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URBAN INTERSECTION IMPROVEMENTS FOR PEDESTRIAN SAFETY

Vol. I. Executive Summary

December 1977

Final Report

Prepared for

FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Washington, D.C. 20590

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FOREWORD

This five-volume report describes pedestrian problems at urban intersections and timing and display improvements for pedestrian signals. This report will be of interest to traffic engineers and others responsible for pedestrian safety.

The five volumes are:

Vol. I - Executive Summary
Vol. II - Identification of Safety and Operational Problems at Intersections
Vol. III - Signal Timing for the Pedestrian
Vol. IV - Pedestrian Signal Displays and Operation
Vol. V - Evaluation of Alternatives to Full Signalization at Pedestrian Crossings

Sufficient copies of the five volumes are being distributed to provide a minimum of one copy to each FHWA Regional and Division office. Additional copies of the Executive Summary have also been provided to allow wider distribution of this report. Copies sent direct to the Division Offices should be distributed to the State highway agency, Governor's Representative for Highway Safety, and to major metropolitan areas.

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

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16. Abstract

The purpose of the study of Urban Intersection Improvements for Pedestrian Safety was to identify problems associated with pedestrian-vehicle interactions at intersections, develop countermeasure concepts that would reduce these problems, and evaluate the most desirable countermeasures to determine their effectiveness. As an additional phase, the Federal Highway Administration included a study to evaluate alternatives to full signalization at pedestrian crossings. The study was divided into three phases:

Phase I was reported in Volume II, Identification of Safety and Operational Problems and was directed at identifying and defining the safety and operational problems associated with the interaction of pedestrians and vehicles at intersections.

Phase II was divided into two tasks. Task A conducted research dealing with signal timing for the pedestrian. Task B was directed towards pedestrian signal display and operation research.

Task A reported in Volume III, Signal Timing for the Pedestrian was directed at making recommendations concerning improvements in the timing of pedestrian traffic signals, both to maximize safety and to minimize delay. The report was divided into three sections:

1. Timing for a Combined Pedestrian-Vehicle Interval. 2. Alternative Phasing Schemes. 3. Other Areas of Pedestrian Signal Research.

Task B was reported in Volume IV. Pedestrian Signal Displays and Operation was directed at evaluating pedestrian signal displays and operation. The study was divided into three parts:

1. Lunar vs. Clear White "WALK" Lens Study. 2. Word Message and Operation Study. 3. Symbol Message Study.

Phase III reported in Volume V, Evaluation of Alternatives to Full Signalization at Pedestrian Crossings, was to develop traffic control devices that could be used as alternatives to full signalization at pedestrian crossings that are located at intersections. These traffic control devices were evaluated at the intersection of an arterial street with a low-volume residential street where adequate gaps in the traffic stream do not exist to allow pedestrians to cross the arterial street safely. The study was divided into two parts: identification of alternative pedestrian crossing designs, and field evaluations.

Volume II – Identification of Safety and Operational Problems at Intersections
Volume III – Signal Timing for the Pedestrian
Volume IV – Pedestrian Signal Displays and Operation
Volume V – Evaluation of Alternatives to Full Signalization at Pedestrian Crossings

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PREFACE

This research project was conducted in three phases. Phase I dealt with the investigation and identification of both operational and safety problems encountered by pedestrians and motorists at urban-type intersections. Phase II dealt with the development, evaluation, and design criteria formulation of countermeasures that address the problems identified in Phase I. Phase III evaluated some alternatitve to full signalization at intersections requiring pedestrian protection.

Volume I of the Final Report is the Executive Summary of the project. Phase I is reported in Volume II and Phase II is reported in Volumes III and IV. Specifically, Volume III addresses the subject of signal timing for the pedestrian; and Volume IV deals with pedestrian signal displays and signal operation. Phase III is reported in Volume V.

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INTRODUCTION

In 1973, approximately 400,000 pedestrians were involved in motor vehicle accidents. About 10,000 of these accidents resulted in pedestrian fatalities. The majority of these fatalities occurred in urban areas, and some 24 percent could be termed intersection accidents.

Installation of traffic control devices (signals, signs, and markings) at intersections has been the traditional approach to reducing vehicle and pedestrian accidents. Overall studies to date have not conclusively shown that traffic signals, signs, or crosswalks substantially improve pedestrian safety. Some studies have shown, however, that certain improvements directed at meeting driver and pedestrian expectancies have resulted in fewer pedestrian accidents.

In addition, the operational efficiency of the intersection must be considered. The competition for space between pedestrians and vehicles is increasing, particularly in densely populated areas. Provisions for pedestrian movements and pedestrian/vehicle conflicts reduce intersection capacity and increase delay. The traffic engineer is thus confronted with two sometimes conflicting considerations: safety and operational efficiency.

In attempting to accommodate both considerations, traffic engineers have sought to improve and standardize traffic control devices. This research project was developed to identify the safety and operational problems of pedestrians at intersections, and to develop standardized procedures and traffic control devices that address these problems.

OBJECTIVES AND SCOPE OF PROJECT

The following are the stated project objectives:

- To identify the problems associated with pedestrians and vehicles at intersections
- To identify countermeasure concepts
- To develop and evaluate potential countermeasures from the standpoints of safety and operational efficiency, using a human factors approach.

Phase I (problem identification) identified two areas that needed further research: signal displays and signal operation. Phase II more fully examined these two broad areas.

- Signal timing for the pedestrian.
- Pedestrian signal displays and operation.

In addition, the FHWA decided it was desirable to include a Phase III in the project to evaluate alternatives to full signalization at pedestrian crossings.

The results of this project were based on reviews of previous research, expert opinion in the area of traffic safety, user understanding surveys, and extensive field testing and evaluation.

PROJECT SUMMARY

Phase I. Identification of Safety and Operational Problems at Intersections (Volume II)

The following four sources of information were used to define the safety and operational problems associated with the interaction of pedestrians and vehicles at intersections:

- Accident data
- Expert opinion
- Behavioral observation
- Conceptual investigations.

The accident data consisted of over 5300 pedestrian intersection accident records from 25 different urban areas and were used to determine the design and operational features of urban intersections that are related to pedestrian/vehicle safety.

Expert opinion was obtained from 70 traffic engineers and safety experts at the city, county, federal, and university level to identify pedestrian safety problems at intersections and identify potential safety countermeasures.

The behavioral observations were obtained at 60 paired high- and low-pedestrian-accident intersections. These observations were used to develop pedestrian behavioral measures and to identify potential intersection accident causal characteristics.

The investigation consisted of reviewing human factors data and concepts relevant to intersection designs for pedestrian safety and a review of behavioral and operational literature dealing specifically with pedestrian and driver safety at intersections. Over 1000 pieces of literature were reviewed, resulting in an annotated bibliography of over 300 relevant references. Based on an in-depth analysis of these sources, four categories were developed to describe the safety and operational problems encountered by pedestrians at intersections.

