is nonexistent, e.g., at a proposed crossing of a freeway. Further, even at locations where pedestrian activity is feasible, safety aspects or other features may inhibit pedestrian crossings. An example of this situation is a 4-lane suburban arterial with heavy traffic volumes and no traffic control devices. Accordingly, a latent demand should be considered. Finally, a valid planning effort should consider future pedestrian demand, especially when a pedestrian facility is being considered for a future highway improvement.

The determination of latent and forecasted pedestrian demand is certainly not an exact science. Pedestrian trips are likely to show considerable variation, as indicated by the large number of trip variables shown in Table 1. A formal planning process which includes the calculation of pedestrian demand has been developed for central city areas where significant pedestrian movement is exhibited over a widespread area.[1] This entire process is, unfortunately, not directly applicable to the isolated suburban location that is the subject of this report. The parts of this process involving trip generation rates are relative to this study, and a small section of the manual which provides information on person-trips for various land uses has been reproduced as Appendix G.

When these rates are applied to a specific land use, an estimate of the total 2-way person-trips per hour generated or attracted to that land use is derived. This number has limited direct application; for example, it may be used to estimate the number of pedestrians utilizing a sidewalk at any of the predominantly attraction land uses. For the most part, however, the number must be modified to reflect the number of actual pedestrian trips, the number of trips by certain purposes, or the number of trips along a certain link. The previously mentioned planning process utilizes a gravity model approach similar to that used for vehicular demands. This method is not suited to an isolated suburban location, and other techniques must be employed.

The literature and survey material obtained did not contain much information on calculating latent or future pedestrian demand. Generally, the techniques must involve the calculation of potential trips between two areas or zones. A simplified origin and destination survey might be feasible, e.g., a survey recording license plates in the origin and destination zones. Another possibility would be to utilize existing trip tables and reduce the zone-to-zone trips to potential pedestrian trips, perhaps based on an acceptable walking distance. The Department has utilized a technique employing various pedestrian characteristics in studies of pedestrian overpasses. Specific pedestrian trip rates for calculating latent or forecasted demand were not found in the surveyed literature.

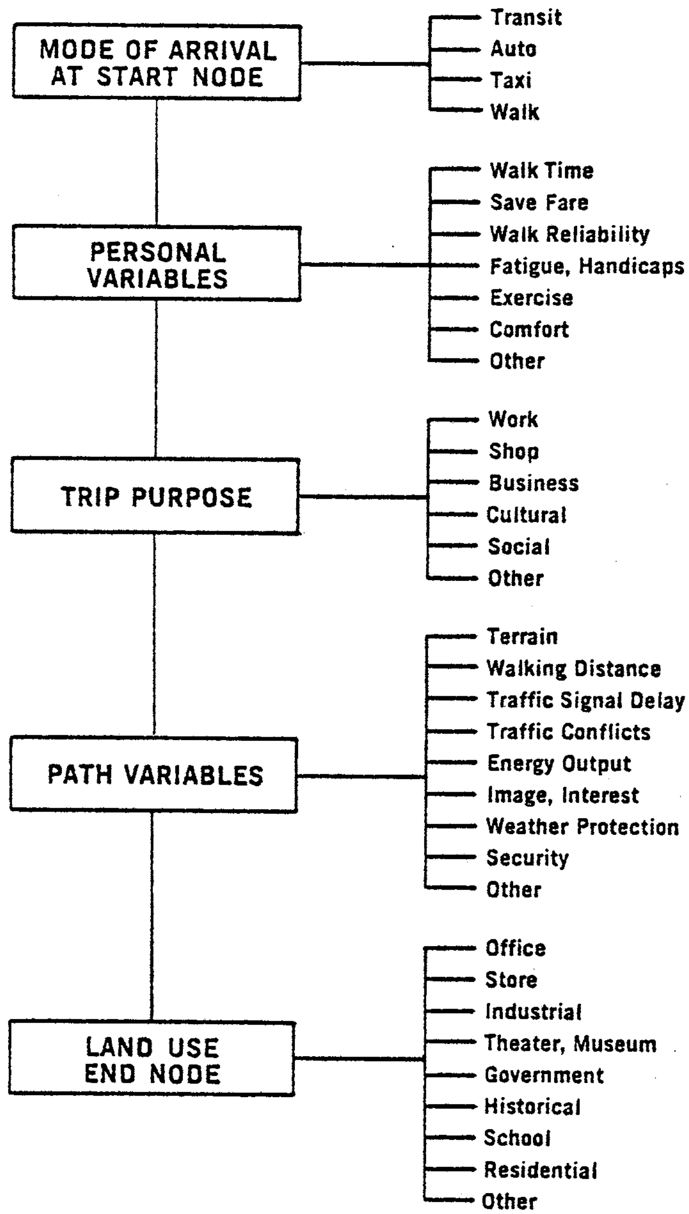
Finally, the research group at the New Jersey DOT has developed a technique assuming that a relationship between the method of predicting auto trips and pedestrian trips would exist when the predicted distances are short.(2) A one-quarter mile radius circle was chosen as a reasonable limit for which this assumption would hold. The proposed pedestrian grade separation would be the center of the circle, with the crossed roadway separating the circle into two zones, each generating trips to the opposite zone. Two pedestrian trips per day per household were assumed, and a percentage of these trips assigned to the four major attractions of school, commercial, institutional, and recreational land uses. This process is more clearly defined in Table 2.

Economic Analyses

An economic analysis, frequently a benefit-cost comparison, has traditionally been performed to evaluate highway improvements. In the case of pedestrian facilities, however, this has generally not been the case. This is evidenced by the information received in the mail survey discussed later in the report. The basic problem encountered in an economic analysis of pedestrian facilities is the quantification of the benefits and even some of the associated costs. Table 3 lists examples of typical costs and benefits associated with a pedestrian facility and the common unit of measurement. The problem of simply quantifying some of these variables is obvious; much more difficult is the assignment of monetary values. Limited documentation is available which attempts to assign monetary values to some of these variables; however, several subjective scoring schemes have been proposed. One such technique is the "value rating" system,(3) an explanation of which has been reproduced as Appendix H. If a more comprehensive scheme is desired, the reader should refer to NCHRP Report 189.(4) Table 4 is a list of the variables for which a numerical scoring scheme has been derived in the report.

Table 1

Pedestrian Trip Variables



Source: Pedestrian Planning and Design, John J. Fruin, Copyright 1971.

Table 2

New Jersey Trip Generation Process

Number of Households: Zone 1 ____________ Zone 2 ____________

Attractions In Zone 1	Trips/Day/Household Assigned			Number of Households in Zone 2		Total Trips/Day Zone 2 to Zone 1
*School	(0 or 1.0)	____	x	____	=	____
**Commercial	(0 to 0.4)	____	x	____	=	____
Institutional	(0 or 0.3)	____	x	____	=	____
Recreational	(0 or 0.3)	____	x	____	=	____
TOTAL		====				====

Attractions In Zone 2	Trips/Day/Household Assigned			Number of Households in Zone 1		Total Trips/Day Zone 1 to Zone 2
*School	(0 or 1.0)	____	x	____	=	____
**Commercial	(0 to 0.4)	____	x	____	=	____
Institutional	(0 or 0.3)	____	x	____	=	____
Recreational	(0 or 0.3)	____	x	____	=	____
TOTAL		====				====

Total Trips Per Day - Zone 2 to Zone 1	____
Total Trips Per Day - Zone 1 to Zone 2	____
Bus Stop Trips Per Day	____
Total Trips	====

* If the actual number of school children is known for either zone, multiply by two and use that number for Total Trips Per Day.

** If Commercial Activity exists:

Trips/Day/Household = 0.1, if there are 1 to 4 establishments,

Trips/Day/Household = 0.2, if there are 5 to 8 establishments,

Trips/Day/Household = 0.3, if there are 9 to 12 establishments,

Trips/Day/Household = 0.4, if there are 13 or more establishments.

Source: Pedestrian Grade Separation Locations — A Priority Ranking System, Volume II, New Jersey DOT, Division of R & D, December 1975.

Table 3

Typical Costs and Benefits of Pedestrian Facilities

Cost Categories	Unit of Measurement
Design costs	Dollars
Construction costs (including manpower)	Dollars
Annual maintenance and operating costs	Dollars
Vehicle delay	Dollars
Vehicle delay	Time
Pedestrian delay	Time
Implementation	Time
Ecological costs	
Air pollution	Parts per million
Noise pollution	Decibels
Visual pollution	Subjective
Cost of an Accident	Dollars

Benefit Category	Unit of Measurement
Accident frequency reduction	Numerical
Accident severity reduction	Numerical
Facility life expectancy	Time
Vehicle delay reduction	Dollars
Vehicle delay reduction	Time
Pedestrian delay reduction	Time
Economic impact	Dollars
Social impact	Subjective
Convenience	Subjective
Ecological impacts	
Air pollution reduction	Parts per million
Noise pollution reduction	Decibels
Aesthetic impact	Subjective

Source: Model Pedestrian Safety Program, User's Manual, U. S. DOT, FHWA, June 1978.

Table 4

Pedestrian Facility Evaluation Variables

1. TRANSPORTATION

 1.1 Pedestrian
 - 1.1.1 Travel Time
 - 1.1.2 Ease of Walking
 - 1.1.3 Convenience (Access and Availability)
 - 1.1.4 Special Provisions for Various Groups

 1.2 Motor Vehicles
 - 1.2.1 Motor Vehicle Travel Costs
 - 1.2.2 Use of Automobiles
 - 1.2.3 Signal/Signing Needs Adjacent to Facility

 1.3 Other Community Transportation
 - 1.3.1 Adaptability to Future Transportation Development Plans
 - 1.3.2 Impact on Use of Existing Transportation Systems

2. SAFETY/ENVIRONMENT/HEALTH

 2.1 Safety
 - 2.1.1 Societal Cost of Accidents
 - 2.1.2 Accident Threat Concern
 - 2.1.3 Crime Concern
 - 2.1.4 Emergency Access/Medical and Fire Facilities

 2.2 Attractiveness of Surroundings
 - 2.2.1 Pedestrian-Oriented Environment
 - 2.2.2 Litter Control
 - 2.2.3 Density
 - 2.2.4 Climate Control and Weather Protection

 2.3 Environment/Health
 - 2.3.1 Effects of Air Pollution
 - 2.3.2 Noise Impacts of Motor Vehicles
 - 2.3.3 Health Effects of Walking (exercise, fatigue, etc.)
 - 2.3.4 Conservation of Resources

3. RESIDENTIAL/BUSINESS

 3.1 Residential Neighborhoods
 - 3.1.1 Residential Dislocation
 - 3.1.2 Community Pride, Cohesiveness, and Social Interaction
 - 3.1.3 Aesthetic Impact, and Compatibility with Neighborhood

 3.2 Commercial/Industrial Districts
 - 3.2.1 Gross Retail Sales
 - 3.2.2 Displacement or Renovation Required or Encouraged by Facility
 - 3.2.3 Ease of Deliveries and Employee Commuting
 - 3.2.4 Attractiveness of Area to Business

4. GOVERNMENT AND INSTITUTIONS

 4.1 Transportation and Land-Use Planning Process
 - 4.1.1 Public Participation in the Planning Process
 - 4.1.2 Conformance with Requirements and Regulations

 4.2 Economic Impacts
 - 4.2.1 Net Change in Tax Receipts and Other Revenue
 - 4.2.2 Resulting Changes in Employment
 - 4.2.3 Change in the Cost of Providing Community Services

 4.3 Community Impacts
 - 4.3.1 Community Activities
 - 4.3.2 Adaptability to Future Urban Development Plans
 - 4.3.3 Construction Period

Source: Quantifying the Benefits of Separating Pedestrian and Vehicles, National Cooperative Highway Research Program Report 189, Transportation Research Board, 1978.

Questionnaire Survey

To determine existing pedestrian planning activities, a questionnaire was mailed to the transportation departments in the 50 states, to 19 cities and urbanized counties in Virginia, and to 14 other cities and urbanized counties throughout the country which the literature review indicated were conducting pedestrian planning activities. Responses were received from 43 other states, 14 localities in Virginia, and 9 localities outside the state. The primary objective of the questionnaire, which is reproduced in Figure 1, was to elicit guidelines, warrants, standards, procedures, etc., being used in planning or evaluating the need for pedestrian facilities. The secondary objective was to obtain information on specific aspects of pedestrian planning activities. Although the relatively high response rate, due in part to follow-up phone calls, is indicative of a successful survey with regard to the latter objective, very little new information regarding the primary objective was received. In fact, only 16 respondents included material in addition to the questionnaire. Table 5 summarizes the questions which are quantifiable, and these questions plus the others are discussed in the remainder of this section.

Eighty-two percent of the respondents indicated that pedestrians are routinely considered in the transportation planning process. Because of the aforementioned lack of methodological information obtained in the survey, however, it is questionable whether that many respondents routinely consider pedestrians in a formal or systematic way. Of those respondents saying that they do, 98% give consideration to pedestrians in the design stage. Pedestrians are considered by less than 50% of the respondents at each of the other stages of planning.

Approximately 63% of the respondents utilize some form of guidelines or rules for mitigating pedestrian-vehicle conflicts. Pedestrian facilities incorporated by over 80% of the respondents are crosswalks with pavement markings only, crosswalks with regular signals, crosswalks with pedestrian signals, and crosswalks with actuated pedestrian signals. Pedestrian underpasses and crosswalks in conjunction with a signal having a delay phase are utilized by less than 51% of the respondents. The other three accommodations are grouped between these extremes. Several other types of pedestrian facilities or strategies were listed. These included crosswalks in conjunction with a reduced speed limit, crosswalks with advanced signing, rerouting of pedestrians, installation of lighting at conflict points, and the use of adult crossing guards at school sites.

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Figure 1. Questionnaire on pedestrian planning activities.

Name of Organization______________________________ Your Phone No.______________
Your Name______________________________ Your Title______________________

1. (a) Does your agency <u>routinely</u> consider pedestrians in the transportation planning process?
   Yes____ No____
   (b) If yes, at what stage in the planning process are they considered?
   Systems___ Design___ Corridor___ Plan Approval___ Location___ Project Approval___
   Other (specify and explain)______________________________
   Comments:______________________________
   ____
   ____
   (Please send any written information, documents, flow charts, etc., that explain when or how pedestrians are considered in the planning process.)

2. Does your agency have any formal or informal guidelines, warrants, or standards for mitigating pedestrian-vehicle conflicts? Yes____ No____
   Comments:______________________________
   ____
   ____

3. What pedestrian accommodations does your agency use to resolve pedestrian-vehicle conflicts?
   Crosswalks with pavement markings only ____ Crosswalks with regular traffic signals ____
   Crosswalks with traffic signals having a delay phase ____ Crosswalks with pedestrian signals_
   Crosswalks with actuated pedestrian signals ___ Underpasses for pedestrians only ____
   Vehicle underpasses with sidewalks ____ Overpasses for pedestrians only ____
   Vehicle overpasses with sidewalks ____ Other (specify)______________________
   Comments:______________________________
   ____
   ____

4. Of the various pedestrian accommodations utilized, is there any one preferred over the other?
   Yes____ No____ If yes, which one and why?______________________
   ____
   ____

5. Which types of pedestrian accommodations, if any, does your agency associate with the following deficiencies?
   Vandalism______________________________
   Crime______________________________
   Loitering______________________________
   Safety hazards to vehicle______________________________
   Safety hazards to pedestrian______________________________
   Other (specify and explain)______________________________
   Comments:______________________________
   ____
   ____

(over)

Figure 1 (cont.)

6. Indicate the extent to which each of the following items influences your ultimate decision to provide or not to provide pedestrian accommodations in a project. Please circle one number for each item.

	No Influence					Very Significant Influence
Existing traffic volume counts	0	1	2	3	4	5
Existing pedestrian volume counts	0	1	2	3	4	5
Vehicle trip generation projections	0	1	2	3	4	5
Pedestrian trip generation projections	0	1	2	3	4	5
Number of pedestrian-vehicle accidents in past	0	1	2	3	4	5
Potential number of pedestrian-vehicle accidents	0	1	2	3	4	5
Public requests	0	1	2	3	4	5
Potential for bisection of a neighborhood	0	1	2	3	4	5
Potential separation of residential area from commercial/ industrial development	0	1	2	3	4	5
Potential separation of residential area from recreational facilities	0	1	2	3	4	5
Distance from nearest alternative legal crossing	0	1	2	3	4	5
Cost-benefit analysis	0	1	2	3	4	5
Number of school age children living adjacent	0	1	2	3	4	5
Number of elderly living adjacent	0	1	2	3	4	5
Number of handicapped living adjacent	0	1	2	3	4	5
Number of non-auto households adjacent	0	1	2	3	4	5

Please specify and explain any factors not mentioned.

Comments: ____

7. (a) If your agency uses a cost-benefit analysis, what factors do you consider on the cost side of the equation?

(b) What factors do you consider on the benefit side?

(c) How do you quantify your costs and benefits?

8. If pedestrian trip generation is used as a planning aid, how do you estimate it?

9. Any additional comments are invited.

Thank you!