1. Undesirable Pedestrian and Vehicle Interactions
    a. Turning vehicle conflicts with pedestrians

b. Pedestrian's acceptance of small vehicle gaps
c. Pedestrians crossing when vehicles are moving through the crosswalk area
d. Pedestrian short time exposure to drivers (appears suddenly in the vehicle's path)
e. Pedestrians required to run while crossing in response to a nearby turning or through vehicle
f. Pedestrian required to hesitate while crossing in response to a turning or through vehicle
g. Pedestrians entering a traffic lane in front of a stopped or standing vehicle (not a parked vehicle).

2. Undesirable Pedestrian and/or Driver Behaviors
   a. Pedestrian crossing the intersection diagonally
   b. Pedestrian running in or into the roadway
   c. Pedestrian crossing against the signal
   d. Pedestrian starting to cross during the caution (clearance) indication on the signal
   e. Pedestrian anticipating the signal (starts to cross against the signal which changes before the crossing is completed)
   f. Vehicle backing into the crosswalk after being trapped by the changing signal
   g. Pedestrian or driver inattention while approaching and traveling through the intersection
   h. Failure by pedestrian to use available traffic control devices (pushbuttons, marked crossings, etc.).

3. Undesirable Intersection Characteristics
   a. Inadequate driver and pedestrian sight distances (caused by parked vehicles, street furniture, or vegetation)
   b. Inadequate roadway lighting
   c. Wide roadways without adequate provisions for pedestrian crossing
   d. Unenforced laws and ordinances
   e. Complex presentation of numerous signs, signals and markings
   f. Environmental and roadway distractions
   g. Inadequate provisions for handicapped pedestrians
   h. Near-side bus stops.

4. Undesirable Traffic Control Device Characteristics
   a. Nonstandard devices or device application
   b. Inadequate signal timing
   c. Nonuniform and/or improper signal color, size, and message
   d. Inconsistent use of messages
   e. Failure of device to convey the proper message

f. Failure of device to meet pedestrian and/or driver expectancies

g. Crosswalks conveying a false sense of security from vehicles to the pedestrians crossing the roadway.

The following potential countermeasures were identified to reduce the problems encountered by pedestrians at intersections:

- Improving enforcement
- Improving driver and pedestrian education
- Clarifying the required pedestrian and driver actions at the intersection by using necessary traffic control devices
- Improving pedestrian signal messages, colors, and displays
- Improving signal timing
- Improving crosswalk applications
- Shielding vehicle and pedestrian signals
- Improving visibility (lighting, etc.)
- Providing far-side bus stops
- Increasing driver and pedestrian sight distances.

Based on the safety and operational problems of pedestrians at intersections and the potential countermeasures identified in Phase I, "Identification of Safety and Operational Problems at Intersections" (Volume II), the following areas were designated for further research in Phase II:

- Improved signal timing
- Improving pedestrian signal messages, color, and displays.

Phase II, Task A Signal Timing for the Pedestrian (Volume III)

The purpose of this task was to examine the timing of WALK/DONT WALK signals in relation to safety and delay for both pedestrians and vehicles, and to develop procedures which would make signal timing more responsive to the needs of both groups.

Timing for a Combined Pedestrian-Vehicle Interval

A combined pedestrian-vehicular interval timing is used at the majority of intersections in the United States. The *Manual on Uniform Traffic Control Devices* (MUTCD) sets the standard upon which the WALK and clearance intervals are based. It states that the WALK interval should be timed for at least 7 seconds and that the clearance interval should be timed using an assumed walking speed of 4.0 ft/sec (1.2 m/sec) over the distance from the curb to the middle of the farthest traveled lane. The first study in this task examined guidelines in three areas:

- Minimum walk interval

- Minimum clearance interval
- Allocation of excess pedestrian time.

Minimum Walk Interval. The results of this investigation were:

- The standard 7-second WALK interval is long enough to accommodate pedestrians at the vast majority of locations and under most conditions.
- Groups of pedestrians requiring more than 7 seconds to discharge, approximately 24 persons, occur rarely and are usually found in certain sections of large metropolitan areas. An average group size of approximately 13 persons, measured over an hour, must be present before the 24-person limit will be exceeded a significant number of times. In these cases, a pedestrian peak hour field study should be performed to determine exact WALK interval requirements.
- Shortening the minimum WALK interval to 4-5 seconds may be applicable under low peak hour pedestrian volume conditions (less than 10 pedestrians per cycle) per crosswalk *and* where increasing vehicle capacity is a *major* concern. However, pedestrian perception/reaction time and the inattentiveness factor must also be weighed in this decision.

Minimum Clearance Interval. Close examination of the factors used to determine the minimum clearance interval revealed:

- The percentage of pedestrian platoon speeds slower than 4.0 ft/sec increases in proportion to pedestrian volumes and can range well over 50 percent on high-volume crosswalks because there are more slow walkers at higher volumes.
- A clearance interval based on a pedestrian walking speed of 3.5 ft/sec should be considered at locations with peak hour pedestrian volumes on either crosswalk of over 15 per cycle in one direction.
- Pedestrians tend not to use the near-side parking lane as a protected waiting area for beginning their crossing.
- Far-side parking lanes should be considered "traveled lanes" unless geometrics or operational constraints preclude pedestrian/vehicle conflicts in that lane.
- Pedestrian walking speeds may be lowered based on engineering judgment if the location is used heavily by elementary school children, the elderly, the handicapped, or to meet the requirements of the population.

Allocation of Excess Pedestrian Time. A comparison as to the best allocation of excess pedestrian time, either to the WALK or clearance interval, revealed the following. A *recommended practice* is that *all* excess pedestrian time be allocated to the WALK interval to the point at which minimum clearance rules. This is beneficial from the standpoints of both delay and compliance. The decrease in pedestrian delay significantly outweighs the increase to vehicle delay such that the total intersection delay (sum of pedestrian and vehicle delay) is reduced. Pedestrian compliance to WALK significantly increased with the allocation of excess time for the WALK interval and compliance to solid DONT WALK was not affected.

Figure 1 illustrates how pedestrian signal timing is determined for the WALK and clearance intervals for a combined pedestrian-vehicle interval.