Please return to: E. D. Arnold, Jr.
Va. Highway & Transp. Research Council
Box 3817 University Station
Charlottesville, VA 22903

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Table 5

Summary of Questionnaire Survey

		Response Rate
1.	Routine consideration of pedestrians in the transportation planning process?	
	Yes	82.1%
	No	17.9%
	If yes, what stage?	
	Systems	32.7%
	Design	98.2%
	Corridor	30.9%
	Plan approval	47.3%
	Location	40.0%
	Project Approval	29.1%
2.	Guidelines, warrants, standards, etc.?	
	Yes	62.7%
	No	37.3%
3.	Pedestrian accommodations used?	
	Crosswalks-pavement markings	86.6%
	Crosswalks-regular signals	88.1%
	Crosswalks-signals with delay phase	40.3%
	Crosswalks-pedestrian signals	83.6%
	Crosswalks-actuated pedestrian signals	88.1%
	Pedestrian underpasses	50.7%
	Vehicle underpass with sidewalks	65.7%
	Pedestrian overpasses	68.7%
	Vehicle overpasses with sidewalks	73.1%
4.	Is there a pedestrian accommodation preferred?	
	Yes	58.2%
	No	41.8%
6.	Average influence of following items? 0 - no influence; 5 - very significant influence	
	Existing traffic volumes	3.9
	Existing pedestrian volumes	4.4
	Projected vehicle trips	2.3
	Projected pedestrian trips	2.8
	Pedestrian/vehicle accident history	4.2
	Pedestrian/vehicle accident potential	3.4
	Public requests	3.4
	Neighborhood bisection	2.9
	Residential/commercial separation	2.6
	Residential/recreational separation	3.6
	Nearest legal crossing	3.3
	Cost/benefit analysis	2.0
	School age children	3.5
	Elderly	2.9
	Handicapped	2.8
	Non-auto households	1.5

A majority of the respondents, 58%, do not have a preference in their selection of pedestrian treatments, primarily because most are evaluated on a case-by-case basis. The most common preference cited is the crosswalk with actuated pedestrian signals. Comments received indicate that this treatment combines aspects of safety, efficiency, and economy. Many respondents also prefer crosswalks with pavement markings only due to economic considerations, and several respondents favor the pedestrian overpass for safety and efficiency reasons.

Over 50% of the respondents associate vandalism, crime, and loitering with pedestrian underpasses or tunnels. To a small degree, the same three activities are also associated with pedestrian overpasses. Vehicle safety is most often associated with pedestrian or vehicle overpasses, primarily due to objects being thrown from the structures. Rear end collisions are also mentioned as a safety problem with pedestrian signals. In addition to the pedestrian safety related to crime discussed previously, all at-grade crossings are generally felt to create safety problems, especially the crosswalks with no traffic control devices. Several respondents feel that the crosswalks with pavement markings only are more dangerous than no crosswalks due to the pedestrians' perception of safety.

As might be expected, the factors having the most significant influence, average rating 3.9-4.4, in decisions regarding pedestrian accommodations are existing pedestrian volumes, the pedestrian-vehicle accident history, and existing traffic volumes. Other factors which are important, average rating 3.3-3.6, include the potential for pedestrian-vehicle accidents, public requests, separation of residential and recreational areas, distance to the nearest legal crossing, and the number of school age children living nearby. The remaining factors have average ratings of less than 3.0, with benefit/cost analyses and number of non-auto households being rated the lowest.

Approximately 23% of the respondents utilize a benefit/cost analysis in making decisions regarding pedestrian accommodations. Costs considered by the respondents include those for initial construction, rights-of-way, maintenance and repair, signing and pavement markings, traffic or pedestrian counts, energy, air pollution, and delays. Benefits include reduced accidents, congestion, energy consumption, and air pollution; neighborhood cohesiveness; and improved accessibility for pedestrians, including the elderly and handicapped. Most of the factors have readily obtainable and associated costs; however, very little information was provided concerning those factors not easily converted to cost figures. Several respondents utilize accident cost figures developed by the National Safety Council.

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Very few respondents utilize pedestrian trip generation projections as a planning aid, a finding that agrees with the relatively low rating that item received in the previous question on the influence of factors in the decision process. No trip rates were provided by respondents; however, factors mentioned in evaluating trip generation include school enrollment, population density, commercial floor space, number of dwelling units, housing occupancy, origin and destination data, industrial development, recreational development, and land use projections.

Current Pedestrian Activities

Within the Department, the majority of the pedestrian activities, particularly those involving an evaluation of needs, is undertaken by the Transportation Planning and Traffic and Safety Divisions. Other divisions in the Central Office and field offices are involved to a lesser degree. Following is a discussion of the activities.

Transportation Planning Division

A formal and systematic evaluation of pedestrian needs is not a part of the planning process; however, an evaluation of pedestrian needs is routinely conducted if there is an obvious or apparent need for a pedestrian treatment. The Transportation Planning Division may also conduct special studies of pedestrian needs if requested to do so by another division. In particular, the Division responds routinely to requests from the Bridge Division regarding the need for sidewalks on bridges. Formal guidelines, warrants, criteria, etc. to justify a need for a pedestrian treatment or to determine the type of pedestrian facility have not been adopted or used on a regular basis. Fundamental data such as pedestrian volumes, vehicular volumes, and geometric conditions are collected, often in cooperation with the Traffic and Safety Division, and then engineering judgment is applied to make the determinations.

Traffic and Safety Division

With regard to evaluating the need for pedestrian facilities, the Traffic and Safety Division is involved in three areas: signals, pedestrian crosswalks, and pedestrian studies. As the Division reviews all projects for signals using the warrants in the Manual for Uniform Traffic Control Devices (MUTCD), pedestrian needs regarding signals are routinely evaluated, since several of the warrants for signals reflect pedestrian volumes. In any matter regarding pedestrians and signals, the Department has officially adopted the warrants and principles outlined in the MUTCD. Also, the needs for pedestrian crosswalks on state roadways are evaluated upon request, with decisions being made on the basis of engineering judgment. Finally, special pedestrian studies collecting the fundamental data mentioned previously are conducted upon request. These studies are concerned primarily with sidewalk needs; however, they have occasionally led to recommendations concerning pedestrian overpasses or underpasses. Again the decision is based mostly on engineering judgment, although the sidewalk guidelines from the 1965 version of the Traffic Engineering Handbook (described in Appendix A) are utilized.

Location and Design Division

When a project reaches the location and design stage, the need for a pedestrian treatment has generally already been determined. Occasionally, a question concerning the need for a pedestrian facility is raised at this stage, and the Location and Design Division may request assistance from another division, typically Traffic and Safety. Division personnel are not involved in evaluating pedestrian needs.

Urban Division

The Urban Division's primary role is to handle urban aid projects within corporate limits, and accordingly it reviews and approves projects requested by cities. Sidewalks are generally acceptable on urban projects, and other divisions are requested to evaluate the need for other pedestrian treatments. Urban Division personnel do not evaluate pedestrian needs.

Secondary Roads Division

The Secondary Roads Division is charged with administering the secondary road system and funds, and accordingly serves in a review and approval role for secondary road projects. Plans submitted from the field offices are reviewed; however, evaluation of proposed pedestrian accommodations is not undertaken.

Bridge Division

Although the Bridge Division is called upon to design pedestrian structures, it is not involved with evaluating pedestrian needs. As indicated previously, the Planning Division is requested to provide recommendations as to sidewalks on highway structures.

Field Offices

Department field offices, especially those of the traffic engineers, are involved in pedestrian activities to varying degrees, depending on the personnel available and level of pedestrian activity. Many decisions must at least be approved by the divisions mentioned previously, and decisions regarding pedestrian needs are often requested of Central Office Divisions. Based on contacts with field personnel, formal guidelines, warrants, etc., are not utilized; rather, decisions are based on engineering judgment.

SUMMARY OF FINDINGS

Contained in this section for quick reference is a brief summary of the more important findings.

General

1. Guidelines, criteria, warrants, etc., are being used by planners to evaluate the need for pedestrian facilities; however, with the exception of the MUTCD's signal warrants, there appear to be no nationally accepted standards for the other facilities, especially specific warrants.

2. The lack of such specific standards is due in part to the many variables affecting pedestrian needs and pedestrian-vehicle conflicts, and the difficulty in quantifying many of the benefits resulting from mitigating the conflicts. There are also many site-specific considerations which cannot be defined in a national standard.

3. The determination of the number of pedestrians who will utilize the facility is very important, especially in the case of the more expensive treatments. Not only is it imperative to count existing pedestrians, it is also important to consider latent and future demand.

4. Based on the various guidelines contained in the appendices, the data items listed in Table 6 must be collected in order to effectively apply all the information.

Questionnaire Survey

1. A large majority of the states and of the cities responding to the questionnaire routinely consider pedestrians in the planning process. Because of the lack of guidelines, warrants, criteria, etc., obtained in the survey, however, it is questionable whether all these agencies consider pedestrians in a formal and systematic way.

Table 6

Data Items Needed to Use Pedestrian Facility Guidelines

General

Pedestrian Volume[a]

Traffic Volume[a]

Costs

Pedestrian Makeup

Land Use

Vehicle Speed

Accident Experience

Speed Limit

Sight Distance

Geometric Conditions

Local Interest

Existing Traffic Control Devices

Specific

Traffic Design Hourly Volume (AASHTO Sidewalk Guidelines)

Highway Design Speed (AASHTO Sidewalk Guidelines)

Average Lot Size (Fairfax County Sidewalk Guidelines)

Crossing Difficulties (Toronto Crosswalk Warrants)

Number of Gaps (MUTCD Signal Warrants)

Average Walk Distance (Washington State DOT Separation Guidelines)

Gap Time (San Diego Crosswalk Warrants)

Pedestrian Delay Time (ITE School Area Guidelines)

Number of Rows of Pedestrians Walking 5 Abreast (ITE School Area Guidelines)

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[a] See guidelines for specific volume measure to use.

2. A majority of the states and of the cities responding utilize some form of guidelines for evaluating pedestrian needs, with the MUTCD and AASHTO policy books being those most commonly used. Apparently many decisions are based on engineering judgment.

3. The type of pedestrian treatment is generally selected on a case-by-case basis; however, respondents having a preference cite a crosswalk with a pedestrian actuated signal.

4. Vandalism, crime, and loitering are associated with pedestrian underpasses and tunnels.

5. Decisions regarding pedestrian facilities are most commonly based on existing pedestrian and traffic volumes and the pedestrian-vehicle accident history.

6. Very few states or responding cities use formal benefit/cost analyses or pedestrian trip generation projections in the decision-making process.

Current Activities of the Department

1. Formal and systematic review of pedestrian needs and facilities is not undertaken by the Department. Rather, evaluations are routinely conducted when a pedestrian need is obvious or apparent, or when requested.

2. Many divisions of the Department, including field offices, are involved with pedestrian matters. The evaluations of pedestrian needs and facilities, however, are conducted by field offices, particularly traffic engineering, by the Transportation Planning Division, and by the Traffic and Safety Division.

3. With the exception of the MUTCD signal warrants and dated guidelines for sidewalks, no guidelines, warrants, criteria, etc., are being utilized in formulating decisions regarding pedestrians. Most decisions are made on the basis of engineering judgment.

RECOMMENDATIONS

Based on the results of this project, the following recommendations are made.

1. The Department should routinely undertake a formal and systematic review of all new or improvement projects in suburban areas to evaluate the need for pedestrian facilities.

2. This review should be conducted by the Transportation Planning Division as a part of the planning process in order to avoid the expenses involved with retrofitting and aftermath planning. Review by this Division has an added advantage in that suburban projects originating outside the planning process, e.g., secondary road and urban projects, must be reviewed by the Division for compliance with transportation plans.

3. Exactly how and when this review is incorporated into the Division's operations must obviously be at the discretion of the division head. This could simply take the form of a directive to the planning staff that formal and systematic review be undertaken for new projects. The review might occur within the scope of transportation systems management (TSM) planning as the non-vehicular mode is an element of that planning process. The Metropolitan Planning Organization should be involved in the larger areas. Maybe the review should be handled in the functional planning activities. It is anticipated that other divisions will provide assistance as requested in conducting the review.

4. The systematic review should consist simply of the application of the guidelines, criteria, warrants, and procedures described in the appendices to this report. Specific standards are not recommended (except as detailed in the MUTCD) because of the problems with the guidelines described earlier in the report. Rather, it is felt that routine and uniform application of the information in the appendices coupled with engineering judgment will enable valid and reliable decisions regarding the need for and type of pedestrian facility. A simplified procedure for utilizing the appendices in a systematic review is described in Table 7.

5. Finally, it is suggested that engineers in field offices and other than the Transportation Planning Division also utilize the guidelines to assist in decisions regarding pedestrian facilities.

Table 7

Suggested Procedure for Utilization of Appendices for Evaluation of the Need for a Specific Pedestrian Facility in a Suburban Area

Step 1. Select types of pedestrian facilities to evaluate, i.e., which appendices to employ.

1. If it is a question of sidewalks, refer to Appendix A.
2. If it is a question of school crossings, refer to Appendix F.
3. If it is a typical crossing situation:
   a. Refer to Appendix D if a grade separation facility is the only alternative, e.g., crossing a limited access facility.
   b. Refer to Appendices B, C, and D if crosswalks, signalization, and grade separation are all feasible alternatives.

Step 2. Review guidelines contained in the above selected appendices.

Step 3. Based on this review, reduce alternatives to be evaluated if possible. For example, readily discernible physical characteristics of a site may make it impossible to construct a grade-separated structure.

Step 4. Determine data needed to apply the appropriate guidelines and collect data. (It may not be necessary to apply every guideline. This should become more obvious as experience in utilizing the guidelines is gained.)

Step 5. Apply the appropriate guidelines to select a proper facility if a choice is to be made or to decide whether a facility is needed. (Remember that with the exception of the MUTCD warrants the guidelines do not represent official policy and can be precluded by other site-specific factors not covered.)

Step 6. Review Appendix E for the need for barriers or refuge islands, especially to complement a selected facility in Step 5.

General

In applying the guidelines, keep in mind latent and forecasted pedestrian demand as discussed on pages 3 and 4 of the report and in Appendix G and economic analyses as discussed on page 4 of the report and in Appendix H.

FURTHER RESEARCH POSSIBILITIES

1. It is apparent from the literature reviewed that there are many elements of pedestrian facility design that should be considered. A compilation of existing guidelines might be of benefit to the Department.

2. Case studies of existing pedestrian facilities, especially grade separations, could be of benefit in developing factors on which to base demand estimates for proposed facilities.

3. The case study information could also be used to calculate the rating scores proposed in the aforementioned New Jersey Study (Appendix D) or the NCHRP Report 189 (see Findings). By building a data base of scores it may be possible to draw conclusions on the real need for a facility rather than on a relative need.

4. Finally, further research could possibly enable the reduction of the information in this report to a single set of guidelines for each type of facility. This would likely involve the establishment of a task group of Departmental engineers and planners.

REFERENCES

1. A Pedestrian Planning Procedures Manual, Vol. I: Overview, Vol. II: Procedures, Vol. III: Technical Supplement, Report No. FHWA-RD-79-46, Federal Highway Administration, Offices of Research and Development, November 1978.

2. Pedestrian Grade Separation Locations — A Priority Ranking System, Volumes I & II, Thomas Batz, John Powers, John Manrodt, and Richard Hollinger, New Jersey DOT Report No. 75-006-7712, Division of Research and Development, December 1975.

3. Model Pedestrian Safety Program, User's Manual, U. S. Department of Transportation, Federal Highway Administration, Offices of Research and Development, 78-6 Implementation Package, June 1978.

4. Quantifying the Benefits of Separating Pedestrians and Vehicles, National Cooperative Highway Research Program Report 189, Transportation Research Board, 1978.

APPENDIX A

GUIDELINES FOR THE PROVISION OF SIDEWALKS

Introduction

The sidewalk is perhaps the most simple and most common pedestrian facility; it has obvious advantages resulting from the separation of pedestrian and vehicular traffic into their own well-defined paths. The provision of sidewalks is frequently beset by controversy because of various construction procedures and maintenance policies. Thus, it is important to justify the need for such a facility in suburban areas.

General Guidelines

1. The AASHTO policy books on urban highways and arterial streets and on rural highways offer general guidance on the provision of sidewalks. Recognizing the potential for pedestrians in undeveloped urban areas, the "Red Book" indicates that "the design should allow for the ultimate installation of sidewalks. However, as a general practice, sidewalks should be constructed initially along all arterial streets that are not provided with shoulders." Regarding freeways, "sidewalks normally should be provided on both sides of a structure overpassing the freeway. For cross streets underpassing the freeway, it is not necessary to provide sidewalks if there is no immediate need, but space should be allowed for their installation in the future."

   The "Blue Book", on the other hand, recognizes that sidewalks are generally needed in rural and suburban areas only at points of community development that result in pedestrian concentrations. Examples include schools, local businesses, and industrial plants. "Justification for the construction of sidewalks depends upon the vehicle-pedestrian hazard, which is governed chiefly by the volume of pedestrian and vehicular traffic, their relative timing, and the speed of vehicular traffic."

   Sources: A Policy on Geometric Design of Rural Highways, 1965, American Association of State Highway & Transportation Officials.

   A Policy on Design of Urban Highways and Arterial Streets, 1973, American Association of State Highway & Transportation Officials.

2. Sidewalks should be provided at locations where the roadway is not clearly delineated from the shoulder; along school routes; in areas of retail, office, service, and institutional use; in areas with high pedestrian and vehicle volumes; and at locations with accidents involving pedestrians walking or standing in the road.

   Source: Model Pedestrian Safety Program, Users Manual, U. S. DOT, FHWA, Offices of Research and Development, June 1978.

3. Table A-1 has been reproduced from a study prepared for the Illinois DOT.

4. Existing walks disturbed by construction should be replaced with the same type, using current design standards. The walk should improve pedestrian safety and not impair motorist safety. The walk should be accessible to users or be part of an overall plan.

   Source: Location and Design Manual, Ohio DOT, Section 406.1, February 1978.

Specific Guidelines

1. Sidewalks should be provided on bridges carrying crossroads which have existing walks. When the crossroad does not have existing sidewalks, a design year pedestrian volume of 50 per day justifies a walk on one side and of 150 per day justifies walks on both sides. The same basic guidelines also apply to crossroads passing under a bridge, except where there are no existing walks, there must also be concurrent walk construction on a substantial length of the crossroad outside project limits.

   Source: Location and Design Manual, Ohio DOT, Section 406.2, February 1978.

2. Fairfax County utilizes the following guidelines for new subdivisions.

   a. A sidewalk is required on both sides of the street if the average lot size is less than 13,000 sq. ft.

   b. A sidewalk is required on one side of the street if the average lot size is less than 18,000 sq. ft.

   c. A sidewalk is required on one side of the street if the average lot size is greater than 18,000 sq. ft. and within a 1-mile radius of an elementary school or 1-1/2 mile radius of an intermediate or high school.

Source: Telephone conversation with personnel in Fairfax County's Department of Public Works.

3. Table A-2 has been reproduced from the AASHTO "Blue Book" of 1954 and the Traffic Engineering Handbook of 1965. It is noted that in both later editions, 1965 and 1976, respectively, this table has been omitted; however, the consultants in the 1975 Illinois DOT study referenced previously felt it advisable to retain the use of these guidelines with appropriate adjustment for children. The pedestrian volume levels should be adjusted by one-half in locations where a significant number of children would use the facility.

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Table A-1

PLANNING GUIDELINES FOR SIDEWALKS ALONG HIGHWAYS AND ON BRIDGES

LAND DEVELOPMENT	PEDESTRIAN CHARACTERISTICS	SIDEWALK SYSTEM
Older, dense residential areas with neighborhood shopping, schools, parks, transit service, churches.	Substantial pedestrian volumes. Many of them in middle to older age brackets.	Normally existing. In any case, they should be provided on new facilities.
Suburban area with multi-family development and convenience shopping.	Limited pedestrian activity between residences and shopping areas. Generally young-age bracket.	Usually lacking. Should be considered with new facilities.
Suburban area with local schools, playgrounds.	School age children if local policy encourages walking for close-by schools.	Occasionally existing. Should be considered on new facilities.
Special housing developments for the elderly, with nearby parks, convenience shopping, transit services, churches.	Usually substantial pedestrian volumes. Mostly older age bracket.	Often lacking. Should be considered with new facilities.
Express bus stops. with park-and-ride facilities.	Commuters during peak morning and afternoon periods.	Usually lacking. Should be considered, particularly if bus stop is remote from parking lot.
Special complementary uses, such as suburban employment areas with nearby commercial developments.	Lunch break activity by employees.	Usually lacking. Should be considered, particularly if walking distances appear reasonable.

Source: Pedestrian-Related Safety Studies, Prepared for the Illinois DOT, Bureau of Traffic, by Wilbur Smith and Associates, February 28, 1975.

Table A-2

PEDESTRIAN AND VEHICLE VOLUMES FOR WHICH THE CONSTRUCTION OF SIDEWALKS MIGHT BE CONSIDERED

AASHO

VEHICULAR TRAFFIC DESIGN HOURLY VOLUME	PEDESTRIANS PER DAY SUGGESTED FOR CONSTRUCTION OF SIDEWALKS WHEN DESIGN SPEED, MPH, IS:	
	30 to 50	60 and 70
Sidewalk, one side:		
30 to 100	150	100
More than 100	100	50
Sidewalk, both sides:*		
50 to 100	500	300
More than 100	300	200

*Smaller pedestrian traffic volume may justify two sidewalks to avoid pedestrian crossings of the highway.

Source: A Policy on Geometric Design of Rural Highways, American Association of State Highway Officials, 1954.

APPENDIX B

GUIDELINES FOR THE PROVISION OF CROSSWALKS

Introduction

A crosswalk is defined as that portion of a roadway designated for pedestrians to cross the street. Although generally thought of as being marked on the pavement, a crosswalk can be unmarked in the case of a prolongation of the boundary lines of sidewalks or pathways through an intersection. Crosswalks can be located at signalized or nonsignalized locations and at intersections or midblock. Several significant problems, which are listed below, are associated with marked crosswalks, primarily at locations with no signal or stop sign control. Thus, careful consideration of the need for a pedestrian crosswalk is necessary.

1. Crosswalks may cause pedestrians to have a false sense of security and assume that the motorist can and will stop in all cases.

2. Crosswalks may cause an increase in the number of rear-end and associated collisions due to pedestrians not waiting for proper gaps.

3. Unjustified marked crosswalks have shown a higher accident rate than unmarked crosswalks.

4. Pedestrians tend to use the shortest and easiest routes and will not use crosswalks if they are inconvenient.

5. Large numbers of crosswalks may increase motorist noncompliance.

General Guidelines

1. The MUTCD indicates that "crosswalks should be marked at all intersections where there is substantial conflict between vehicle and pedestrian movements". They should also be located at other points of pedestrian concentration, e.g., loading islands, midblock crossings, or where the pedestrian could not otherwise recognize the proper place to cross. The manual further indicates that an engineering study should be required for locations away from traffic signals or stop signs.

   Source: Manual on Uniform Traffic Control Devices, U.S. DOT, FHWA, 1978.

2. Marked crosswalks should be at the following locations:

   a. Intersections in downtown or commercial areas, and along school routes.

   b. Complex or confusing intersections requiring pedestrian channelization.

   c. Signalized intersections.

   d. Midblock locations where many pedestrians cross.

   e. Areas of high pedestrian concentration.

   f. Locations with low or moderate vehicle flow.

   g. Not at locations at the top of a hill.

   Source: Model Pedestrian Safety Program, Users Manual, U. S. DOT, FHWA, Offices of Research and Development, June 1978.

Specific Guidelines

1. Crosswalks should be provided at all urban signalized intersections. Otherwise, it is suggested that marked crosswalks be provided at intersections which have pedestrian and vehicular volumes amounting to 50% of the pedestrian warrant for signals in the MUTCD. This would amount to 300 vehicles per hour for each of any 8 hours during the day with a corresponding pedestrian volume of 75 during this same time period.

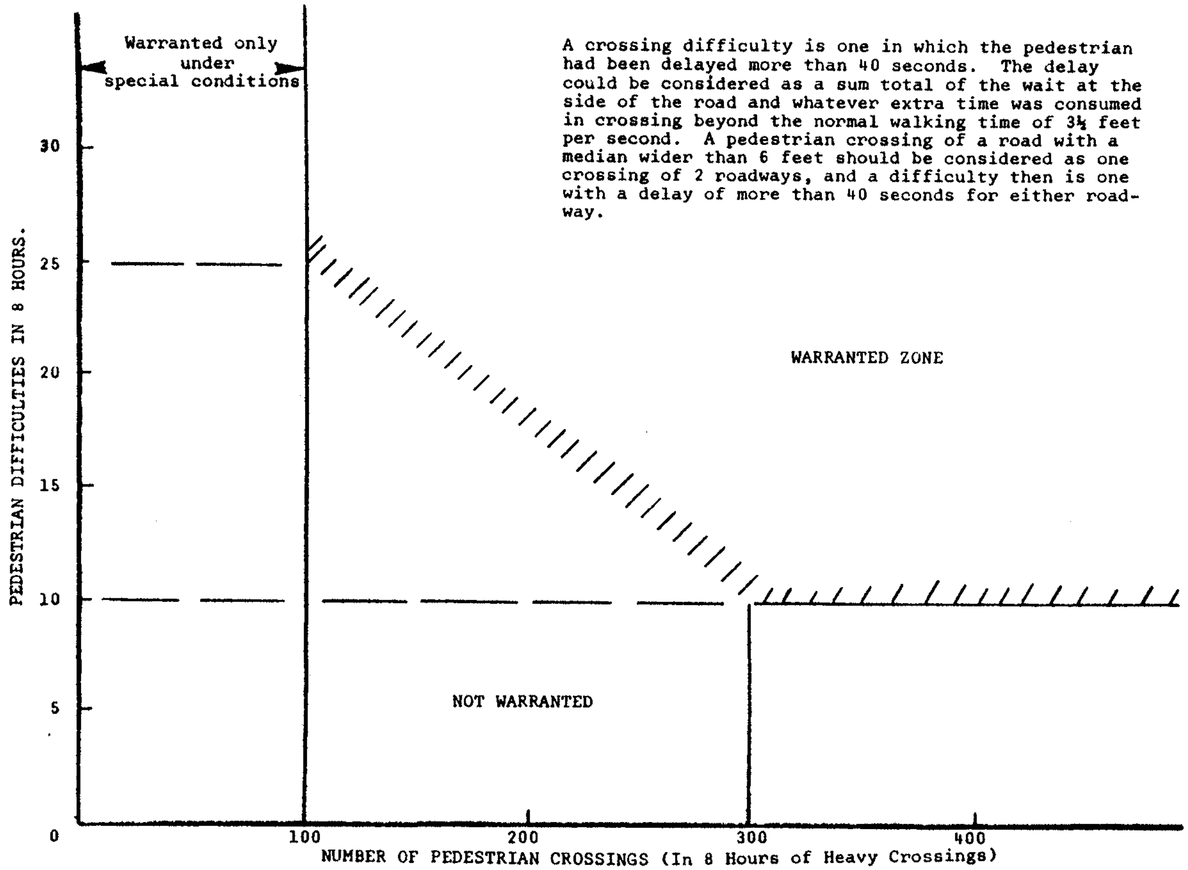
   Source: Pedestrian-Related Safety Studies, Illinois DOT, Bureau of Traffic, by Wilbur Smith and Associates, February 28, 1975.

2. The following set of warrants for marked crosswalks at non-signalized locations are utilized by the city of Toronto.

   The minimum warrants are met if the following 3 conditions are satisfied:

   (1) The results of a pedestrian delay study, when plotted on the "Graph for Pedestrian Crossover Evaluation" (Figure B-1) indicates a situation as being within the warranted zone.

Figure B-1. Graph for Pedestrian Crossover Evaluation.



Source: Information provided by city of Toronto in mail survey.

(2) There are at least 100 pedestrian crossings for an 8-hour study; except under special conditions such as where a substantial percentage of the pedestrians are senior citizens or school children.

(3) The location is more than 700 feet to adjacent traffic control signals or pedestrian crossovers.

With the minimum warrants met, a pedestrian crossover is warranted upon judicial decision with due recognition of the following conditions:

(a) The crossover should not be used on a roadway wider than 4 lanes.

(b) A location at an offset intersection should be avoided.

(c) The location should offer good visibility of the pedestrian.

(d) A location is unsuitable for a crossover where advertising signs or other objects are overpowering distractions to the motorists.

(e) A crossover should not be in a position where cross traffic or turning movements are excessive.

(f) A crossover should not be considered for a road with a speed limit in excess of 40 MPH.

(g) A crossover should not be located where consistent violation of the 30-foot NO STOPPING zone may be expected.

3. The following set of warrants for marked crosswalks at non-signalized and non-school locations are utilized by the city of San Diego.

In order to qualify for a marked crosswalk, a location must (A) meet the following basic warrants and (B) rate 16 points or more under the following point system:

A) <u>Basic Warrants</u>

<u>Pedestrian Volume Warrant</u>

Crosswalks will not be installed where the pedestrian volume is less than 10 pedestrians per hour during the peak pedestrian hour.

Approach Speed Warrant

Crosswalks will not be installed on roadways where the 85th percentile approach speeds are in excess of 45 mph. The approach speeds shall be determined by approved engineering speed study techniques.

Visibility Warrant

Crosswalks will not be installed unless the motorist has an unrestricted view of all pedestrians at the proposed crosswalk site, for a distance not less than 200' approaching from each direction. Sites with grades, curves and other sight restrictive features will require special attention.

Illumination Warrant

Proposed crosswalk site must have adequate crosswalk lighting in existence or scheduled for installation prior to the installation of the crosswalk.

B) Warrant Point System

Pedestrian Volume Warrant

Criterion	Point Assignment	
	Pedestrian Total	Points
The total number of pedestrians crossing the street under study during the peak pedestrian hour. This includes pedestrians in both crosswalks at an intersection. Crosswalks will not be installed where the ped volume (peak ped hr.) is 10 or less	0-10	0
	11-30	2
	31-60	4
	61-90	6
	91-100	8
	Over 100	10
	Maximum	10

General Conditions Warrant

	Points
(a) Will clarify & define pedestrian routes across complex intersections.	2
(b) Will channelize pedestrians into a significantly shorter path.	2
(c) Will position pedestrians to be seen better by motorists.	2
(d) Will position pedestrian to expose him to fewer vehicles.	2
Maximum	8

Gap Time Warrant

Criterion

The number of unimpeded vehicle time gaps equal to or exceeding the required pedestrian crossing time in an average five-minute period during the peak vehicle hour.

Point Assignment

Average number of gaps per 5-minute period	Points
0 - 0.99	10
1 - 1.99	8
2 - 2.99	6
3 - 3.99	4
4 - 4.99	2
5 or over	0
Maximum	10

Computations

(1) Pedestrian Crossing Time = $\dfrac{\text{Street width curb to curb}}{\text{4.0 feet per second}}$

(2) Average Number of Gaps per Five-minute Period =

$$\frac{\text{Total usable gap time in seconds}}{\text{Pedestrian Crossing Time} \times 12}$$

Provisions

(A) The above criterion is based on a one-hour field survey consisting of 12 five-minute samples.

(B) All roadways having a raised median or a painted median (4-foot minimum width) will be considered as two separate roadways, if the pedestrian has a protected place to stand out of the path of traffic.

(C) See Appendix One for survey methods and warrant field form.

San Diego Warrants Continued

APPENDIX ONE

Survey Methods and Field Form

I. Survey Methods

A. Personnel Requirements: One man

B. Equipment: Stop watch (in seconds)
Wrist or pocket watch
Warrant field forms and clipboard
Tally counter board (optional)
Measuring wheel (optional)

C. Duration of Survey: One hour during the morning or evening peak period of pedestrian travel, whichever is greater. If the interval for the peak pedestrian hour cannot be determined, use the peak vehicle hour.

II. Use of the Crosswalk Warrant Field Form

A. Evaluate "Basic Warrants" in the field to determine whether conditions are acceptable.

1. Pedestrian Volume: Make 100% count, during the 60 minute peak, of pedestrians crossing the street in the crosswalk area under study. This includes pedestrians in both crosswalks at intersections. Ped volume data may be hand tallied in space provided on back of form simultaneously with gap time study.**

2. Approach Speed: Use speed data based on floating car technique or radar speed study. Posted speed limits usually are a good indication of the 85th percentile speed. (Radar speed study is preferred.)

3. Visibility: While in car, check drivers' visibility at 200' distance from each approach to the proposed crosswalk.

4. Illumination: Check to see if there is adequate street lighting in the immediate location of the proposed crosswalk. If not, show on sketch existing utility poles available to mount street lights. Make office check to verify feasibility of installing such lights.

B. Make field sketch of intersection and proposed crosswalk area.

1. Measure street width(s) or obtain widths from street inventory book in office.

2. Field sketch or condition diagram should include general geometrics, offsets, islands, lane miles, pavement markings, traffic controls, luminaires, bus stops, mail boxes and other pedestrian generation features; possible sight obstructions, shrubs, grades, swales, etc.

3. Note proposed crosswalk position where gap study is made.

4. Note pedestrian generators in area (schools, factories, etc.) and any unusual activity affecting pedestrians.

C. Compute the "Pedestrian Crossing Time" and enter the figure (in seconds) in appropriate space.

D. Begin 60 minute survey of the "Usable Gap Time". Record under "Field Data" on the back sheet.

Note: "Gap Time" is the time representing unimpeded traffic gap between successive vehicles* crossing a reference point. Usually, it is counted at the proposed crosswalk site (a) by starting the stop watch as the rear bumper of vehicle one crosses the imaginary reference line, and (b) by stopping the stop watch as the front bumper of vehicle two crosses the line from either direction.

"Useable Gap Time" is defined as the gap time that equals or exceeds the calculated "Pedestrian Crossing Time". Record the start of each 5 minute increment and itemize each usable gap time in seconds to correspond with these increments. Count all gaps, but list only those that equal or exceed the pedestrian crossing time.

All divided roadways having a raised or painted median at least 4-feet wide will be considered as two separate roadways if the pedestrian has a protected place to stand out of the path of traffic.

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*Bicycles are not counted in this study. However, a bicyclist "walking" his bicycle across the street in the crosswalk area will be counted as a pedestrian.

Source: Information provided by the city of San Diego in mail survey.