Alternative Pedestrian Signal Phasing Schemes

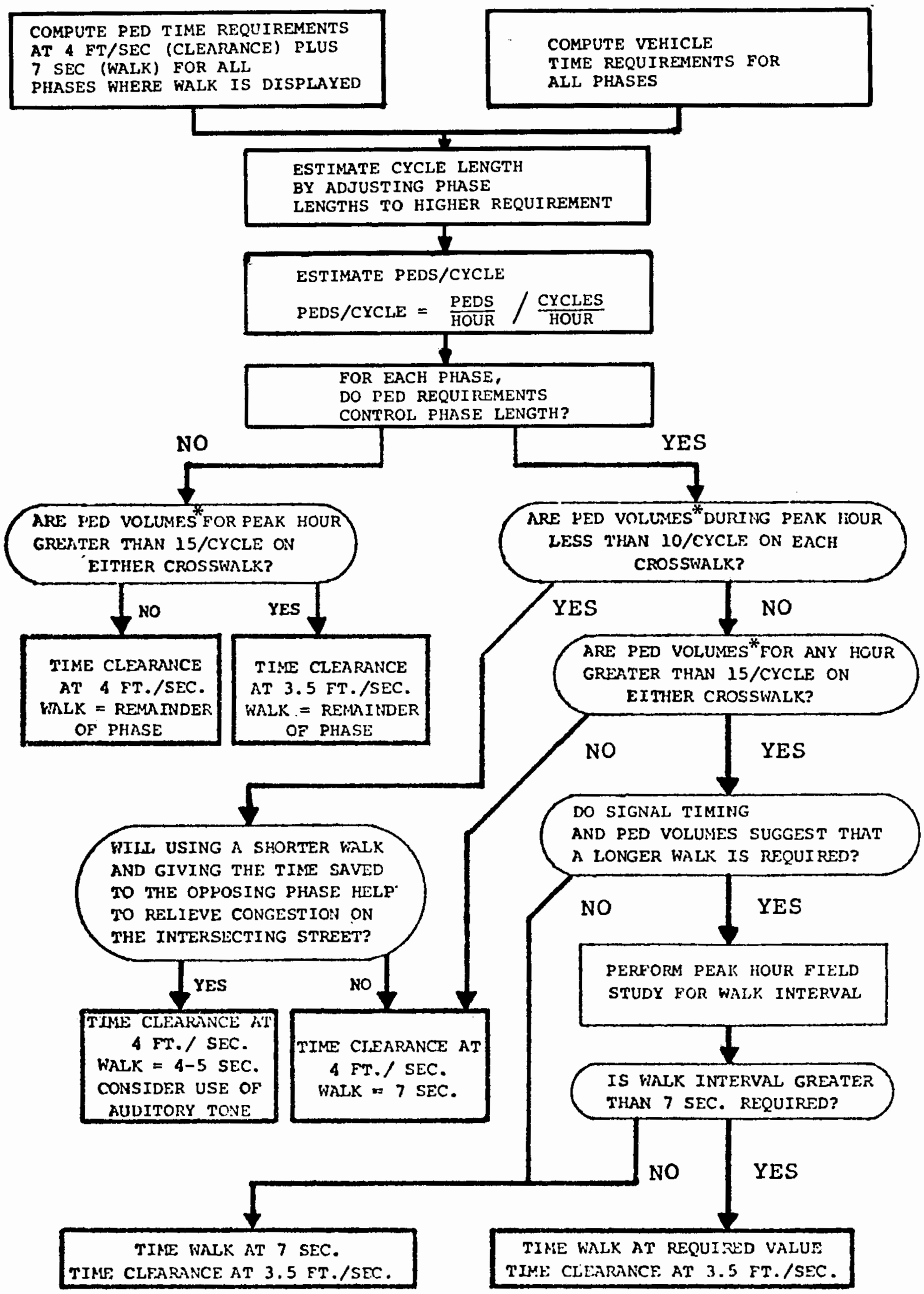
This study examined the desirability of using pedestrian signal phasing schemes other than the combined pedestrian-vehicular interval. Alternative phasing schemes included:

- *Early release* of pedestrians with respect to vehicles, which allows pedestrians to leave the curb prior to the release of turning vehicles.
- *Late release* of pedestrians with respect to vehicles, which holds pedestrians at the curb until several of the right-turning vehicles have passed the crosswalk.
- *Scramble* pedestrian timing, which provides an exclusive pedestrian phase for all directions including diagonals.
- *Partial crossing* of wide, channelized streets.

Figure 2 illustrates examples of the first three alternative timings and for standard timing.

Early and Late Pedestrian Releases. After close examination of early and late pedestrian release, the following conclusions were developed:

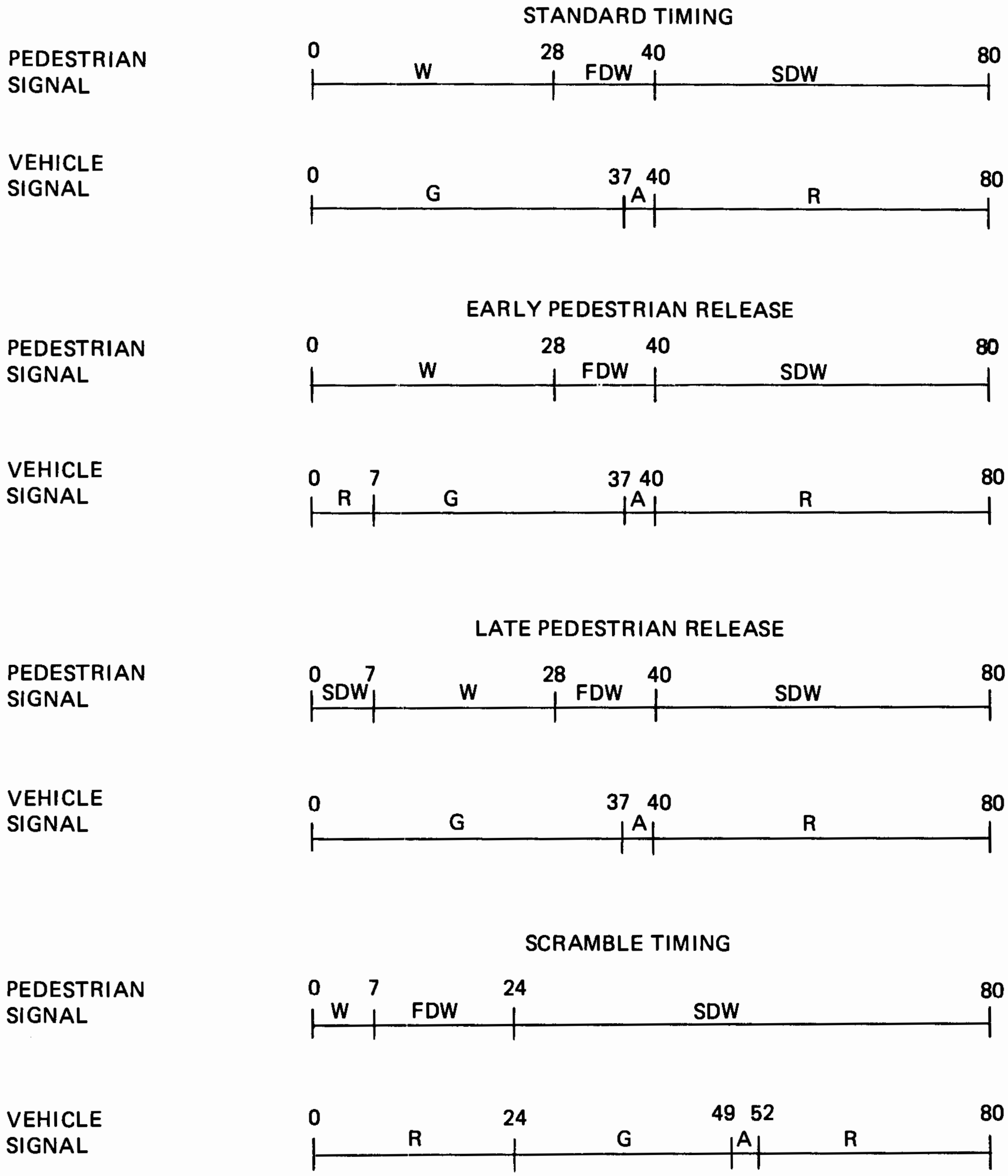
- Compared to standard phasing, early pedestrian release significantly increases total delay at an intersection. Pedestrian delay is not affected, but vehicle delay is greatly increased where right-turn movements are frequent. Though early release may provide some measure of additional safety, the benefits are not precisely determined.
- Late pedestrian release significantly increases pedestrian delay and tends to increase total delay for most volume levels. However, where a vehicle queue consistently exists in a right-turn lane, late release is beneficial for increasing lane capacity and, with certain combinations of pedestrian and vehicle volumes, will reduce overall intersection delay.
- Late release does not adversely affect pedestrian compliance rates; however, installations may have a long acclimation period when introduced into new cities. Signs for both pedestrians and vehicles should be used to minimize the initial adverse consequences.



NOTE: If this process gives different answers for various hours of day and if hardware configuration will allow, change timing by time-of-day.

* Pedestrian Volume, by Crosswalk, Both Directions.

Figure 1. Pedestrian Signal Timing for WALK and Clearance Intervals



Legend

W= Walk Interval
FDW= Flashing DONT WALK Interval
SDW= Solid DONT WALK Interval
G= Green Indication
A= Amber Indication
R= Red Indication

Figure 2. Pedestrian Signal Phasing Schemes

Scramble Operation.

- Scramble timing is most applicable where conditions include high pedestrian volumes, low vehicular through volumes with medium to heavy right-turn volumes on *all* approaches and narrow street widths (approximately 50 feet (15.2 m) or less curb to curb).
- Scramble timing *always* increases pedestrian delay, often by 200 percent when compared with standard timing. Vehicular delay is highly dependent on vehicle arrival patterns. For very high turning percentages, any vehicle delay that is saved nearly equalizes the additional delay incurred by pedestrians. A lower turning percentage reduces the vehicle delay advantages of scramble timing substantially, and if few vehicles turn or if the street is very wide, scramble would more likely increase vehicle delay.

Figure 3 illustrates the procedure for selecting the pedestrian signal phasing scheme.

Partial Crossing of Wide, Channelized Streets. Timing for the partial crossing of wide, channelized streets should be avoided if possible. This type of timing leaves many pedestrians in the street at the end of the clearance interval. The clearance interval should be timed for the entire crossing unless the median is wider than 20 feet (6.1 m). If this type of timing must be used to minimize the side street green time, signs indicating the intent of timing and/or specially designed barriers should be provided on the median.

Other Areas of Pedestrian Signal Research

Other areas of research not directly related to either of the two previous categories were examined. These are highlighted below.

Time-of-Day Adjustments of Pedestrian Signal Timing. Time-of-day adjustments to pedestrian signal timing has little potential for practical application. Variations in the required length of pedestrian intervals based on pedestrian volume variations will usually be only several seconds at the maximum.

Hardware considerations may also preclude the effective use of time-of-day adjustments. The only case in which time-of-day adjustments would be practical is when the signal controller uses a separate off-peak timing plan which does not include one of the three pedestrian peak periods (morning, noon, and evening).

Correction Factors for the Highway Capacity Manual. The development of final pedestrian correction factors would best take place along with the restructuring of the "Intersection Capacity" chapter of the Manual, should that occur.