CROSSWALK WARRANT EVALUATION

CITY OF SAN DIEGO, CALIFORNIA
PUBLIC WORKS DEPARTMENT
TRAFFIC ENGINEERING SECTION

LOCATION		
DATE	SUMMARIZED BY	TR

SUMMARY

Pedestrian Crossing Time:

Width of street / 4 ft. per second = ____ / 4 = ________

Average Number Gaps Per Five Minute Period:

Total Usable Gap Time in Sec. / Ped. Crossing Time x 12 = ________ = ________

One Hour Pedestrian Volume: ________

Legal Approach Speed: ________

General Conditions: ________________________

____

WARRANT EVALUATION

(A) Basic Wrrants	ACCEPTABLE	UNACCEPTABLE
(1) Pedestrian Volume		
(2) Approach Speed		
(3) Visibility		
(4) Illumination		

(B) Warrant Point System	POINTS	MAXIMUM POINTS
(1) Pedestrian Volume		10
(2) General Condition		8
(3) Gap Time		10
Total		28

FORM CE-133

SKETCH:

LOCATION: ____________________

DATE: ____________________ DAY: ____________ WEATHER: ____________

RECORDED BY: ____________________

FIELD DATA

TIME	USABLE GAP TIME (SEC.)	TIME	USABLE GAP TIME (SEC.)	TIME	USABLE GAP TIME (SEC.)	TIME	USABLE GAP TIME (SEC.)	TIME	USABLE GAP TIME (SEC.)
								TOTAL	
								PEDESTRIAN COUNT	
								TOTAL ______	

REMARKS:

APPENDIX C

GUIDELINES FOR THE PROVISION OF TRAFFIC/PEDESTRIAN SIGNALS

Introduction

Signalization is obviously one method of mitigating pedestrian-vehicle conflicts by providing a time separation. Traffic signals, which are installed primarily to control vehicular flow, are beneficial to pedestrians since stopping of vehicles causes a gap which can be utilized for pedestrian crossings. Pedestrian signals supplement traffic control signals by advising pedestrians, through the use of words or symbols, when it is safe to cross. There are four basic combinations of pedestrian and traffic signal phasing — the combined pedestrian-vehicular interval, the exclusive crosswalk interval, the leading pedestrian interval, and the exclusive pedestrian phase. These are fully defined in the MUTCD. Although pedestrians should be accommodated in a safe manner, vehicular delay should also be held to a minimum; therefore, guidelines and warrants are important considerations.

Guidelines

1. A traffic signal is warranted by the MUTCD when, for each of any 8 hours of an average day, the following exist.

   a. On the major street, 600 or more vehicles per hour enter the intersection (total of both approaches); or where there is a raised median island 4 feet or more in width, 1000 or more vehicles per hour (total of both approaches) enter the intersection on the major street; and

   b. During the same 8 hours above there are 150 or more pedestrians per hour on the highest volume crosswalk crossing the major street.

   When the 85-percentile speed of major street traffic exceeds 40 mph in either an urban or rural area, or when the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the signal is warranted at 70% of the requirements above.

   Traffic signals may be installed at non-intersection locations (midblock) provided the above requirements are met, and provided that the related crosswalk is not closer than 150 feet to another established crosswalk.

2. A traffic signal may be warranted by the MUTCD at an established school crossing when the number of adequate gaps in the traffic stream during the period when children are using the crossing is less than the number of minutes in the same period. This is based on a traffic engineering study of the frequency and adequacy of gaps as related to the number and size of groups of children.

3. Under the accident experience warrant, a traffic signal is warranted by the MUTCD by satisfying 80% of the pedestrian warrant's values if certain other conditions regarding accident experience are also satisfied (see the MUTCD).

4. In exceptional cases a traffic signal may be justified by satisfying 80% of the pedestrian warrant's values (number 1 above) if 80% of the values stated in the minimum vehicular volume warrant and/or interruption of continuous traffic warrant (see the MUTCD) are also satisfied.

5. A pedestrian signal shall be installed in conjunction with a traffic signal under the following conditions.

    a. A traffic signal is installed under the pedestrian volume or school crossing warrant as described above.

    b. An exclusive interval or phase with all conflicting vehicular movements being stopped is provided for pedestrian movement in one or more directions.

    c. Vehicular indications are not visible to pedestrians or are in a position which does not adequately serve pedestrians.

    d. An intersection signalized under any warrant is an established school crossing.

6. A pedestrian signal may be installed in conjunction with a traffic signal under the following conditions.

    a. The volume of pedestrian activity requires the use of a pedestrian clearance interval or it is necessary to assist pedestrians in making a safe crossing.

    b. Multi-phase indications tend to confuse pedestrians guided only by the traffic signal indications.

    c. Pedestrians are expected to cross only part of the street during a particular traffic signal interval.

7. In the specific case of traffic-actuated signals, and where pedestrian signals are not otherwise warranted as described above, the following is applicable.

    a. When occasional pedestrian movement exists and there is inadequate opportunity to cross without undue delay, pedestrian detectors (usually push buttons) shall be installed to interrupt vehicular flow.

b. When a pedestrian movement exists which does not have adequate crossing time during the green interval, pedestrian signals and detectors shall be installed to interrupt vehicular flow.

8. In a study for the Illinois DOT, consultants proposed pedestrian and traffic volume combinations which warrant signalization of right-turn lanes in order to avoid pedestrian-vehicle conflicts. The graph depicting this has been reproduced on the following page (Figure C-1).

Sources: Manual on Uniform Traffic Control Devices, U. S. DOT, FHWA, 1978.

Pedestrian-Related Safety Studies, Illinois DOT, Bureau of Traffic, prepared by Wilbur Smith and Associates, February 28, 1975.

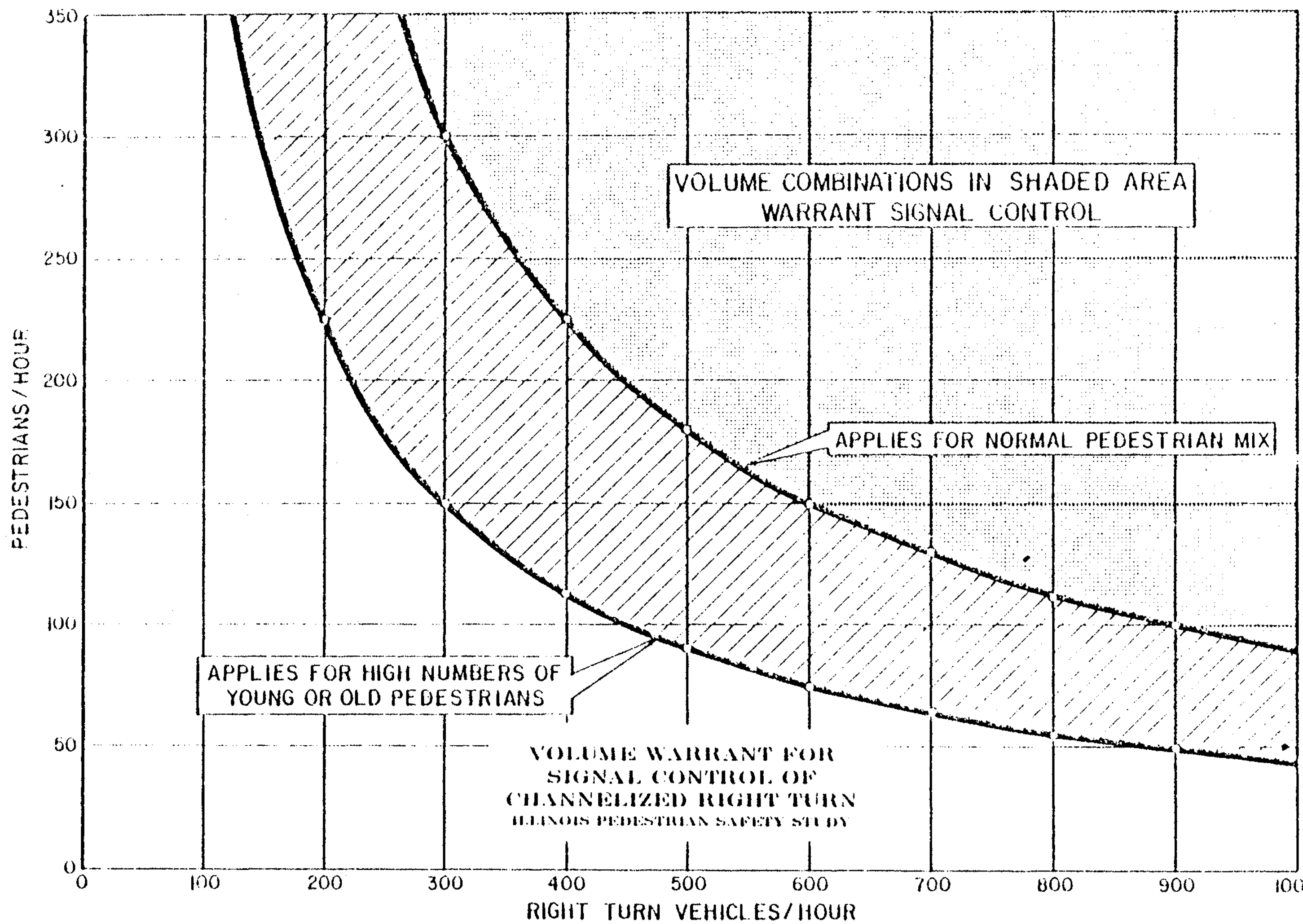

Figure C-1.

Source: Pedestrian-Related Safety Studies, Illinois DOT, Bureau of Traffic, prepared by Wilbur Smith & Associates, Feb. 28, 1975.

APPENDIX D

GUIDELINES FOR THE PROVISION OF PEDESTRIAN GRADE SEPARATIONS

Introduction

In extreme cases of pedestrian-vehicular crossing conflicts, the physical separation of the two modes of travel is necessary. Grade separations can be constructed with either a pedestrian overpass/bridge or pedestrian underpass/tunnel. This solution to pedestrian-vehicle problems is very expensive and should be considered only if there are no other viable alternatives. Further, grade separated structures frequently are not used if alternative paths with fewer impediments are available. Even if the facility is the only path, it may not be used as anticipated because of traits of pedestrians. Thus it is very important that valid guidelines be employed in determining the need for a pedestrian overpass or underpass.

Before presenting guidelines, it is pertinent to discuss the advantages and disadvantages of overpasses versus underpasses. On the positive side, overpasses are less expensive, are easier to maintain, are safer, generally require less lighting, and are less subject to vandalism. On the negative side, however, overpasses can be aesthetically displeasing, do not protect pedestrians from inclement weather, may be longer due to the vertical clearance required for trucks, and provide an opportunity for items to be dropped onto the roadway.

General Guidelines

1. In a report on pedestrian and bicycle planning prepared for the state of Wisconsin, the consultants listed the following questions as factors to consider in analyzing the need for pedestrian separation structures.

    a. Are there other reasonable crossing alternatives?

    b. Are the traffic volume and pedestrian volume levels in excess of those required by MUTCD to warrant installation of a pedestrian or school signal?

    c. Are there no traffic signals, stop sign control, or other grade-separated crossing within 600 feet of the proposed location?

d. Are pedestrian accident problems evident on the street under consideration?

e. Is vehicular traffic speed such that it poses significant hazard to pedestrians?

f. Is there no way to prevent pedestrians from crossing at grade?

g. Have organized groups expressed a high degree of interest for the separation?

h. From a decision standpoint, is it practical to construct the separation within existing physical conditions?

Source: Planning Guide for the Development of Pedestrian and Bicycle Facilities, State of Wisconsin, Governor's Office of Highway Safety, Prepared by JHK and Associates, August 1977.

2. The state of California's Highway Design Manual states that each crossing situation should be investigated and considered on its own merits. The investigation should entail studies of the following items.

   a. Pedestrian generating sources in the area.

   b. Pedestrian crossing volumes.

   c. Type of highway to be crossed.

   d. Location of adjacent crossing facilities.

   e. Circuity.

   f. Zoning.

   g. Land Use.

   h. Sociological and cultural factors.

   i. Predominant type and age of person using facility.

   General rules include the fact that previously established pedestrian patterns should be maintained across freeway routes. If combined vehicular-pedestrian crossings are inadequate for pedestrians, separate structures should be provided. Special consideration should be given to school crossings. Finally, if a circuitous route is involved, a pedestrian separation may be warranted even though the number of pedestrians is small.

Source: Highway Design Manual of Instructions, State of California DOT, Section 7-105.2, August 1, 1979.

3. The Ohio Department of Transportation utilizes the following guidelines for consideration of pedestrian overpasses.

   a. A substantial desire for a pedestrian overpassing should exist. This desire for an overpass generally will be generated by citizens, a school, a public official, or some other community group.

   b. A reasonable alternate route or mode for pedestrians is not available.

   c. There is no signal, stop intersection, pedestrian tunnel, or pedestrian crossing available within 660 feet of the proposed location.

   d. Pedestrians can be prevented from crossing at grade.

   e. Physical conditions permit construction.

   f. The traffic volume and pedestrian volume are above those required to warrant the installation of pedestrian signals as stated in the Manual of Uniform Traffic Control Devices for Streets and Highways. This stipulation can be waived in special cases such as limited sight distances.

Source: Location and Design Manual, Ohio DOT, Section 406.4, February 1978.

Specific Guidelines

1. The Washington State Department of Transportation requires that conditions necessitating the crossing are permanent, that the physical characteristics of the proposed site make the structure feasible from an engineering standpoint, and that there is no possibility of changes in bus routes or school districts which would eliminate the need for such a structure in the vicinity of a school or other heavily used facility.

   In addition to the above criteria, one of the following must be satisfied in the case of a crossing at a fully controlled access highway.

a. Forecasted pedestrian volume is greater than 200 pedestrians per hour for 2 hours each day and the additional average walking distance required for 85% of the pedestrians having the shortest walking distance would exceed 1/2 mile if there were no structure.

b. Severance damages for the taking of recreational, educational, industrial, athletic, commercial, or residential property is more than the cost of the structure necessary to cure the severance.

For partially controlled and non-controlled access highways, the first criterion plus one of the following must be satisfied.

a. The yearly cost of the structure is less than the yearly cost of installing and maintaining the required signal and appurtenances. Also, the additional average walking distance required for 85% of the pedestrians having the shortest walking distance must exceed 1/2 mile if there were no structure.

b. The vehicular and pedestrian traffic is so great that a traffic signal could not handle both without being overloaded during peak hour traffic.

Source: Highway Design Manual, Washington State DOT, Section 330.04, October 1978.

2. The Massachusetts Department of Public Works uses a point warrant to determine the need for a pedestrian overpass on non-limited access highways. This procedure is reproduced in the following.

The type warrant described is the point warrant. It is developed by first selecting those factors that logically affect the degree of need for a pedestrian separation facility, and secondly assigning proportional weights (determined by judgement) to the various factors. Factors that this warrant considers in determining the relative need for a pedestrian overpass are:

1. Pedestrian volumes
2. Vehicular volumes
3. Accident history
4. Geometric conditions
5. Traffic speeds
6. The presence of traffic control devices
7. The availability of alternative crossings
8. Miscellaneous considerations

These factors are then weighted on a scale of 100 points as described below.

40 pts. - To the combination of pedestrian and vehicular volume as determined by the nomograph shown in figure 1.

15 pts. - On accident history, on the basis of 5 points (to a max. of 15) for each correctable pedestrian accident regardless of severity.

45 pts. - All other factors (to a max. of 45) based on engineering judgement of miscellaneous conditions according to the following:

10 points for an existing marked school crossing

10 additional points if the school is an elementary school

5 additional points if the school is a Jr. High or a High School

10 additional points if an adult guard is being used.

Up to 15 points may be awarded for such items which are peculiar to a site as: severe sight distance deficiencies, or the potential of increased pedestrian or vehicular traffic.

2 points for each 10 feet of street width to cross

4 points are to be deducted if a raised median island of at least 4 feet wide exists

2 are deducted if the median refuge area is not raised

To determine a point score for a particular location.

1. Enter table (Figure D-1) with the average weekday vehicular volume plus the pedestrian volume. Drop down on the table to where the percentage of pedestrian traffic to the total of the weekday plus pedestrian traffic intercepts. Follow this intercept horizontally to obtain the volume score.
   (0 - 40 pts.)
2. Five points, to a maximum of 15 points, are awarded for each correctable pedestrian accident which occurred in the last five years.
   (0 - 15 pts.)
3. Points awarded for miscellaneous considerations as described above.
   (0 - 45 pts.)