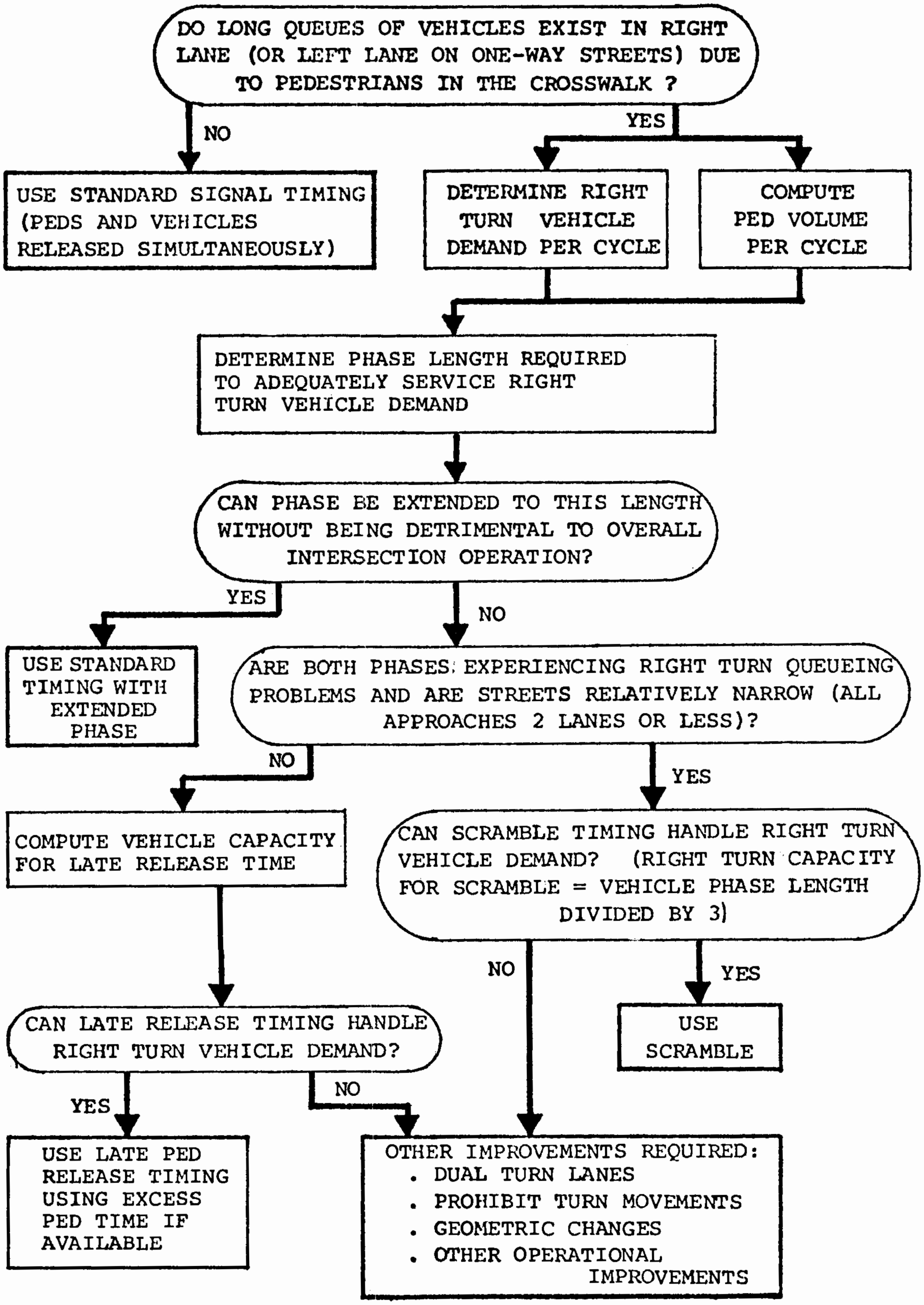


Figure 3. Selection of Pedestrian Signal Phasing Scheme

The primary problem with the use of pedestrian factors, given that they can be developed, lies in the data which will be required by the traffic engineer for their application. These data must include a two-way pedestrian count, length of the crosswalk, cycle length or an estimate of cycle length, and any unusual conditions or compliance problems encountered.

General Observations on Pedestrian Flow Characteristics. Pedestrian peak hours for central business districts usually occur during the morning and evening peak traffic periods and during the lunch-hour period, depending upon adjacent land use. Peak hours outside the CBD (central business district) are somewhat less predictable, also being contingent upon the predominant land use.

Daily pedestrian volume on one crosswalk has been found to be as much as four times the volume on other crosswalks at the same intersection. Timing requirements for a given pedestrian phase should be based on the higher volume crosswalk.

The arrival rate of pedestrians at a signalized intersection crosswalk is not uniform, but is higher just prior to and during the WALK interval.

Phase II, Task B. Pedestrian Signal Display and Operation (Volume IV)

This phase examined the message, color, and operation of the pedestrian signal. Four separate studies examined the following:

- Difference between "lunar" and "clear" white WALK lenses in pedestrian signals
- Methods to display the clearance interval using DONT WALK, DONT START, and flashing DONT WALK indications
- Methods to display the WALK interval using steady WALK and flashing WALK
- Concept of using symbolic pedestrian displays in place of the current word displays.

Lunar vs Clear White WALK Lens

The use of "lunar" white had been criticized on the basis of its susceptibility to "sun Phantom" or "wash out" when the sun was shining directly into the lens. Conclusions drawn from analysis of the data indicate:

- "Clear" has a much better target value under all conditions tested.
- "Clear" is better in terms of readability for conditions where bright sunlight cannot be prevented from shining directly into the lens.
- "Lunar" is better for all other light conditions with respect to readability and its effectiveness in this regard increases as the level of illumination decreases.
- Neither "lunar" nor "clear" is best for all conditions.

Word Message and Operation

Two questions were addressed in this study:

- What is the most effective way to present the concept of a pedestrian clearance interval?
- How effective is the practice of flashing the WALK indication to warn pedestrians that vehicles might be turning through their crosswalk during the WALK interval?

These areas were addressed in three comparative experiments:

- Steady DONT WALK clearance indication was compared to the standard flashing DONT WALK clearance indication
- Steady DONT START clearance indication was compared to the standard flashing DONT WALK clearance indication
- Steady WALK permissive indication was compared to the standard flashing WALK permissive indication.

All three experiments were conducted simultaneously in two cities, using a "before/after" study design. Each experiment was conducted at two test intersections in each city and measured three types of variables: pedestrian behavior, pedestrian compliance, and user understanding.

The following conclusions were drawn from an analysis of the data:

- A steady DONT WALK clearance display appears to have the same effectiveness as a flashing DONT WALK clearance display.
- The DONT START message offers little or no improvement over the current DONT WALK message.
- Flashing WALK is not an effective means of warning pedestrians about turning vehicles.
- Based on pedestrians' stated expectancy in regard to turning vehicles, there is a need to make pedestrians more aware of turning vehicles.
- Further research is needed to determine (1) the optimal clearance indication, and (2) the best means of alerting both drivers and pedestrians to turning vehicle conflicts.

Symbol Message

This study evaluated the concept of using symbolic pedestrian displays in place of the current standard word message displays. The initial part of the study consisted of conducting five preference surveys to determine: (1) which symbols and colors had the most intuitive meaning, and (2) whether these symbols and colors would be a suitable replacement for WALK-DONT WALK. The second part was the field evaluation of the selected symbol displays.

Preference Surveys. The following five preference surveys were conducted to evaluate the concept of using symbolic pedestrian displays:

1. The first survey was directed at 45 traffic engineers and safety experts. It was designed to elicit comments on the ten suggested pedestrian displays shown in Figure 4, and to provide an opportunity to suggest additional ideas.
2. A second engineer's survey was designed to obtain additional information on symbol preference and operational concept. Responses were received from 45 engineers and safety experts.
3. A user survey was designed to find which symbols and colors had the most intuitive meaning to pedestrians. Over 300 pedestrians were interviewed.
4. A second user survey was conducted to determine if the pedestrians would understand the symbol displays as they would appear during the field tests, and not be confused in a manner that could produce adverse safety effects.
5. The final survey, of elementary school children, was conducted to determine the impact that symbolic pedestrian signals might have on school-age pedestrians.

The following points are a summary of the survey findings:

- The first engineer's survey indicated a preference for the hand and standing man displays and a three-section, three-color signal head.
- The second engineer's survey favored the hand over the standing man with a preference for a two-section, three-color signal. Orange and white were the preferred colors, even though red and green came in a respectable second. Yellow was the favored clearance indication color. Symbols were thought to be a suitable replacement for words in pedestrian signal displays.
- The first user's survey overwhelmingly attached the most intuitive meaning to the circle with symbol and to red and green for pedestrian signal display colors.
- The second user survey indicated that symbols could be field tested without adverse safety effects. Preference for the hand and circle slash displays were evenly split.
- The school-age survey indicated that the symbols did have some degree of intuitive meaning, but that unless an educational program were provided, the field test sites should not be located on elementary school walking routes.

Field Evaluation. Based on the results of the preference survey, three alternative symbolic pedestrian displays were designated for field evaluation. Figure 5 shows alternative displays:

- Hand – Walking Man
- Standing Man – Walking Man
- Circle Slash – Walking Man.