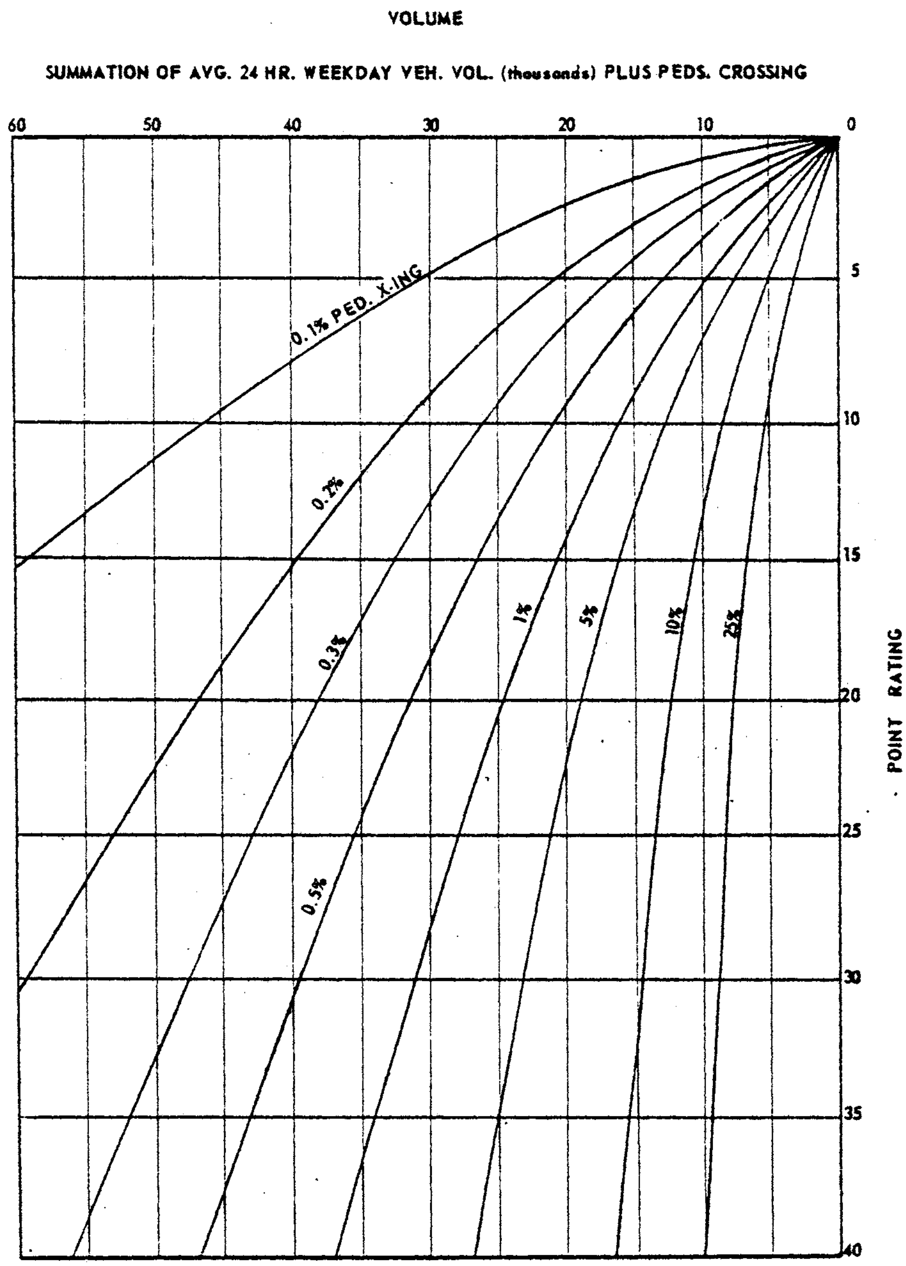

Figure D-1. Pedestrian overpass study, volume point rating.
Source: Information provided by Massachusetts DOT in mail survey.

The total of the scores in each of these three sections determines which category the location falls in. The following scale indicates the action to be taken:

NOT WARRANTED	FURTHER CONSIDERATION	WARRANTED
0 — 48 points	48 — 75	75 — 100

If a location falls within the 48 to 75 point range the request for an overpass should be given further consideration. These further considerations would be.

1. How severe have the pedestrian accidents been?

2. What are the peaking characteristics of the pedestrian volumes, and do they coincide with the peaking of the vehicular traffic?

3. How actively does the community making the request desire the overpass and would the town make the necessary land transfers usually involved for the footings and abutments of the structure?

4. Are there possibilities for other solutions?

Source: Information provided by the Massachusetts DOT in mail survey.

3. The New Jersey DOT has developed a priority ranking system for pedestrian grade separation locations. A priority ranking system was chosen rather than an economic analysis to evaluate the need for a grade separation because of the difficulty in costing pedestrian benefits, e.g., a fatality or pedestrian delay. The method called for selecting those parameters that most affect pedestrian-vehicle movement and then "weighting" the parameters to reflect their relative importance. The parameters selected and the weights assigned are summarized in the following. Locations are divided into two categories: one where pedestrian activity occurs, e.g., where pedestrians are observed at grade on the roadway, and the other where pedestrian activity is not possible, e.g., at a controlled access highway.

Pedestrian Activity Possible		Pedestrian Activity Not Possible	
Parameter	**Weight**	**Parameter**	**Weight**
Pedestrian and vehicle volume	40%	Trip generation	35%
Actual sight distance/ desirable sight distance or maximum vehicle green and yellow	25%	Distance to alternate crossing	35%
		Judgement	30%
School crossing	15%	Safety at alternate crossing	2.5%
Distance to alternate crossing	15%	Surplus trip generation	10.0%
Judgement	5%	Uniqueness of location	17.5%

Based on a maximum score of 200 points, researchers next developed a detailed set of instructions and data forms which can be utilized to derive a numerical score for each proposed crossing A computer program was also developed to facilitate the calculations.

The primary advantage of the New Jersey system is that a relative ranking of proposed locations results from application of the methodology. It does not actually address the real need for the facility which is the primary consideration in this research project. However, the parameters selected and methodology utilized to develop the points can be of benefit. If a need to prioritize previously justified sites arises, then the procedures can be applied directly.

Source: Pedestrian Grade Separation Locations — A Priority Ranking System,

Volumes I & II, by Thomas Batz, John Powers, John Manrodt, and Richard Hollinger, New Jersey DOT, Division of R & D, Bureau of Operations Research, NJDOT Report No. 75-006-7712, December 1975.

APPENDIX E

GUIDELINES FOR THE PROVISION OF MISCELLANEOUS PEDESTRIAN TREATMENTS

Introduction

Two other relatively minor pedestrian facilities are sometimes needed to mitigate pedestrian-vehicle conflicts. These include barriers and pedestrian refuge islands and are described below.

Barriers

Barriers are chains, fences, or similar devices which separate pedestrian and vehicular traffic. Positive barriers channelize pedestrians to safe crossings whereas negative barriers prevent pedestrians from crossing at hazardous locations. Barriers should be considered at locations with poor sight distance, with inadequate lighting, where children may dart out into the street, where pedestrians deliberately violate laws or go where not intended, where use of signs is insufficient to prevent unsafe behavior, along high speed roads, around school yards, and with high incidence of mid-block crossing and accidents.

Source: Model Pedestrian Safety Program, Users Manual, U. S. DOT, FHWA, Offices of Research and Development, June 1978.

Pedestrian Refuge Islands

Refuge islands provide a place of safety for pedestrians who cannot cross the entire roadway at one time because of changing traffic signals or oncoming traffic. Examples of locations where islands are beneficial include the following.

a. On multi-lane roadways

b. In large or irregularly shaped intersections.

c. At complex or busy signalized intersections

d. On streets with many elderly and handicapped pedestrians.

Sources: Model Pedestrian Safety Program, Users Manual, U. S. DOT, FHWA, Offices of Research and Development, June 1978.

Manual on Uniform Traffic Control Devices, U.S. DOT, FHWA, 1978.

AFFENDIX F

GUIDELINES FOR THE PROVISION OF PEDESTRIAN FACILITIES IN SCHOOL AREAS

Introduction

Several of the guidelines listed previously have indicated special consideration should be given when a school is in the area or should children be using the facility. In some instances special manuals or procedures have been developed to evaluate the need for pedestrian facilities specifically for school children. Two such procedures are discussed in the following.

San Diego, California

Warrants for school area traffic signals used by San Diego are a combination of local warrants and those contained in the Manual for Uniform Traffic Control Devices. Traffic signals are not installed at locations where there is an existing, adequately controlled crossing or programmed installation of a traffic signal within 600 feet of the proposed location and where there are less than 35 children actually crossing during the peak pedestrian crossing hour. Locations must also receive at least 30 points out of a possible 50 points. The point system is based on vehicle speed, sight distance, pedestrian volumes, vehicle volumes, and street width, and is described below.

a. Warrant No. 1 — Critical Speed

Critical speed is defined as the 85 percentile speed measured during normal school hours but at a time when vehicular speeds are not affected by school children crossing the street.

Critical Speed	Points
Less than 25 MPH	0
25 - 27	1
28 - 29	2
30 - 32	3
33 - 34	4
35 - 37	5
38 - 39	6
40 - 42	7
43 - 45	8
Over 45	10

b. Warrant No. 2 — Sight Distance

The minimum acceptable sight distance is based upon a driver's height of eye of 3.75 feet and an object height of 0.5 foot.

Table 2

Approach Speed (Critical)	Required Sight Distance
30 MPH	200 feet
40 MPH	275 feet
50 MPH	350 feet

If the available sight distance does not meet this criterion, assign 10 points. If the required sight distance is available, no points shall be assigned.

c. Warrant No. 3 — Pedestrian Volumes

Pedestrian volumes shall be obtained for each of any 2 hours daily when children are crossing to or from school. Vehicle volumes for Warrant 4 shall be obtained for the same 2 hours.

Table 3

Average Pedestrian Volume Per Hour	Points
35 - 49	1
50 - 74	2
75 - 99	3
100 - 124	4
125 - 149	5
150 - 174	6
175 - 199	7
200 - 224	8
225 - 250	9
Over 250	10

d. Warrant No. 4 — Vehicle Volume

Vehicle volumes on the street being crossed by school pedestrians shall be obtained for each of any 2 hours daily when children are crossing to or from school. The vehicle volumes shall be obtained for the same 2 hours during which pedestrian volumes under Warrant No. 3 are obtained.

Table 4

Average Vehicle Volume Per Hour	Points
70 to 99	2
100 to 199	3
200 to 299	4
300 to 399	5
400 to 499	6
500 to 599	7
600 to 699	8
700 to 800	9
Over 800	10

e. Warrant No. 5 — Street Width

Street widths are the curb to curb distance, if curbs are in place. If curbs are not in place, then street width shall include the shoulder area.

Table 5

Street Width	Points
Less than 40 feet	2
40 feet to 59 feet	5
60 feet or more	10

Minimum criteria for the installation of pedestrian separation structures at unsignalized locations in school areas are listed in the following. All of the conditions must be met.

a. Major street volume exceeds 3,000 vehicles in a continuous 4-hour period.

b. Minor street volume is less than 125 vehicles in the same continuous 4-hour period.

c. Pedestrian volume crossing the major street exceeds 300 in the same continuous 4-hour period. A child under 12 years of age is the equivalent of 2.5 pedestrians for the purpose of this warrant.

d. There is no existing or programmed traffic signal within 750 feet of the proposed structure.

e. The 85 percentile speed of vehicles on the major street exceeds 30 mph.

f. It is feasible to physically prohibit pedestrians from crossing the major street in the immediate vicinity of the proposed structure.

g. The area is substantially developed and the traffic patterns and volumes are stabilized.

h. An economic analysis indicates that for a 10-year period, a pedestrian separation structure will be less expensive than a traffic signal.

Source: School Pedestrian Safety, Policies and Warrants, City of San Diego, 1971.

Institute of Transportation Engineers

In a recommended practice of the Institute of Transportation Engineers (ITE), the graph reproduced in Figure F-1 is utilized to determine the need for control at school crossings. Detailed procedures for determining D, W, and N are provided in the appendices of the below referenced source, which are reproduced at the end of this section. If the point located by plotting D and W is to the left of the line for N, i.e., point A, then control is not needed. On the other hand, if the point is to the right, i.e., point B, then control is needed. The graph can also be employed to establish priorities for improvements by considering the distance between the appropriate N line and the point. For example, the crossing location depicted by point P and an N of 6 takes priority over the crossing depicted by point Q and an N of 1.

Once the need for control has been established, the following criteria should be considered for particular types of facilities.

A. Pedestrian Grade Structures

1. The general conditions that require the school crossing are sufficiently permanent to justify such a structure (for example: a school route crossing a freeway).

2. An economic comparison between the cost of the structure and the cost of other controls indicates that the structure is justified from a long-range standpoint.

3. The physical characteristics of the location make such a structure feasible from an engineering standpoint.

4. The initial cost of such an improvement does not limit available funds to the point where other essential school crossing protection is neglected.

5. Such a structure will serve other pedestrians besides school children.

6. There is no possibility that the replanning of school routes or school districts will eliminate the need for such a structure.

B. Traffic Signals

1. Signals are more feasible from a practical and economical standpoint than other types of school crossing control.

2. There is no probability that the replanning of school routes or school districts will eliminate the need for such an installation.

3. The following installation requirements for traffic control signals installed solely to provide adequate gaps at school crossings, as given in Section 7D-4 of the Manual on Uniform Traffic Control Devices for Streets and Highways, 1970 Edition, are met:

   "1. Pedestrian indications shall be provided at least for each crosswalk established as a school crossing.

   2. At an intersection the signal normally should be traffic-actuated. Intersection installations that can be fitted into progressive systems may use pretimed control.

   3. At non-intersection crossings the signal should be pedestrian-actuated, parking and other obstructions to view should be prohibited for at least 100 feet in advance of and 20 feet beyond the crosswalk, and the installation should include suitable standard signs and pavement markings. Special

police supervision and/or enforcement should be provided for a new non-intersection location."

Traffic signal control should not be considered if there is forseeable need for supplemental costly protection because of the inability of school children to handle the signal system. In this regard, the following points are especially pertinent:

1. In connection with traffic control signals installed for school crossings, it should be understood that a traffic signal is not the only remedy nor is it necessarily the correct solution to the perplexing problem of traffic conflicts between vehicles and school children. Brief periods during which hazards are unusually high are often better handled by officer control or adult crossing guards.

2. In some circumstances the pupils' response to traffic signal indications is so inadequate that the signal can become a contributory factor in increasing rather than decreasing accidents. The response to officer control or adult crossing guards is less uncertain.

C. Adult Crossing Guards and Police Officers

1. An adult crossing guard or police officer is more feasible and economical than either a pedestrian grade separation structure or a traffic control signal specially installed to handle the crossing problem.

2. There are special hazards, at either signalized or non-signalized locations, that can be properly handled only by adult supervision. These hazards would include unusual conditions such as extreme fog, complicated intersections, heavy vehicular turning movements, and high vehicular approach speeds.

3. A change in school routes or school districts is imminent, thus requiring protection at the location for only a limited time.

Source: A Program for School Crossing Protection, A Recommended Practice of the Institute of Transportation Engineers.

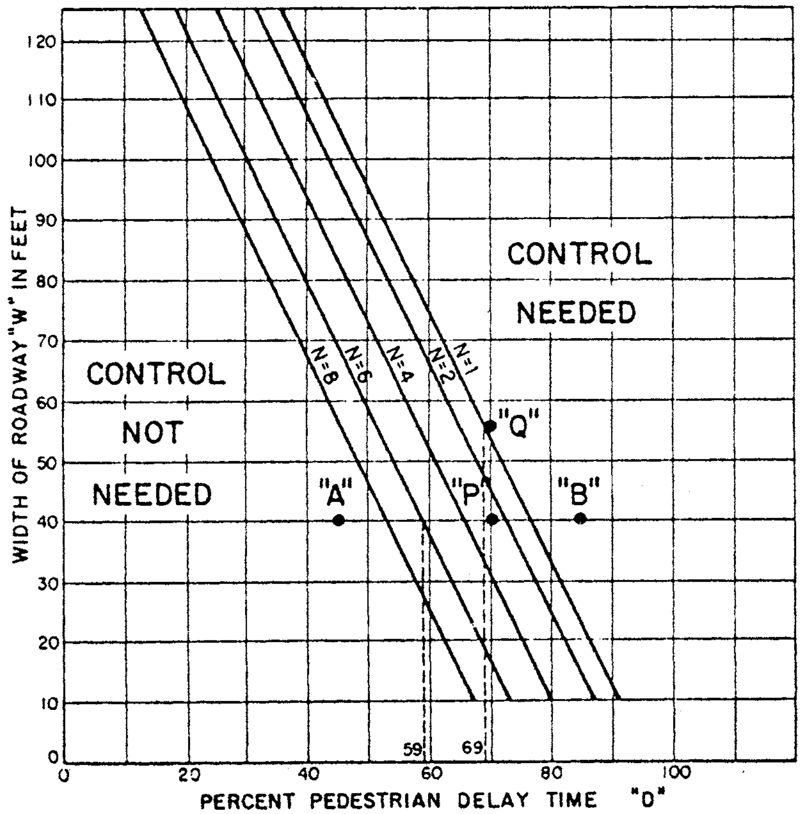

Figure F-1. Determination of need for traffic control at school crossings.
Source: A Program for School Crossing Protection, A Recommended Practice of the Institute of Transportation Engineers.

APPENDIX A

Procedure for Making Field Studies in Step 3

Determination of "N" – the number of rows

It is assumed that five pedestrians will walk abreast when a group crosses a roadway. Therefore, if the group size is determined and divided by five, the required number of rows, "N", will be obtained. The 85th-percentile group size is used so as to include most situations.

There is a natural tendency for pedestrians to group together before crossing a roadway as they wait for a break or gap in the traffic stream. Thus, an observer can count the number of pedestrians that gather in each of these groups at the crossing under study and record the size on a form such as suggested in Exhibit No. A-1. A simple computation will yield the 85th-percentile group and the value of "N" for the group size can be found in the second column. Note that "N" is taken as a whole number since even one pedestrian in excess of an even five will make an additional row, which will require extra clearance time.

These pedestrian counts should be made on a normal school day during the heaviest hours of crossing activity in the morning or afternoon, preferably both.

Determination of "W" – the pavement width

This is the curb-to-curb width as measured at the crossing under study. If the roadway is divided and the center island is wide enough for the maximum-sized group of pedestrians to stand on it in safety, the curb-to-curb width of only one roadway is used for "W". This information should be obtained at the same time that the pedestrian group size study is made by recording the information suggested at the top of Exhibit No. A-1.

Determination of "D" – the actual pedestrian delay time

This information is developed in a second field survey based on the information obtained in the Pedestrian Group Size Study.

Before the field survey is made to determine pedestrian delay time at the location under study, it is necessary to find the minimum length (in seconds) of a gap in traffic which will permit an 85th-percentile group of pedestrians to cross a roadway of specified width. This minimum gap in traffic, known as the Adequate Gap Time (G), includes both the perception-reaction time and the time needed to walk across the roadway without coming into conflict with passing vehicles.

The Adequate Gap Time may be selected from the table in Exhibit No. A-2, or it may be computed using the following equation. In either case the values for "W" and "N" are those determined in the Pedestrian Group Size Study.

Adequate Gap Time – G (in seconds)

$$= \frac{W}{3.5} + 3 + (N - 1)\,2$$ where: W divided

PEDESTRIAN GROUP SIZE STUDY

Study date 5/1/62 Time: From 8 a.m to 9 a.m Location 4th ND

Crosswalk across D Street Curb-to-curb distance 40

Divided roadway? Yes (No) Width of island None

Group size	Number of Rows (N)	Number of Groups: Tally	Number of Groups: Total	Cumulative	Computations
46 - 50	10				
41 - 45	9				
36 - 40	8	/	1	1	
31 - 33	7	///	3	4	
26 - 30	6	⊯ //	7	11	This figure includes "9" the cutoff for the 85th percentile group size. Therefore: N = 6
21 - 25	5	//// ⊯ ///	13		
16 - 20	4	⊯ ⊯ ⊯ ///	18		
11 - 15	3	⊯ ⊯ //	12		
6 - 10	2	⊯	5		
5 or Less	1	/	1		
		Total Number of Groups	60	x 0.15 = 9	N = 6

Exhibit No. A-1

TABLE OF ADEQUATE GAP TIMES (in seconds)										
	Number of Rows - "N"									
Roadway Width - "W"	1	2	3	4	5	6	7	8	9	10
16 - 19	8	10	12	14	16	18	20	22	24	26
20 - 22	9	11	13	15	17	19	21	23	25	27
23 - 26	10	12	14	16	18	20	22	24	26	28
27 - 29	11	13	15	17	19	21	23	25	27	29
30 - 33	12	14	16	18	20	22	24	26	28	30
34 - 36	13	15	17	19	21	23	25	27	29	31
37 - 40	14	16	18	20	22	24	26	26	30	32
41 - 43	15	17	19	21	23	25	27	29	31	33
44 - 47	16	18	20	22	24	26	28	30	32	34
48 - 50	17	19	21	23	25	27	29	31	33	35
51 - 54	18	20	22	24	26	28	30	32	34	36
55 - 57	19	21	23	25	27	29	31	33	35	37
58 - 61	20	22	24	26	28	30	32	34	36	38
65 - 68	22	24	26	28	30	32	34	36	38	40
75 - 80	25	27	29	31	33	35	37	39	41	43

Exhibit No. A-2

by 3.5 = Walking Time – the number of sec[illegible]ds required to [illegible]lk across the roadway. This value is equal to the width of roadway (W) in feet, divided by the walking speed in feet per second (assumed to be 3.5 ft./sec.).

3 = Perception and Reaction Time – The number of seconds required for a child to look both ways, make a decision, and commence to walk across the street. This interval is assumed to be 3 seconds.

(N – 1) 2 = Pedestrian Clearance Time – additional seconds of time required to clear large groups of children from the roadway. Children are assumed to cross the roadway in rows of five with two-second time intervals between each row. The clearance time interval is equal to (N – 1) 2 where N is the number of rows, 1 represents the first row, and 2 is the time interval between rows.

Pedestrian Delay Time Field Study. After the Adequate Gap Time has been selected, the field study to determine the actual delay time to pedestrians caused by passing traffic can be undertaken. This study actually measures the time intervals between passing vehicles. Those intervals or traffic gaps that are equal to or greater than the Adequate Gap Time are the periods during which children must cross the roadway. The intervals between these gaps are the delay periods, the sum of which is the Actual Pedestrian Delay.

Either of the following methods may be used to determine the gaps in the traffic stream. If the entire roadway must be crossed once the pedestrian leaves the curb, traffic flow in all lanes regardless of direction must be considered together.

1) *The Graphic Recorder Method* – A graphic recorder similar to the Esterline-Angus recorder is used. The [illegible]en on the reco[illegible]r may be actu[illegible] by a radar speedmeter aimed at passing traffic or a manually-operated push-button arrangement. Passing vehicles are recorded on the moving tape of the recorder as a series of sharp peaks. Traffic gaps are measured in seconds of time from one peak to the next peak. The total time of all gaps (t) which is equal to or greater than the Adequate Gap Time (G), and the total time of survey are used in the analysis of the crossing.

Upon completion of the survey, the form suggested in Exhibit No. A-3 can be used to tally the results.

2) *The Metronome Method* – This method makes use of a mechanical or electrical metronome, which marks time by a ticking sound. Electrical metronomes, which usually can be constructed in the traffic signal workshop, require an inverter to adapt the power from the car battery. Traffic gaps are measured with the metronome by ear and sight. The instrument is set for one-second click intervals. The field observer counts the number of clicks between passing vehicles. In this way, the length of all gaps which are equal to or greater than the Adequate Gap Time (G) is measured and recorded; lesser gaps are discarded. The form suggested in Exhibit No. A-3 can be used as a field sheet for this purpose. The overall survey time is also recorded. The metronome method of survey is recommended because of its simplicity and its low cost in equipment and manpower.

The survey should be conducted immediately before or after the period in which children are using the crosswalk, so that they will not affect the vehicular traffic pattern. At least two surveys should be made, in the morning

PEDESTRIAN DELAY TIME STUDY

Study date 5/11/62 Location 14th & D Crosswalk across D Street

End of Survey (to nearest minute) 8:57 a.m. Number of Rows – "N" 6

Start of Survey (to nearest minute) 8:02 a.m. Roadway Width – "W" 40 ft.

Total Survey Time (minutes) 55 Adequate Gap Time – "G" 24 secs.

Gap Size (Seconds)	Number of Gaps: Tally	Number of Gaps: Total	Multiply by Gap Size	Computations
8				
9				
10				
11				
12				
13				
14				
15	Discard gaps of less than 24 seconds from study.			
16				
17				
18				
19				
20				
21				
22				
23				
24	/	1	24	
25	////	4	100	
26	///	3	78	
27	//	2	54	T = Total survey time x 60
28	/	1	28	
29	///	3	87	
30	卌	5	150	T = 55 x 60
31	//	2	62	
32	////	4	128	T = 3300 secs.
33		0	—	
34	///	3	102	
35	////	4	140	
36		0	—	
37	/	1	37	$D = \left(\frac{T - t}{T}\right) 100$
38				
39				$D = \left(\frac{3300 - 990}{3300}\right) 100$
40				
41				$D = 70$
42				
43				
"t" (total time of all gaps equal or greater than "G")			990 secs.	D = 70 %

Exhibit No. A-3

and in the afternoon, of the heaviest traffic weekday. Additional surveys may be necessary to verify results.

Computation of Actual Pedestrian Delay. When the field survey is completed, the total time of all gaps in which pedestrians could cross is found by adding the length, in seconds, of each gap which was equal to or greater than the Adequate Gap Time (G). This figure is known as "t" and is subtracted from the total survey time in seconds (T). The following equation is then used to determine the percentage of actual pedestrian delay:

Actual Pedestrian Delay – D (in %)

$$= \left(\frac{T-t}{T}\right)100$$

APPENDIX B

Analysis of School Crossings at Signalized Intersections

In the body of this program the analysis has assumed that traffic control signals have not been installed at the location under study. However, certain school crossings may be located at complicated and congested signalized intersections where heavy turning movements create confusion and hazard, particularly for small children. Special controls of the type discussed in Step 5A may be necessary to assist children at these locations.

Hazard is created as right- and left-turning vehicles (moving on the same green signal interval as the children) traverse the pedestrian crosswalk being used by the children. This hazard is determined by measuring those gaps which are equal to or greater than the Adequate Gap Time (G) in the traffic turning across the crosswalk. In this instance, the width of roadway (W) is equal to one-half of the roadway, since the children are "Protected" on the other half by vehicles waiting for the green light on the cross street. Except for one further consideration, the need for additional traffic control is calculated in the same manner and with the same equations as used previously.

The additional item of information which must be considered is the cycle length of the traffic control signals. The cycle length is the factor "C" in the following equation for the family of lines which appear on the graph in Exhibit No. 2:

$$D_a = \left(\frac{C - G}{C}\right)100$$

where D_a = Allowable Pedestrian Delay Time (in per cent)

C = Cycle Length
G = Adequate Gap Time

Since $G = \frac{W}{3.5} + 3 + (N - 1)2$,

the equation can be written as:

$$D_a = \left[1 - \left(\frac{\frac{W}{3.5} + 3 + (N-1)2}{C}\right)\right] 100$$

"D_a," which by definition is the maximum delay time that is acceptable to a pedestrian, is equivalent to the green and yellow vehicle signal interval of a hypothetical traffic signal. The Adequate Gap Time (G) is used as the green and yellow signal interval of the pedestrian phase. The Allowable Delay Time is found by subtracting the Adequate Gap Time from the signal cycle (C).

In developing the graph in Exhibit No. 2, "C" was assumed to be 60 seconds in accordance with assumption 2, at the beginning of Step 4. At a signalized intersection, if "C" does not equal 60, it will be necessary to calculate "D_a" using the above equation.

To determine whether or not a special form of protection or control is needed, the calculated "D_a" is compared with "D", the actual percentage of pedestrian delay, as found by field studies. If "D" is less than "D_a" no special steps need be taken. Conversely, if "D" is greater than "D_a", one or more of the measures set forth in Step 5A may be appropriate.

Note that in cases where "D" is greater than "D_a" the difference can be used to set priorities for undertaking installation of controls among several locations.

APPENDIX G

TRIP GENERATION RATES

Source: A Pedestrian Planning Procedures Manual, Vol. II, Technical Supplement, Report No. FHWA-RD-79-47, November 1978.

A. Offices

Generation factors, R, for offices are expressed as the average number of trips generated per hour per 1,000 square feet on an average weekday between 7:00 AM and 7:00 PM.

Representative values of R are given in Table 2, together with measures of the standard deviation and range associated with the field measurements examined. These measures can be used as guidelines for adjusting R to suit local conditions. The size ranges shown in the figure are for guidance only.

Secondary Land Use Category	Size Range (1000's Square Feet-Gross)		
	Less Than 200	200 - 400	More Than 400
A1 Local Use Buildings	R = 5.4 Std. Dev. = 1.4 Range 3.4 to 7.2		
A2 Headquarters Buildings	R = 1.5 Std. Dev. = 0.7 Range 0.6 to 2.6		R = 1.2 Std. Dev. = 0.4 Range 0.4 to 2.1
A3 Mixed Use Buildings	R = 1.8 Std. Dev. = 0.6 Range 0.9 to 2.8		
All Office Uses	R = 2.5 Std. Dev. = 1.7 Range 0.6 to 7.2	R = 1.7 Std. Dev. = 0.6 Range 1.1 to 2.8	R = 1.2 Std. Dev. = 0.4 Range 0.4 to 2.1

Table 2

Trip Generation Factors
For Offices (Category A)

Table 3 is a sample list of land uses and accompanying size and generation data to be used as further guideline in the selection of R-values.

	Use	Hourly Trips/ 1000 sq. ft.	Size/ 1000 sq. ft
A1 Local Use Buildings	Motor Vehicles Dept.	14.6	15
	Post Office	14.6	36
	City Hall	7.2	18
	Medical Office	6.5	20
	Medical Office	6.2	39
	Medical Office	5.5	10
	Stockbrokers	4.0	100
	Municipal Bldg.	3.4	184
A2 Headquarters Buildings	Banking Headquarters	2.1	852
	Insurance Headquarters	1.5	1000
	Government Bldg.	1.4	863
	Headquarters (unspec.)	1.2	1634
	Headquarters (unspec.)	1.1	1048
	Insurance Headquarters	1.1	1060
	Banking Headquarters	1.0	1460
	Banking Headquarters	0.9	949
	Insurance Headquarters	0.8	500
	Government Building	0.4	1660
A3 Mixed Use Buildings	Corporate Headquarters	2.6	90
	Corporate Headquarters	1.7	109
	Insurance Headquarters	1.3	127
	Corporate Headquarters	1.3	266
	Insurance Headquarters	0.6	100

Table 3

Sample Office Land Uses And Their Generation

As a subset of office land use, local use buildings appear to exhibit several other trip generation characteristics. For the limited data examined, there was an inverse relationship between R and the building size, as shown in Figure 18. That is, the generation rate for local use buildings decreases as building size increases. This would appear to be a reasonable situation - as building size increases, less intensive uses may be attracted, in some cases, related uses, such as pharmacies in buildings of doctor's offices, would tend to reduce the trip rate per 1000 square feet, while not generating additional trips.

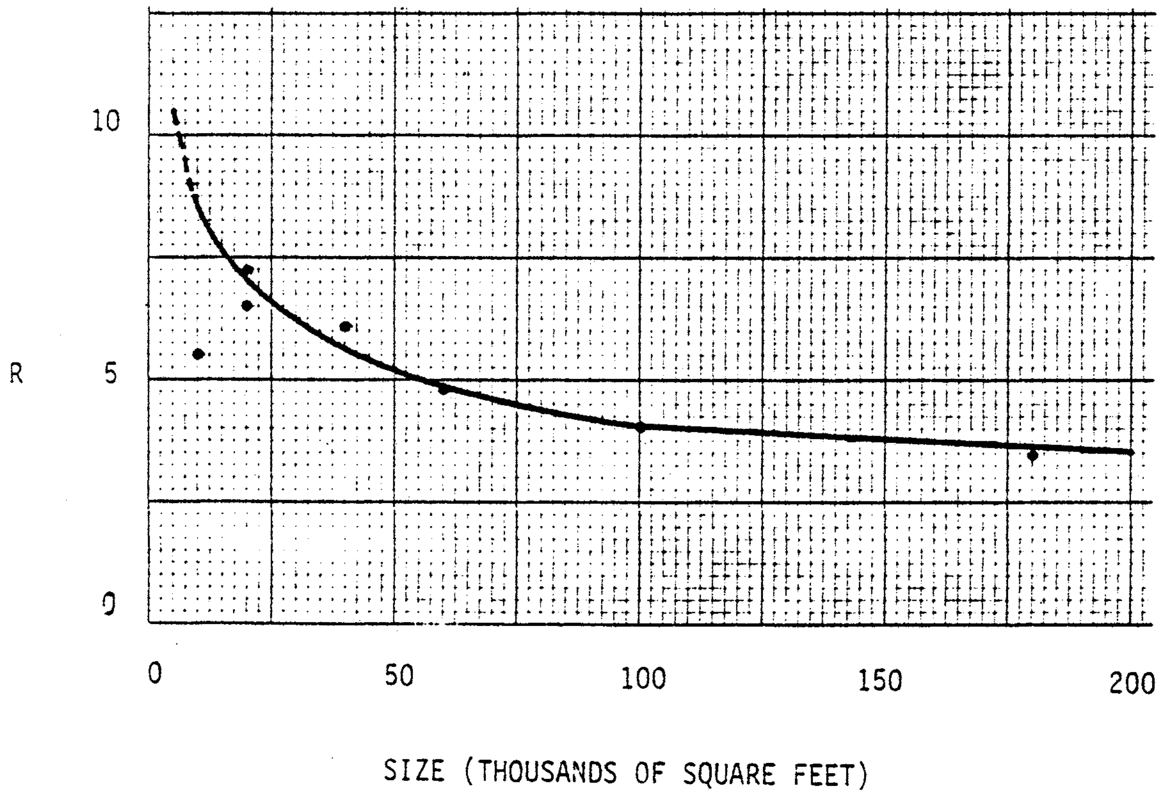

Figure 18

Relationship Between R and Building Size
For Local Use Office Buildings (Category A1)

Also, several data points, associated with a post office and a motor vehicles department, indicated an R of about 15 trips per hour per 1,000 square feet. The R for these points exceeded the group average by more than six standard deviations. Hence they clearly did not exhibit generation values characteristic of the group and were excluded; however, the potential existence of such high intensity generators should be recognized when applying the factors.

B. Retailing (Excluding Food-Related)

Except where otherwise specified, the generation factors, R, for this category of retailing are expressed as the average number of trips generated per weekday hour of operation per 1,000 square feet of gross area.

Representative values of R are given in Table 4, together with measures of the standard deviation and range associated with the field measurements examined. These measures can be used as guidelines for adjusting R-values to suit local conditions.

Secondary Land Use Category	Typical Size Range (1000's Sq. Ft.)	Average Hourly Generation Rates
B1 Specialty Retailing	20 or Less	R = 29.6 Std. Dev. = 14.2 Range 13.6 to 67.2
B2 Normal Retailing	200 to 1000	R = 5.1 Std. Dev. = 1.0 Range 3.0 to 6.2

Table 4

Trip Generation Factors
For Non-Food Retailing (Category B)

Using average within the retailing subgroups, an inverse relationship between R and building size (gross area) was obtained. The relationship is shown in Figure 19; note that R is approximately equal to 100 divided by the square root of the gross building size in 1,000's of square feet.