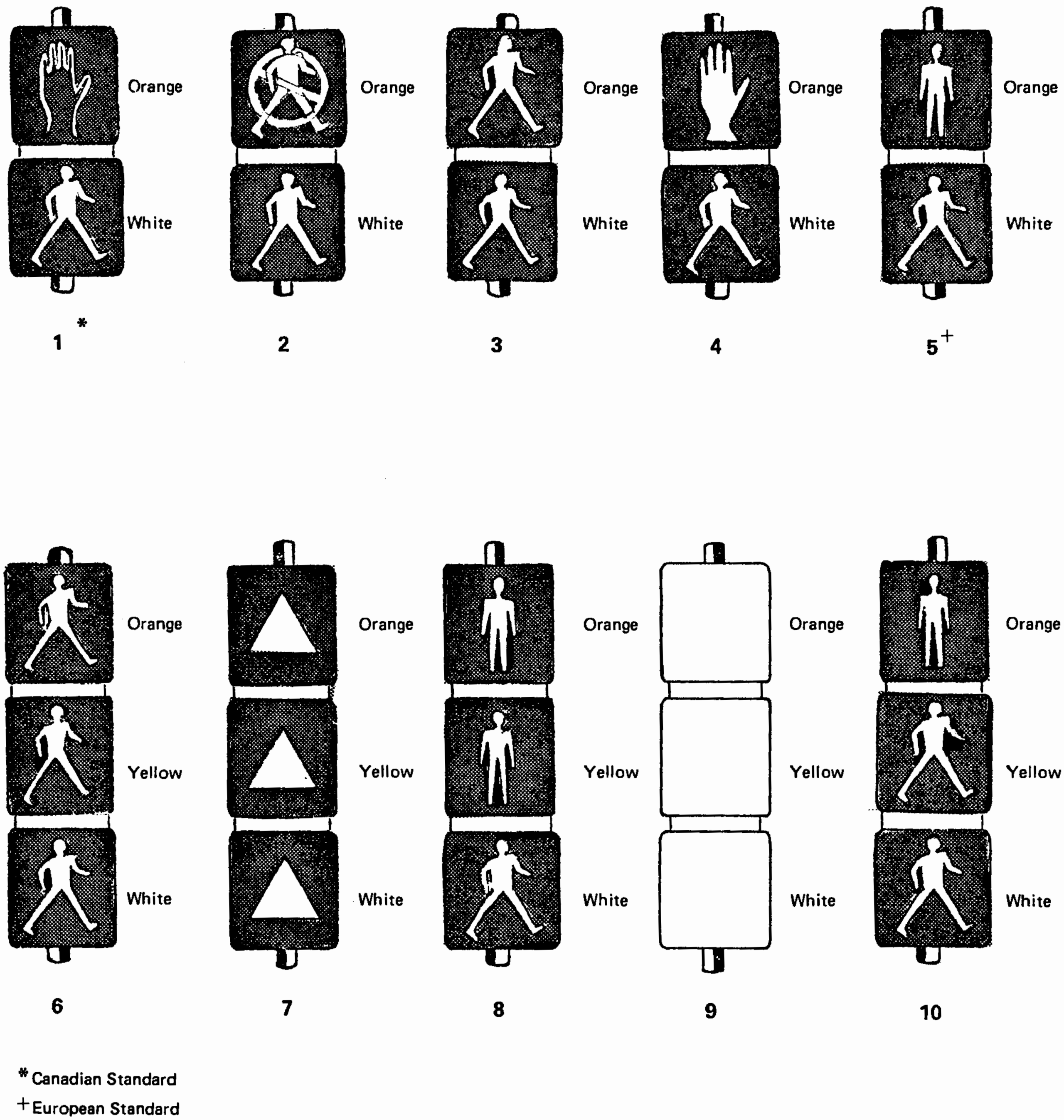


Figure 4. Suggested Pedestrian Displays

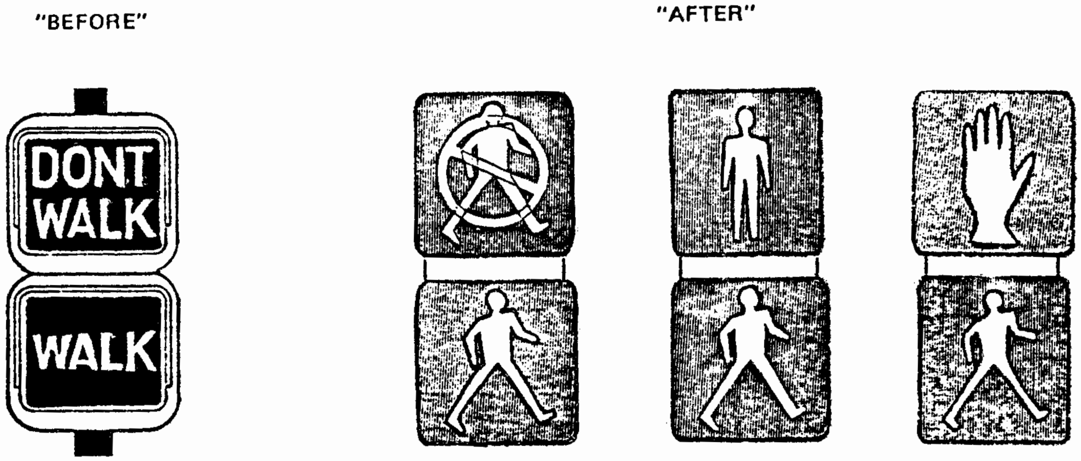


Figure 5. "Before/After" Displays for Symbol Study

The three symbolic pedestrian displays in two color sets (red-green and orange-white) were evaluated in before/after studies in two cities for each display. Three types of variables were used in evaluating the displays: pedestrian behavior, pedestrian compliance, and user understanding. Another validation study was conducted for the best symbol display of the initial three (Hand – Walking Man), repeating the experimental design in two additional cities.

The following conclusions were drawn from the analysis of the field evaluations:

- The Hand – Walking Man symbol display is a significant improvement over the standard DONT WALK – WALK display.
- The Standing Man – Walking Man symbol display appears to be as effective as the DONT WALK – WALK display.
- The Circle Slash – Walking Man symbol is not as effective as the DONT WALK – WALK display.
- Even though pedestrians indicated a preference for red and green signal indication colors, compliance with orange and white was significantly higher.
- If symbolic pedestrian signals come into use, an educational program will be necessary for elementary school pedestrians.

Phase III. Evaluation of Alternatives to Full Signalization at Pedestrian Crossings (Volume V)

The purpose of this study was to evaluate school-pedestrian crossing designs developed for an intersection of a major arterial street with a low-volume residential street. These intersections were located where there are no adequate gaps allowing pedestrians to cross the arterial street safely without an unreasonable time delay and otherwise would not require a traffic signal.

The study was divided into three parts:

1. Develop alternative school-pedestrian crossing designs at intersections
2. Evaluate the five best alternative school-pedestrian crossing designs using controlled field experiments
3. Recommend the safest and most effective treatment for a school-pedestrian crossing design at the intersection.