The data is based on gross building area. On the average, sales area represents about 76.1% of the gross area; or trip generation rates based on sales area should be adjusted to be about 31% higher than those associated with gross area.

The data base used for the derivation of R-values suggests that downtown urban stores are typically either small and specialized or very large and diversified. Where stores of intermediate size exist, then depending on their nature, Rvalues may be selected from:

- The low range of B1 retailing
- The high range of B2 retailing
- The graph in Fig. 18

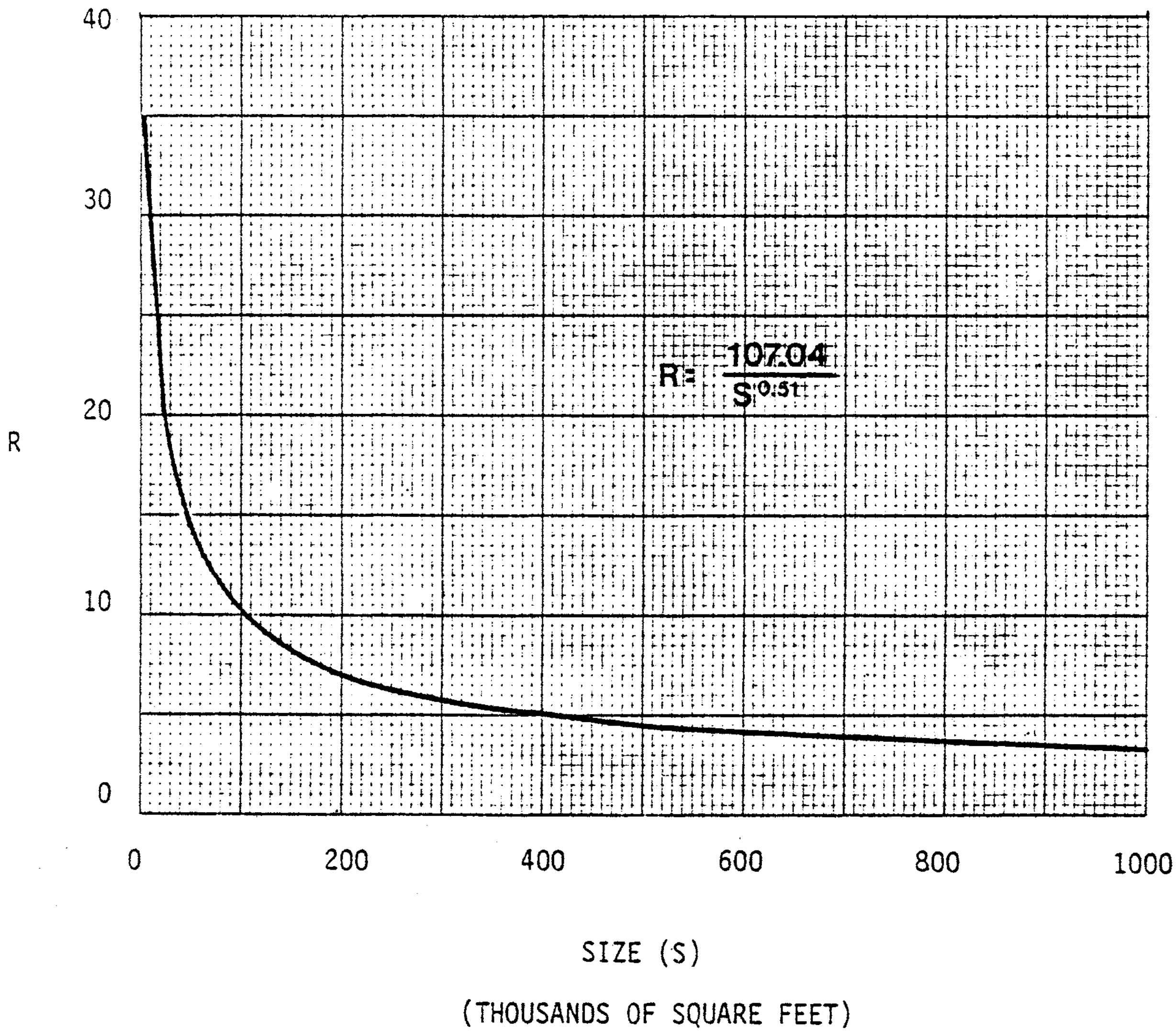

Figure 19

Relationship Between R And Building Size
For Non-Food Retailing

If the planner is uncertain about the relationship between generation levels in the study area and those provided in the manual (for example, if retailing is in decline), then peak hour counts at selected stores can provide a general factor for scaling the R-values to this particular situation.

	Use	Hourly Trips/ 1000 sq. ft.	Size/ 1000 sq. ft.
B1 Specialty Retailing	Bookstore	54.8	2.2
	Bookstore	41.1	2.5
	Supermarket	35.7	7.5
	Shoe Store	34.2	2.9
	Women's Clothing	32.7	6.5
	Junior Dept. Store	32.1	69.6
	Supermarket	31.0	14.5
	Branch Bank*	28.6	7.8
	Office Supplies	28.2	3.6
	Boutique	25.6	3.4
	All Specialty Retailing	25.3	68
	Men's Shoes	25.3	2
	Supermarket	23.8	7.5
	Branch Bank (Savings & Loan)	23.5	-
	Office Supplies	15.2	38
	Gift Store	13.6	.8
	Men's Clothing	3.1	2
B2 General Merchandising Stores	Department Store	6.2	600
	Department Store	5.7	524
	Department Store	5.6	200
	Department Store	5.5	250
	Department Store	5.3	242
	Department Store	5.1	18
	Department Store	4.3	792
	Department Store	3.0	971

Table 5

Sample Data From Category B - Retailing

*The public floors of downtown banks have been included as B1 Retail-Private Floors internal to the bank would be considered under A2 or A3 Headquarters Buildings.

Owing to the wide range of values in the B1 category (see Fig. 14 for example), judgement will have to be exercised in the selection of R-values. Table 5 depicts some data samples which may aid in the selection. The locations surveyed to develop the data however, were in areas of intense retail activity and where activity is less intense, lower values should be used.

C. Retailing (Food-Related)

The generation factors, R, for this category of retailing are expressed as the average number of trips generated per hour of weekday operation based on two size parameters: (1) per 1,000 square feet, and (2) per seat.

Representative values of R are given in Table 6, together with measures of the standard deviations and ranges associated with the field measurements examined. These measures can be used as guidelines for adjusting R to suit local conditions.

Secondary Land Use Category	Typical Size Parameters	Average Hourly Weekday Trip Generation	
		Per 1000 Sq. Ft.	Per Seat
C1 Fast Food Carry Out	3000 Sq. Ft. or Less 100 Seats or Less	R = 128.4 Std. Dev. = 41.2 Range 88.0 to 205.0	R = 3.1 Std. Dev. = 0.7 Range 2.5 to 3.9
C2 Fast Food With Service	3000 - 5000 Sq. Ft. 100 - 200 Seats	R = 47.6 Std. Dev. = 6.7 Range 36.3 to 53.6	R = 1.4 Std. Dev. = 0.4 Range 1.0 to 1.7
C3 Full Service	5000 Sq. Ft. or More 80 Seats or More	R = 11.5 Std. Dev. = 5.2 Range 4.9 to 14.4	R = 0.43 Std. Dev. = 0.22 Range 0.10 to 0.74

Table 6

Trip Generation Factors For Food-Related Retailing (Category C)

The turnover rate of an establishment (the number of patrons served per seat per unit of time), is reflected in the trip generation factor based on seating capacity. However, the factors shown in Table 6 are based on trip ends, or two trips per patron served. Hence, the turnover rate, converted, if required, to patrons served per hour per seat, could be doubled to obtain factors comparable to those shown in Table 6. Turnover rates are data that may be available to the user.

Based on the data examined, the most reliable estimators within secondary categories are as follows:

Fast food, carry-out - trips per seat
Fast food with service - trips per 1,000 square feet
Full service - use either measure

D. Parking

The generation factors, R, for parking are expressed as the average number of trips generated per hour per parking space on an average weekday between 10:00 A.M. and 6:00 P.M. This time period was apparently chosen, in the parking studies reviewed, to encompass a peak and an off-peak period.

Representative ranges for R are given in Table 7. Users can develop estimates within these ranges to suit local conditions.

D3 - Parking Lot	0.6 to 1.1
D4 - Parking Garage	0.4 to 0.6
Average - Off Street	0.5 to 0.9

Table 7

Trip Generation Factors
For Parking (Category D)

Distinguishing short- and long-term parking may aid in interpreting the ranges in Table 7. Such data, furthermore, can be used in the exchange model where different friction factors for short- and long-term parking are provided. If this data is unavailable, the variances in site specific parking rates can be used as surrogates or failing this, simple distance from the points of high land use concentration.

Generation data on curb parking is provided in Supplement 2. This data has not been included in the procedures since its contribution to generation is usually small and evenly spread. (The planner may of course, require a count of curb parking spaces and turnover for investigating traffic management strategies in Task 17.)

E. Residential

The generation factors, R, for single family and apartment dwellings are expressed as the average daily number of trips generated per dwelling unit and per resident on an average weekday. For hotel/motels, R is expressed as the average daily number of trips generated per occupied room and per 1000 square feet.

Representative values of R are given in Table 8, together with measures of the standard deviation and range associated with the field measurements examined. All rates are for 24-hour weekday periods.

Secondary Land Use Category	Average Daily Generation	
	Per Dwelling Unit	Per Resident
E1 Single Family Dwelling	R = 15.6 Std. Dev. = 3.2 Range 10.9 to 19.4	R = 4.6 Std. Dev. = 0.8 Range 3.1 to 6.3
E2 Apartment Dwellings	R = 8.1 Std. Dev. = 2.2 Range 5.1 to 12.4	

	Per Occupied Room
E3 Hotels and Motels	R = 13.4 Std. Dev. = 3.8 Range 6.5 to 20.5

TABLE 8

Trip Generation Factors
For Residences (Category E)

Single family dwellings were characterized by 3.7 residents per dwelling unit, and apartments exhibited 1.8 residents per unit. For the data examined, the factors were reliable for relating trips per dwelling unit and trips per unit.

F. Modal Transfer

General factors, R, for bus stops, taxi stands, subway stations, railroad stations, bus terminals and similar facilities will have to be derived or approximated from local public transit ridership data.

APPENDIX H

VALUE RATING SYSTEM

Source: Model Pedestrian Safety Program, User's Manual, U. S. DOT, FHWA, June 1978.

To combat this problem, Step 3 describes a variation of Benefit-Cost Analysis, different from traditional analyses in that monetary values are not directly used in the comparison. Instead, a "Value Rating," based on the local situation, is assigned to each cost and benefit variable.

Value Rating System Method

The methodology of the Value Rating System is a six-step process. Two additional analysis options can also be used if warranted.

Step A: List all cost and all benefit variables for the alternatives under consideration.

Step B: Determine realistic ranges for each of the cost and benefit variables.

Step C: Convert the anticipated outcome level (expected cost or benefit) of each variable of each alternative to a Value Rating using the appropriate Value Rating scale. Sum the cost and benefit Value Ratings for each alternative.

Step D: Determine each alternative's Benefit-Cost Ratio.

Step E: Consider constraints (goals and limitations).

Step F: Select alternative(s) meeting these constraints.

Analysis Option 1: Sensitivity Analysis.

Analysis Option 2: Variable Priority Weighting.

To facilitate the understanding of this method, the explanation will be made through an example. In this example, four possible actions (Alternatives A, B, C and D) have been identified that are relevant to some problem. *Note that the numerical values and ranges used in this example are arbitrary and are examples only.*

- Step A: List all cost and all benefit variables for the alternatives under consideration.

Tables 3-1 and 3-2 listed some of the possible cost and benefit variables which relate to pedestrian facility installation and operation. Of course, not all of the variables will be applicable to every alternative. Likewise, additional variables not listed can be considered for other problem alternatives. The variables identified here are examples, and you should expand or edit the list according to your own locality's situation.

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Table 3-1

Sample Categories of Costs Incurred in Pedestrian Facility Installation and Operation

Cost Categories	Unit of Measurement
Design costs	Dollars
Construction costs (including manpower)	Dollars
Annual maintenance and operating costs	Dollars
Vehicle delay	Dollars
Vehicle delay	Time
Pedestrian delay	Time
Implementation	Time
Ecological costs	
Air pollution	Parts per million
Noise pollution	Decibels
Visual pollution	Subjective
Cost of an Accident	Dollars

Sample Categories of Benefits Received from Pedestrian Facility Installation and Operation

Benefit Category	Unit of Measurement
Accident frequency reduction	Numerical
Accident severity reduction	Numerical
Facility life expectancy	Time
Vehicle delay reduction	Dollars
Vehicle delay reduction	Time
Pedestrian delay reduction	Time
Economic impact	Dollars
Social impact	Subjective
Convenience	Subjective
Ecological impacts	
Air pollution reduction	Parts per million
Noise pollution reduction	Decibels
Aesthetic impact	Subjective

- Step B: Determine realistic ranges for each of the cost and benefit variables.

The process of evaluation in the Value Rating System converts the anticipated level of a cost or benefit variable to a "neutral" number. Because this outcome amount (e.g. Construction Cost) will vary between alternatives, a range of possibilities for each variable should be identified. In this example, Alternative A will cost $10,000 to construct, Alternative B $1000, and Alternative C $20,000. Alternative D, the "Take No Action' Alternative, would have no cost. Therefore, the range for the variable "Construction Cost" could be from less than $1000 (<$1000) to greater than $25,000.

Similarly, a range for each benefit variable should be listed. For example, Life Expectancy of an installed countermeasure may range from <2 years to 20+ years.

The Value Ratings for each variable are determined by a point scale from 0-100. Tables 3-3 (Costs) and 3-4 (Benefits) illustrate the listing of the variable ranges. The 0-100 Value Rating Scale is at the left of each table. Because some of the variables are not commonly evaluated in numerical terms, the 100-point scale is supplemented by a five-division subjective "Poor-Excellent" scale. Thus, nonnumerical variables such as Visual Pollution, can be assigned a Value Rating based on its subjective evaluation (e.g. Poor, or Much additional Visual Pollution resulting from a countermeasure's installation, equals 10 points).

- Step C: Convert the anticipated outcome level (expected cost or benefit) of each variable of each alternative to a Value Rating using the appropriate scale. Determine the Total Cost Value Rating and Total Benefit Value Rating for each alternative.

Once the range has been established for each cost and benefit variable, the anticipated levels of each variable for each alternative can be converted to Value Ratings. Table 3-5 gives example cost and benefit levels for the four alternatives. Using Tables 3-3 and 3-4, these benefits and costs are converted to the Value Ratings shown in Table 3-6.

The Total Benefit Value Rating for a particular alternative is determined by adding the Value Ratings of the individual benefit variables for that alternative and dividing by the number of variables. That is:

$$B = \frac{V_1 + V_2 + V_3 + \ldots}{N}$$

where

B = Total Benefit Value Rating for that alternative

$V_1, V_2 \ldots$ = Individual Value Ratings for the benefit variables

N = Number of benefit variables considered for that alternative

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Table 3-3

Value Rating of Pedestrian Facility Costs*

Value Rating Scale	Cost Variables	Design Costs ($)	Construction Costs ($)	Annual Maintenance & Operation Costs ($)	Implement. Time (Mo.)	% Increase Total Vehicle Delay	% Increase Total Pedestrian Delay	Increase Visual Pollution	% Increase Noise Pollution	% Increase Air Pollution
0		5000+	25,000+	2000+	10+	10+	10+		10+	10+
10	Poor (10) (Much)	4500	22,500	1800	9	9	9	P (Much)	9	9
20		4000	20,000	1600	8	8	8		8	8
30	Fair (30)	3500	17,500	1400	7	7	7	F	7	7
40		3000	15,000	1200	6	6	6		6	6
50	Average (50)	2500	12,500	1000	5	5	5	A	5	5
60		2000	10,000	800	4	4	4		4	4
70	Good (70)	1500	7,500	600	3	3	3	G	3	3
80		1000	5,000	400	2	2	2		2	2
90	Excellent (90) (None)	500	2,500	200	1	1	1	E (None)	1	1
100		< 500	< 2500	< 200	< 1	< 1	< 1		< 1	< 1

*NOTE: The numerical values and ranges for each variable and in each cell of the table are arbitrary and are example values only. Each locality should list variables and ranges appropriate to its own situation.

Table 3-4
Value Rating of Pedestrian Facility Benefits*

Value Rating Scale	Benefit Variables	% Acc. Reduction (Total)	% Acc. Reduction (Fatals)	% Decrease in Injury Severity	Life (yrs.) Expectancy	Economic Impact	Social Impact	Implement. Time (Mo.)	Resultant Flow Level of Service	Aesthetic Value	% Dec. Vehicle Delay (Total)	% Dec. Ped. Delay (Total)	% Dec. Noise Pollution
0		<5	<5	<5	<2			10+			<2	<2	<5
10	Poor (10) (Low)	5	5	5	2	P	P	9	P	P	2	2	7
20		10	10	10	4			8			4	4	9
30	Fair (30) (Low-Average)	15	15	15	6	F	F	7	F	F	6	6	11
40		20	20	20	8			6			8	8	13
50	Average (50) (Average)	25	25	25	10	A	A	5	A	A	10	10	15
60		30	30	30	12			4			12	12	17
70	Good (70) (High-Average)	35	35	35	14	G	G	3	G	G	14	14	19
80		40	40	40	16			2			16	16	21
90	Excellent (90) (High)	45	45	45	18	E	E	1	E	E	18	18	23
100		50+	50+	50+	20+			<1			20+	20+	25+

*NOTE: The numerical values and ranges for each variable and in each cell of the table are arbitrary and are *example values only*. Each locality should list variables and ranges appropriate to its own situation.

Table 3-5

Example: Benefits and Costs of Four Action Alternatives

Benefits	Alternative A	Alternative B	Alternative C	Alternative D
Accident Reduction	15%	20%	45%	0%
Fatality Reduction	10%	25%	45%	0%
Injury Severity Reduction	20%	15%	30%	0%
Life Expectancy	3 Yr.	6 Yr.	10 Yr.	N/A
Economic Impact	N/A	N/A	High	N/A
Social Impact	Average	Average	High	High
Implementation	4 Mo.	5 Mo.	10 + Mo.	N/A
Level of Service	Low Average	Average	Low Average	Average
Aesthetic Value	Low Average	Low	High	High
Vehicle Delay Decrease	N/A	N/A	N/A	0%
Pedestrian Delay Decrease	N/A	N/A	N/A	0%
Noise Pollution Reduction	7%	N/A	15%	N/A
Costs				
Design Cost	$2000	$400	$5000	$0
Construction	$10,000	$1000	$20,000	$0
Maintenance	$1000	$2100	$600	$300
Implementation	4 Mo.	5 Mo.	10 + Mo.	N/A
Vehicle Delay Increase	2%	2%	5%	0%
Pedestrian Delay Increase	1%	1%	3%	0%
Visual Pollution Increase	A (Average)	E (None)	E (None)	E (None)
Noise Pollution Increase	N/A	2%	N/A	N/A
Air Pollution Increase	N/A	N/A	N/A	N/A

Table 3-6

Example: Value Ratings of Four Action Alternatives

Benefits	Alternative A	Alternative B	Alternative C	Alternative D
Accident Reduction	30	40	90	0
Fatality Reduction	20	50	90	0
Injury Severity Reduction	40	30	60	0
Life Expectancy	15	30	50	–
Economic Impact	–	–	90	–
Social Impact	50	50	90	90
Implementation	60	50	0	–
Level of Service	30	50	30	50
Aesthetic Value	30	10	90	90
Vehicle Delay Decrease	–	–	–	0
Pedestrian Delay Decrease	–	–	–	0
Noise Pollution Reduction	10	–	50	–
Total	285 (N=9)	310 (N=8)	640 (N=10)	230 (N=8)
Costs				
Design Costs	60	100	0	100
Construction	60	100	20	100
Maintenance	50	10	70	85
Implementation	60	50	0	–
Vehicle Delay Increase	80	80	50	100
Pedestrian Delay Increase	90	90	70	100
Visual Pollution Increase	50	90	90	90
Noise Pollution Increase	–	80	–	–
Air Pollution Increase	–	–	–	–
Total	450 (N=7)	600 (N=8)	300 (N=7)	575 (N=6)

Similarly, the Total Cost Value Rating for a particular alternative is obtained by adding the individual cost variables' Value Ratings and dividing by the number of variables:

$$C = \frac{V_1 + V_2 + V_3 + \ldots}{N}$$

where:

C	=	Total Cost Value Rating for that alternative
$V_1, V_2 \ldots$	=	Individual Value Ratings for the cost variables
N	=	Number of cost variables considered for that alternative

For the four alternatives in this example, the Total Cost and Total Benefit Value Ratings are:

	Benefits	Costs
Alternative A	$\frac{285}{9} = 31.7$	$\frac{450}{7} = 64.3$
Alternative B	$\frac{310}{8} = 38.8$	$\frac{600}{8} = 75.0$
Alternative C	$\frac{640}{10} = 64.0$	$\frac{300}{7} = 42.9$
Alternative D	$\frac{230}{8} = 28.8$	$\frac{575}{6} = 95.8$

- Step D: Determine each alternative's Benefit-Cost Ratio.

The Benefit-Cost Ratio is expressed as

$$\rho = \frac{B}{C}$$

where:

B = the Total Benefit Value Rating for an alternative

C = the Total Cost Value Rating for the same alternative

In this example, the four Ratios are:

Alternative A: $\rho = \frac{B}{C} = \frac{31.7}{64.3} = .49$

Alternative B: $\rho = \frac{B}{C} = \frac{38.8}{75.0} = .51$

Alternative C: $\rho = \frac{B}{C} = \frac{64.0}{42.9} = 1.49$

Alternative D: $\rho = \frac{B}{C} = \frac{28.8}{95.8} = .30$

It must be realized that this ratio is *not* a measure of the relative quality of particular alternatives. That is, a countermeasure with a ratio of 2.0 is not twice as good as another with a ratio of 1.0. In addition, because this method does not deal with monetary values, it is *not* necessary for the ratio to be greater than 1.0 in order for an alternative to be acceptable. The B-C Ratio is simply a numerical statement of the benefits expected versus the costs outlayed.

After determining each alternative's Benefit-Cost Rating, they should be evaluated in sequence, starting with the one with the highest Ratio. The highest rated alternative should be the one selected.

In the example, Alternative C obviously has the highest B-C Ratio and, if there are no constraints, would be the facility to select. However, constraints (e.g., cost limitations, and/or desired minimum benefit levels) will affect whether or not the highest rated alternative will be the one implemented. Step E discusses constraint consideration.

- Step E: Consider constraints (goals and limitations).

Constraints are desired or required prerequisites which a solution to a particular problem must meet. Possible cost-variable constraints are the total funds available or the immediacy that the problem solution must be installed. Example benefit-variable constraints are a minimum desired level of accident or injury severity reduction, or no additional visual pollution at the installation site.

For this example, the constraints are:

- Construction costs cannot exceed $10,000.
- It must be totally implemented within 6 months.
- Vehicle delay increases cannot exceed 3 percent.

- Expected fatality reduction must be at least 10 percent.
- Its unattended life expectancy must be 3 or more years.

Step F describes the method of final alternative selection.

- Step F: Select highest rated alternative meeting the constraints.

After the Benefit-Cost Ratio for each alternative has been calculated, the alternative with the largest Ratio *and* meeting the constraints should be selected for implementation.

In this example, Alternative C has the highest B-C Ratio (return on investment). However, its high design, construction and maintenance costs, and long implementation time do not meet the stated constraints. On the other hand, it has a very high anticipated accident reduction level, positive effects on the local economy, and aesthetic value. In a case where one alternative has such a higher B-C Ratio but does not meet the initial constraints, it may be appropriate to try to meet those constraints (e.g. find the extra money, or be less concerned about the implementation time).

Alternative D, the "Take No Action" alternative, also does not meet all the stated constraints – specifically the desired 10 percent reduction in accident fatalities. Although this alternative is certainly a feasible choice, and incurs practically no costs, the expected benefits are minimal as well. In some situations, the No Action Alternative may be better than the Do Something Alternatives if the constraints are met.

Both Alternatives A and B meet the stated constraints in this example. Assuming that no additional constraints are added when only these two alternatives are left, the choice is Alternative B, which has the higher Value Rating Ratio (.49 vs. .51).

Subjectivity Problems with Benefit-Cost Analysis

Although Benefit-Cost Analyses use numbers a great deal, in reality they are very subjective. The anticipated benefits of a countermeasure are only guesses of what will occur in the future. Although past experience may help generate estimates with greater accuracy, the figures are still conjectures for the specific location under consideration.

Certainly the most useful tool for a Benefit-Cost Analyst/Decision Maker to have is a method which accurately forecasts the future. However, numerous unknowns about future events present some level of uncertainty and risk in making such predictions. In estimating the anticipated outcome levels of individual benefit and cost variables, the analyst *must* use sound and well-based judgment. A thorough understanding of the variables and their potential effects is a prerequisite for accurate forecasting.

Similarly, in developing the scales for the Value Rating conversion tables, realistic and sound ranges must be used. The range must be such that small incremental changes in the outcome estimate of a variable will not *drastically* change the final Value Rating. At the same time, the range *should* permit large variations in individual variables to be reflected in the final total Value Rating for the alternative.

Accurate forecasting through sound rational judgment must be supplemented by professional integrity on the part of the B-C Analyst. Whenever a quantitative analysis is being made, the outcome is directly affected by the data input. It is imperative that the numbers used reflect reality, and not personal biases, as much as possible. An alternative selection based on incorrect data may not be effective and certainly will waste time and funds. Verifying the numerical values to be used in the analysis is more important than the mathematical computations themselves.

Several techniques enabling a decision maker to better guess possible future situations are available. Sensitivity Analysis forecasts several futures for individual events (variables). It is not a required step in a Benefit-Cost Analysis, but can give a better indication of what alternative to select. Analysis Option 1 describes this technique.

- Analysis Option 1: Use Sensitivity Analysis if desired.

Sensitivity Analysis is a technique allowing estimation of more than one possible future condition for any or all variables for one or all alternatives. Instead of one "best guess" level for a variable, three estimates are made: an optimistic, a pessimistic, and a midrange level. The Total Benefit or Total Cost Value Rating and the Benefit-Cost Ratio are then recomputed for that alternative for each of the three estimates, and the alternatives are again compared. It is possible that the most advantageous alternative will change depending on whether optimistic or pessimistic conditions occur.

The decision maker-analyst must decide which of the possible future environments for a variable is the most likely, rather than one "best guess" outcome. That decision will identify which alternative is selected. Of course, if the same alternative comes out ahead through all conditions, then the decision is much easier to make.

In the example, say that Alternatives A and B have midrange Life Expectancies of 3 years and 6 years (the previous calculation). However, optimistic and pessimistic Life Expectancy estimates and the equivalent Value Ratings may be the following:

Life Expectancy	Alternative A	Alternative B
Optimistic	6 (= 30)	10 (= 50)
Midrange (Earlier calculation)	3 (= 15)	6 (= 30)
Pessimistic	1 (= 0)	2 (= 10)

Recomputing the Benefit-Cost Ratio under these possible Life Expectancy conditions, the new Ratios are:

B-C Ratio	Alternative A	Alternative B
Optimistic	.52	.55
Midrange (Earlier calculation)	.49	.51
Pessimistic	.47	.48

It can be seen that the optimistic Alternative A has a better B-C Ratio than both the midrange and pessimistic Alternative B, and that the midrange Alternative A is better than the pessimistic Alternative B.

Note that Sensitivity Analysis can become very mathematically complex. If every Benefit and Cost variable is assigned three values and all possible combinations (using some optimistic, or some pessimistic, or some midrange levels, etc.) are tested, a computer would be absolutely required. This technique should only be used when it is truly difficult to determine the one likely "best guess" for a variable. Of course, it is possible that a pessimistic occurrence of one variable may cause an optimistic occurrence of another variable. Variable interrelationships must be watched when using Sensitivity Analysis.

This discussion has so far assumed that all the cost and benefit variables are of equal importance. In reality, each locality has a different set of priorities based on budgetary, accident rate and other criteria. The second analysis option presents a technique for emphasizing and deemphasizing variables if desired.

- Analysis Option 2: Use Variable Priority Weighting if desired.

A benefit and cost Variable Weighting scheme is recommended when the most important variables to a decision making process should be maximized and variables of lesser importance to the individual locality minimized. To use this technique, a mathematical Weighting Factor is assigned to each variable. The Factor value, from 0 to 1, is multiplied with the Value Rating of that variable. A weight of 1 gives full value to the variable; a weight of 0 eliminates the variable. Mathematically, the Weighting Factor procedure is stated as:

$$B = W_1 V_1 + W_2 V_2 + W_3 V_3 + \ldots$$

where:

B	=	Total Benefit Value (as above).
$V_1, V_2 \ldots$	=	Individual Values for the benefit variables (as above).
$W_1, W_2 \ldots$	=	Individual Weighting Factors for the associated benefit variables.

Similarly:

$$C = W_1 V_1 + W_2 V_2 + W_3 V_3 + \ldots$$

where:

C	=	Total Cost Value (as above).
$V_1, V_2 \ldots$	=	Individual Values for the cost variables (as above).
$W_1, W_2 \ldots$	=	Individual Weighting Factors for the associated cost variables.

Selection of the Weighting Factors is somewhat arbitrary. If it is not possible to determine which variables are more important than others, no weighting should be used.

Using the data from the example, *possible* Variable Priorities might be as follows (Table 3-7):

Table 3-7

Example: Priority Weights for Benefit and Cost Variables

Benefits	Weight	Costs	Weight
Accident Reduction	1.0	Design Costs	1.0
Fatality Reduction	1.0	Construction Costs	1.0
Injury Severity Reduction	1.0	Maintenance	1.0
Life Expectancy	.8	Implementation	.2
Economic Impact	.7	Vehicle Delay Increase	.8
Social Impact	.2	Pedestrian Delay Increase	.6
Implementation	.2	Visual Pollution	.2
Level of Service	.4	Noise Pollution	.7
Aesthetic Value	.2	Air Pollution	.5
Vehicle Delay Decrease	.6		
Pedestrian Delay Decrease	.6		
Noise Pollution	.4		

Note: The numerical values are arbitrary and are *example values* only. Each locality should list priorities appropriate to its own goals and limitations.

Using the Value Ratings from Table 3-6, the Total Benefit and Total Cost Value Ratings can be recalculated (Table 3-8).

Table 3-8

Example: Recalculated Value Ratings of Four Action Alternatives Using Variable Priority Weighting

Benefits	Alternative A	Alternative B	Alternative C	Alternative D
Accident Reduction	30 (1.0) = 30	40 (1.0) = 40	90 (1.0) = 90	0 (1.0) = 0
Fatality Reduction	20 (1.0) = 20	50 (1.0) = 50	90 (1.0) = 90	0 (1.0) = 0
Injury Severity Reduction	40 (1.0) = 40	30 (1.0) = 30	60 (1.0) = 60	0 (1.0) = 0
Life Expectancy	15 (.8) = 12	30 (.8) = 24	50 (.8) = 40	–
Economic Impact	–	–	90 (.7) = 63	–
Social Impact	50 (.2) = 10	50 (.2) = 10	90 (.2) = 18	90 (.2) = 18
Implementation	60 (.2) = 12	50 (.2) = 10	0 (.2) = 0	–
Level of Service	30 (.4) = 12	50 (.4) = 20	30 (.4) = 12	50 (.4) = 20
Aesthetic Value	30 (.2) = 6	10 (.2) = 2	90 (.2) = 18	90 (.2) = 18
Vehicle Delay Decrease	–	–	–	0 (.6) = 0
Pedestrian Delay Decrease	–	–	–	0 (.6) = 0
Noise Pollution	10 (.4) = 4	–	50 (.4) = 20	–
Total (= B)	146 (N=9)	186 (N=8)	411 (N=10)	56 (N=8)
Costs				
Design Costs	60 (1.0) = 60	100 (1.0) = 100	0 (1.0) = 0	100 (1.0) = 100
Construction	60 (1.0) = 60	100 (1.0) = 100	20 (1.0) = 20	100 (1.0) = 100
Maintenance	50 (1.0) = 50	10 (1.0) = 10	70 (1.0) = 70	85 (1.0) = 85
Implementation	60 (.2) = 12	50 (.2) = 10	0 (.2) = 0	–
Vehicle Delay Increase	80 (.6) = 48	80 (.6) = 48	50 (.6) = 30	100 (.6) = 60
Pedestrian Delay Increase	90 (.6) = 54	90 (.6) = 54	70 (.6) = 42	100 (.6) = 60
Visual Pollution	50 (.2) = 10	90 (.2) = 18	90 (.2) = 18	90 (.2) = 18
Noise Pollution	–	80 (.7) = 56	–	–
Air Pollution	–	–	–	–
Total (= C)	294 (N=7)	396 (N=8)	180 (N=7)	423 (N=6)

Using these new values and the procedures in Step C, the Total Beneift and Total Cost Value Ratings for the four alternatives are:

	Benefit	Cost
Alternative A	16.2	42.0
Alternative B	23.3	49.5
Alternative C	41.1	25.7
Alternative D	7.0	70.5

The Benefit-Cost Ratios for the four alternatives are:

Alternative A	=	.39
Alternative B	=	.47
Alternative C	=	1.60
Alternative D	=	.10

Referring back to Step D, it can be seen that the sequence for considering alternatives has not changed. The high-to-low sequence both with and without Variable Priority Weighting is C-B-A-D. However, the Priority Weighting values can affect the Benefit-Cost Ratio and, therefore, the possible best alternative.

Summary

Benefit-Cost Analysis is an important decision-making tool because it provides a technique to make Alternative selections based on mathematical analysis. This is not to say that B-C Analysis should be the only basis for selecting an alternative. Political and public demand, historical precedent, and your specific situation have roles to play. However, a quantitative analysis provides the element for more rational, and subsequently justifiable, decisions.

Rational decision making is particularly necessary because of the great demand for safety improvement funds at all levels of government – a demand which is expected to increase in the future. The method outlined in Step 3 (and illustrated in Figure 3-1) is conducive to use at all governmental levels. (See Appendix E for a specific discussion of its use at the state level.)

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