Selection of School-Pedestrian Crossing Designs

The selection of the school-pedestrian crossing design was accomplished using three sources of information:

1. Existing data on school-pedestrian crossing designs currently being used
2. Design development survey of traffic engineers and safety experts
3. Recommendations of project advisory panel.

Existing Data. Little existing data were available except for (Sg-44) signal and stop sign (a school-pedestrian) crossing device used by many western states) and the school crossing guard.

Survey. The purpose of the survey was to find out from traffic engineers and safety experts the types of traffic control devices currently in use and their ideas and concerns regarding school-pedestrian crossings at intersections. Their major concerns were violations of driver expectancy, effectiveness in producing a safe gap for pedestrians, and confusing operation of the traffic control devices.

Project Advisory Panel. The project advisory panel had three objectives: to develop general site criteria, to develop general measures of effectiveness and to recommend alternative school-pedestrian crossing designs for evaluation. The general site criteria developed by the advisory panel were:

1. The intersection does not meet the vehicle or pedestrian volume warrants (MUTCD), particularly with respect to minor street vehicular volume.
2. The intersection should meet the School Crossing Warrant (Warrant 4, MUTCD).
3. School children, senior citizens and/or handicapped persons crossings should be located at these intersections.

The Project Advisory Committee expressed the following concerns:

- Effectiveness in protecting pedestrians
- Efficiency in minimizing delay and stops for vehicular traffic
- Installation costs
- Violation of users' expectancy concerning traffic control configurations
- Impact on traffic patterns, i.e., route diversions
- Effect on type and number of accidents
- Ease of understanding and acceptanceceptance by pedestrians and motorists.

The Project Advisory Committee reviewed the survey responses and selected the following designs for school-pedestrian crossings for further evaluation (Figures 6-10).

- Sign and stop sign
- Flashing yellow signal and flashing red beacon
- (Sg-44) signal and stop sign
- Crossing guard.

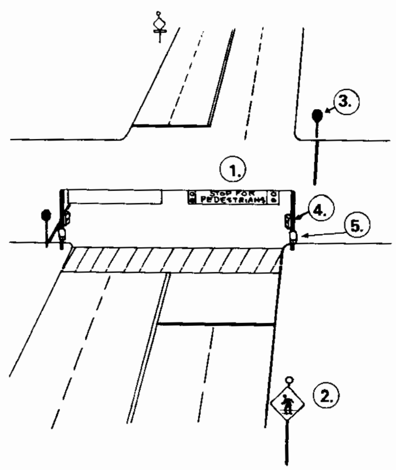
Field Evaluation

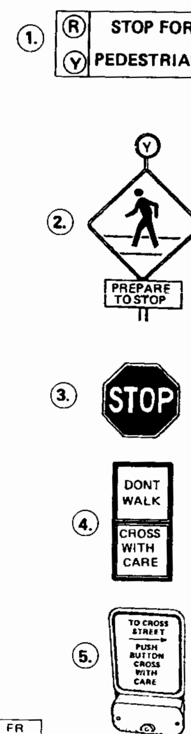
The five school-pedestrian crossing designs were evaluated in a time series, matched experimental-control site design. Each design was located in two cities in different regions of the United States using existing school-pedestrian crossing design locations where possible. Six measures of effectiveness were used in evaluating the school-pedestrian crossing designs: compliance, behaviors, and volume for both pedestrians and vehicles, vehicular delay, gaps in the major street vehicular traffic stream, and driver understanding data.

Data Analysis

The data analysis consisted of two parts. The first consisted of a detailed comparison of the measures of effectiveness between each school-pedestrian crossing design and its control site. The second was a comparison of the measures of effectiveness among the five school-pedestrian crossing designs. This permitted conclusions to be drawn concerning each school-pedestrian crossing design as compared to full signalization and the type of school-pedestrian crossing design that is more desirable, keeping in mind site and regional differences.

TRAFFIC CONTROL DEVICES



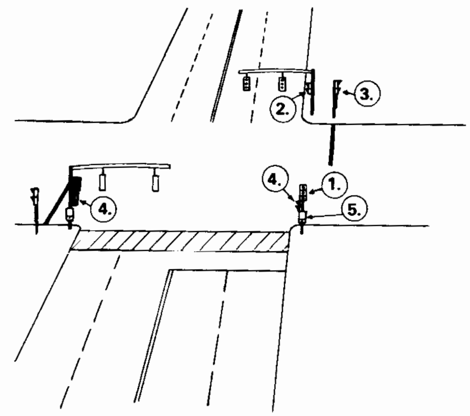


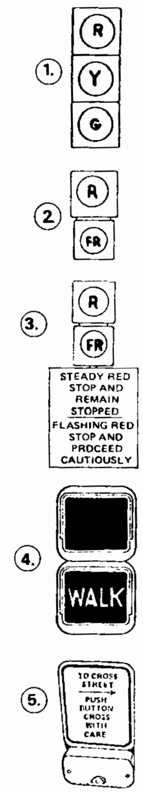
OPERATION

Approach	Dwell	Ped Act			
O.H. Sign	Dark	Y	FR	FR	FR
Advance sign	Dark	FY	FY	FY	FY
Ped Signal	DW	DW	DW	Cross with care	FDW

Figure 6. E-1, Sign & Stop Sign

TRAFFIC CONTROL DEVICES

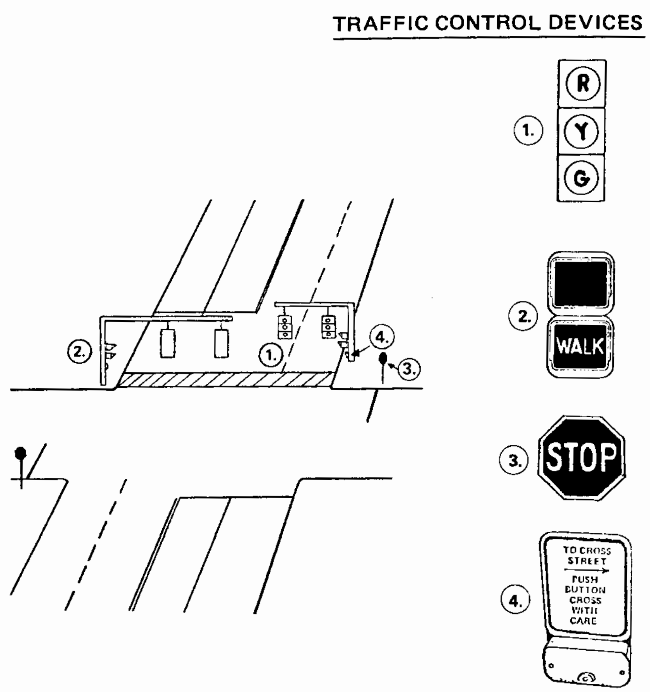




OPERATION

Approach	Dwell	Ped Act.			
Main	FY	G	Y	R	R
Minor	FR	R	R	R	R
Ped Signal	DW	DW	DW	W	FDW

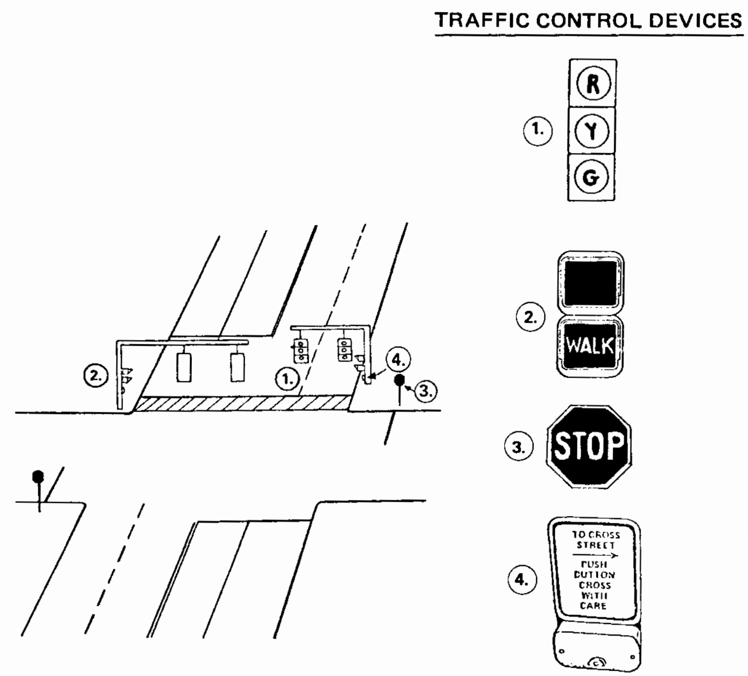
Figure 7. E-2, Flashing Yellow Signal & Flashing Red Beacon



OPERATION

Approach	Dwell	Ped Act		
Major	FG	Y	R	R
Minor	Stop Sign			
Ped Signal	OW	DW	W	FDW

Figure 8. E-3, Flashing Green Signal & Stop Sign



OPERATION

Approach	Dwell	Ped Act.		
Major	G	Y	R	R
Minor	Stop Sign			
Ped. Signal	LW	DW	W	FDW

Figure 9. E-4, (Sg-44) Signal & Stop Sign

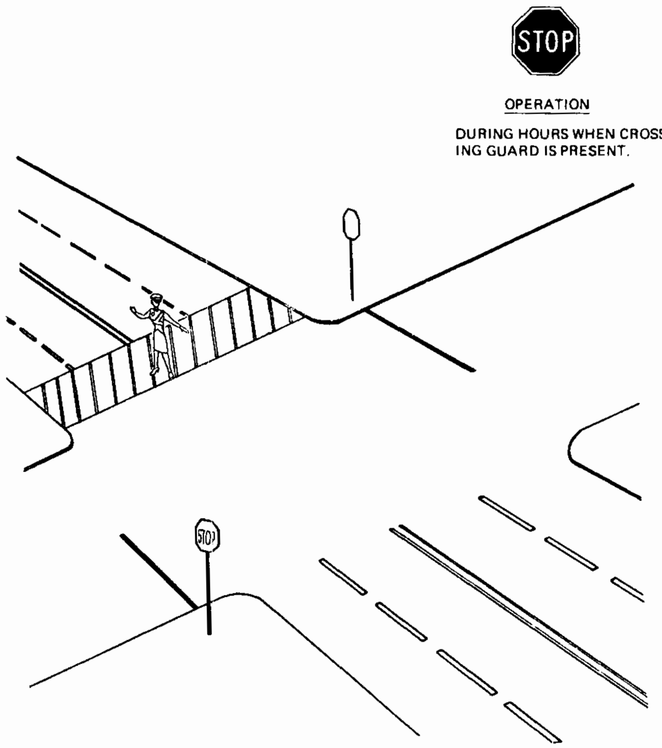


Figure 10. E-5, Crossing Guard

Conclusions and Recommendations

The conclusions and recommendations were divided into four parts: general advantages and disadvantages of the school-pedestrian crossing designs compared to the control sites, conclusions based on the detailed comparison of each school-pedestrian crossing design compared to its control site, recommended school-pedestrian crossing designs, and guidelines on the type of intersection where the school-pedestrian crossing design is more applicable.

General Advantages and Disadvantages of the School-Pedestrian Crossing Designs Compared to Full Signalization. Based on the comparison between each school-pedestrian crossing design and its fully signalized control site, the following general conclusions were drawn about school-pedestrian crossing designs:

Advantages:

- Increased pedestrian compliance to the pedestrian signal

- Reduction in the stop time per vehicle on the major street approach
- Reduction in installation costs.

Disadvantages:

- Reduction in both pedestrian and driver understanding of how the traffic control devices operate
- Increase in vehicle angle conflicts, but non-significant.

Comparison of Each School-Pedestrian Crossing Design to Full Signalization. The comparison between each school-pedestrian crossing design and its fully signalized control site resulted in the development of the following conclusions:

- Full signalization is more desirable than the sign and stop sign design.
- Flashing yellow signal and flashing red beacon is equivalent to full signalization, except that full signalization may generate through traffic on the minor street approach.
- Crossing guard, (Sg-44) signal and stop sign, and flashing green signal and stop sign are more desirable than full signalization.

Recommended School-Pedestrian Crossing Design. Based on the comparison between school-pedestrian crossing design, the following recommendations were made:

- Crossing guard and (Sg-44) signal and stop sign are the most desirable school-pedestrian crossing designs of those used in the evaluation.

Guidelines for Selection of School-Pedestrian Crossing Design Locations. the following guidelines should be used for selecting school-pedestrian crossing design locations:

A. Intersection has the following characteristics:
   1. Major Street (assume two lanes in each direction)
      - Number of adequate gaps in the traffic stream during periods of pedestrian activity is less than the number of minutes in that same time period
      - Minimum AADT 7000 – 10,000 vehicles, both directions
      - Minimum peak hour volume 1100 – 1400 vehicles, both directions.
   2. Minor Street (assume one lane in each direction)
      - Maximum AADT 900 – 1200 vehicles, both approaches
      - Maximum peak hour 100 – 150 vehicles, both approaches
      - Local residential street.

B. The arrival pattern of pedestrians throughout the day at each location should be considered in selecting a design due to differences in times of operation between the two recommended school-pedestrian crossing designs.

C. The pedestrian crosswalk should be located so that turning vehicle volume through the crosswalk is minimized.

D. The pedestrian crosswalk should be located at the crossing with the largest pedestrian volume.

E. Response time from the point at which the pedestrian push-button is depressed until the WALK interval appears should be minimized to ensure maximum pedestrian compliance to the pedestrian signal.

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FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

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

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

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

7. Improved Technology for Highway Maintenance

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

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

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